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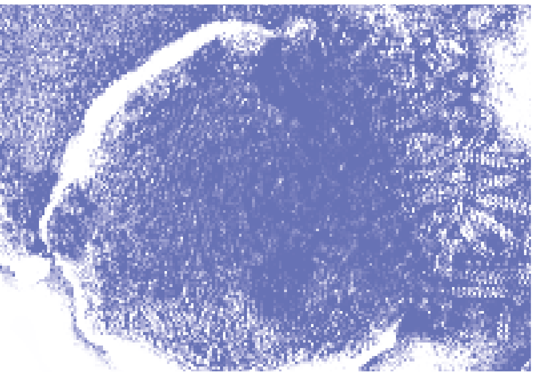
RINDERPEST
AND ITS ERADICATION








RINDERPEST
AND ITS ERADICATION

WILLIAM TAYLOR, E. PAUL J. GIBBS,
SANTANU K. BANDYOPADHYAY,
PAUL-PIERRE PASTORET & PROTUS ATANG (Editors)

Published by
the World Organisation for Animal Health
and
the Food and Agriculture Organization of the United Nations

Paris, 2022

Required citation:
Taylor W.E., Gibbs E.P.J., Bandyopadhyay S.K., Pastoret P-P., Atang P. (2022). - *Rinderpest and its eradication*. Paris, OIE and FAO, 816 p. (DOI: https://doi.org/10.20506/9789295115606). Licence: CC BY-NC-SA 3.0 IGO.

ISBN [FAO] 978-92-5-136090-3
ISBN [OIE] 978-92-95115-60-6

Copy-editing and proofreading: Prepress Projects Ltd

Design Director: Paloma Blandín Parras

Indexer: Laurence Errington

This book is dedicated to those who, over centuries, relentlessly battled the scourge of rinderpest and ultimately succeeded in its eradication.

It is also dedicated to the memory of those countless animals that died of rinderpest.

Biographies

William Taylor graduated from the Royal (Dick) School of Veterinary Studies, Edinburgh, United Kingdom of Great Britain and Northern Ireland, in 1962 and then with a BSc (Bacteriology) from the University of Edinburgh in 1963 and a PhD from the Australian National University, Canberra, in 1972.

From 1963 to 1969 he worked at the East African Veterinary Research Institute, Muguga, Kenya, manufacturing, safety testing and quality assuring rinderpest vaccine for the East African Common Services Organisation, introducing the tissue culture rinderpest vaccine strain in the process. In addition, he studied the pathogenesis of the virus in cattle and the epidemiology of the virus in the Serengeti wildebeest population.

From 1973 to 1978 he worked at the National Veterinary Research Laboratory, Vom, Nigeria, monitoring the post-JP15 rinderpest immunity levels in vaccinated cattle. He also resolved the mystery of rinderpest neutralising antibodies in local sheep and goats showing that these were caused by peste des petits ruminants virus. He isolated and attenuated this new virus.

From 1979 to 1986 he worked at the Animal Virus Research Institute, Pirbright, United Kingdom, demonstrating the existence of peracute strains of rinderpest present on the Arabian peninsula. He also directed the making of a FAO film demonstrating the clinical and laboratory diagnosis of rinderpest.

From 1986 to 1989 he worked with the Pan-African Rinderpest Campaign in Nairobi as an FAO Epidemiologist and as a EU Technical Assistant. In 1989 he moved to New Delhi, India, where he remained for seven years working as the EU Technical Assistant to the National Project for Rinderpest Eradication. From 1997 to 2010 he served as an FAO Consultant with the Global Rinderpest Eradication Programme, working extensively in Pakistan and Central Asia.

In 2010 he served as Chairman of the Joint FAO/OIE Committee on Global Rinderpest Eradication, submitting its final report to the OIE General Session in 2011 and announcing that rinderpest had ceased to exist as a freely circulating virus.

From 2012 to 2022 he served as senior editor and author during the development of this book.

E. Paul J. Gibbs graduated as a veterinarian from the University of Bristol, United Kingdom, in 1967 and subsequently received a PhD from the same institution for epidemiological and diagnostic studies on pox and herpes virus infections of cattle. Between 1970 and 1979 he was on the staff of the Pirbright Institute in England, reaching the rank of Principal Veterinary Research Officer. During this time he worked on bluetongue and related arboviruses, including field studies in Cyprus and West Africa. In 1974, he spent several months working with the Centers for Disease Control in the USA on the epidemiology of equine viral encephalitis. In 1976, he was awarded a Fellowship of the Royal College of Veterinary Surgeons for studies on the susceptibility of five species of deer in the United Kingdom to foot-and-mouth disease. In 1978, in support of William Taylor's work on peste des petits ruminants in Nigeria, he led a small team at Pirbright that established the identity of the virus as separate from rinderpest virus.

In 1979, he joined the College of Veterinary Medicine at the University of Florida as Professor of Virology. In Florida his professional focus has been the prevention and control of emerging diseases, including those of zoonotic importance, through research, education and policy development. This work has involved several state, federal and international agencies, including the FAO and the OIE.

More specifically, in the 1980s he organised a programme across the Caribbean region investigating the epidemiology of bluetongue and assisted the US, Mexican and Canadian governments in their collective response to the introduction of African swine fever to the Dominican Republic and Haiti. Following the introduction of West Nile virus to the USA in 1999, he helped in the development of a recombinant vaccine for horses, and in 2004 he assisted in establishing a team that led to the discovery that equine influenza virus was the cause of a nationwide epidemic of respiratory disease in dogs.

In support of his teaching responsibilities, he co-authored three editions of Veterinary Virology and has been an editor of several other books.

Santanu K. Bandyopadhyay graduated with a Degree in Veterinary Science from the University of Calcutta in 1973, a Masters in Veterinary Science from the Indian Veterinary Research Institute (IVRI) in 1976 and a PhD from the University of Cambridge, United Kingdom, in 1989.

He joined the Indian Agricultural Research Service in 1977 and worked at IVRI's Mukteswar Laboratory for 18 years on infectious diseases of animals, such as rinderpest, peste des petits ruminants (PPR), foot-and-mouth disease and bluetongue. His notable contributions include developing a monoclonal antibody (MAb)-based competitive enzyme-linked immunosorbent assay (c-ELISA) for rinderpest (World Reference Laboratory accredited), a MAb-based sandwich ELISA (s-ELISA) and a c-ELISA for PPR, and developing and commercialising PPR vaccine technology using a lineage IV virus strain (Sungri) from India.

He was the Animal Husbandry Commissioner (Chief Veterinary Officer) of the Government of India from 2004 to 2009. He represented India as the Chief of Delegation in World Organisation for Animal Health (OIE) General Sessions and secured the official freedom from rinderpest disease and infection for the Government of India during this period. He was elected a member of the OIE Biological Standards Commission in Paris and served from 2006 to 2009. He worked as a member of the Agricultural Scientists Recruitment Board of the Indian Council of Agricultural Research between 2012 and 2015. He was Senior Technical Coordinator and Team Leader for the Emergency Centre for Transboundary Animal Diseases of the Food and Agriculture Organization of the United Nations (FAO), Viet Nam (2009–2012) and FAO Coordinator for the Regional Support Unit for the South Asian Association for Regional Cooperation countries in Nepal (2015–2017).

Paul-Pierre Pastoret graduated as a Doctor in Veterinary Medicine from the University of Liège, Belgium, in 1970. After two years in rural practice he then specialised in virology and immunology and obtained a PhD in Virology from the same university. He then pursued post-doctoral studies at the University of Saskatchewan, Canada, and subsequently became Professor of Virology, Immunology/Vaccinology and Viral Infectious Diseases at his alma mater.

In collaboration with Transgene (Strasbourg, France), the rabies laboratory of Nancy (France), the Wistar Institute (Philadelphia, USA) and Merial (Lyon, France), he contributed to the development of the recombinant vaccinia–rabies virus for vaccinating wildlife against rabies by the oral route. The vaccine was largely responsible for the elimination of rabies in several western European countries.

His other major research focuses were the molecular biology of bovine herpesvirus 1 and 4, the pathogenesis of bovine viral diarrhoea/mucosal disease in cattle, rotavirus infections of cattle and dogs, and bovine spongiform encephalopathy.

He was the co-founder and the first President of the European Society for Veterinary Virology. For six years he was also a member of the board of the International Livestock Research Institute. Between 2002 and 2005, he was Director of the Institute for Animal Health in the United Kingdom.

He was Professor Emeritus at the University of Liège and, from 2006 to 2009, Head of the Publications Department of the OIE, in which capacity he initiated the development of this book.

Paul-Pierre Pastoret was the author or co-author of 840 scientific papers and editor or co-editor of many textbooks, including *Veterinary Vaccinology* (Elsevier, 1997), *Handbook of Vertebrate Immunology* (Academic Press, Elsevier, 1998) and *Rinderpest and Peste des Petits Ruminants: Virus Plagues of Large and Small Ruminants* (Academic Press, Elsevier, 2005).

Paul-Pierre Pastoret passed away in 2015

Protus Atang graduated from the University of Glasgow, United Kingdom, as a veterinary surgeon and became a member of the Royal College of Veterinary Surgeons. Later on, he studied tropical veterinary medicine at the University of Edinburgh.

Dr Atang's veterinary career began in Cameroon in 1964 as a veterinary officer, rising to the post of Director of Veterinary Services, responsible for all animal health and animal production activities. In 1966, Dr Atang was seconded to the Inter-African Bureau for Animal Health (IBAH) with responsibility for monitoring and improving the activities and performance of the bureau in response to animal diseases in Africa. In 1968, now as Director of IBAH, he extended the activities of the bureau to include animal health and animal production, and thereafter changed the name of the bureau to the Interafrican Bureau for Animal Resources (IBAR) in 1971.

Two of IBAR's major achievements during Dr Atang's term as Director were the conclusion of JP15 and the groundwork undertaken for planning the Pan-African Rinderpest Campaign, which started in 1968. In December 1984, Dr Atang completed his tenure at IBAR. Between 1984 and 1988, he relocated to the FAO, Rome, as Chief, African Region Operation Service, Division of Agriculture. In 1988, he was posted to Nigeria as the FAO Country Representative until his retirement in 1995.

However, even in retirement he was called upon to serve the interest of the animal resources sector in Africa, undertaking a number of consultations for FAO and the African Union up to as recently as 2010. In June 2011, Dr Atang received a certificate and a medal from the FAO in recognition of his contribution to the work on the eradication of rinderpest.

All biography photos courtesy of the book's editors.

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Acknowledgements

The editors wish to acknowledge the assistance of the following people and groups in the preparation of this book.

From the Food and Agriculture Organization of the United Nations (FAO), Felix Njeumi and Akiko Kamata for their efforts in ensuring the accuracy and referencing of technical material presented by authors over the course of the FAO Global Rinderpest Eradication Programme. The assistance of the FAO Communications Department is also acknowledged with gratitude.

The World Organisation for Animal Health (OIE) Publications Unit spent a number of years in bringing this book to fruition led in turn by Daniel Chaisemartin, Annie Souyri and Lucy Hogan. During that period significant assistance was provided by Michel Thibier and the staff of the World Animal Health Information and Analysis Department, the Status Department and the Communication Department at the OIE.

Gathering this wealth of information would not have been possible without the commitment, dedication and generous participation of a large number of contributors from all over the world. The patience and industry of all authors and co-authors has ensured the authenticity of this important contribution to the history of veterinary medicine; this is acknowledged.

From the earliest stage of its development, the editors determined that this book should be as broadly illustrated as possible. Accordingly, they particularly wish to acknowledge the contribution of all those who made a wide range of photographs available, thus helping realise this objective.

William Taylor, E. Paul J. Gibbs, Santanu K. Bandyopadhyay

Foreword

The global eradication of rinderpest, proclaimed in 2011, was a major milestone that parallels the extermination of smallpox worldwide in 1980. Both diseases, although caused by distinctly different viruses, inflicted untold misery and death for centuries and both diseases were finally overcome through the use of vaccines.

This book, a collaboration under the lead of the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) together with a wide range of contributors, traces the history of the highly contagious rinderpest disease from its first appearance to its eradication.

Rinderpest appears to have spread from Central Asia westwards into Europe early in the first millennium AD. Around the same time, it also swept to Siberia and East Asia, as well as southwards to the Indian subcontinent.

From the early 17th century, rinderpest control was explored in Europe; however, during the 18th and 19th centuries it remained endemic, with an overall death rate that numbered in the millions. The disease continued to be in Asia and by 1887, also reached Africa in epidemic proportions.

At the start of the 19th century, there was no effective treatment or prophylaxis available and attempts to reduce the disease's impact in Europe relied on strong zoo-sanitary regulations, supported by related legislation – an approach that resulted in the abolition of rinderpest. With advances in modern medicine, vaccination became an effective tool to protect cattle from rinderpest. Early vaccines made it possible not only to protect cattle, but more importantly to control rinderpest at the continental level.

Recurring epidemics of rinderpest led directly to the foundation of the OIE in 1924, and controlling such outbreaks through international vaccination efforts was central to FAO's first international assistance programme after its founding in 1945. Indeed, FAO considered that, among the many threatening livestock diseases, rinderpest was the prime candidate for global eradication.

In the period immediately after the Second World War to the early 1960s, new vaccines became available and an ambitious internationally-funded mass vaccination programme was introduced. By 1994, FAO observed that rinderpest was under control in Eurasia, the Middle East, the Indian subcontinent and Africa, and concluded that a window of opportunity existed to achieve global eradication. Success hinged, however, on major international funding to support national Veterinary Services in a Global Rinderpest Eradication Programme. Following a large-scale coordinated response and funding effort, the last case of rinderpest occurred in 2001.

A decade later, a Joint Committee of FAO and OIE experts concluded that the Global Rinderpest Eradication Programme and the related strategy were successful in ensuring that 'rinderpest as a freely circulating viral disease had been eliminated from the world'.

This book celebrates the 2011 proclamation of a rinderpest-free world. It reviews the science and expertise that went into the eradication efforts; the contributions by numerous UN agencies and other international organisations as well as the outstanding role played by the national Veterinary Services involved.

As the world faces other great challenges, from climate change to the COVID-19 pandemic, we hope that you will find inspiration in the extraordinary account of how FAO and the OIE were able to lead global efforts that resulted in a world free from rinderpest.

Qu Dongyu

Director-General
Food and Agriculture Organization
of the United Nations

Monique Éloit

Director General
World Organisation
for Animal Health

Preface

REFLECTING ON THE ERADICATION OF RINDERPEST IN THE TIME OF COVID-19

As I began writing this in May 2020 we were in what could, in Winston Churchill's words, be the 'end of the beginning' of the coronavirus disease (COVID-19) pandemic. The causative virus (severe acute respiratory syndrome coronavirus 2 [SARS CoV-2]) seems to be about as contagious as human influenza, has spread intercontinentally with incredible speed and has, at current count, according the World Health Organization (WHO), killed more than 6.06 million people globally. The only certainty is that many more will die. No recent experience has shown us so starkly how interconnected the human family is across this small, green and blue planet we call our home. The rapid dissemination of the virus reflects, of course, the nature of international air travel and the dynamics of globalisation, especially of international trade. Great good has come of globalisation, but there are also substantial, and often underappreciated, risks.

We have short memories. One lesson that COVID-19 is teaching us yet again is what the world learnt, between 1939 and 1945, that we cannot go forward in the absence of global cooperation and amity. That dynamic led, of course, to the founding of the United Nations (UN) and the development of major international agencies, such as the WHO, the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). These organisations give a seat at the table to each of their member nation states, no matter how powerless or remote that country might be from global centres of influence. Such structures are, of course, politically and organisationally complex and, like all human institutions, imperfect. But, if we go below that top level where tensions can at times be manifest, we see international networks and facilitators functioning effectively in ways that benefit humankind and promote peace and sustainability.

We are seeing the great importance of the WHO as its experienced professionals coordinate and validate what has to be done globally to minimise the medical, economic and social impacts of the COVID-19 catastrophe. I am pleased that the Doherty Institute has an important role in assisting the WHO in the fight against COVID-19.

Although I qualified as a veterinarian and spent the first decade of my career working on bacterial and virus infections of species that are important in animal production systems, my direct involvement, after 1971, with the world of transmissible diseases of domestic animals was largely limited to serving as a board member of the International Laboratory for Research on Animal Diseases (ILRAD), now the International Livestock Research Institute (ILRI). Located in Nairobi, Kenya, ILRAD/ILRI is funded as part of the Consultative Group for International Agricultural Research (CGIAR), which, along with FAO, is focused on feeding the world.

Then, living in Australia at the time, I was the first chair of the Scientific Advisory Committee for the high-security Australian Animal Health Laboratory (AAHL), now called the Australian Centre for Disease Preparedness (ACDP). Scientists working at the AAHL were, for instance, intimately involved in working out the pathogenesis of the lethal disease processes caused by the hitherto unknown, bat-borne (like SARS-CoV-1 and -2) Hendra and Nipah viruses. Through the early years of the 21st century, I had the pleasure of working with Martyn Jeggo, both during his time as the AAHL Director and through our joint involvement in promoting the One Health initiative. Partly through that, I met others who, like Martyn, had been directly involved in the Global Rinderpest Eradication Programme. Rinderpest had been a scourge compromising food availability, farming practices and human well-being for centuries. When it comes to thinking in terms of the history of science-based animal agriculture, 18th century efforts to deal with rinderpest were a powerful force in the establishment of the very first veterinary schools.

Being a student of history, it was an immense pleasure and privilege to be invited to FAO headquarters in Rome to participate in the events associated with the FAO–OIE joint Declaration of Global Freedom from Rinderpest on 28 June 2011. Rinderpest is, after smallpox, the only infectious disease we have ever succeeded in eliminating from the planet and, as with smallpox, the use of vaccination was central to that enterprise. As I listened to and talked with those who had been involved in eradicating rinderpest, I came to understand how economically and intelligently that had been done, using a pragmatic, targeted, evidence-based approach. Unsung heroes: I was immensely impressed!

As with COVID-19 and the WHO, the access to expertise and the level of coordination made possible by the FAO and OIE mechanisms were central to the eradication of rinderpest. What was also essential, of course, was the involvement of those nation states and financial institutions that provided the money, the combined experience and competence of the veterinary infectious disease sector and the vaccine industry, the involvement of professionals in the field, the facilitation by political leaders, diplomats and key administrators from different national governments, the efforts of their public sector employees, and the engagement of cattle herders and farming communities.

Dealing with a veterinary disease is, providing there is no substantial wildlife reservoir, somewhat simpler than limiting, say, the global COVID-19 pandemic. We have much more control over animal movement than we have over people's activities, and there are other restrictions and strategies available for animal diseases that cannot be applied to human populations. But there is always much less money devoted to dealing with problems in animal disease and we can in no way underestimate the collective human achievement that the eradication of rinderpest represents. Could that have been possible without the facilitation and networks provided by FAO and the OIE? The obvious answer is a resounding, 'No!'. We put the whole human family at risk when we underfund and undervalue the importance of the UN and its global agencies.

Peter C. Doherty

Nobel Laureate in Physiology or Medicine
Department of Microbiology and Immunology
University of Melbourne

Peter Doherty Institute for Infection and Immunity
792 Elizabeth St, Melbourne
VIC 3000, Australia

18 March 2022

Introduction

Summer days in Rome are invariably hot and, as the sun rose over the Apennines to the east on 28 June 2011, for the average Roman it presaged another typical summer day. For those chief veterinary officers and other dignitaries who had travelled from many parts of the globe to gather at the gleaming white headquarters of the Food and Agriculture Organization of the United Nations (FAO) close to the Circus Maximus, it was to be an exceptional day. This was the day when FAO, jointly with its sister organisation the World Organisation for Animal Health (OIE), was to announce and reiterate something that had been announced previously by the OIE, that the world was free of the scourge of rinderpest, only the second viral disease to be eradicated globally after smallpox was eradicated in 1980.

For centuries, rinderpest had been feared as a disease that could quickly kill the majority of cattle in a herd. It was a disease that travelled with armies and trade. A disease recognisable as rinderpest was noted in Europe in the fourth century AD, brought from the steppes of Central Asia with the invading armies of the Huns; in Asia the disease was noted in China in AD 75 and AD 447. In the 1880s, rinderpest accompanied another army, that of Italy when it invaded Abyssinia, modern-day Ethiopia. The resulting epidemic, which has famously become known as the Great African Rinderpest Pandemic, tore through the continent killing countless cattle and ruminant wildlife and causing starvation in human populations dependent upon their cattle. This was a pandemic of such impact that the vultures forgot how to fly.

But in one of those beautiful coincidences, one might say symmetry, Rome was not only the city in which in 2011 it was announced that rinderpest had been eradicated, it was also the city in which in 1715 Lancisi, physician to Pope Clement the 11th, had laid down the major principles by which the ravages of rinderpest could be halted, namely those of stamping out and disinfection. These principles, conceived before there was any understanding of microbiology, were successfully applied with little modification over the next two centuries in Europe until epidemic rinderpest had been conquered. Elsewhere in the world, but particularly in Africa, it would require the invention of effective vaccines before rinderpest could be initially controlled and finally eradicated.

This book tells the story of rinderpest and its eradication. The focus is on the international coordination that came together after the Second World War in the confident belief that, with vaccines available, the eradication of rinderpest was a practical possibility. In both Africa and South Asia, beginning in the 1960s, there was an initial dramatic success through the coordinated vaccination of cattle across the continents. Unfortunately, follow-up measures could not prevent the return of epidemic rinderpest, albeit to a lesser extent. Chastened by failure, the international community refocused with renewed energy to achieve eradication. The vaccination programmes broadened to reflect a multidisciplinary approach to disease eradication. FAO and the OIE, together with international aid agencies, coordinated policy with the nation states and guided implementation of the eradication programmes until success was achieved.

In telling the story, the book is divided into nine parts, most with several chapters.

PART 1 CHARACTERISTICS OF THE VIRUS AND DISEASE

The first of two chapters in Part 1 explores the history of rinderpest from antiquity to modern times. Against this historical backdrop, various aspects of the phenotype and genotype of the causative virus are described to give some understanding of its evolution and of how its susceptibility to control led to its eradication. Rinderpest is classified as a morbillivirus and is one of a group of very closely related and clinically important viruses such as measles, canine distemper, and peste des petits ruminants. Rinderpest virus has only one main serotype and all known 'strains' of the virus, including attenuated vaccines, fully immunise against all other strains, despite genetic and minor antigenic variation. There is also a detailed exploration of the virus's subdivision into 'clades' or lineages, an understanding of which proved helpful in epidemiological backtracing.

Infection of domestic cattle and domestic buffaloes usually produced disease with recognisable clinical signs including, at times, the devastating and economically unacceptable levels of mortality that forced humans to pursue its eradication. The second chapter within Part 1 describes the clinical appearance of the different stages of classic rinderpest from the initial fever and excessive salivation, through the erosive stages of the disease affecting the respiratory and alimentary tracts, to the almost invariable death of the animal from the dehydration caused by the profuse diarrhoea. This chapter is extensively illustrated with photographs of rinderpest in cattle and domestic water buffalo, which serve to remind us of the clinical severity of rinderpest.

PART 2
THE HISTORY OF RINDERPEST EPIDEMICS

There are eight chapters in this part of the book, which opens by describing the origins of the disease in Central Asia around the first millennium AD and its subsequent widespread dissemination both westwards to Europe and eastwards to other parts of Asia, giving rise to major epidemics followed by residual endemicity.

Until the end of the 19th century, Africa had mostly been unaffected by rinderpest, but this situation changed dramatically with the introduction of the virus into Ethiopia in 1887. The second chapter in Part 2 describes the catastrophic impact of the virus on the cattle and wildlife populations as it spread throughout most of the continent. This event became known as the Great African Rinderpest Pandemic. Thereafter, rinderpest was endemic in Africa, causing periodic epidemics in both cattle and wildlife. To illustrate the situation in Africa in the 20th century, one chapter describes rinderpest epidemics in Nigeria in the early 1980s and another an epidemic in wildlife in Kenya.

Rinderpest has a history of re-emerging when control is relaxed. During the 20th century, extensive epidemics occurred in several areas where rinderpest was thought to have been under control. Several epidemics in the Near East (1920s and 1969–1973), Pakistan (1993–1994) and India (1980–1988) are described and the reasons for the re-emergence of the disease are discussed, live animal trade within and out of the subcontinent being particularly to blame. One chapter describes several puzzling outbreaks of rinderpest, between 1989 and 1998 in areas of Georgia, Mongolia and the Russian Federation where the cattle were routinely vaccinated against rinderpest. While never decisively demonstrated, the conclusion was that these outbreaks were possibly associated with the attenuated vaccine reverting to virulence.

PART 3
THE PRINCIPLES UNDERLYING RINDERPEST CONTROL AND ERADICATION

The third part comprises ten chapters that describe the principles underpinning the eradication of diseases and the tools that were employed in support of eradication. Rinderpest was eradicated from most of Europe before the advent of vaccination, mostly through the use of movement control and depopulation of affected animals and those in contact, a policy that has become known as zoosanitary control. To begin with, zoosanitary control was enforced based on the clinical recognition of rinderpest, but, as the discipline of virology developed, clinical diagnoses were confirmed by increasingly sophisticated laboratory techniques. As a consequence of the Great African Rinderpest Pandemic, there was intense interest in developing vaccines, recognising that zoosanitary control was not feasible in many regions of the world. Subsequently, a range of different types of vaccines was produced to control and later eradicate the disease. Once vaccination was in common use, complementary laboratory tests to determine the antibody response of either previously infected or vaccinated animals were required to promote disease surveillance and monitoring of vaccination rates. When international eradication programmes were developed, a quality control programme for vaccine production was established. Effective eradication required knowledge of where the disease was endemic. An epidemiological approach, called participatory disease surveillance, which involved tapping into the local knowledge of farming communities, assisted greatly in the final stages of eradication, as it allowed focused vaccination. Each of these topics is discussed in Part 3, together with two chapters that describe the use of participatory disease surveillance in two very different countries.

PART 4
REGIONAL CONTROL AND ERADICATION PROGRAMMES

Part 4 has no fewer than 68 individual chapters and is devoted to charting the road to eradication through the various national vaccination programmes that were designed to control rinderpest and later, as the number of epidemics reduced, became integrated with international programmes seeking eradication.

The various chapters that describe the progress towards eradication are grouped by region.

In Africa, early steps toward eradication began in the 1960s with Joint Programme 15 (JP15), an ambitious and ground-breaking programme based on the phased implementation of mass vaccination across the sub-Saharan region. The JP15 programme was initially considered to have been successful, but epidemic rinderpest returned to this region in the 1980s. Its successor, the Pan-African Rinderpest Campaign, succeeded in eradicating rinderpest.

In the Middle East, where endemic rinderpest was not an issue, FAO, through the United Nations Development Programme (UNDP), engaged in strengthening vaccine production and diagnostic capability over a similar 30-year time frame, culminating in a round of regional mass vaccination termed the West Asia Rinderpest Eradication Campaign.

Somewhat ahead of Africa, India, where rinderpest was heavily entrenched, pioneered the use of vaccines as the tool for rinderpest eradication in the mid-1950s, completing the task 40 years later. A South Asia regional coordination programme was mooted but did not materialise, although, except for Pakistan, regional countries worked in concert. Pakistan experienced rinderpest at two levels, as point epidemics and as a cryptic condition in Sindh province, both of which were finally resolved in the year 2000.

In the aftermath of the Second World War and benefiting from reconstruction efforts, the countries of Southeast Asia, quickly subdued rinderpest by vaccination. Operating alone, China had conquered the disease by 1956.

Having eliminated rinderpest in 1928, Russia and the Central Asian republics never again succumbed to endemic rinderpest by maintaining a vaccine belt along their southern borders.

For those countries that were considered infected with rinderpest at the commencement of the final drive to eradication, which started in 1994 when the Global Rinderpest Eradication Programme was established (see Part 6), epidemiological proof of freedom from rinderpest was required. Starting from a point at which outbreaks had ceased to occur, countries progressed through evidence-based stages until they achieved 'freedom from rinderpest infection', as recognised by the 'OIE Rinderpest Pathway' (see Part 7). Details of the activities of each country, including the evidence proving freedom from rinderpest infection, are provided for each of the regions.

Finally, for the countries within a region, a detailed timeline is provided to allow the reader to gain an appreciation for the continuing presence of rinderpest in terms of reported outbreaks, along with the volume of vaccine administered in attempts to control the disease. The timelines are based on the reports of the national Veterinary Services up to the point at which vaccination had eliminated the disease.

PART 5
STAKEHOLDERS

Rinderpest would not have been eradicated without the extensive and committed involvement of many stakeholders. Their collective role is examined in 13 chapters within Part 5, which starts by addressing the critical role of the national Veterinary Services as the major stakeholder for the implementation of measures to control and eradicate rinderpest. The substantial contributions, both technical and financial, of the international aid agencies of many countries and those of the European and African Unions were invaluable in supporting the various programmes described previously. Non-governmental organisations (NGOs) also made critically important contributions, particularly in war-torn countries. The control of rinderpest had been seen as important from the very foundation of the United Nations. Several agencies, but principally FAO, UNDP, the International Atomic Energy Agency and the United Nations Refugee Agency (UNHCR), provided critical technical and administrative expertise and, when necessary, emergency funds in support of the control and later eradication of rinderpest. The OIE, working with FAO, provided the regulatory environment for the control of rinderpest, which became increasingly important once the OIE's Members embarked on the pathway to eradication.

PART 6
GLOBAL COORDINATION

Part 6 has four chapters that address the establishment and activities of the Global Rinderpest Eradication Programme (GREP). The feasibility of the global eradication of rinderpest had been suggested by the success of several of the early rinderpest control activities described in Part 4, but the resurgence of rinderpest in Sahelian and sub-Sahelian Africa in the 1980s was a blow to the international community. In response, there was an international drive to establish a new programme to control rinderpest in

Africa. Concurrently, FAO was encouraged to take the initiative to develop a programme that would examine the eradication of rinderpest in a wider context. This led in 1994 to FAO, in partnership with the OIE, establishing GREP, the secretariat for which was based in the FAO's headquarters in Rome. GREP projected the conviction that rinderpest eradication was feasible and developed a vision of how to proceed, which in turn provided motivation for the eradication process and ensured its eventual success. The establishment of a diagnostic and surveillance network and an effective communication strategy were critical to the success of GREP.

PART 7
GLOBAL FREEDOM

Part 7 consists of three chapters. The first describes the OIE Rinderpest Pathway, which was a series of steps from an initial self-declaration of provisional freedom from disease to the OIE-accredited stages of 'freedom from disease' and 'freedom from infection'. This, combined with the concept that GREP was to be a time-limited exercise ending in 2010, set the scene for eradication. The second chapter describes the work of the joint FAO/OIE Committee on Global Eradication. This committee, which met on several occasions between 2009 and 2011, had the important task of examining the evidence that rinderpest virus was no longer circulating in nature. Upon determining that this was indeed true, the committee made a recommendation to both the OIE and FAO that resolutions should be passed by both organisations that global eradication had been achieved. This committee was also charged with making recommendations regarding the guardianship of the remaining rinderpest virus stocks and the steps to contain the risk of any reintroduction. The final chapter in Part 7 describes the ceremonies in several countries that marked the historic declaration of the world's freedom from rinderpest.

PART 8
POST-ERADICATION PERIOD

Part 8 has only two chapters. The first examines the reasons why GREP was successful. There were several reasons for its success, such as a good communications strategy, but a better understanding of the epidemiology of the virus was arguably the most important. Soon after GREP had been established, it was realised that, despite the many control and eradication programmes that preceded it, very little information was available on the global distribution of rinderpest virus. Subsequent studies in different regions of the world revealed that the virus was being maintained in relatively small reservoirs of infection from which epidemic extension occurred. Armed with this information and coupled with participatory disease surveillance, eradication was focused on these reservoirs of infection; success followed quickly.

The consequences of rinderpest re-emergence, should it ever occur, are discussed in the second chapter in Part 8. Whether it be from an accidental laboratory release, through bioterrorism or from a hitherto unrecognised wildlife reservoir, an effective response would require cooperation between multiple stakeholders at the national, continental/regional and international levels. To address these concerns, FAO and the OIE have developed a Global Rinderpest Action Plan, which is directed to stakeholders on how to prepare, prevent, detect, respond to and recover from rinderpest were it to re-emerge.

PART 9
CONCLUSION

Part 9 discusses the way in which the different elements necessary for eradication were identified and integrated into the momentous and successful effort that ended rinderpest's existence.

William Taylor, E. Paul J. Gibbs,
Santanu K. Bandyopadhyay, Protus Atang

June 2020

RINDERPEST
AND ITS ERADICATION

PART 1
CHARACTERISTICS OF THE VIRUS AND DISEASE

CHAPTERS

CHAPTER 1.1

EVOLUTIONARY CHARACTERISTICS OF RINDERPEST VIRUS LEADING TO ITS ERADICATION

P. ROSSITER[(1)*], M.D. BARON[(2)] & C. KAI[(3)]

(1) St Michael's House, Poughill, Devon EX17 4LA, United Kingdom (Formerly staff member of the Food and Agriculture Organization of the United Nations [FAO] and rinderpest consultant)

(2) Honorary Institute Fellow, Pirbright Institute, Ash Road, Pirbright, Surrey, United Kingdom

(3) Director, Laboratory Animal Research Centre, Institute of Medical Science, University of Tokyo, 4-6-1 Shirokanedai, Minato-ku, Tokyo 108-8639, Japan

*Corresponding author

SUMMARY **This chapter briefly explores the history of rinderpest from antiquity to modern times. Against this historical backdrop, various aspects of the phenotype and genotype of the causative virus are described to give some understanding of its evolution and of its susceptibility to control by humans that has led to its eradication. It is possible that some other morbilliviruses of terrestrial mammals will be eradicated in the foreseeable future, but, as a genus, the morbilliviruses look set to survive in other hosts such as marine mammals.**

KEYWORDS **Evolution – Genotypes – History – Morbillivirus – Rinderpest virus.**

INTRODUCTION

A pinnacle in veterinary science, the global eradication of rinderpest was the culmination of a long campaign between humans and rinderpest virus (RPV), the causative agent of the disease. With the benefit of 20/20 hindsight, it was a war that the virus was always going to lose. Like smallpox before it, rinderpest had all the natural requirements of an eradicable disease and was too destructive for humans to live with. Although it can naturally infect all artiodactyls, RPV was maintained in just two domestic species, cattle (*Bos* spp.) and buffaloes (*Bubalus* spp.), which are both accessible to human interventions. There were no wild maintenance species, and no chronic carrier state, because recovered animals developed lifelong immunity and never re-excreted live virus. The virus is (very small quantities are still present on Earth in laboratory containment) fragile, unable to survive long outside the body or in meat, and transmission was primarily by simple close contact without any arthropod or other vectors. The virus has only one main serotype and all known 'strains' of the virus, including attenuated vaccines, fully immunise against all other strains, despite genetic and minor antigenic variation. Infection of domestic cattle and domestic buffaloes usually produced disease with recognisable clinical signs (see Chapter 1.2) including, at times, the devastating and economically unacceptable levels of mortality, 'cattle plague', that forced humans to pursue its eradication.

The simple disease cycle of close contagion from sick to healthy susceptible animals laid the foundation for the first means of gaining some control over the infection, namely through strict quarantine and hygiene (see Chapter 3.2). This worked well where livestock movement could be effectively controlled and was the main technique used to eradicate rinderpest from Europe. Unfortunately, livestock movement was of limited use in controlling disease in the mobile cattle and domestic buffalo populations of Asia and Africa, which remained strongholds for the virus. Since the 18th century, and probably much earlier, it was known that cattle that recovered from rinderpest never suffered the disease again. Following the extraordinary success of smallpox vaccination, and without fully understanding the concept of active immunity, numerous unsuccessful attempts were made to immunise cattle against RPV in the 18th and 19th centuries (1). Eventually, advances in treatment and prevention of rinderpest with serum from recovered livestock in Russia (2) and in South Africa during the Great African Rinderpest Pandemic showed the potential for using deliberate immunisation to achieve large-scale eradication (3). This became reality with the advent and immediate success of a live 'one shot' RPV vaccine attenuated by passage through goats in India (4). Mass immunisation was rapidly taken up throughout Asia and Africa, with steady improvement through a succession of increasingly safe, immunogenic vaccines, culminating in the cell culture attenuated viruses (see Chapter 3.4). These, together with reliable laboratory assays for diagnosis and seroepidemiology, confirmed the technical feasibility for the eradication of rinderpest from Africa and Asia (5, 6). Rinderpest's ruinous socio-economic impact ensured that political and institutional support for eradication was strong and finances readily forthcoming. Furthermore, by the second half of the 20th century, the presence of rinderpest, by then a relatively low-hanging fruit for disease control, came to be regarded as a failure of Veterinary Services: if countries and regions could not control rinderpest, then what other serious transboundary animal diseases were they harbouring? There was a trade incentive to eradicate the disease.

Rinderpest only just made it into the 21st century, the last officially reported case in the world being from Kenya in 2001 (7), and the disease was confirmed to be globally eradicated in 2011 (8). Although the disease has been eradicated, RPV is still present in laboratory archives. The Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) are jointly reducing the risk posed by these collections of virus by decreasing their size and number and by ensuring global preparedness for the unlikely event of an outbreak of rinderpest in the world's now entirely susceptible cattle (9) (see Chapter 8.2).

Rinderpest virus is a member of the genus *Morbillivirus*, a group of very closely related viruses of humans and animals. This chapter looks at some of the attributes of the morbilliviruses, especially those leading to their possible demise, at how some morbilliviruses may have evolved differently and more successfully than RPV, and then it explores some of the hard and not-so-hard facts behind the origin and evolution of RPV itself.

RINDERPEST VIRUS AS A PARAMYXOVIRUS AND A MORBILLIVIRUS

Concerning virology and taxonomy

Most of the viruses of mammals are composed of a protein shell or coat, sometimes surrounded by a lipid membrane, encasing a nucleic acid genome. They broadly divide into two groups, those with deoxyribonucleic acid (DNA) and those with ribonucleic acid (RNA) genomes. The RNA viruses can be subdivided into those with single strands of RNA and those with multiple strands of RNA and, in turn, the single-stranded RNA viruses are further split into those with a positive strand of RNA and those with negative-sense RNA. This latter category of viruses with single-stranded negative-sense genomes are grouped in the order *Mononegavirales* (10), which includes the families of the rhabdoviruses (e.g. rabies virus), the filoviruses (e.g. Ebola and Marburg viruses), and many others infecting plants, fish, reptiles, birds and mammals. One family is the *Paramyxoviridae,* with diverse genera that include mumps virus, Hendra virus, Newcastle disease virus of birds, the parainfluenza viruses, and the genus *Morbillivirus* that includes RPV.

The origin of these viruses from possible common ancestors to separate species is difficult to pin down (11). All paramyxoviruses are relatively fragile viruses that rarely establish persistent infections in their hosts requiring relatively large host populations to provide a continuous supply of fresh susceptible hosts in which the virus maintains itself. There is increasing evidence that there are very large numbers of paramyxoviruses circulating apparently subclinically in bat populations worldwide (12, 13, 14). The recently emerged Henipah viruses appear to have entered first pigs and then humans from fruit bat populations. It may be that, at some time in the distant past, other paramyxoviruses, including the morbilliviruses, crossed species barriers and, upon finding a suitable environmental 'niche' in which they could be maintained, became established in that population.

Understanding how RPV may have evolved requires some appreciation of how it replicates, which has been significantly advanced by studies of the interactions between morbilliviruses and their host cells (15, 16). As mentioned previously, the RPV genome consists of a single strand of negative-sense RNA containing six genes N, P, M, F, H, and L, which first must be transcribed to make viral messenger RNAs (mRNAs), which are then translated into viral structural proteins with the same nomenclature. This contrasts with, for example, foot-and-mouth disease virus (FMDV), which is a positive-strand RNA virus, and the viral genome itself is one giant mRNA. All types of RNA viruses are very simple viruses, with a relatively small number of proteins, and genomes of 10,000–20,000 nucleotide bases. In contrast, most DNA viruses (such as herpes viruses, pox viruses, and African swine fever virus) are much larger, with genomes encoding many hundreds of proteins. This is because DNA polymerases are much more accurate than RNA polymerases, so a large DNA genome can be replicated accurately, but a large RNA genome cannot, so RNA viruses must have small, simple genomes. On the other hand, most RNA viruses mutate very rapidly and, because hundreds to tens of thousands of progeny virus can be produced in each infected cell, are often present in the infected host or culture as a genetically diverse mutant swarm or 'quasispecies'. As a result, through preferential selection of the most suitable mutants in the quasispecies, these viruses can more easily change/adapt to changing environmental pressures. However, in the paramyxoviruses, which includes the morbilliviruses, the genetic diversity of the quasispecies is not as great as with many other RNA viruses – a significant factor contributing to the possible eradication of some paramyxoviruses, including RPV. This is because the replication mechanism generally inhibits gross changes to the genome, because of the requirements that a viable genome must be a multiple of six bases, which ensures the integrity of the major genes and gene products that are essential for the success of the virus. The requirements for cotranscriptional encapsidation of the replicating genome also prevents the mixing of genetic material with other viruses through recombination, thereby further limiting evolutionary possibilities. These are important considerations when we consider the origin of RPV and its host range.

The original trio: rinderpest, measles and canine distemper

The morbilliviruses (the word 'morbilli' was previously used to describe and distinguish measles from more serious plagues 'morbus' such as smallpox) are a small group of closely related viruses, each responsible for severe disease in different mammals. The original studies linking the first three members of the group to be discovered, measles virus (MV) of humans, canine distemper virus (CDV) and RPV, are a classic early example of the 'One Health' concept. Clinical, pathological and epidemiological observation had associated measles and canine distemper (17, 18, 19), and when Thiery (20), through studying the histopathology of rinderpest, described viral inclusions and syncytia typical of measles and canine distemper, this disease was tentatively assigned to the same group. During the 1950s, the golden age of cell culture virology, the viruses of these three mammalian plagues were grown in monolayer cell cultures in test tubes inoculated with infectious materials (21, 22, 23). Based on their cytopathology, biochemistry, and structure when viewed using electron microscopy, the three were classified as the related measles–rinderpest–distemper (MRD) subgroup or genus within the *Paramyxoviridae* (24, 25, 26). Further evidence of their close relationship was their shared antigenicity in serological tests using recovered and hyperimmune sera (24, 25) and varying degrees of heterologous cross-immunisation by one member against the disease caused by another member. For instance, RPV protected dogs against canine distemper (27). In 1978, based on their lack of neuraminidase and shared antigenicity, the MRD subgroup was officially designated the genus *Morbillivirus* (28). The members of the genus, which now includes at least four more viruses, with tentative newcomers under study, are designated as species. Within each species there are numerous different strains based upon their original history (location and date), their ability to cause pathology and disease (phenotype), details of their modification through passage in cells and atypical hosts, and, more recently, on genetic differences (genotype – as discussed below under 'Genetic variation').

Peste des petits ruminants virus

For any consideration of the possible origin and evolution of RPV and its replication in ruminants, the other most important morbillivirus affecting ruminants is peste des petits ruminants virus (PPRV). When the syndrome 'peste des petits ruminants' or 'plague of small ruminants' (PPR) was first observed in Côte d'Ivoire in 1940 (29), its clinical similarity to rinderpest in sheep and goats inevitably caused some confusion. Eventually, classic serological studies by W.P. Taylor in Nigeria (30) distinguished PPRV from RPV, and it was finally designated as the fourth morbillivirus species in 1979 (31). The sudden appearance of this new 'rinderpest-like' disease in small ruminants naturally led to the view that PPRV was an 'emerging' virus that had evolved from RPV (32). Subsequent monoclonal antibody and genetic studies showed, however, that PPRV is very distinct from RPV, which itself is more closely related to MV (Fig. 1; see also 'Evolutionary relationships between morbilliviruses').

A recent genetic study of different strains of PPRV (33) proposed that PPRV evolved in

West Africa early in the 20th century and linked it to the recognition of the disease there in 1940 (29). The molecular clock technique employed by this study and some caveats are discussed further below (see 'Evolutionary relationships between morbilliviruses'). If correct, this comparatively very recent emergence of a 'new' morbillivirus species raises several challenging questions, for instance what would have been the common ancestor of PPRV and where did it emerge from? Interestingly, PPR-like syndromes, with little or no disease in nearby cattle, were being reported as rinderpest in small ruminants in South Asia around the same time that PPR was first studied in Côte d'Ivoire in 1940 (34). Possibly these outbreaks were rinderpest, or perhaps not, in view of the widespread recognition of PPR throughout South Asia in the 1980s, and any older archived samples from small ruminants, even serum, still available in South Asia would be very valuable for differential analysis (35).

The aquatic morbilliviruses

In the late 1980s and 1990s new morbillivirus diseases were described in aquatic mammals. An epidemic affecting both harbour and grey seals in northern Europe revealed a new morbillivirus, phocine distemper virus (PDV) (36, 37). This virus is related to but distinct from CDV, which itself was found in diseased seals in Lake Baikal in 1987/1988, and in the Caspian Sea in 1997 and 2000 (38). Subsequent genetic studies (see 'Evolutionary relationships between morbilliviruses') confirmed that CDV and PDV are less divergent from each other than the divergence seen between other morbilliviruses and that they may have parted from each other more recently. During the same period, investigation of mass mortalities in dolphins and porpoises isolated two additional new and very closely related morbilliviruses: dolphin morbillivirus (DMV) and porpoise morbillivirus (PMV), which are both sometimes referred to as cetacean morbillivirus (CeMV). Genotypically, this virus is unique, being distant from PDV and CDV and more closely related to PPRV, RPV and MV. Surveillance shows that CeMV infects an ever-widening range of cetaceans in almost all oceans.

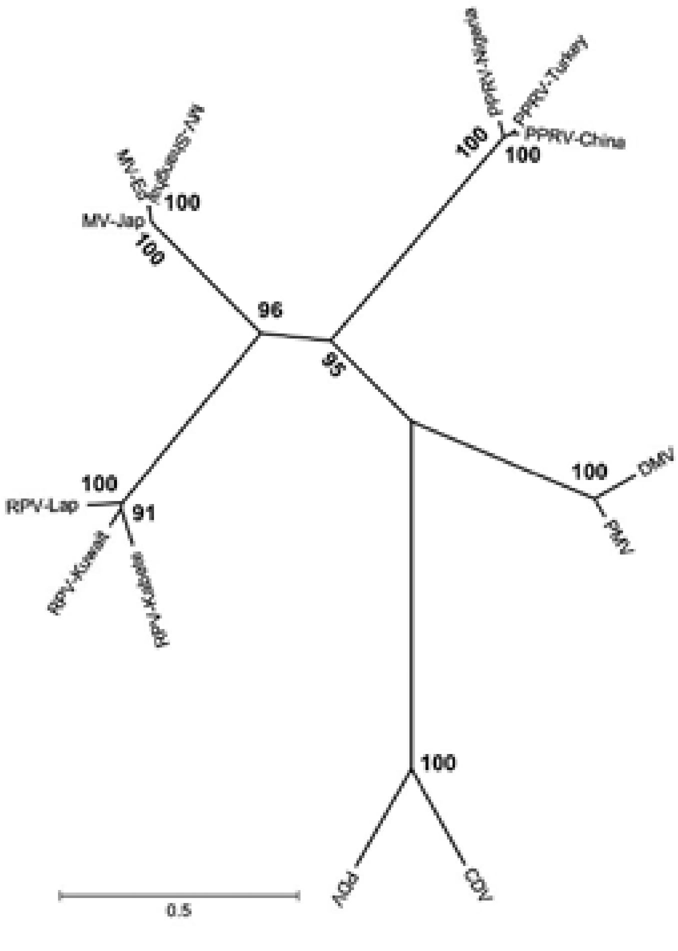
The growing list of morbilliviruses and their hosts

The morbillivirus genus continues, and probably will continue, to grow, as does the list of primary hosts for these viruses. In 2012 Woo and colleagues (39) described a 'morbillivirus-like' agent associated with a tubulonephritis in cats in Hong Kong, and this virus has now been recognised by the International Committee on Taxonomy of Viruses as a morbillivirus (FeMV) (40). CDV continues to show a propensity for new hosts (41). One early report described a morbillivirus in hedgehogs (42), but the original virus appears to have been lost and no further morbilliviruses have been found in this species. Recently, several closely related sequences of morbillivirus-like RNA have been found in samples from an almost global survey of rodents and bats (13). Might RPV and the other morbillivirus species eventually turn out to have originated from bats or rodents like so many other viruses causing serious diseases of humans and other mammals?

FIG. 1
RELATIONSHIPS BETWEEN THE MORBILLIVIRUSES BASED ON MOLECULAR PHYLOGENY

The evolutionary history of the morbilliviruses was inferred from the sequences of their respective N genes. The tree was determined by using the maximum likelihood method based on the general time reversible model, and allowing some sites to be evolutionarily invariable: the tree with the highest log likelihood is shown. The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. 1,000 bootstrap replicates were calculated to provide a measure of confidence in each branch. The percentage of trees in which the associated viruses clustered together in the bootstrap test are shown next to the branches. The analysis was conducted in MEGA6

Courtesy of the authors



Evolutionary relationships between morbilliviruses

Rinderpest appears to have been the first morbillivirus disease to be described. Severus Sanctus described a plague that decimated Europe's cattle from AD 376 to 386 and which is widely considered to be rinderpest (1, 43, 44, 45). From that time, regular reports show rinderpest periodically sweeping west through Europe from endemic strongholds in Russia and further east. In contrast, the earliest accepted description of measles as a distinct disease is in the writings of Abu Bakr Mohammad ibn Zakariya al-Razi, known as 'Rhazes', in the tenth century AD (16), although he does not write of it as a new disease. Appel (46), acknowledging that few diseases in dogs, other than rabies, cause such high mortality as canine distemper, reasoned that many historical records of plagues and high mortality in dogs may have been distemper. Nevertheless, it was not until 1761 that this specific disease was reported to have entered Europe through Spain from Asia or Peru (17).

In the late 1980s, monoclonal antibody and molecular techniques began unravelling the antigenic relatedness, the amino acid sequences of the proteins, and the nucleotide sequences of the genes of the different morbilliviruses including RPV. Using panels of monoclonal antibodies to compare morbillivirus antigens, Norrby and others (47) suggested that RPV could be the archevirus of the genus. However, the genetic evidence did not support this theory, rather it appears that all the known morbilliviruses originated from some unknown 'ancestral' virus (48) (Fig. 1). The genetic distance between the viruses indicates that measles and rinderpest are more closely related to each other than to other morbilliviruses. Given that suitably large wild bovid populations probably preceded human populations that were large enough to support the circulation of a morbillivirus (discussed below in 'Morbilliviruses in populations'), it is possible that MV may have evolved from RPV, or that both evolved from a common ancestor infecting either cattle or cattle and humans (49, 50). Similar analysis emphasises the even closer relationship between CDV and PDV, supporting their overlapping host range. The genetic evidence does not support the evolution of PPRV from RPV.

A study of the genetic sequences of several MV and RPV isolates to calibrate their 'molecular clock' (see Box 1) calculated that the two viruses diverged from each other between the 11th and 12th centuries (51). In the authors' own words 'this result was unexpected because emergence of MV was previously considered to have occurred in the pre-historic age'. There are other cases where such analyses have differed from the previously accepted historical record. For instance, in their study of the molecular clock of PPRV, Muniraju and others (33) suggested that MV and RPV diverged around AD 1,500. Another example is the evolution of filoviruses, single negative-strand viruses like the morbilliviruses, which has been variously estimated to range from 10,000 years (52) to tens of millions of years (53) – making firm assumptions about times of evolution difficult indeed.

Phylogenetic comparison of different isolates of each morbillivirus shows these viruses are continuing to evolve. Individual viruses, including MV and CDV (54, 55), have a range of slightly different genetic forms that tend to group into clades or lineages with a geographical and/or historical and/or pathogenic basis. Three main lineages have been found within RPV, lineages Africa 1 and Africa 2, and Asia 1 (56). Barrett (57) considered the possibility of PPRV having originated in Asia (where, as mentioned above, PPR may have been confused with rinderpest long before it was confirmed there in the 1980s [58]) because both MV and RPV were believed to have originated there, and the pattern of lineages is similar for RPV and PPRV (a single Asian lineage with multiple African lineages – suggesting repeat introductions from a single established and stable source). More recent genetic analysis has supported this with the authors suggesting that PPRV was introduced to Africa in live small ruminants shipped from Asia (59). More details of the phylogeny and evolution of RPV itself are discussed under 'Genetic variation'.

The vacant niche left by rinderpest virus

A frequently asked question is whether the eradication of RPV from the world's cattle has left a niche waiting to be filled by another morbillivirus (60). In theory, yes, but fortunately there is little to suggest this is happening or will happen.

History and field observation show that for at least two centuries, in areas free of RPV, such as America and Europe, and before the development and widespread use of vaccines against MV and CDV, susceptible cattle lived alongside dogs with distemper and people with measles without developing a new bovine morbillivirus plague. Rinderpest-susceptible cattle have also lived for decades, and continue to do so, alongside small ruminants with PPR, and despite widespread, frequent infection of the large ruminants with PPRV, as confirmed by serology (61), there is (as yet) no evidence of clinical PPR in cattle.

In contrast, laboratory studies are enigmatic. Before genetic typing was possible 'morbillivirus-like' agents were reported in samples collected from sick cattle in both Europe and North America in the late 1970s (62, 63) but have never been found again in either diseased or healthy cattle. Later, in the gene-sequencing era, analysis revealed an unexplained morbillivirus sequence in material in North America (64), but this also has not been found again. The extensive, widespread serology carried out in cattle during the final stages of rinderpest eradication did not detect any inexplicable new antibodies. Admittedly, in wildlife, the specificity of virus-neutralising antibody results, especially with sera from African buffaloes (*Syncerus caffer*) was sometimes complicated. Buffalo sera that cross-neutralised PPRV equally or more strongly than RPV were common during serological studies in Maasailand, a geographical area covering parts of Kenya and the United Republic of Tanzania, in the 1980s (P. Rossiter, E. Ndungu & H.M. Wamwayi, unpublished data, 1992). However, a high proportion of these sera were always unequivocally positive to RPV when retested by enzyme-linked immunosorbent assay (ELISA) (P. Rossiter, E. Ndungu & H.M. Wamwayi, unpublished data). Recently, a novel serological test detected the opposite effect, whereby antibodies detected in some cattle and wild bovids in the United Republic of Tanzania have greater affinity to RPV than to other morbilliviruses including PPRV (65) raising questions that must be resolved. Overall, however, the evidence suggests that the likelihood of other morbilliviruses replacing RPV is uncertain, but probably low.

Finally, in the theoretically possible event of a morbillivirus adapting itself to the large ruminant niche, it is possible that, because of the common pathogenesis, pathology and clinical signs shared between all morbillivirus diseases, the resulting 'new' disease could look and behave very much like rinderpest. Hopefully, although not rinderpest of old, this new morbillivirus cattle plague will be detected and eradicated by current global rinderpest preparedness planning (see Chapter 8.2).

BOX 1
THE MOLECULAR CLOCK: ITS BASIC CONCEPT AND SOME CONSIDERATIONS (44)

The molecular clock (evolutionary clock or gene clock) utilises estimated rates of random mutational change in genes. Using these rates, it is possible to calculate and compare the time taken for known differences in the nucleotide or amino acid sequence of closely related viruses or other organisms to arise. The time reflects the point when the two organisms were not different from each other and when their common ancestor existed, from which they both subsequently diverged and evolved. The underlying randomness of mutation rates means that exact timings are not yet possible, but the most recent use of this technique implies that virus evolution, or aspects of it, is moving much faster than originally estimated from phenotypic and other more conventional studies.

Several studies have cautioned that the results of molecular clock studies may be open to interpretation. Among various factors that may affect the estimate, there is evidence that the selection of purified populations of virus may mask older origins of the virus in question and that vaccination can have a significant effect on apparent evolutionary rates.

Morbilliviruses in their hosts

Morbilliviruses in populations

All morbilliviruses have a similar cycle of infection: continuous transmission from infectious to susceptible hosts. In a closed population, in which most adults have recovered from infection and are immune, endemicity needs a constant and sufficiently large supply of non-immune hosts that is provided through the recruitment of newborns. This requires a host population sufficiently large and interconnected enough to ensure this supply and will vary with the reproductive rate of the host species involved.

Not surprisingly, therefore, the known morbillivirus species have adapted to being maintained in some of the most populous species of mammal on earth. Humans, cattle and domestic buffaloes (combined), and sheep and goats (combined) have global populations of over 7 billion, 1.2 billion and 2.1 billion, respectively. The global populations of domestic dogs and cats is estimated at 600 million each, although the large litter sizes of these species effectively increase their population sizes for CDV and FeMV. The requirement for large host populations may help to identify likely species that could harbour as yet unrecognised morbilliviruses, as recent surveys in rodents and bats suggest (13).

Although individual morbilliviruses are maintained in only one or very few host species, they may infect and cause epidemics of severe disease in a much wider range of species. For instance, MV can probably infect all primates, but, except for humans, their populations are too small and fragmented to maintain virus transmission. The classic studies of Bartlett (66) and Black (67) estimated the size of a closed population required for continuous maintenance of MV to be some 250,000 to 500,000 people, and modelling studies (68, 69) have estimated similar or slightly lower numbers of cattle for the maintenance of RV. With rinderpest, all artiodactyls plus a few laboratory species and carnivores are susceptible to RPV (44). In most of these species RPV fails to transmit continuously either because it does not cause enough clinical disease to excrete sufficient virus or because the population size is too small, whereas the virus does persist in the larger populations of cattle and domestic buffaloes. With PPRV, which has a constantly widening host range of domestic and wild animals (70), the maintenance hosts remain domestic sheep and goats. Canine distemper virus infects virtually all carnivores and a growing range of other species, including wild ungulates such as peccaries (71) and captive non-human primates (72), but the domestic dog is still considered the primary maintenance host. Whether greater control of CDV in the domestic dog alone is enough to stop all transmission of the virus is uncertain. There is growing evidence for a more complex situation in some areas where CDV persists for significant periods either in some non-canine species (73, 74) or in mixed populations of different carnivores (41, 54, 75, 76). The main reservoir hosts for the aquatic morbilliviruses, as opposed to hosts of epidemics, remains unknown, although harp seals (*Pagophilus groenlandicus*) and pilot whales (*Globicephala* spp.), which are both relatively numerous compared with their related species, may be candidates for PDV and CeMV, respectively (77, 78).

Identifying the maintenance hosts for each morbillivirus is essential for targeting disease control and, therefore, for the continuing evolution or extinction of each species of virus. In the case of rinderpest, a strategy focused on control and elimination of virus from cattle and domestic buffaloes led to the global eradication of the disease. Immunisation against MV in humans has brought this disease tantalisingly and frustratingly close to global eradication (79, 80), and the recently launched global programme against PPRV (81) will concentrate on its eradication in sheep and goats. Having eradicated RPV, and with these targeted efforts against the major terrestrial morbilliviruses, the continuing evolution of the genus may have to rely on the aquatic morbilliviruses that have swum beyond the current reach of humans, and on yet undiscovered new species of the genus.

Morbilliviruses in individuals

Pathogenesis, host cell tropisms and specificity

The pathogenesis of morbillivirus infections begins with the inhalation of aerosols containing infectious virus particles into the upper and lower respiratory tract where they bind to and grow in macrophages and/or dendritic cells and immediately draining lymphoid tissue. This is followed by a primary viraemia with infected mononuclear cells including T and B lymphocytes, widespread growth throughout the lymphoid system and then dissemination by secondary viraemia to specific epithelial surfaces (82). Growth with cytopathology in the epithelia of the respiratory, alimentary and urinary tracts causes the typical clinical and pathological signs of the associated diseases, and releases virus into the environment for transmission to new susceptible hosts. Immune system cells and epithelial cells are the major targets for replication of these viruses, with infections in both cell types being important for the transmission cycle of the virus. Strong binding and entry into immune system cells improves the virus's opportunity to infect new hosts and to replicate and develop a systemic infection that leads in turn to the epithelial cells that are essential to allow its release from the body to find new hosts. The morbilliviruses have evolved separate specific binding mechanisms for lymphoid cells and for epithelial cells.

Lymphoid cells

Activated macrophages and mitogen-stimulated bovine and goat lymphoblasts readily support the growth of RPV and PPRV, with each virus better adapted to grow in cells of its primary mammalian host (83). Continuously growing bovine lymphoblastoid cell cultures proved equally sensitive for the isolation and growth of both attenuated and virulent strains of RPV, and of PPRV, and showed that RPV grows in both B and T subsets of lymphocytes (84). Subsequently, a continuously growing marmoset lymphoblast cell line, known to be sensitive for MV, proved equally sensitive for the growth of the Nakamura-L strain of RPV (85). A key receptor molecule involved in T-cell activation that is widely expressed on the surface of activated T and B lymphocytes, macrophages and dendritic cells is the surface lymphocyte activation molecule (SLAM). In 2000, Tatsuo and others identified SLAM as the host cell receptor for MV (86), which was confirmed for CDV (87) and RPV (88), and it is probably the main immune system receptor for all morbilliviruses. The SLAM contains two immunoglobulin-like domains, V and C2, in the extracellular region. A 32-amino-acid peptide in the V domain is the essential binding site for the morbillivirus H protein. Ohishi and others (89) determined the different amino acid sequences of the V domain binding peptides of different host species and showed the close relationship between these in a phylogenetic tree (Fig. 2a), and then compared this with the phylogenetic tree for the H binding sites on the surface of corresponding morbilliviruses (Fig. 2b). Figure 2a clearly shows the close taxonomic relationship between the different sequences of the SLAM binding site, with carnivores, primates, artiodactyls and cetaceans each having their own clusters of species-specific molecules. The striking graphic similarity between Figures 2a and 2b emphasises how close the evolutionary link is between the different host and morbillivirus binding sites. Furthermore, the sequence differences between the binding sites of seal and dog, between cow and sheep, and between human and marmoset is only two amino acids in each case, which may help to explain why morbilliviruses can easily infect closely related host species: for instance, epidemics of CDV in Baikal and Caspian seals, measles infection of marmoset species, and cross infection between RPV and PPRV in cattle and small ruminants.

The specific binding between viral H protein and SLAM has influenced the evolution of the morbillivirus genus and the susceptibility of some of its species to eradication. By determining the maintenance hosts of each virus, this specific binding (90) has determined the overall divergence and evolution of the genus and the opportunities to prevent some infections through the development and use of vaccines. The specificity also constrains the morbilliviruses' ability to evade their host's immune response (91) (discussed further below in 'How SLAM and H protein binding constrains the antigenic diversity of morbilliviruses'). Both these traits contributed to the demise of RPV.

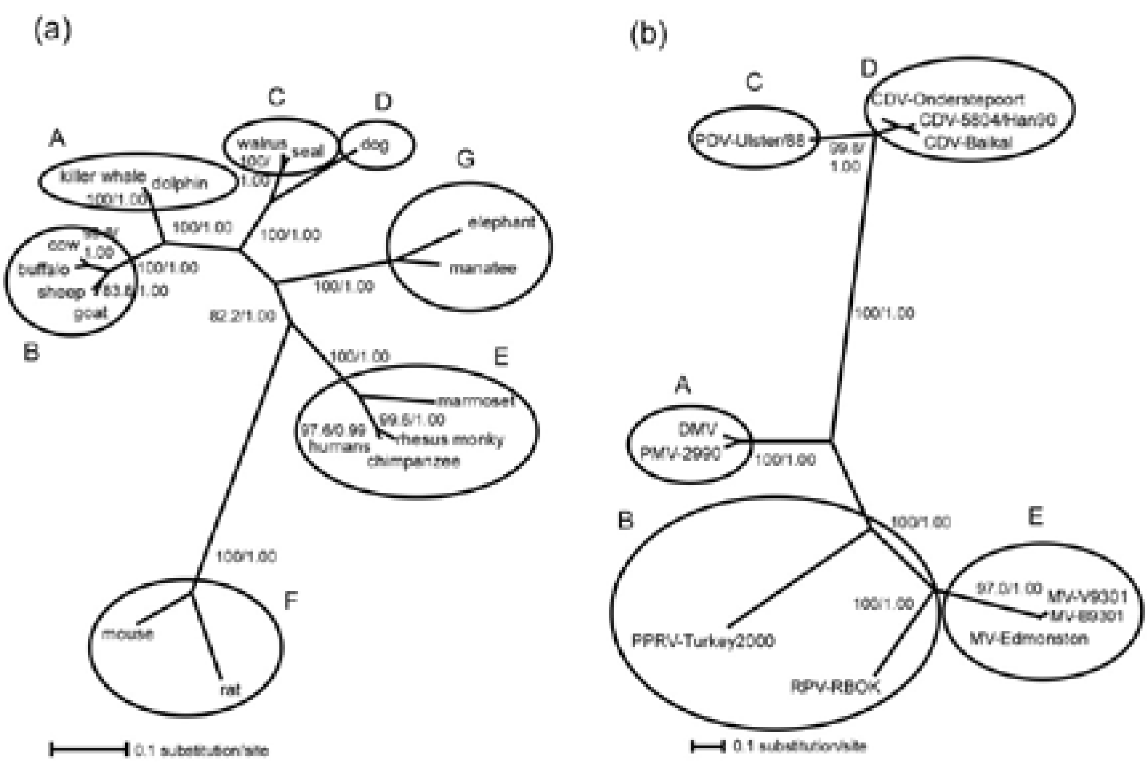
Epithelial cells

The immunoglobulin-like glycoproteinnectin-4, which is important for adherencebetween cells in tissues such as epithelia, hasbeen identified as the receptor for MV on epithelial cells (92, 93). The binding site on the virus is on the H protein, but it utilises domains different from those that bind to SLAM (94), and, as shown above for SLAM and H protein (in section 'Lymphoid cells'), there is a close phylogenetic relationship between the different nectin-4 molecules and the H proteins of the corresponding morbilliviruses (95). In the final stages of the pathogenesis of MV, infection of the primary airway epithelial cells is believed to occur via the basolateral surface, presumably through contact with infected immune cells. Infected T and B lymphocytes migrate into the lung tissue from blood vessels, where they may induce degradation of the basement membrane before travelling between adjacent epithelial cells. The virus then binds to nectin-4 expressed in adherens junctions and enters the epithelial cell where it replicates and is shed apically into the airway lumen to be exhaled into the environment (90). Binding to the nectin-4 site is also the mechanism used by morbilliviruses to infect nerve cells and possibly to establish persistent infections (96, 97, 98). Nectin-4 has been suggested as the epithelial cell receptor for CDV (96) and PPRV (99), and

FIG. 2

PHYLOGENETIC TREES OF SLAM PEPTIDE SEQUENCES (A) AND MORBILLIVIRUS H PROTEINS (b)

Source: Ohishi K. *et al.*, 2012 (87)



in view of the close phylogenetic relations between all morbillivirus species it is probably the epithelial cell receptor for RPV. (The restrictions placed on the handling and use of RPV after global eradication was confirmed in 2011 has meant that many experimental studies with this virus will never be carried out.)

Relating receptors to pathogenicity and transmissibility

Exactly how the binding of these cell surface receptors to different strains of individual morbillivirus species affects the virulence of the resulting infection is uncertain. Comparing the pathogenesis of RPV in experimental infections with a highly virulent strain (RGK/1) and the extremely attenuated vaccine strain (RBOK), Plowright and co-workers (100, 101) showed that virulent virus grew widely and to a high titre in both lymphoid and epithelial tissues, whereas attenuated virus grew to readily detectable levels only in lymphoid tissues, with minimally detectable viraemia, and to much lower levels in epithelial tissues. This closely corresponds with clinical, pathological and epidemiological findings in cattle, in which virulent RPV such as strain RGK/1 causes severe disease, with visible clinical and pathological signs and transmission to susceptible animals, but the RBOK vaccine strain causes no clinical disease, no observable pathology and no excretion to infect other animals.

How SLAM and H protein binding constrains the antigenic diversity of morbilliviruses

Unlike several other negative-strand RNA viruses, such as influenza virus, each morbillivirus has only one main antigenic type or 'serotype'. This high antigenic stability has meant that no change has been required to classic morbillivirus vaccines during decades of use. Most other paramyxoviruses bind to sialic acid residues on host glycoproteins through a specific binding site in the centre of their H surface glycoprotein. Because this site is partially buried, these viruses can accommodate changes in the antigenic sites on the surface of their H proteins without affecting receptor binding and can thus escape vaccine immunity (102). In contrast, all the morbilliviruses seem to use the same, well-conserved SLAM (86, 88, 103) and nectin-4 (92, 93, 99, 104) host proteins as their receptors. Consequently, while sequence analysis shows a residual signature of the sialic acid binding site in morbillivirus H proteins (105) and low level enzyme activity in the expressed H proteins of RPV and PPRV (105, 106), this site no longer seems functionally conserved, presumably because of the move to very specific protein–protein interactions with SLAM and nectin-4. The H protein binding sites for SLAM and nectin-4 overlap with conserved antigenic sites on the surface of the protein (107, 108, 109). The virus is obliged to preserve these sites if it is to retain its ability to enter host cells and to be excreted from the host. Doing this, however, effectively prevents it from escaping the pressure of the immune system following recovery and vaccination.

The immune response to morbilliviruses

Although morbilliviruses are strongly lymphotropic and can be immunosuppressive, most infected animals mount a classic and vigorous immune response to the virus (110, 111). The humoral component has been most easily and widely studied, although cell-mediated immunity is thought to play an important role (112). Virulent strains cause severe, and eventually fatal, pathological change before the protective effects of the response are achieved (112). During infections caused by less virulent or fully attenuated (vaccine) strains of virus, not only are these strains less able to 'attack' the epithelial cells and cause serious disease, the immune system has more opportunity to respond in time to eliminate the virus before it can cause serious pathology in the host.

The solid, usually life-long, immunity found after infection with a morbillivirus ensures that the virus can never reinfect that individual to cause clinical disease with virus excretion. A very small proportion of humans and dogs that recover from MV and CDV, respectively, may develop complications associated with their original infection, such as central nervous signs (113, 114), and possibly Paget's disease in humans and dogs (115), but these sequels do not lead to renewed virus excretion and have no epidemiological significance. Morbillivirus immunity is effectively sterile, and recovered animals play no further role in the epidemiology and transmission of the disease.

The long-lasting and readily detectable antibodies found in nearly all recovered hosts have been vital in studying the epidemiology of all morbillivirus infections, especially for better understanding herd immunity, monitoring control programmes based upon immunisation, and the identification of susceptible species. The reliability of the antibody response also contributed significantly to the downfall of rinderpest. To remove any chance of overlooking mild or subclinical forms of infection during the final stages of eradication, all countries with a recent history of the disease or of using vaccine confirmed their freedom with statistically based seroepidemiological surveys that were expected to show very few if any antibodies in unvaccinated cattle and buffaloes.

EVOLUTION OF RINDERPEST VIRUS: HISTORY, PHENOTYPE AND GENOTYPE

History

Antiquity: 7000–0 BC

Most classic reviews of plagues of humans and animals and of rinderpest begin with a voyage through time quoting recorded outbreaks of severe mortality in cattle that might or might not have been rinderpest (1, 43, 44, 116, 117, 118, 119, 120, 121). These reports centre on deaths in cattle, and, admittedly, few other infectious diseases of this species can inflict the same levels of mortality as rinderpest, although contagious bovine pleuropneumonia, haemorrhagic septicaemia and anthrax can sometimes come close. However, the picture is far from clear because many of these 'ancient' reports of cattle disease also mention concurrent mortality in a wide range of other species, including horses, dogs, rodents and, sometimes, humans, often in the sequence in which they succumbed. The possible involvement of pathogens such as Rift Valley fever virus or *Bacillus anthracis*, both of which can cause severe disease and mortality in a wide range of non-artiodactyl species including humans, has been raised (1). Where only cattle and humans were affected the possibility of a common ancestor of both rinderpest and measles has been suggested (50). The association between severe epidemics in cattle and mortalities in humans may, however, have another explanation. In more recent and well-recorded times, a sequel to severe cattle plague affecting draught oxen was famine, with starvation causing high mortality in humans (122). Since early modern humans also relied on livestock for tilling their crops, such as in ancient Egypt, the source of many historical accounts, it would be understandable for the authors to have seen and recorded the deaths of both cattle and humans as a related episode.

As already discussed, today's morbilliviruses are maintained in large populations of one or very few host species, and it seems reasonable to assume that the common ancestors of today's morbilliviruses would have done the same. Both Scott and Spinage (1, 44) suggested that rinderpest may have 'evolved' in the herds of ancient wild bovines and related herbivores that were common and widespread throughout Eurasia from around 2 million years ago until the modern era. These would have included wild bison and auroch (*Bos primigenius*), from which all modern cattle are derived (123). Catching, taming and handling auroch would have been no easy matter, requiring perhaps centuries of effort to produce stock akin to today's compliant cattle. Nevertheless, it must have been an advantageous step for humans, as the domestication of cattle took place more than once: in Central Asia/the Middle East (*Bos taurus*) (124), South Asia (*Bos indicus*) and Far East Asia (125) (probably *B. taurus*). If wild auroch played a role in the maintenance of ancestral RPV, having either evolved there or been introduced from another source, then its introduction to newly domesticated 'cattle' would almost certainly have followed. Whether the new populations of migratory domestic cattle were large enough and cohesive enough to maintain the ancestral virus themselves or required its periodic reintroduction from wild populations may never be known. Maintainance of the ancestral virus would have benefited from the much larger combined population of wild and domestic bovines between which contact could have been close. Yamna cattle herders, who moved westwards through Europe as recently as 3,000 years ago, encouraged their domestic cows to mate with male wild auroch (126), which would have saved the herders from the risk of keeping dangerous bulls – in the same way, and for the same reason, that domestic and wild gaur (*Bos gaurus*) and even elephants are encouraged to mate in parts of South Asia today.

It is also possible that the domestication of *B. taurus* cattle took place in the 'fertile crescent' (126) where there is ample evidence of their husbandry, somewhat later than sheep and goats, as part of the farming revolution that changed the Neolithic way of life. With little need to hunt or find pasture, people settled to form more sedentary permanent communities, which, as they grew, may have had populations of both humans and bovines large enough to sustain an ancestral morbillivirus and begin its evolution and differentiation into RPV and MV of modern times (50, 67, 127). Unavoidably, the descriptions of what may have been RPV during this era are almost impossible to verify and may remain so unless and until validated by genetic archaeology or paleogenomics.

The Common Era: approximately AD 0–1900

Better record keeping brought better descriptions of possible rinderpest. One of the most widely accepted is by Severus Sanctus describing the plague that decimated Europe's cattle between AD 376 and 386 (1, 43, 44, 45). From then on, reports clearly show rinderpest periodically sweeping west through Europe from endemic strongholds in Russia and further east. Whether the virus became endemic in Europe is uncertain, but the repeated reports of epidemics sweeping from east to west suggests that it may not have done. More detailed study of old records from Europe, Russia and Asia could shed new light on this piece of the rinderpest history jigsaw.

By the 16th and 17th centuries rinderpest or cattle plague was well recognised in Europe and the emerging science of that time identified its contagious nature and the simple sanitary methods needed for its control (128, 129). Sadly, however, the messages had to be reinforced many times before they took hold, especially in Great Britain where institutional memory in 1740 and again in 1866 had quite lost what had been successfully applied and achieved by Bates in 1714 (129).

'Modern' times: 1900 to the present

This period allowed more accurate reporting and detailed study of the disease and, importantly, of the virus itself. Observational studies showed different patterns of clinical disease ranging from the classic severe cattle plague of epidemics to milder forms where the infection had become endemic, together with estimates of how quickly, or how slowly, this change could take place (130). This confirmed that RPV had the ability to evolve into strains that can cause different degrees of clinical disease – effectively, in evolutionary terms, different phenotypes. Discussion of the clinical phenotypes of RPV is complicated by the fact that there are two variables involved, with the virus and the host both influencing the clinical outcome of infection. For instance, a strain of RPV that was very mild, almost attenuated, in zebu cattle could cause severe disease with mortality in Jersey dairy cattle. However, the same type of zebu cattle that were only slightly affected by a mild strain could still suffer severe disease from another strain. Originally it was thought that mildness, especially in cattle, was predominantly due to the host having been selected for 'resistance' following repeated infection of their population and that the virus played little or no role. In view of the very much shorter generation time of the virus, and the resultant much higher number of generation cycles it may pass through in just one animal, let alone a population, it is now appreciated that changes within the virus itself are a significant means for generating new strains with varying clinical profiles (68).

Exactly a century before the last officially reported outbreak of the disease in the world (7) Nicolle and Adil Bey in Turkey (131) confirmed that rinderpest was caused by a filterable agent – a widely accepted test then used for distinguishing a virus from a bacterium. During the ensuing 50 years various physico-chemical properties of the 'virus' of rinderpest were determined, such as inactivation by glycerine and by formalin, its ability to withstand freezing and its sensitivity to heat (summarised by Plowright [45]). In the late 1950s the virus was isolated in cell culture (21), allowing its more detailed study and eventual classification as a morbillivirus. Finally, the development of molecular virology and genetic typing in the 1980s and 1990s provided a powerful new lens through which to view the evolution of RPV alongside those of history and phenotype. Some of the new findings were highly significant for the evolution of the virus. Separate groups of isolates of RPV appeared to have restricted geographic distributions in Africa and Asia (56), confirming that the virus was evolving, albeit slowly.

Phenotype: variation in pathogenicity of the virus

Natural infection

Influence of the maintenance hosts: cattle and domestic buffaloes

A classic feature of rinderpest was that epidemics, especially, as Scott (44) put it, in 'virgin populations', were typified by severe clinical disease with very high case mortality rates: 'cattle plague'. Over time, especially where the infection became endemic, the clinical picture often became less severe and sometimes mild. Early descriptions of clinical rinderpest often referred to this milder syndrome, where one or more clinical signs might be absent or less obvious, as 'atypical'. From an evolutionary standpoint, however, this mild rinderpest should perhaps be considered typical rinderpest, in which RPV and the host had adjusted to a persistent cycle of infection in the population (but not in individual animals) as it may have done for centuries on the Central Asian steppes.

As mentioned earlier, before isolates of RPV from endemic areas were characterised in experimental infections (132, 133), it was widely assumed that the decline in virulence in endemic circumstances was solely or predominantly due to the progressive selection of cattle or domestic buffaloes with innate resistance to the virus – a 'population of survivors' (117). The reputation of Indian hill cattle for being highly vulnerable to strains of RPV that were little more than a nuisance to cattle on the plains is rinderpest lore (134). This was reconfirmed in 1993 when virus spread from the dairy colonies of southern Pakistan, where Red Sindhi (*B. indicus*) cattle showed few clinical signs, to the Northern Areas, where hill cattle died in their tens of thousands (135). It is easy to imagine that the population of cattle in secluded mountain valleys had always been insufficient to maintain the virus and that epidemics died out before resistant hosts could be 'selected'. The same is true for *B. taurus* or 'European' cattle, in which rinderpest was historically maintained in the Grey Steppe cattle (reputedly ancestors of today's Hungarian and Ukrainian Grey cattle) with presumably acceptable levels of clinical disease. However, introductions of RPV through trade or warfare into the cattle of western and southern Europe caused serious 'cattle plague', which either burnt itself out or was eradicated before resistant populations of cattle could be generated. The extreme susceptibility of Japanese and Korean cattle, as opposed to other East and Central Asian cattle, is similarly well recorded.

Differences in the clinical susceptibility of closely related breeds of cattle, separated perhaps geographically, showed that selection for resistance against the virus probably did take place in subpopulations of cattle, as shown by the following series of related events. When Edward's Indian goat vaccine, almost harmless for Indian plains cattle (*B. indicus*), was first tested on *B. indicus* cattle in Kenya it was too virulent to be considered for use. However, after further passaging in goats (inadvertently, as will be discussed in section 'The historical nature of vaccine strains') this same virus became less virulent and suitable for use in East African *B. indicus* (but not *B. taurus*) cattle, and was selected to create what became known as Kabete/Kenya attenuated goat (KAG) vaccine. Then when this vaccine was sent to Nigeria it again proved too virulent for the local *B. indicus* breeds there and required further attenuation to be acceptable. And finally, samples of KAG sent from Nigeria to Cairo required even further passage in goats to be safe for Egyptian *B. indicus* cattle (136).

Influence of other species

Apart from cattle, rinderpest was consistently recorded in small domestic ruminants and wild cloven-hoofed species throughout the 18th, 19th, 20th and 21st centuries (including unspecified deer in South America during the brief introduced epidemic in Brazil in 1921 [137]). In most situations, these species were not considered to be permanent reservoirs of infection (138, 139), other than in South Asia, where small ruminants, in which rinderpest was commonly reported, were thought to be significant hosts for the virus. Undoubtedly, they could transmit the disease to cattle, as proved during repeat introductions to Sri Lanka (see Chapter 4.13.9) (140, 141). How frequent the transmission of virus was from cattle and buffaloes to sheep and goats and vice versa is uncertain, but each change in host population could have been an opportunity for genetic change. There is phenotypic evidence that this was probably happening, because by the 1940s rinderpest in sheep and goats in Pakistan and India was so mild and caused so little disease in nearby cattle that it warranted comment and description (34, 140). Intriguingly, much of what was believed to be rinderpest in small ruminants in India was later ascribed to PPR (58, 142), and rinderpest was eradicated from South Asia without having to resort to vaccination or extensive surveillance for the disease in small ruminants.

The opposite was true with susceptible wild species. In Asia, there was very limited concern about infection of wildlife, which, although often severe, was considered the result of infection from nearby cattle. In Africa, however, especially East Africa where infection persisted long after it had been eradicated from southern Africa by strict control measures, the situation was more controversial. The frequent reports of rinderpest in the wide range of populous wild bovids encouraged extensive debate about a more complicated epidemiology and phenotype and about whether the infection could ever be eradicated from this region (117). The blue wildebeest (*Connochaetes taurinus*) with its high numbers, was thought to be the key species in maintaining RPV independently of cattle. Fortunately, intensive and focused immunisation of cattle with goat-attenuated vaccine (see Chapter 3.5 and section below 'Experimental infection in-vivo') in southern Kenya and northern Tanzania in the late 1950s and early 1960s led to the eradication of rinderpest there, not only from cattle but also from all wildlife.

Nevertheless, although not maintenance hosts, RPV could cycle for months, perhaps even a few years, in African wildlife, which did appear to exert an influence on the virulence of the strains of virus involved. In the 1930s and 1940s, reports began to be filed of rinderpest being milder in cattle when they were infected by virus from wildlife (143, 144). This included a report (145) of local pastoralists deliberately infecting their cattle with 'material' from affected eland (*Taurotragus oryx*) trusting that the ensuing disease in their own animals would not be lethal and would leave them immune to future outbreaks. Although a high-risk strategy (e.g. Carmichael [146] passaged an eland isolate through 20 cattle in Uganda with 100% mortality), the observation on local immunisation with wildlife virus was borne out when Robson and others (132) showed that an eland isolate from Tanzania was mild in both zebu and grade cattle (*B. taurus* × *B. indicus* cross) and remained so for at least nine serial passages in cattle. Clearly, the virus was being sufficiently altered by passage through wildlife for the pastoral cattle keepers to observe this and recognise its significance. Isolates with the same phenotype, moderate to severe disease in wildlife causing only mild disease in cattle, were again found in a buffalo (*S. caffer*) in Tanzania in 1961 (isolate RbuffT/1) (133) and in lesser kudu (*Tragelaphus imberbis*), eland and buffaloes during outbreaks in Kenya between 1994 and 2001 (147). Figure 3 shows several isolates collected from buffaloes and eland at that time, clustering closely as a subclade in Africa lineage 2. Unfortunately, all cattle isolates recovered in the same 1994–2001 epidemic were contaminated with vaccine virus. As Kock (148) observed, rinderpest virus was moving regularly between cattle and wild species in East Africa for many decades. The continual switch between hosts may have resulted in a repeated pattern of change to the virus, with it becoming severe in wildlife and then mild when passaged back to cattle, in which, after a relatively short number of passages, it might revert to a more virulent form (149). Perhaps if wildlife populations had been sufficiently large to maintain RPV independently of cattle, a distinct new African wildlife form of the virus might have evolved. Fortunately, it did not.

A further example of how phenotype and genotype may differ significantly is shown by two contemporary isolates of Africa lineage 2 virus collected from field outbreaks in the early 1960s: the RBT/1 strain, isolated from a sick domestic cow in northern Tanzania in 1961, and the RGK/1 strain, isolated from a sick giraffe near Garissa in Kenya in 1964. Evaluating the clinical syndromes produced by these viruses in similar types of experimentally infected cattle, Plowright and co-workers (100, 133) showed that RGK/1 was one of the most severe and lethal viruses that they had encountered (also confirming that not all RBV isolates from wildlife were mild for cattle), whereas RBT/1 produced very mild, almost subclinical, disease. Although they could not have been more different in their phenotypic expression in cattle, subsequent genotyping shows them both to be closely related in Africa lineage 2 (150) (Fig. 3).

The influence of herd immunity

As already emphasised, fatal 'cattle plague' affecting all or nearly all ages of animal was usually the typical clinical syndrome seen during major epidemics. Under endemic conditions, however, the clinical syndrome, predominantly affecting younger animals, was usually less severe, with lower case fatality rates and often sufficiently mild to require laboratory confirmation. This situation was recognised as early as the 18th century and continued until the last focus of rinderpest in the Somali ecosystem (Chapter 4.4). Virulence, as a reproducible phenotypic expression of the virus, was confirmed by experimental infections. Isolates from epidemic or severe outbreaks consistently produced severe disease (such as was seen by Holmes in India [134] and by Montgomery for the early passage of Old Kabete or Kabete 'O' [151]). Conversely, isolates from endemic infection, such as those from Maasailand in the 1950s and early 1960s, consistently induced mild or very mild clinical signs in experimentally infected zebu and grade cattle (133). The time required to bring about this change in the virulence of the virus, from mild to severe or vice versa, is uncertain and probably variable. After the Great African Pandemic in which rinderpest devastated zebu herds and wildlife in East Africa between 1890 and 1892, a much milder syndrome, initially confused with coccidiosis and even, strangely, malignant catarrhal fever (152), emerged just after the turn of the century and was later proved beyond 'small doubt' (151) to be rinderpest. Perhaps the interlude of 10 to 15 years simply reflects the absence of veterinary investigation at that time because Branagan and Hammond (130) noted that an extremely virulent and invasive (transmissible?) epidemic on the Kenya–Tanzania border in 1945 had settled into an almost unrecognisable syndrome in calves within a year. This tendency towards mild disease in younger animals in endemic populations is unlikely to be due to increased innate resistance in young animals, which, once their maternal immunity has fully waned, are if anything, more clinically susceptible than older stock. The time required for the opposite transformation, from mild to more obvious and serious disease, may be even shorter because reports from Tanzania and elsewhere (130, 149) suggest that where mild virus spreads to groups of susceptible adult cattle it could take only a few weeks for a more typical clinical syndrome to be recognised.

The very much shorter generation time of the virus, measured in hours, provides far more opportunity for rapid change than does the generation time of cattle, measured in years. Virus is transmitted in infected secretions and excretions that are common in animals with typical clinical signs, especially the virulent forms seen in epidemics. In milder disease, however, in which diarrhoea and even mouth lesions may be absent or transient, the amount of virus available for transmission is much less. Based on this, and because the virus within the host exists as a 'swarm' or 'quasispecies' of slightly different genotypes of the agent, it was proposed (68) that in a fully susceptible host population the virus that transmitted most readily between animals would selectively come to predominate, and this would necessarily be virus that caused severe disease. In outbreaks with insufficient susceptible animals, these highly transmissible viruses would run out of new hosts to infect unless the virus could find an alternative survival strategy. Under these circumstances, selection from within the 'swarm' of a variant virus that moved more slowly through the population, never running out of hosts and allowing a more stable and longer lasting host–parasite relationship, would have the advantage. If such a less transmissible virus predominated, it would probably be, in contrast to more transmissible virulent virus, likely to cause less pathology and thus milder disease.

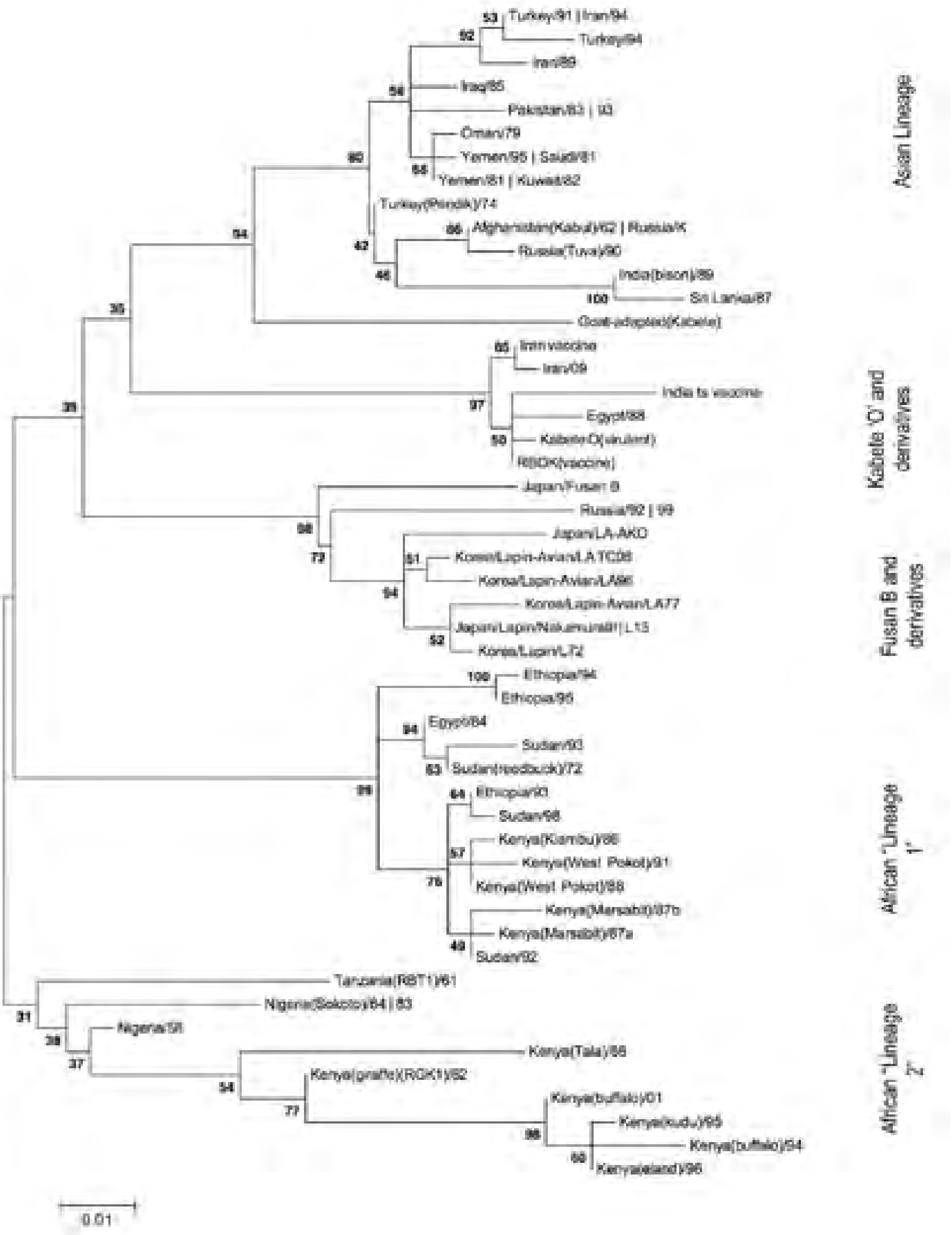
Computer modelling supported this hypothesis, initially with theoretical constructs (68) and then with data from the field (69). In larger populations, it was the immunity in recovered animals

FIG. 3

MOLECULAR PHYLOGENETIC ANALYSIS OF RINDERPEST VIRUS ISOLATES BASED ON F GENE POLYMERASE CHAIN REACTION FRAGMENTS

The evolutionary history of the various RPV isolates was inferred from the sequences of a 322 base fragment of the RPV F gene of each isolate. The tree was constructed from isolates sequenced during the eradication campaign along with genome sequence data published more recently. The tree was determined by using the maximum likelihood method, and the tree with the highest log likelihood is shown. The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. One thousand bootstrap replicates were calculated to provide a measure of confidence in each branch. The percentage of trees in which the associated virus isolates clustered together in the bootstrap test are shown next to the branches. Note that, where two or more RPV isolates had identical sequences over this 322 base region, they are represented by a single sequence, in order to avoid bias in the bootstrap resampling of the dataset, e.g. Turkey/91 and Iran/94. Only isolates for which the complete 322 base sequence was known have been included. The analysis was conducted in MEGA6

Courtesy of the authors



Just how mild these viruses were in the endemic areas is illustrated by an anecdote from Kenya in the early 1960s. A group of Maasai stock owners visited the government veterinary office in Ngong to collect anthelminthic drugs for their animals. Leaving to continue their trip to the nearby market, they casually mentioned to the then colonial veterinary officer that their calves had rinderpest and that, although they were not concerned about the disease, he was welcome to go to their homestead if he wanted to do something about it.

that effectively removed susceptible hosts for the virus and thereby influenced the generation of new phenotypes of the virus. Efficient vaccination had the same effect of very rapidly removing all susceptible hosts from the population, leaving the virus nowhere to survive. On the other hand, suboptimal levels of vaccination (as occurred when vaccination became an institutionalised annual task rather than a tool focused on a clear objective) may have helped create the conditions for endemicity by ensuring that a small but sufficient proportion of older unvaccinated cattle were available to boost calf numbers and maintain a slowly transmitting mild virus.

Where RPV could exist in a constant transmission cycle there can have been little requirement for significant evolutionary change. Rinderpest was maintained in the large dairy colonies of Karachi, Pakistan, from the 1970s until the late 1990s. During that time, the disease had settled into a stable epidemiological situation, in which it caused clinically obvious albeit usually non-lethal disease in domestic buffaloes, and in this population it was maintained by large daily supplies of susceptible new buffaloes from elsewhere in Pakistan. Limited analysis of a fragment of the F gene of two isolates, RPak83 and RPak93, collected a decade apart from the Landhi Dairy Colony (Fig. 3), failed to distinguish them, suggesting that this Asian lineage of virus may have evolved very little during that time, possibly because it was under no pressure to do so or had no opportunity.

Experimental infection (and the production of attenuated vaccines)

Experimental infection in vivo

An account of the development and use of live attenuated RPV vaccines is included in Chapter 3.5 in this book. The topic is briefly addressed here only because the development and subsequent use of vaccines were selection pressures that provided opportunities for evolutionary changes.

Goat (caprinised) attenuated live vaccine was first successfully produced by Edwards in 1927 at Mukteswar in India (153). Intending to produce infectious material uncontaminated by other bovine pathogens for use in the double inoculation technique for immunising cattle, Edwards and Sterling (154) found that after passaging virulent 'bull' virus through goats for two years, it could be inoculated into *B. indicus* 'plains' cattle without the ameliorating effects of immune serum. Although the virus was still too virulent for *B. taurus* cattle, and for Indian hill cattle, the search for the first live vaccine against rinderpest was over. Almost immediately, from 1928, the original vaccine was released for use and production throughout South Asia and exposed to possible evolutionary pressures through widespread passage in different types of goat. In 1935, it was sent to Burma and from there to Thailand in 1937 and back to Madras in India in 1939. In 1937, the annual report of Mukteswar shows goat blood and tissues being sent to 'foreign' countries.

The benefits of caprinised vaccine were not lost on veterinary authorities in Africa. In 1931, the veterinary department in Nigeria was attempting to use goats both as carriers for cattle virus and to attenuate virus. In 1934, after 934 passages of local cattle RPV in goats, with few signs of any reduction in virulence for cattle, the Nigerian veterinary authorities, no doubt severely frustrated, decided that attenuation would not work in African goats, only in Indian ones! In 1937, the Mukteswar virus was sent from India to Kabete in Kenya where it was deemed too virulent for Kenyan cattle, and a local virus was selected for development as KAG, which was widely and successfully used throughout Africa from 1939 until the introduction of cell culture vaccine in the mid-1960s. The genotype of this virus and its origins are discussed further below in 'The historical nature of vaccine strains'.

Unfortunately, caprinised vaccine was too virulent for highly susceptible *B. taurus* breeds of cattle in both Africa and Asia and for domestic buffaloes (*Bubalus bubalis*) and mithuns (*B. frontalis*) in Asia. Consequently, Nakamura and colleagues in Japan, which was free of rinderpest but had suffered severely in the past (Chapter 2.1), began in 1934 to passage in rabbits the highly virulent Fusan strain of RPV from Korea. They developed a lapinised virus innocuous enough for use either alone as a vaccine in many East Asian cattle, including those of Mongolia, or with simultaneous inoculations of small quantities of immune serum in exceptionally susceptible Japanese and Chinese breeds (155) (Chapter 3.4). In the late 1940s and early 1950s, the newly established FAO promoted and distributed the

L strain of lapinised vaccine to multiple laboratories throughout Africa and South Asia, where it was safe in *B. taurus* cattle, N'dama-type West African breeds and Indian hill cattle, although it remained highly virulent for several wild East African artiodactyls (156). The pattern of change for caprinised and lapinised viruses was similar – multiple passaging through the chosen atypical host, progressively selecting a virus that was more virulent for that host species and, usually after a further period of passage, less virulent for cattle (mimicking the reduction in virulence for cattle of virus that had been passaged in wildlife – see 'Influence of other species'.

An additional selection pressure created by humans may also have changed the virulence, transmissibility and host preferences of the virus. Transmission by needle passage appeared to favour selection of viruses that did not need to transmit themselves: goats and rabbits infected with caprinised and lapinised RPV did not readily transmit infection, nor did cattle infected with these vaccines. Something similar had also occurred with the virulent laboratory strain of the Kabete 'O' virus. The original isolate was collected from an outbreak in which mortality rates of 20% to 57% were reported in different herds, and it killed only 6 of the first 53 crossbred (*B. taurus* × *B. indicus*) steers into which is was experimentally inoculated (157). Some 40 years later, after continuous needle passage from infected to susceptible cattle, it had become one of the most lethal strains known, killing more than 90% of all inoculated cattle. During this prolonged passage it also lost its ability to cause mouth lesions and to transmit readily between cattle: a useful characteristic for a virus routinely used to challenge cattle inoculated with each new batch of vaccine (158, 159). A similar loss of transmissibility was reported also for the stock virulent Fusan strain of RPV that was maintained in cattle by needle challenge (more details in Chapter 3.5). It is tempting to speculate that the needle passage progressively selected viruses that did not require epithelial lesions to ensure their natural transmission and survival and that had no need to naturally balance their transmission rate with the availability of new susceptible hosts (continuously provided by humans), and, therefore, there were no constraints on their virulence.

The widespread use of rinderpest viruses attenuated in atypical hosts, especially caprinised vaccine, was not without its problems, some of which might have provided opportunities for RPV to evolve further or compete with another morbillivirus, PPRV. Crawford (140) considered that the extensive use of caprinised vaccine in India had led to an increase in rinderpest in goats and sheep, which had been uncommon or rare before and was responsible for transmission of rinderpest to cattle in previously disease-free areas. This 'new' problem of rinderpest in small ruminants continued in India even after cell culture vaccine (see below) became the vaccine of choice (caprinised vaccine finally ceased to be used in India as late as 1991). Later investigation showed that much or most small ruminant rinderpest in India was PPR (58, 142), and, as already mentioned, rinderpest eradication was achieved there without requiring vaccination of small ruminants. Whether PPRV was responsible for the increase in small ruminant disease that Crawford referred to as rinderpest may be impossible to know, but one can speculate on the impact that PPRV might have had in a country with numerous institutes making RPV vaccines through inoculating tissues from thousands of infected small ruminants into hundreds of thousands of goats, and on where some of these vaccines may have been exported to.

Experimental infection **in vitro**

The first attempts to grow RPV in cultures of isolated cells were undertaken in the mid-1950s, using strains previously adapted to goats, rabbits or eggs and primary cells homologous to the animals in which they had been adapted or using primary bovine cells. None of these attempts was successful, and the first cell culture-grown RPV was achieved with the direct adaptation of the virulent rinderpest bovine old Kabete (RBOK) strain (usually referred to as Kabete 'O') of RPV to bovine kidney (BK) cells (21). A cytopathic effect was not seen until the fifth passage in BK cells but thereafter was easy to observe. Interestingly, the virus became more pathogenic for cattle over the first ten passages (160), perhaps due to the elimination of defective interfering (DI) particles. Unfortunately, those early isolates have not been preserved for genetic study. From the 16th passage, the virus progressively began to lose virulence; from the 21st passage only febrile reactions were seen and none of the characteristic clinical signs of rinderpest. Virus of the 70th, 90th and 120th passages was fully attenuated, and virus of the 90th passage remained attenuated through seven back passages in cattle (161).

The process underlying the selection of an attenuated variant in cell culture is unlikely to have been the same as for caprinised and lapinised viruses. First, the speed of attenuation of the virus in different systems was quite dissimilar: only 90 passages were required in BK cells, compared with nearly 400 passages in rabbits and over 650 passages in goats (and caprinised virus was never fully attenuated for cattle). Possibly, the more extreme the deviation from a natural host system, the more rapid and complete the attenuation. Epithelial tissue used to produce the BK cell cultures is not the primary target for RPV, whereas immune cells bearing the SLAM receptor would be found in whole animals such as rabbits and goats even if the H protein–SLAM binding affinity was not optimal. Adaptation to the BK cells, however, required adapting to a new receptor (88) as well as a different type of host cell. Second, the much quicker selection of an attenuated virus in cell culture using terminal-dilution passage (162) confirmed the quasispecies nature of the original virus and that both virulent and naturally attenuated variants were probably present together in the same virus 'swarm'.

GENETIC VARIATION

Diversity in rinderpest virus

The use of the nucleotide sequence of a defined region of the F gene (see earlier section 'On virology and taxonomy') of RPV to identify a specific lineage of the virus, and to provide information about the relationships between different virus isolates, was first proposed by Barrett and his team (56). These original studies with the fragment of F gene revealed three main related groupings or lineages of the virus: Africa 1, Africa 2 and Asia, with the Kabete 'O' group (including the cell culture attenuated vaccine) forming a distinct group of their own. Within Africa it appeared that lineage Africa 2 had been widely dispersed from west to east, whereas lineage Africa 1 was restricted to eastern and north-eastern Africa (as discussed in Chapter 1.2). Lineage Asia 1 was restricted to Asia. There was no evidence that in modern times, from 1950 onwards, confirmed outbreaks of rinderpest in Asia were due to African lineages or that any in Africa were due to the Asian lineage of virus.

More recent work in which the sequences of a larger number of field isolates were compared with the original data shows a more complex picture in which the concept of three clearly defined main lineages may be too rigid (Fig. 3).

For instance, 'African lineage 2' includes several older isolates that cluster there only about 30% of the time in the bootstrap tests and may be individual representatives of separate clades, implying greater genetic diversity, possibly resulting from earlier separation of the different clades. The 322 bases of the F gene, which is all that is available for most RPV isolates, is too little to be the basis of a detailed analysis of relationships within clusters: in many cases, there are only two or three bases that are different between isolates. Nevertheless, the sequence data show that viruses collected from specific epidemics, for instance the Kenya wildlife isolates from 1994 to 2001, are slightly different from each other, implying slow ongoing evolution of the virus under those circumstances. In contrast, the complete identity of the two isolates in 1983 and 1993 from the Landhi Dairy Colony in Karachi, Pakistan, where endemic rinderpest was maintained through the constant introduction of new susceptible buffaloes, suggests a very steady state in which the virus probably had no pressure to evolve. However, Nigeria 64 and 83 which also appear to be identical at the F gene fragment, are very unlikely to be representatives of a steady endemic state – the virus having been effectively/apparently eradicated there in the period between isolating Nigeria 63 and the re-introduction of virus in two major epidemics in1982 and 1984.

Most recently, as part of the global drive to reduce the risk that RPV poses to a rinderpest-free world, the complete genomes of as many isolates of the virus as possible are being sequenced before their destruction. The first detailed report of this work, from the former World Reference Laboratory for Rinderpest at the Pirbright Institute, United Kingdom of Great Britain and Northern Ireland, now provides what may be the last word on RPV strains and their evolutionary relatedness (163). The overall picture is one of broadening genetic diversity. There is less evidence for the development of distinct clades or lineages, as found when comparing smaller specific gene fragments, and it may be that the diverse range of African viruses are derived from just one introduction.

The historical nature of vaccine strains

Recently available sequences from Japanese and Korean isolates and their derived vaccine strains, and from the Kabete 'O' lineage, show that the two virus 'parents' and their descendants are different from those of the other lineages, possibly because of their age (Fig. 3). The Fusan strain, isolated in Korea in the early 1920s and its vaccine offspring cluster quite distinctly from the other Asian strains (Fig. 3). Similarly, the Kabete 'O' strain, obtained in Kenya in 1910 just over 20 years after the start of the Great African Rinderpest Pandemic in 1887 (see Chapter 2.2) and then maintained (see section 'Experimental infection *in vivo*') by needle passage in cattle for over 40 years, is clearly distinct from the other known African strains. As already discussed, maintaining RPV by needle passage appeared to remove its ability to spread, which probably restricted or removed its opportunities to evolve and diversify. Most historical reports suggest that the Great African Pandemic was due to the introduction of cattle from Asia into Africa, possibly through what is Eritrea today (1, 117, 164, 165), and the Kabete 'O' lineage clusters loosely with the main Asian cluster.

One Kabete 'O' descendant, however, is notably different from the rest of its supposed lineage. The KAG vaccine virus is more strongly related to the main Asia lineage than to Kabete 'O' and especially to Indian goat vaccine virus (Fig. 4) (57). This is highly unlikely to have happened under natural conditions. When caprinised vaccine from Mukteswar in India arrived in Kenya around 1937 the Veterinary Research Laboratory immediately embarked on transmission studies with the Indian vaccine, which was soon found to cause unacceptable levels of disease in East African cattle. At that time, the laboratory was concurrently passaging at least four other local strains of RPV, including Kabete 'O', in goats and cattle. Accepting that the Indian virus was too virulent for use as a vaccine in East Africa, a local strain, believed to be Kabete 'O', was chosen for further passage in goats. This work led to a suitably attenuated virus that was developed as the vaccine now widely known as Kabete attenuated goat or KAG (136). Through genotyping it now appears that the origins of the KAG virus are in India not Africa, as previously thought. This is almost certainly a consequence of cross-contamination during the process of repeatedly passaging so many viruses simultaneously.

There is perhaps no better example of the overall stability and antigenic homogeneity of RPV than that KAG vaccine from Asia made a significant contribution towards virtually eradicating RPV from much of Africa during the JP15 campaign and that Plowright's Kabete 'O'-derived cell culture vaccine from Africa played the main role in finally eradicating rinderpest from Asia. Despite the introduction of different lineages of RPV to different hosts in different continents, the virus was unable to take advantage of these opportunities to evolve further.

Relating genotype to phenotype

Despite the varying virulence for cattle of most isolates of RPV, there is no clear linkage between lineage and virulence: for instance, both mild and highly virulent strains of Africa lineage 2 were isolated from East Africa in the early 1960s. The relationship between virulence and attenuation, and different genetic sequences were investigated in virulent Kabete 'O' and the Plowright vaccine strains and although many changes were found throughout the genome, none appeared to be critical for attenuation (167). Deeper insight came from a series of recombinant Kabete 'O' viruses in which whole or partial genes were replaced with the equivalent sequence from the vaccine strain (168). These studies found that almost every gene carried at least one attenuating mutation, as did the promoter regions at the beginning and end of the genome (169). This multiplicity of attenuating features, in which no single mutation could restore virulence, is probably the reason why the vaccine proved to be so very stably attenuated and unable to revert to the pathogenic phenotype.

Likewise, the original highly virulent Fusan strain (passaged approximately 1,000–1,500 times in Korean cattle and then 219 times in Japanese black cattle or Holstein cattle) and its derivative L vaccine (Nakamura III) (passaged approximately 500 times in Korean cattle and then 1,261 times in rabbits [170]) were compared at the molecular level for evidence of attenuating genes. This study compared rates of substitution and change of nucleotides in the different genes of each virus and compared these with deduced amino acid sequences (171). The C and V proteins of morbilliviruses are not essential for replication in tissue culture but are known to be virulence determinants through their ability to counteract the innate immune responses to viral infection, such as interferon production. The results suggested that the C and the V genes of RPV contributed to its pathogenicity for cattle and that the P gene (from which C and V are derived) was a major determinant of cross-species pathogenicity (172). Accordingly, nucleotide/amino-acid substitutions in the P, C and V genes were speculated to be one of the key factors determining the different pathogenicity for cattle of the Fusan and L strains. Further comparison of the L strain and the more attenuated LA-AKO strain showed a 13 amino acid difference in the base sequences of the F protein (173).

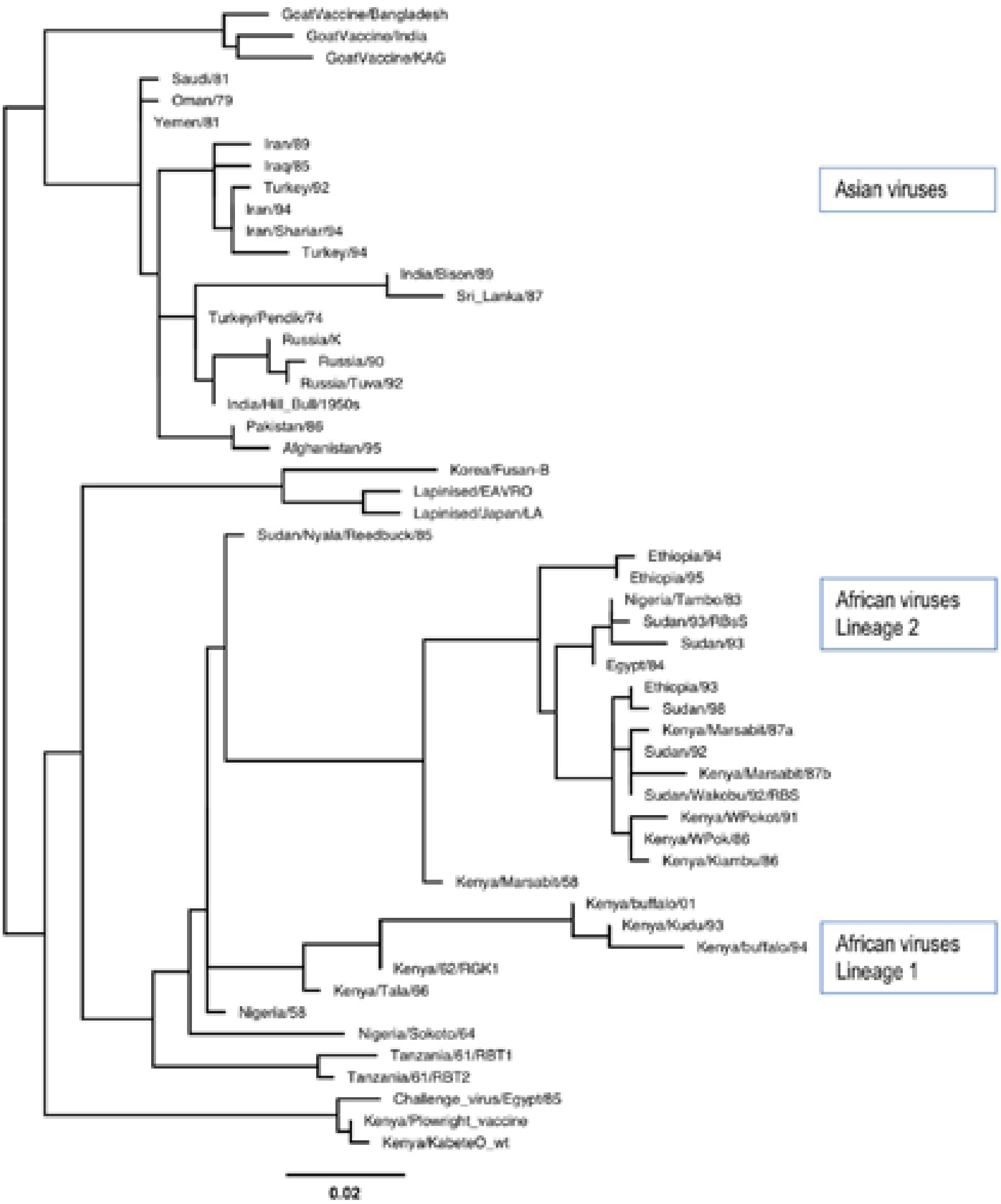
Molecular determinants of virus host range and of pathogenicity were also investigated by using recombinant viruses in rabbits in which the L strain causes severe rinderpest and the virulent (for cattle) Kabete 'O' strain has no visible effect. The H, N, and P genes of the Kabete 'O' strain were replaced stepwise with those of the L strain. Replacement of H protein, necessary to bind to the SLAM cellular receptor, of the L strain did not induce virulence. Recombinant viruses with the H and the P gene from the L strain induced some but not full pathogenicity in the infected rabbits and are considered important determinants of cross-species pathogenicity (172, 174). Involvement of the L gene in the cross-species pathogenicity was also examined in the same way and it was found that the effect was very limited. In other studies, the genomic and antigenomic promoter (GP and AGP) activity of the Kabete 'O' and L strains on viral RNA was significantly different in cultured cells (175). Recombinant RPVs in which the GP/AGP regions of the Kabete

FIG. 4

PHYLOGENETIC TREE SHOWING THE RELATIONSHIPS BETWEEN THE DIFFERENT ISOLATES OF RINDERPEST VIRUS BASED ON PARTIAL SEQUENCE DATA FROM THE FUSION (F) PROTEIN GENE

A specific primer set was used to amplify a 372 bp DNA fragment as described by Forsyth and Barrett (1995). The tree was derived using the PHYLIP DNADIST and FITCH programmes (Felsenstein, 1990 [166]). The branch lengths are proportional to the genetic distances between the viruses and the hypothetical common ancestor that existed at the nodes in the tree. The numbers on the figures represent the year of isolation

Source: Barrett, 2001 (57)



'O' strain and L strain were exchanged revealed that the leader sequence of RPV also plays a significant role in pathogenicity (C. Kai and co-workers, unpublished data). As with Kabete 'O' and its vaccine derivative, the highly stable attenuation of the vaccines derived from Fusan virus seems to be due to changes at several sites in the genome.

Some differences in genotype can be related to minor differences in antigenicity. Early work showing that certain antisera could distinguish between different strains of RPV (133, 176, 177) culminated in the use of monoclonal antibodies to distinguish different strains and lineages of the virus (178). The potential for using monoclonal antibodies as a typing system for the virus was overtaken by the concurrent development of genetic typing. The availability of these monoclonal antibodies, however, led to a new generation of ELISAs for antibody detection in animals and serosurveillance. One of these ELISAs, the competitive (c)-ELISA (179) (see also Chapter 3.3) was based upon competition between serum antibodies and a monoclonal antibody raised against Kabete 'O' vaccine virus. This monoclonal antibody bound strongly to Kabete 'O' and to lineages Africa 1 and Asia, but only weakly, if at all, to lineage Africa 2 virus (178). When used in the field, antibodies were not detectable in cattle during the initial stages of infection with lineage 2 virus, whereas the test worked well in vaccinated animals and those infected with the other two lineages. Fortunately, the humoral immune response in infected animals broadens as it develops and RPV-specific antibody eventually became detectable using this assay in most animals infected with lineage Africa 2 (180). The c-ELISA went on to be widely and successfully used to confirm the absence of all lineages and strains of RPV in Africa and much of Asia, but the episode showed, for probably the only time, a practical aspect of the slight but steady evolution of the virus and that genetic and antigenic diversity in RPV could be more than theoretical branches on a phylogenetic diagram. Fortunately, this was perhaps as close as RPV ever came to escaping the immune response, and it failed.

REASONS WHY RINDERPEST WAS THE FIRST MORBILLIVIRUS TO BE ERADICATED

As mentioned in the introduction, RPV, like smallpox virus before it, had features that predisposed it to eradication. These included causing a disease with, usually, clearly recognisable clinical signs, no carrier state in recovered animals, simple and sensitive diagnostic tests (111), life-long immunity with long-lived detectable antibodies in recovered and vaccinated animals and those infected by very mild strains (181, 182, 183), just one main serotype, and excellent immunogenic and safe vaccines – all of which played their part in eradication. But these features are shared with many other viruses, including other morbilliviruses, so why was RPV the first member of the genus to be eradicated?

While the virus's reliance on the H protein–SLAM receptor binding mechanism was an effective mechanism for infecting and potentially compromising the host's immune system, it had two major and very final negative implications for the virus. The first of these was the specific binding of RPV to ruminant, particularly bovine, cells. This ensured that RPV became reliant on cattle and buffaloes for its survival and is probably the main cause of its demise. The severe socio-economic losses caused by the virus in one of humankind's oldest and most treasured assets meant that rinderpest was long earmarked for attention. While the origins of RPV (and MV) may lie in cattle ancestors that in ancient times might have outnumbered humans, the situation today is quite different. Current global populations of cattle and buffaloes are significantly less numerous than the human population, and their movements are far more rigidly controlled than those of humans, the host of MV. Because of this, eradication of rinderpest from countries in western Europe, and elsewhere, was possible long before the advent of vaccines, whereas such methods of control were, and still are, more difficult with measles or canine distemper. When vaccines became available, cattle and buffaloes worldwide were readily accessible for vaccination (especially where appropriate methods of delivery were used [184]), and their owners, unlike human parents, were less likely to refuse vaccination on religious or unfounded scientific grounds.

The second feature of the H protein–SLAM binding mechanism contributing to the eradication of RPV was the inability of the virus to develop antigenic variants to evade immune pressure. As increasingly effective vaccines were produced against RPV, this weakness in the virus was fully exploited, leading to its global eradication at the start of the 21st century. The same weakness, despite difficulties posed by the more infectious nature of MV compared with RPV (requiring higher levels of herd immunity for full control) or the faster recruitment rates of small ruminants as opposed to cattle for PPRV, should surely allow the eradication of MV and PPRV in the foreseeable future and eventually perhaps even CDV.

CONCLUSION

The origins of rinderpest virus remain uncertain, and the main sources of information give quite divergent timings for its evolution. Interpretations of early human history suggest that the disease may have been associated with ancestral cattle herds and wild bovids in Central Asia or in domestic cattle and buffaloes in the Egyptian or Mesopotamian cultures. In the historical era, written descriptions of a clinical syndrome that appear to be rinderpest indicate that it was present from at least the fourth or fifth century and became well recognised during the 'Enlightenment' (~1685–1815). More recently, genetic analysis predicted RPV's origin from a common ancestor in the 11th to 12th centuries (51). More detailed analysis and comparison of the genomes of RPV isolates and the other morbilliviruses is needed to unravel the origin of 'common ancestors' of the genus and, eventually, of RPV itself.

Although we do not yet fully understand the origins of RPV, we can point to key elements of its evolution that contributed to its demise. If the virus emerged on the Asian steppes in large herds of wild bovines then this was its most successful period – free to transmit and under no external pressure. This would have continued even when it adapted to domestic cattle on a regular or permanent basis. In fact, this would have conferred an important evolutionary advantage on the virus, as its former wild hosts were gradually reduced to less numerous and fragmented populations eventually incapable of supporting it. But this new advantage came at a cost: cattle were too valuable to humans, who were unable to accept and live with the losses that the virus caused. Following the success of the strict animal movement controls of Lancisi and Bates against RPV, humankind waged for almost 300 years an increasingly effective war against the virus, culminating in the final search and destroy techniques of the Global Rinderpest Eradication Programme (GREP). Locked into cattle by its highly specific cell receptor and unable to adapt to a different permanent host or develop new antigenic serotypes, the virus could not evade the pressure applied to it by humans and their vaccines and so, unsuccessful at last, became the first morbillivirus to be eradicated. The demise of RPV and the beckoning eradication of other infamous morbilliviruses of humans and their domestic animals is, however, a relatively small setback for the genus. The morbilliviruses stand a much better chance of long-term survival through their members that have established themselves in hosts beyond humans' current reach, such as wild aquatic mammals, assuming that humankind allows these hosts to survive too.

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CHAPTER 1.2

THE CLINICAL DISEASE AND POST-MORTEM APPEARANCE OF RINDERPEST

P. ROEDER [(1)], G. LIBEAU [(2)] & W. TAYLOR [(3)*]

(1) Hollyhedge Cottage, Spats Lane, Headley Down, Hampshire GU35 8SY, United Kingdom (Former Secretary of the Global Rinderpest Eradication Programme, Food and Agriculture Organization of the United Nations [FAO], Rome)

(2) Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), UMR ASTRE, and Université de Montpellier, F-34398 Montpellier, France

(3) 16 Mill Road, Angmering, West Sussex, BN16 4HT, United Kingdom (Former Head, Department of Bluetongue and other Exotic Diseases, Animal Virus Research Institute, Pirbright [now the Pirbright Institute], United Kingdom)

*Corresponding author

SUMMARY

The discharges of animals affected by rinderpest were infectious and, irrespective of the form of the clinical disease, fresh cases could arise only from contact between an infected and a susceptible animal. At the end of an incubation period ranging from 4 to 11 days, classic signs of rinderpest in cattle developed over the course of a six- to ten-day period, during which time affected animals were constantly febrile.

Initially, animals showed non-specific clinical signs, i.e. inappetence, depression and serous discharges from the nose and eyes plus excess salivation. Within a few days the mucous membrane of the oral cavity developed focal necrotic lesions on the lower lip, gums, cheek papillae, underside of the tongue and nasal septum – signs against which a diagnosis of rinderpest could be made. As the disease progressed, the nasal and ocular discharges increased in volume and became mucopurulent, while the extent of the oral necrosis also increased, with lesions becoming coalescent and denuded of epithelium. Affected animals usually developed diarrhoea and became recumbent; in around 70% of such cases death quickly followed.

While such lesions and outcome were associated with the classic form of the disease, a peracute form existed and was characterised by a brief pyrexia and 100% mortality, prior to the development of classic clinical signs. Equally, mild forms of the disease existed in which little more than a low-grade pyrexia developed. The post-mortem lesions described here relate to the acute form of the disease. Experienced clinicians could generally diagnose rinderpest using a combination of clinical and post-mortem signs, but for the mild or peracute forms confirmatory antigen detection or virus isolation results were required (see Chapter 3.3).

KEYWORDS

Anorexia – Depression – Incubation period – Pyrexia – Mucous membranes – Necrosis – Peracute – Rinderpest – Subacute.

RINDERPEST IN CATTLE AND DOMESTIC WATER BUFFALOES

Classic acute rinderpest

The incubation period between infection and the first signs of illness could be between 4 and 11 days (1). At the end of this incubation period, the infected animal developed a pyrexia lasting between six and nine days. Measured from its onset, the temperature of the sick animal climbed steadily for the first two to four days to between 40 °C and 41.5 °C. During an initial prodromal period, the animal would show reduced rumination, reduced milk production, constipation, partial anorexia and depression. Affected animals became restless and separated themselves from the remainder of the herd. In addition, there could be excess salivation (Fig. 1), the mucosae of the eye and nose would be congested, accompanied by light serous discharges (Fig. 2), and there would be a dry muzzle (Fig. 3). This period of non-specific malaise generally lasted two to three days.

The prodromal period ended with the appearance of a series of highly characteristic necrotic mouth lesions – ushering in the start of a four- to five-day period of acute illness. Although causing the animal considerable pain, a detailed examination of the inside of the mouth was necessary and could lead to a diagnosis of rinderpest. Commencing at the height of pyrexia, foci of necrotic epithelium made their appearance on the nasal septum (Fig. 4) – where they were often obscured by the mucopurulent

FIG. 1
EXCESS SALIVATION
Source: FAO EMPRES Photo Library

FIG. 2
SEROUS OCULAR DISCHARGE
Source: FAO EMPRES Photo Library

FIG. 3
DRY MUZZLE
Source: FAO EMPRES Photo Library

discharge – on the inside of the lower lips and gum (Fig. 5) and on the margin between the upper gum and the dental pad (Fig. 6); similarly lesions could also be found on the underside of the tongue (Fig. 7) and on the dental caruncles. At the same time, the epithelium of the cheeks and the cheek papillae became denuded (Figs 8 and 9).

In quick succession, additional foci appeared while previously existing ones enlarged and coalesced so that, from one day to the next, the distribution and extent of the necrotised epithelium could increase dramatically (Fig. 10). Owing to movement of the tongue, much of this necrotic material became detached leaving shallow, non-haemorrhagic ulcers (Figs 11–14).

In addition, during the acute phase the discharges from the eye (Fig. 15) and nose (Fig. 16) became more profuse and mucopurulent, while at times the muzzle might desquamate (Fig. 17). During this erosive phase, necrosis might also be observed in the vulva and vagina, and on the preputial sheath.

Diarrhoea was another characteristic feature of rinderpest and developed one to two days after the onset of mouth lesions. The diarrhoea was usually copious and watery at first (Figs 18 and 19), but later in the course of the disease might contain mucus,

FIG. 4

FOCAL NECROSIS OF EPITHELIUM OF NASAL SEPTUM (SMALL WHITE AREA AGAINST PINK BACKGROUND)

Source: Pirbright Institute

FIG. 5

FOCI OF EPITHELIAL NECROSIS ON LOWER LIP AND GUM

Source: Pirbright Institute

FIG. 6

NECROTIC EPITHELIUM ON BOTH UPPER AND LOWER GUMS

Source: Pirbright Institute

FIG. 7

FOCI OF EPITHELIAL NECROSIS ON ANTERIOR OF UNDERSIDE OF TONGUE

Source: Pirbright Institute

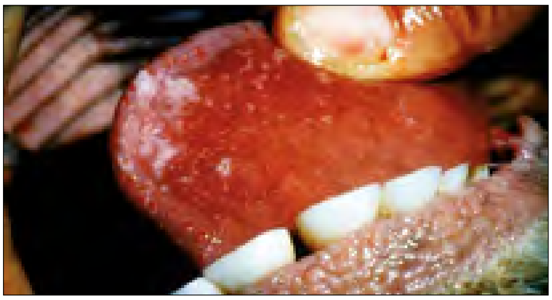


FIG. 8

DENUDED CHEEK PAPILLAE

Source: Pirbright Institute

FIG. 9

NUMEROUS EROSIONS ON AND BETWEEN THE BUCCAL PAPILLAE

Source: Plum Island Animal Disease Center, New York

Photo ID: RP_005

FIG. 10

ENLARGING AREAS OF EPITHELIAL NECROSIS

Source: Plum Island Animal Disease Center, New York

Photo ID: RP_003

FIG. 11

EXTENSIVE LOSS OF EPITHELIUM OF LOWER GUM

Source: Pirbright Institute

FIG. 12
EXTENSIVE NECROSIS ON UNDERSIDE OF TONGUE
Source: Pirbright Institute

FIG. 13
ENLARGED FOCI OF EPITHELIAL NECROSIS ON LOWER GUM AND COMPLETE LOSS OF EPITHELIUM ON UNDERSIDE OF TONGUE
Source: Plum Island Animal Disease Center, New York

FIG. 14
EXTENSIVE NECROSIS OF HARD PALATE
Source: FAO EMPRES Photo Library

FIG. 15
MUCOPURULENT OCULAR DISCHARGE
Source: Centers for Disease Control/Brian W.J. Mahy, BSc, MA, PhD, ScD, DSc. Courtesy: Public Health Image Library

FIG. 16
MUCOPURULENT NASAL DISCHARGE
Source: Pirbright Institute

FIG. 17
DESQUAMATING MUZZLE
Source: P. Roeder

blood and shreds of epithelium, and in severe cases it could be accompanied by tenesmus.

On an individual basis, the outcome of the infection would be determined during the erosive phase of

FIG. 18
ANUS OF COW SOILED WITH DIARRHOEA
Source: P. Roeder

FIG. 19
RINDERPEST DIARRHOEA IN DOMESTIC WATER BUFFALO CALF
Source: P. Nicoletti/P. Gibbs

the disease. In surviving cases, the pyrexia remitted slightly in the middle of the period and then, two to three days later, the temperature rapidly returned to normal, accompanied by a quick resolution of the mouth lesions, a halt to the diarrhoea and an uncomplicated convalescence. Otherwise, animals entered the terminal stages of the illness, becoming depressed, weak and recumbent for 24–48 hours prior to death (Figs 20 and 21). Their breath also became foetid. Some animals collapsed and died within a matter of hours of entering this stage, frequently showing an abnormally low body temperature before they did so. Others became recumbent, in pain and severely dehydrated for one or two days before death. Terminally, such animals often produced a distinctive, checked expiration.

With classic rinderpest, although deaths occurred, depending on the virus, the breed of cattle infected and environmental conditions, the mortality rate varied from 60% to 70% in European cattle breeds, and from 20% to 30% in zebu cattle. In an epidemic,

FIG. 20
RECUMBENT ANIMAL IN TERMINAL STAGE OF RINDERPEST
Source: FAO WAREC

FIG. 21
RECUMBENT ANIMAL IN TERMINAL STAGE OF RINDERPEST
Source: P. Roeder

the mortality rate usually rose as the virus gained progressive access to large numbers of susceptible animals and increased in virulence.

Peracute and mild rinderpest

Depending on the virulence of the infecting strain, as alternatives to the signs associated with classic rinderpest, the disease could manifest the clinical signs of either a peracute infection or a very mild infection.

The main characteristics of the syndrome associated with the peracute disease was the fierce onset of a pyrexia exceeding 41.6 °C and the early death of infected animals, either during the prodromal phase or early in the erosive phase. In such cases, a specific clinical diagnosis could be difficult in the event of a number of animals dying before the onset of lesions. Mortality rates of 100% were characteristic.

Although the development of strains of reduced virulence was a general phenomenon arising out of a long-term endemic association between the virus and the host, it came to be exemplified by African lineage 2 rinderpest virus in eastern Africa. Beyond the incubation period, the ensuing clinical disease in cattle was little more than a subacute febrile attack. The fever was short lived (three to four days) and low (38–40 °C). The clinical depression that characterised more acute forms of rinderpest was absent, and, as a result, cattle often did not lose their appetite but continued to graze, drink and trek with the herd. Diarrhoea, if present, was not marked. On close examination, there might be some slight congestion of the visible mucous membranes, and small focal areas of raised whitish epithelial necrosis might be found on the lower gum – sometimes no larger than a pin head – along with a few eroded cheek papillae. Some animals totally escaped the development of such erosions, the appearance of which was, in any case, fleeting. Other animals might show a slight, serous ocular or nasal secretion but, in contrast to the more severe forms of the disease, these did not progress to become mucopurulent.

RINDERPEST IN WILDLIFE

In highly susceptible wildlife species (tragelaphine species, such as lesser kudu and eland, African buffalo and giraffe) rinderpest caused fever, nasal discharge, typical erosive stomatitis, gastroenteritis and death. Kock (2) observed that, in addition, African buffaloes infected with lineage 2 showed enlarged peripheral lymph nodes, plaque-like keratinised skin lesions and keratoconjunctivitis. Lesser kudus were similarly affected, but, whereas blindness – caused by a severe keratoconjunctivitis – was common, diarrhoea was unusual. Eland also showed necrosis and erosions of the buccal mucosa, together with dehydration and emaciation.

FIG. 22
ENGORGED TURBINATE BONES (NASAL CONCHAE)
Source: Pirbright Institute

POST-MORTEM APPEARANCE IN CATTLE AND DOMESTIC WATER BUFFALO

Typically, the carcass was dehydrated, emaciated and soiled. The nose and cheeks would probably bear evidence of mucopurulent discharges, and the eyes would be sunken and the conjunctiva congested.

On incision, external lymph nodes were enlarged and congested; otherwise pathological changes were largely associated with mucous membranes and intestinal epithelia.

The turbinate bones would be heavily engorged (Fig. 22), and engorgement could extend to the trachea (Fig. 23) and major bronchi. A diffuse necrotising tracheitis could develop (Fig. 24). In the lungs, the most common pathological change was that of interlobular emphysema (Fig. 25).

FIG. 23
EPIGLOTTIS AND ENGORGED TRACHEA
Source: FAO EMPRES Photo Library

FIG. 24

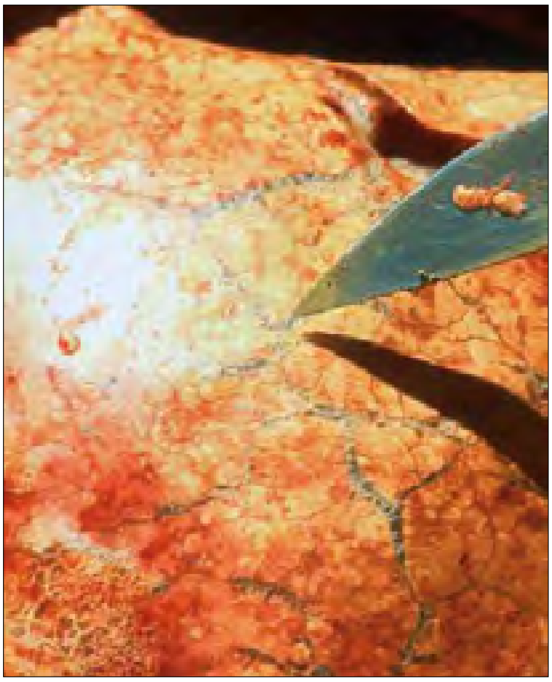
SEVERE DIFFUSE NECROTISING TRACHEITIS

Source: Plum Island Animal Disease Center, New York

FIG. 25

INTERLOBULAR EMPHYSEMA

Source: Pirbright Institute



In the oral cavity, there was often evidence of extensive desquamation of the epithelium leaving shallow, sharply demarcated areas of erosion, contrasting with the adjacent areas of healthy mucosa.

Epithelial necrosis was frequently seen on the soft palate, the root of the tongue and pharynx (Fig. 26) and the proximal oesophagus (Fig. 27).

The rumen, reticulum and omasum were usually unaffected, although on occasion the rumenal epithelium was discoloured and necrotic plaques could be encountered on the ruminal pillars.

The abomasum, especially the pyloric region, was severely affected and showed congestion, petechiation and oedema of the submucosa (Fig. 28).

FIG. 26

EPITHELIAL NECROSIS OF THE LINGUAL TONSIL AND THE FLOOR OF THE PHARYNX

Source: Pirbright Institute

FIG. 27

NECROSIS OF PROXIMAL OESOPHAGUS

Source: Pirbright Institute

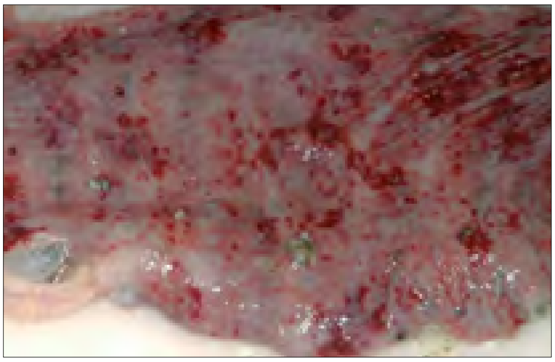
FIG. 28

ENGORGEMENT AND PETECHIATION OF THE ABOMASUM

Source: Pirbright Institute

The small intestine was generally normal in appearance but occasionally mildly engorged or haemorrhagic (Fig. 29). Mesenteric lymph nodes were usually engorged.

FIG. 29
NUMEROUS SMALL HAEMORRHAGIC EROSIONS ARE WIDELY DISTRIBUTED THROUGHOUT THE MUCOSA
Source: Plum Island Animal Disease Center, New York



By contrast, there would generally be striking changes to the Peyer's patches, where lymphoid necrosis and subsequent sloughing left the supporting architecture engorged (Fig. 30) or blackened.

FIG. 30
DISCOLOURED REMNANT OF PEYER'S PATCH – LYMPHOID TISSUE HAS BEEN LOST
Source: Pirbright Institute

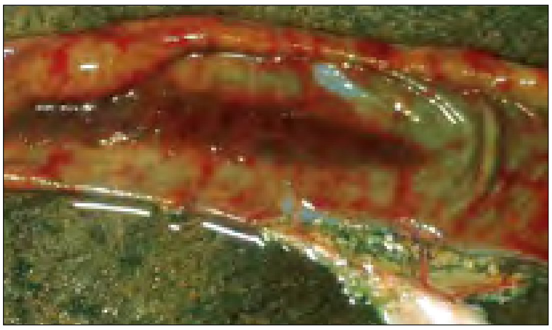
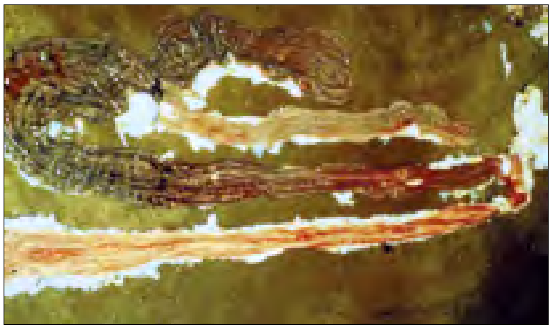


FIG. 31
ACUTE ENGORGEMENT OF FOLDS OF LARGE INTESTINE
Source: FAO EMPRES Photo Library

FIG. 32
DELAYED DEATH; BLACKENING OF THE FOLDS OF THE MUCOSAE IN THE CAECUM AND COLON SO-CALLED ZEBRA STRIPING
Source: FAO EMPRES Photo Library



In the large intestine, changes involve the ileocaecal valve, the caecal tonsil and the crests of the longitudinal folds of the caecal, colonic and rectal mucosae. The folds appear highly engorged in acute deaths or darkly discoloured in long-standing cases; in either event, the lesions are referred to as zebra striping (Figs 31 and 32).

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PART 2
THE HISTORY OF RINDERPEST EPIDEMICS

CHAPTERS

CHAPTER 2.1

A BRIEF ACCOUNT OF RINDERPEST'S HISTORICAL DISTRIBUTION

W. TAYLOR [(1)*], P. ROSSITER [(2)] & A. SHIMSHONY [(3)]

(1) 16 Mill Road, Angmering, West Sussex BN16 4HT, United Kingdom (Former Head, Department of Bluetongue and other Exotic Diseases, Animal Virus Research Institute, Pirbright [now the Pirbright Institute], United Kingdom)
(2) St Michael's House, Poughill, Devon, EX17 4LA, United Kingdom (Formerly staff member of the Food and Agriculture Organization of the United Nations [FAO] and rinderpest consultant)
(3) 44/41 Rabindranath Tagore Street, Tel-Aviv 6934102, Israel (Former Chief Veterinary Officer for Israel, Koret School of Veterinary Medicine, the Hebrew University of Jerusalem)

*Corresponding author

SUMMARY **Rinderpest appears to have spread from Central Asia westwards into Europe and Russia early in the first millennium AD giving rise to major epidemics followed by residual endemicity; it remained there for the next millennium and a half, its eventual eradication being largely due to the imposition of zoosanitary controls. As well as moving westwards the virus also spread eastwards, probably around the same time, to Siberia, Mongolia, Manchuria, China, the Korean Peninsula and Japan. Rinderpest was still present in Southeast Asia early in the 20th century. China eradicated rinderpest in 1956 using zoosanitary controls, while the countries of Southeast Asia eradicated the virus through the use of attenuated vaccines in the period following the end of the Second World War.**

A further route of historical dissemination, possibly through Afghanistan, introduced the virus to West Asia and probably carried it south onto the Indian subcontinent. West Asian epidemics of the 19th and 20th centuries are identified, along with the more recent Near East Pandemic of 1969–1972. India launched a nationwide mass vaccination virus eradication programme in 1954 but achieved its aim only in 1995.

Africa escaped endemic infection until around the turn of the 19th century when, in 1887, the virus was introduced into cattle through the Eritrean port of Massawa. This initiated the so-called Great African Rinderpest Pandemic, which subsequently led to the establishment of rinderpest across sub-Saharan Africa. The same pandemic carried the virus down the eastern side of the continent to South Africa where it failed to become endemic. A second African incursion occurred through the Egyptian port of Alexandria in 1903. Internationally sponsored mass vaccination campaigns led to the eventual elimination of endemic rinderpest from Africa in 2001.

KEYWORDS **African lineages – Central Asia – China – Control – Egypt – Europe – Great African Pandemic – Gulf – Japan – Reduction in virulence – Rinderpest – Russia – South Asia – Southeast Asia – West Asia.**

THE EARLY GEOGRAPHICAL RECOGNITION OF RINDERPEST

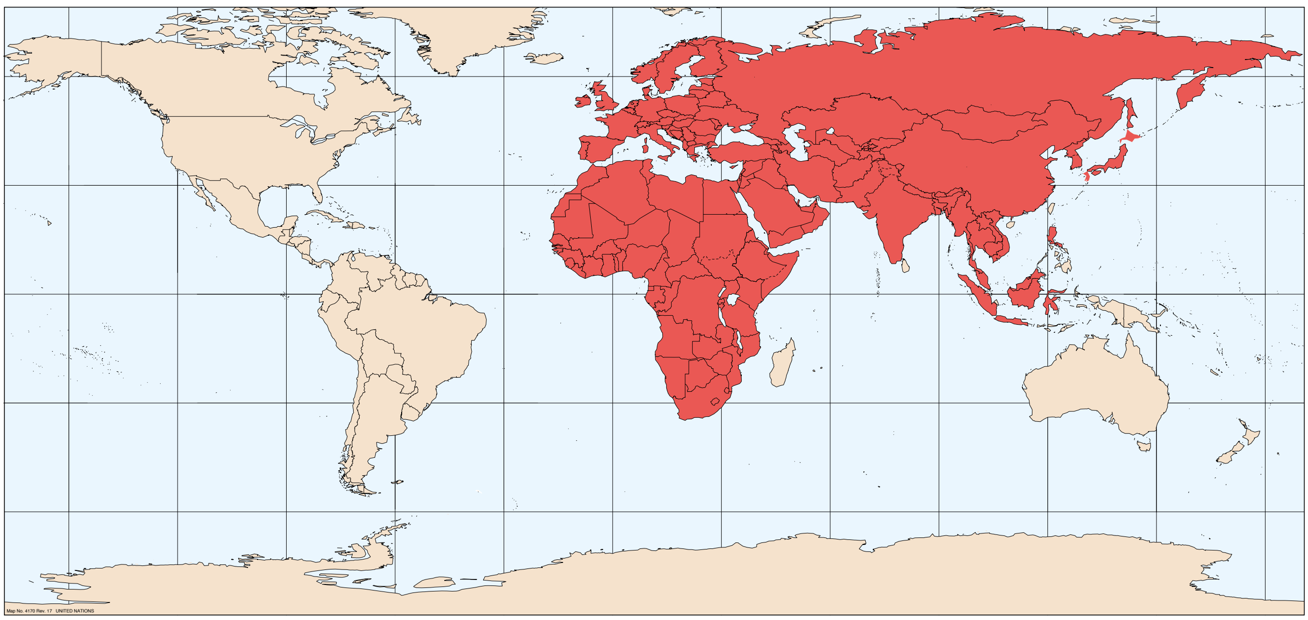
The first two chapters of this book have introduced the reader to the rinderpest virus (Chapter 1.1) and to rinderpest, the disease that it causes (Chapter 1.2). Now, in order to understand the succeeding chapters with regard to its eradication and the timescale over which this happened, it is necessary to provide an overview of time and place. Laktionov (1) advanced the argument that the classical writings of the Greeks and the Romans, while embracing rabies and tuberculosis, did not provide a description of a disease resembling rinderpest, concluding that they had probably never encountered it. He concluded that the description of a disease that ravaged cattle across Hungary, Italy, France, Belgium and Germany between AD 376 and 386 represented the first reliable description of rinderpest in Europe. This outbreak must have reached Europe from an external source, one that realistically must have lain to the east. Accordingly, it is suggested that the cattle maintained by the tribes of the vast Central Asian Steppe, extending from Hungary to Mongolia, could have been the source of the infection. During the first millennium BC, deteriorating agricultural conditions led to these tribes being displaced across Central Asia and the Middle East. At the head of this movement, the Huns, a cattle-keeping people who began moving westwards in the first century AD, completed the process in the fourth and fifth centuries when they moved into the southern part of the Russian Federation and the Danube Basin, prior to raiding deeper into Europe, possibly initiating the fourth century epidemic referred to by Laktionov (1). As Dunlop and Williams (2) point out, the modern Russian word for rinderpest is 'tchouma' and is same word that was used by the Mongols and Tartars, suggesting a common understanding. It is of course possible that rinderpest existed on the Central Asian Steppe for some time prior to spreading to Europe, and Scott's (3) belief that a Tamil treatise dating from the first millennium BC contained a recognisable description of rinderpest begs the question of whether there was a spread of the virus to the Indian subcontinent before the tribal movements discussed above occurred. On the eastern side of the steppe the earliest record of the appearance of a disease that we can consider rinderpest is that of Di Cosmo (4), cited by Spinage (5), in respect of an epidemic occurring in Mongolia in 88 BC.

Accepting Laktionov's theory then, our working supposition places rinderpest in an endemic situation in cattle on the Central Asian Steppe in the period preceding and shortly after the birth of Christ, and assumes that subsequent movements of cattle-keeping nomads carried the virus westwards into Europe, south-westwards into Asia Minor and beyond, and eastwards into China and South Asia. From these early beginnings the virus continued to spread, at the start of a distribution that came to involve practically the entire European and Asian continents, culminating early in the 20th century with its spread across large tracts of Africa, thus defining the areas (Fig. 1) from which its eradication needed to be considered.

FIG. 1

THE HISTORICAL RINDERPEST WORLD

Source: United Nations, 2020 (6), modifed to indicate countries historically affected by rinderpest. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Sudan and South Sudan has not yet been determined



A BRIEF ACCOUNT OF RINDERPEST IN EUROPE AND RUSSIA

From the fourth century AD onwards, epidemic waves of rinderpest occurred across Europe, notably so in the 9th, 10th, 11th, 12th and 13th centuries. Scott (3) associated that of the 9th century with the 30 years of campaigning across Central Europe by Charlemagne, King of the Franks (circa AD 800), while those of the 13th century were the aftermath of the Mongol invasions of western Europe begun by Genghis Khan in AD 1222.

In 1709 a fresh rinderpest epidemic began on the banks of the Rivers Don and Volga (i.e. near Volgograd – erstwhile Stalingrad – in southern Russia) as a peracute infection characterised by uniform and sudden death and a high level of contagion. Spreading west into Little Tartary (modern-day Ukraine) and north-west towards Moscow, by 1710 rinderpest had reached Kyiv. Thereafter, it continued to spread westwards on a broad front, so that by 1711 it had reached Austria, Germany, Hungary, Switzerland, Prussia and Poland. At much the same time a second (unconnected) epidemic began, carrying the disease from Dalmatia (a region of modern-day Croatia) to the territories around Venice and from there to Padua and to Rome where, between 1713 and 1714, Pope Clement XI lost more than 26,000 cattle (5). As Lisle Wilkinson (7) has pointed out, the absence of veterinary science as an independent discipline, coupled with the awesome damage being wrought by rinderpest, stimulated the contemporary medical authorities to undertake a study of livestock diseases. As a result, in 1711 Professor Bernardo Ramazzini, Professor of Practical Medicine at the University of Padua, was able to outline the contagious nature of the disease and show that epidemics had sources and routes of spread (8). A few years later in 1715 Dr Giovani Lancisi, Pope Clement's personal physician (9), outlined a rinderpest control concept based on preventing the transfer of infection between infected and uninfected livestock. In 1718, Mr Thomas Bates, a surgeon in the British Navy, proposed a similar approach for its control (10).

For the remainder of the 18th and 19th centuries rinderpest remained endemic at the European level with an overall death toll numbered in millions (five), even though individual countries might be free of the disease for considerable periods of time. At the start of the 19th century, the opposing military campaigns of Napoleon and Czar Alexander helped redistribute the virus (3). With no effective treatment or prophylaxis available, attempts to reduce the impact of the disease in Europe and Russia had to rely on strong zoosanitary regulations backed by appropriate legislation. This approach, applied through the 18th and 19th centuries, freed Europe of rinderpest (see Chapter 3.2 for a discussion of zoosanitary control methods).

In addition to providing the first scientific description of the disease, the European experience of rinderpest proved to be a catalyst for the founding of European veterinary teaching institutions, which created a cadre of professionals capable of applying preventive measures against the disease so that, finally, around the turn of the 19th century and after a sojourn of around 1,500 years, Europe was able to eliminate the virus.

RINDERPEST IN SIBERIA, CENTRAL ASIA AND MONGOLIA

For non-European Russia, Fleming (11) remarks that rinderpest was extremely prevalent and destructive in Siberia in 1809–1810, suggesting a continued presence in the east, while Curasson (12) speaks of its longstanding presence across the Central Asian domain of the Russian Empire. As 'European' control measures began to take effect in European Russia, the abattoir in St Petersburg appeared to act as a collecting point for infected cattle coming from the last foci of the disease either in Russia or Transcaucasia – an area roughly corresponding to modern Georgia, Armenia and Azerbaijan. Spinage (5) indicates that infected cattle arrived there from Siberia in 1908, implying that the Siberian region of Russia must have still harboured the virus. At much the same the time, the disease was brought to St Petersburg by rail from Transcaucasia. Both incidents were quickly controlled, but in 1917 rinderpest again crossed the Caucasus spreading to Bulgaria, Romania and Ukraine. The Caucasus was probably free of rinderpest after the 1920s.

In Central Asia, rinderpest was first described in the 18th century from the Semirech'ye grasslands in the south of Kazakhstan. It remained an endemic disease throughout Kazakhstan during the 19th century, its presence being associated with caravans coming from China or migrant farmers coming from Ukraine (13). During the Soviet era, rinderpest was eradicated by the Soviet Government as part of a nationwide programme through the adoption of strict zoosanitary measures (the slaughter of cases and suspected cases) together with the use of serum–virus immunisation (the simultaneous inoculation of immune serum and live virus). The last registered case was in the Akmola oblast in 1927. While Kazakhstan was part of the Soviet Union, a vaccine belt was maintained along the border with China.

There is no comparable history for Tajikistan, although the country was apparently prone to infection coming from Afghanistan; the last such incidence was in 1949. As with Kazakhstan, Tajikistan vaccinated along the borders with China and Afghanistan until 2002 (14).

The last occurrence of rinderpest in Uzbekistan was in 1928. From 1970 to 1998 annual vaccination was undertaken on the border with Afghanistan (15).

Rinderpest was eradicated from Turkmenistan in 1928 but reappeared briefly in 1954. From 1954 to 2001 vaccination was undertaken on the borders with Afghanistan and the Islamic Republic of Iran.

Laktionov (1) mentions that in 1920 V.I. Lenin designated 'special authorised officers' who were instrumental in rinderpest eradication from the whole of the Soviet Union, which was finally achieved in 1928. He also mentions subsequent incursions of rinderpest in Primorsky Kray (the far eastern region of the modern Russian Federation) starting in 1939 with the arrival of the virus from Mongolia and followed by a repeat episode occurring in 1944. By this time, protection with immune serum was an accepted part of the rinderpest control regimen. The first time rinderpest was officially recorded in Mongolia was in 1910 by Russian veterinarians. Between 1912 and 1917, annual losses in Mongolia averaged 120,000 cattle. Rinderpest was officially reported from Mongolia in 1936, 1938 and 1945, and in 1947 endemic infection ended (16).

Between 1978 and 1980 a live attenuated rinderpest vaccine was developed at the Research Institute for Agriculture in Kazakhstan. In as much as the Soviet Union chose to maintain a belt of vaccinated cattle along its southern border to prevent re-entry from South Asia, latterly this vaccine was employed in the various border vaccination programmes mentioned above. Rinderpest outbreaks appeared along this belt, possibly associated with the vaccine itself, although these never threatened to get out of control. Thus Georgia – also included in the Russian border vaccination programme – experienced an outbreak in 1989 probably due to a reversion to virulence associated with the K37/70 live attenuated vaccine then in use (17). Between 1991 and 1998 two similar rinderpest outbreaks occurred either on the border of the Russian Federation with Manchuria or among vaccinated Russian cattle that had migrated into Mongolia, effectively preventing the Russian Federation and the Central Asian countries from claiming the elimination of rinderpest at an earlier date, although endemic infection with field strains had long since ceased (see Chapter 2.7).

TABLE I
THE YEAR OF LAST OCCURRENCE OF ENDEMIC RINDERPEST IN EUROPE, RUSSIA, CAUCASUS AND CENTRAL ASIA AND LATER NON-ENDEMIC INTRODUCTIONS

Country	Date of last occurrence
Albania	1934
Armenia	1928
Austria	1881
Azerbaijan	1928
Belgium	1872 (1920 imported in cattle)
Bosnia and Herzegovina	1883
Bulgaria	1913
Croatia	1883
Czechia	1881
Denmark	1782
Finland	1877
France	1870
Georgia	1928 (1989 vaccine associated; see Chapter 2.7)
Germany	1870
Greece	1926
Hungary	1881
Ireland	1866
Italy	1874 (1947 introduced to Rome zoo)
Kazakhstan	1927
Latvia	1921
Mongolia	1947 (1992 vaccine associated; see Chapter 2.7)
Netherlands	1869
Poland	1921
Romania	1886
Russia	1928 (1998 vaccine associated; see Chapter 2.7)
Serbia	1883
Slovakia	1881
Slovenia	1883
Sweden	1700
Switzerland	1871
Tajikistan	1949
Turkmenistan	1954
United Kingdom	1900
Uzbekistan	1928

The dates of the last occurrence of endemic rinderpest in the countries of Europe, the Soviet Union and the Caucasus are shown in Table I.

THE SPREAD OF RINDERPEST TO CHINA, JAPAN, KOREA AND SOUTHEAST ASIA

China, Japan, Korea

In keeping with a probable spread from the Central Asian Steppe and westwards into Europe, rinderpest probably also spread eastwards into Manchuria and southwards onto the plains of China – where the official Chinese rinderpest history notes the presence of a rinderpest-like disease in AD 75 (Yongping year 18, East Han Dynasty) and again in AD 447 in Xilinghaote District, Inner Mongolia. There is no similar history of the early presence of rinderpest in Mongolia whence it might have originated.

Historical outbreaks in Korea imply the existence of an endemic situation in neighbouring Manchuria in the 16th and 17th centuries, prompting the observation that at this time rinderpest would have been continuously endemic across the whole of the Eurasian land mass. Manchurian endemicity continued to fuel outbreaks in Korea into the early 20th century. Elsewhere in China outbreaks were also reported from the southern province of Fujian in 1912, 1914, 1915, 1918, 1920 and 1921, where the disease was also clearly endemic. Rinderpest was regarded as being seasonally active in China and occurred mostly in winter and spring when feedstuff was scarce and disease resistance was low. During a major epidemic that struck Sichuan, Tibet and Qinghai provinces between 1938 and 1941, more than one million cattle died (18).

In 1946, under the auspices of the post-war United Nations Relief and Rehabilitation Administration, a chick-embryo adapted attenuated rinderpest vaccine developed at Grosse Isle (Canada) was successfully tested on Chinese yellow cattle but was not exploited. Meanwhile, in Korea, a rabbit attenuated vaccine was being recognised as an essential tool for rinderpest control. Eventually, a sheep adapted substrain of this virus was developed in China in 1953. These developments are fully discussed in Chapter 3.4.

After the founding of China in 1949, strict rinderpest prevention and control measures were implemented, and in 1956 it was announced that China had eradicated rinderpest. Coming ahead of the broad level of international involvement in rinderpest eradication that this book attempts to chronicle, this achievement is poorly documented. In 1994 an outbreak of rinderpest in the northern areas of Pakistan, adjacent to the Chinese border, caused the Chinese authorities to employ vaccine, thereby technically compromising the prior rinderpest-free status and occasioning nationwide surveillance before China's international acceptance as a rinderpest-free country was reinstated in 2008. China's Taipei province (modern-day Taiwan or Chinese Taipei) was endemically infected with rinderpest from at least 1895 but became free in 1949.

The early Korean accounts of rinderpest are important in that they too establish the eastwards spread of the virus from Central Asia. Pastoret *et al.* (19) cite a study of the medical history of Korea describing outbreaks in cattle in which combined evidence of contagion, rinderpest-like clinical signs and an 80% mortality rate were accepted as rinderpest. Six possible rinderpest epidemics occurred between 1541 and 1684, each lasting between two and four years. These probably originated in Manchuria. Another major outbreak occurred in 1894, also coming from Manchuria, and was noted for demonstrating the extreme sensitivity of yellow cattle to rinderpest. The dates of the last Korean outbreaks are 1931 for the modern-day Republic of Korea and 1948 for the Democratic People's Republic of Korea.

In Japan, Kishi (20) reported a severe rinderpest epidemic lasting from 1638 to 1641 associated with the death of half a million cattle. This is believed to be the earliest recorded rinderpest outbreak in Japan and was probably associated with an outbreak in neighbouring Korea between 1636 and 1637. Another Japanese outbreak occurred between 1672 and 1673, again following a Korean outbreak in 1672, which was said to have destroyed nearly all the cattle in Asia. The author included an old Japanese illustration (from 1720) of a Japanese cow said to be suffering from a highly fatal and highly infectious disease assumed to be rinderpest (see Chapter 3.4). In addition to the usual purulent lachrymal discharge, corneal opacity is present – a sign seen in some affected African game animal species but only rarely seen in contemporary cases in cattle. The virus never became endemic in Japan.

Between 1872 and 1922 a total of 25 epidemics were recorded, about half of them coming from the Korean Peninsula, a few from Shanghai and Qingdao in China and the remainder of unknown origin (21). Japan's last case was recorded in 1924.

The dates of the last rinderpest outbreaks in these countries are given in Table II.

TABLE II
THE YEAR OF LAST OCCURRENCE OF ENDEMIC RINDERPEST IN CHINA, KOREA AND JAPAN

Country	Date of last occurrence
China	1956
Chinese Taipei	1949
Republic of Korea	1931
Democratic People's Republic of Korea	1948
Japan	1924

Southeast Asia

Regarding Southeast Asia, it is possible to view the heavily forested and cattle-free terrain of the India–Myanmar border as a barrier to the eastwards spread of a cattle-transmitted disease out of India or, conversely, its westward movement out of Myanmar. Thus, when Spinage (5) places rinderpest in Myanmar in 1800, it is probable that it was also present throughout the entire Southeast Asian region at that date, having spread southwards from

China rather than eastwards from India. However, there do not appear to be any accounts of major rinderpest epidemics in this region, so in terms of outlining its distribution and control in Southeast Asia, we can do little more than use the dates of the first and last reports of the disease in the countries of the region to provide a measure of its relatively recent endemicity.

Cambodia was constantly threatened by outbreaks in Thailand and Lao People's Democratic Republic and outbreaks were reported in 1915–1916, 1921–1922 and 1927– 1928. The last epidemic occurred between 1957 and 1961 and was said by J.R Hudson (22), a vaccine specialist at the Food and Agriculture Organization of the United Nations (FAO), to have affected the whole of the country. Spinage (5) quotes from the theses of Jauffret (23) and Baradat (24) to show that rinderpest was also present in Laos, Cambodia and the area constituting present-day Viet Nam in the 1920s, the disease usually spreading from Laos to Cambodia and then to Viet Nam. In Viet Nam, rinderpest was seen as recently as 1977 (Y. Ozawa, unpublished report to FAO).

Curasson (12) states that the disease was known in Borneo and Indonesia (Java and Sumatra) between 1879 and 1883 and that 223,443 cattle died of rinderpest. It was eradicated from Indonesia in 1907.

According to Scott (25), rinderpest was possibly present in buffaloes on the Malaysian Peninsula in the 19th century, but it was not until 1903 that it was differentiated from haemorrhagic septicaemia. Thereafter, outbreaks were controlled using antiserum and by regulating animal movements. The disease was eradicated in 1935.

The United States of America colonised the Philippines in the 1880s and in the process introduced rinderpest from mainland Asia. The resulting epidemics were savage, causing up to 90% losses. Although a veterinary department was quickly established (26), it took 30 years to eliminate the disease. Rinderpest returned to the Philippines in the 1940s and 1950s but was eliminated by 1955.

It is difficult to find an early record of rinderpest in Thailand. Spinage (5) suggests that a traditional trade in buffaloes and cattle brought rinderpest from Myanmar to Thailand, re-seeding it almost annually. Officially, rinderpest was first recorded in 1926, when cattle, buffaloes, sheep, goats and pigs were all affected, and was last seen in 1956.

From the foregoing it would appear that Southeast Asia was the last part of the Eurasian landmass to be invaded by rinderpest virus. In the period after the Second World War, eradicating rinderpest from Southeast Asia was an activity strongly supported by FAO through the introduction of recently developed vaccine technology plus expert assistance to national Veterinary Services. In the event the virus was relatively easily eradicated (see Chapters 4.15 and 4.16).

The dates of the last occurrences of rinderpest in Southeast Asia are listed in Table III.

TABLE III
THE YEAR OF LAST OCCURRENCE OF ENDEMIC RINDERPEST IN SOUTHEAST ASIAN COUNTRIES

Country/region	Date of last occurrence
Cambodia	1964
Indonesia	1907
Lao People's Democratic Republic	1966
Malaysia	1935
Myanmar	1957
Philippines	1955
Singapore	1930
Thailand	1956
Viet Nam	1977

THE SPREAD OF RINDERPEST ACROSS WEST ASIA AND SOUTH ASIA AND THE INVOLVEMENT OF THE GULF STATES

West Asia

Coincident with its spread westwards into Europe and southwards into Mongolia and China, rinderpest clearly found a further route taking it southwards to the Indian subcontinent, perhaps via Afghanistan and Iran, and in the process opened the way for the contamination of present-day Iraq followed by its spread along the Tigris and Euphrates valleys to Turkey. Mention has already been made of Scott's belief (3) that rinderpest had reached the southern tip of India in the first millennium BC, which is certainly in keeping with the notion that the virus began moving away from a putative ancestral homeland around or slightly more than two millennia ago.

Scott (25) speaks of Turkey's southern and eastern provinces as having been infected 'from time immemorial'. Erk (27) cites the 16th century Turkish historian Ali who described a devastating epidemic of cattle disease named 'Malkiran' (a term still used among Turkish farmers for rinderpest), which was introduced from Iran to Turkey in 1592, spreading to western Turkey in the space of four years and as a result of which food supplies such as yoghurt, cheese and milk became very scarce.

More recently there were epidemics in 1847, 1877, 1881, 1888, 1889, 1893, 1894, 1898, 1899, 1905 and 1906; some of these are known to ave spread to other parts of the Ottoman Empire, notably Ottoman Syria, a geographical entity existing from the latter part of the 19th century until the end of the First World War and made up of the provinces (vilayets) of Aleppo, Beirut, Syria (also known as Vilayet of Damascus) and the Jerusalem sanjak. Endemic rinderpest was eliminated from Turkey in 1932.

In 1969, the so-called Near East Pandemic (1969–1972) began in Afghanistan and affected almost all countries of the region with spread up to the Mediterranean coast and onto the Arabian Peninsula. The virus entered Turkey in October 1969 from Iran. In each of three successive years all the cattle and buffalo population (about 14 million) were vaccinated against rinderpest, and by 1972 this incursion had been completely eradicated (27). In 1991, rinderpest again invaded eastern Turkey, this time from Iraq (and caused alarm in Europe). Finally, a further upsurge of infection in an area straddling neighbouring parts of Iraq, the Islamic Republic of Iran and Turkey in 1993–1994 was resolved through a strong response by FAO (17).

The cattle population of the Syrian Arab Republic is too limited to have supported an endemic situation, although the country was possibly contaminated by the passage of infected cattle en route from the Baghdad region of Iraq to Egypt early in the 19th century (28), and this may have been responsible for initiating an extended epidemic of rinderpest in Syria in the 1920s (29).

Since the end of the 19th century, the territories west of the Jordan river, i.e. Israel and Palestine, have experienced five rinderpest epidemics: 1894/1895, 1903–1905, 1913/1914 (actually lingering to 1920), 1926/1927 and 1983.

Lebanon experienced rinderpest during 1905, when the disease was reported from the Upper Galilee, at that time part of Beirut vilayet. The disease was circulating in Lebanon in 1926 and 1927, as is evident from the report of the regional rinderpest meeting of January 1927, which reached an agreement on the measures required to prevent the reintroduction of rinderpest to Palestine and Jordan from Syria and Lebanon (29). Rinderpest next reached Lebanon in August 1970; 182 outbreaks were reported in the official monthly World Organisation for Animal Health (OIE) bulletins, the last one being in October 1973. The disease recurred in 1982 through the importation of infected animals.

In 1926 rinderpest was present in Jordan, which at that time was a British protectorate termed the Emirate of Transjordan. Rinderpest next reached Jordan in January 1971 (30) during the Near East Pandemic (1969–1973). A more detailed account of these West Asian epidemics is provided in Chapter 2.3.

Writing in 1905, Littlewood (28) implicated 'Bagdadli' – the name given to cattle traded out of Iraq in large numbers during the early 20th century – as being notorious for transmitting rinderpest without themselves being seriously affected. Endemic rinderpest, characterised by a reduced level of virulence, crops up more than once in the history of rinderpest but its earliest identification was perhaps in Iraq in the early 1900s. In 1918, a more virulent strain was introduced into Iraq, reportedly following the importation of Indian buffaloes. This outbreak was controlled, and eradicated in 1923, by using movement restrictions and slaughter, a process that seemingly eliminated the mild strain at the same time. During this period the present Iraq Veterinary Service was established in Baghdad. Although Iraq apparently escaped involvement in the Near East Pandemic of 1969–1973, the country again became badly affected in 1985 following the importation of a shipment of infected dairy buffaloes through Kuwait into southern Iraq, setting off a country-wide epidemic in the fully susceptible national herd. In one enterprise alone (in Baghdad) rinderpest killed half the 30,000 resident buffaloes (31). Mass vaccination of cattle and buffaloes was undertaken with a locally produced vaccine and modified stamping out, by slaughtering clinically affected cattle, was applied during the first months of the epidemic. Between 1985 and 1991, vaccination brought about a reduction in the incidence of new outbreaks but sporadic outbreaks persisted throughout Iraq. In 1991, as part of FAO's West Asia Rinderpest Eradication Campaign (WAREC; see Chapter 4.10) a national survey for clinical rinderpest was conducted. The condition was found to be prevalent and consequently mass vaccination was continued and intensified. The last case of rinderpest in central and southern Iraq was reported at the end of 1994, but cases continued to appear in the Kurdish region in the north of the country until the last case in Erbil in 1996.

While northern Iran probably served as the historical gateway for rinderpest to reach the Indian subcontinent, in recent times (i.e. the 20th century) the Islamic Republic of Iran was free of endemic disease but experienced a series of intermittent epidemics, suggesting the presence of endemic disease in neighbouring countries. The first of these was recorded in 1924, when rinderpest penetrated the western borders spreading across the north of the country (see Chapter 4.11.2). Another, in 1931, was reported from the western provinces. By 1924, the Razi Institute had been established and the 1931 outbreak was controlled through vaccination with the institute's killed vaccine and by destruction of affected and susceptible animals that had been in contact with the disease. The next incursion occurred in 1949 in the east of the country due to movement of cattle across the eastern borders from infected Afghanistan. This outbreak was eradicated through modified stamping out, mass vaccination and quarantine measures. Thereafter, the disease was absent until 1960 when it again returned to the eastern provinces, where it was eventually controlled again through mass vaccination and the implementation of special regulations over animal movement throughout the country.

A larger epidemic occurred in 1969 with high mortality of cattle in most parts of the country. At least 20,000 cattle died in this outbreak. This epidemic spread to neighbouring countries within what became known as the Near East Pandemic (see Chapter 2.3). From 1969 until 1981, the Islamic Republic of Iran remained free from rinderpest, but in 1981 cattle movements from Afghanistan and Pakistan again brought the disease to Khorasan province in eastern Islamic Republic of Iran with subsequent spread to the centre of the country. This outbreak was quickly controlled, but mass vaccination and enhanced surveillance continued for some time thereafter. Effectively the eastern portal had been closed, but in 1987 outbreaks were reported from Khuzestan and Hamedan provinces, in the south-west, while in 1990 rinderpest affected Kordestan province in the west of the country close to the Iraqi border. These outbreaks were localised and only a few cases were reported. The last rinderpest outbreaks occurred in 1994 in West Azerbaijan province in an area close to the border with Iraq and Turkey. The disease spread to the central provinces affecting feedlot cattle; another outbreak was reported in buffalo farms in the marshy area close to the Arvand river (Shat-Al-Arab) in Abadan city, south-west Khuzestan. This outbreak was controlled by stamping out and vaccination of cattle at risk.

The dates of the last occurrences of rinderpest in West Asia are listed in Table IV.

TABLE IV
THE YEAR OF LAST OCCURRENCE OF RINDERPEST IN WEST ASIA

Country	Date of last occurrence
Islamic Republic of Iran	1994
Iraq	1996
Israel	1983
Jordan	1972
Lebanon	1982
Syrian Arab Republic	1983
Turkey	1996

South Asia

If rinderpest reached southern India before the birth of Christ, there does not appear to be any account supporting such an early arrival. Nevertheless, it is quite possible that the virus could have spread to South Asia at much the same time as it began to spread from the Eurasian landmass. In the process of reaching southern India rinderpest would probably also have become endemic in Afghanistan, the Islamic Republic of Iran, Pakistan and Bangladesh.

Regarding Afghanistan, Roeder *et al.* (17) took the intermittent nature of outbreaks between 1950 and 1995 to suggest a lack of endemicity but also highlighted the country's role as a source of regional epidemics with a history of spreading the infection into either Turkmenistan or Tajikistan and possibly also the Islamic Republic of Iran. The actual source of the infection probably lay in Sindh province in Pakistan and in the livestock trade between Pakistan and Afghanistan. Thus, Pakistan might have served as the real source of the Near East Epidemic, which ostensibly began in Iran in 1969, but is linked with an outbreak in Afghanistan's Nimroz province (see Chapter 2.3).

Prior to 1947, the land mass making up India and modern-day Pakistan and Bangladesh experienced a common rinderpest history, which is to say a continual endemic/epidemic presence across the subcontinent. After 1947 only two major epidemics were recorded in Pakistan. Commencing in 1956 the first of these involved the central districts of the Punjab and most districts of the North-West Frontier province; heavy losses were experienced between 1958 and 1962. There do not appear to be any official statistics relating to this episode, although Raja (32) suggests that hundreds of thousands of animals died. Chaudhry and Akhtar (33) state that, during the succeeding decade from 1962 to 1972, there were no reports of clinical or suspected rinderpest in Pakistan and that the reason underlying this favourable situation lay with the completion of a nationwide vaccination campaign followed by regular calfhood immunisation.

Although nationwide vaccination allowed the country relative freedom from rinderpest, an intractable endemic situation in Sindh province caused continuing problems in the milking cattle and buffaloes of the Landhi dairy cattle colony of Karachi district. The second major epidemic occurred in Pakistan's northern areas (Gilgit–Baltistan) from 1994 to 1996 (34; see also Chapter 2.6) and the final cases of rinderpest occurred in small numbers of animals in urban dairies around Karachi in 2000 (35). A more detailed account of Pakistan's rinderpest history may be found in Chapter 4.13.8.

Although having probably existed throughout the Indian subcontinent for centuries and having come to be known by 120 different names up and down the country, the key to placing rinderpest on an 'official' footing lay with the presence in India of veterinarians who were familiar with the condition in Europe. In 1838, the Committee of the Indian Provincial Medical and Surgical Association maintained that the disease seen in Indian cattle was the same disease as that first described by Ramazzini many years earlier (8). By the 1860s, a number of expatriate observers were convinced that the rinderpest they were seeing in India was the same as that which had recently been observed in England. So great were the losses experienced between 1800 and 1868 that in 1870 the Indian Government appointed a commission to enquire into the subject. The Indian cattle plague commissioners of 1870–1871, under the presidency of J.H.B. Hallen, staff veterinary surgeon of the Bombay Army, concluded that the Indian 'murrain' was identical with that occurring in Europe and Russia, noting that the low overall mortality rate was similar to that present in (endemic) Russia but the opposite of that present at that time in (epidemic) Britain (36). The commissioners' report led to the creation of the Imperial Bacteriological Research Laboratory in 1889, initially sited at Pune but subsequently relocated to Mukteshwar in the Kumoan hills, where, uniquely, Robert Koch was able to note the similarity of the pathological changes seen in infected cattle from India with those from South Africa in 1897 – from where he had just come, showing that rinderpest was a disease simultaneously present in Africa, Europe, India and Russia. A mere 25 years later, working at Mukteswar, J.T. Edwards developed the first widely applied live attenuated rinderpest vaccines, thereby sealing the virus's ultimate fate! Taken with improvements in zoosanitary control measures recommended by the commissioners and the later reliance on vaccines, their report marked the start of the 80-year-long struggle to eradicate rinderpest from India (see Chapter 4.13.4).

After 1947 Bangladesh experienced occasional rinderpest outbreaks, the last one being in Sylhet district in 1957–1958 when an estimated three million cattle and buffaloes died (37).

It is unlikely that Bhutan ever experienced endemic rinderpest. A severe epidemic occurred in 1948 and the last and only official outbreak was in 1971 (38).

Although it was intimately connected to events taking place on the plains of northern India, Nepal did not officially recognise rinderpest until 1939 when a serious outbreak occurred in the Kathmandu valley. Between 1952 and 1989 the virus moved into Nepal from India on 13 occasions (see Chapter 4.13.7).

Spinage (5) dates the earliest epidemic of rinderpest in Sri Lanka to 1842, while Crawford (39) states that up until 1930 the disease occurred annually, being introduced with cattle imports from India; temporary freedom was attained by prohibiting such imports. The situation deteriorated again during the Second World War when the disease was introduced by infected Indian goats, a situation that repeated itself in 1987 after which the disease persisted until 1994 (17; see also Chapter 4.13.9).

The dates of the last cases of rinderpest in the South Asian region are shown in Table V.

TABLE V
THE YEAR OF LAST OCCURRENCE OF RINDERPEST IN SOUTH ASIA

Country	Date of last occurrence
Afghanistan	1995
Bangladesh	1958
Bhutan	1971
India	1995
Nepal	1990
Pakistan	2000
Sri Lanka	1994

Gulf states

During the 1980s a number of cases of rinderpest were recorded from Gulf countries and in a number of instances samples were forwarded to the Pirbright Institute, United Kingdom of Great Britain and Northern Ireland, for virus isolation. When phylogenetics became an aid to back-tracing isolates, it was found that all such viruses came from a virus lineage characteristic of the Indian subcontinent, implying that the virus was imported in infected cattle through poorly applied trade controls.

Rinderpest was confirmed in Kuwait in August 1968 in local dairy herds and in Bahrain in October 1969.

Roeder *et al.* (17) mention repeated reports of rinderpest in Oman over the period from 1979 until 1991–1993. The infection came either from a market in Al Ain on the border with the United Arab Emirates or from (infected) fighting bulls imported from Pakistan. An Asian lineage virus was identified from Oman in 1979. Oman became rinderpest-free in 1996.

Rinderpest was confirmed in local cattle in Saudi Arabia in 1965 and again in 1981 when an Asian lineage virus was isolated from an established dairy farm in Riyadh belonging to Princess Anood. Hafez and colleagues (40) noted an outbreak in traditional rural cattle in Qassim in November 1982 and considered it possible that rinderpest was briefly endemic in Saudi Arabia in the 1980s.

The first record of rinderpest in the United Arab Emirates was in 1977. The Emirates gained an unenviable reputation for importing live rinderpest-infected cattle from the subcontinent and then disseminating them within the region. The last incidence was probably in 1995.

In Yemen rinderpest was first confirmed in the highlands and on the Tihama between 1971 and 1972 (see Chapter 4.11.12). This outbreak was controlled by heavy vaccination provided with United Kingdom technical assistance. There were no reports of rinderpest between 1972 and 1976 but thereafter the virus managed to become re-established and remained continuously present until 1995. A major outbreak in 1981 began in the north and was blamed on animal imports from Africa, although an Asian lineage virus was isolated in 1982. The endemic virus was twice shown to belong to the Asiatic lineage. Surveillance evidence suggests that it could have lingered on until 1995.

The dates of the last occurrence of rinderpest in the Gulf states are shown in Table VI.

TABLE VI
THE YEAR OF LAST OCCURRENCE OF RINDERPEST IN GULF STATES

Country	Date of last occurrence
Bahrain	1980
Kuwait	1985
Oman	1995
Qatar	1987
Saudi Arabia	1999
United Arab Emirates	1995
Yemen	1995

RINDERPEST IN AFRICA

East Africa as the point of origin of the Great African Rinderpest Pandemic

From the early 19th to the early 20th centuries it seems highly probable that Persian and Indian livestock traders brought rinderpest to the East African seaboard causing intermittent epidemics, some of which were intense enough to reach West Africa. Curasson (12) chanced across an old oral legend of the Peulh people of West Africa, which recorded the waves of rinderpest that reached their cattle every 25 or 30 years or so – but always from the east. This corresponded with the dates of known West African epidemics – such as the one in 1828, which (according to Curasson) a veterinary artist named Olivier saw in Senegal, and another in 1865. These epidemics would have spread to West Africa along established 19th century Sahelian cattle trade routes linking the east with the west (41).

This pattern repeated itself one more time, with the disease reaching Senegal in 1892 within an event that came to be described as the Great African Rinderpest Pandemic, widely accepted as commencing with a shipment of infected Indian cattle entering the Eritrean port of Massawa in 1887 (see Chapter 2.2). Curasson (12) indicates that – within the pandemic – the disease began in the French and British colonies of West Africa in 1890 and by May 1891 it had spread as far as Dori in Burkina Faso. Following a route from Darfur via Wadai (Chad), and moving into the Fulani cattle of the Sahel, the disease ultimately spread further west to reach Dakar in June 1892. During this initial spread, cattle losses in French West Africa and German Cameroon were said to have approached 98%. Perhaps the incredibly high level of virulence and the associated absence of survivors caused the first wave of infection to die out through an absence of suitable hosts. In any case, there appears to have been two waves of infection with a disease-free period in between them. In 1915, slightly over a decade after the first one, a fresh wave of (possibly less virulent) infection returned to West Africa, again from the east. Aldige (42) provides a detailed history of the disease, which was first diagnosed at the beginning of 1915 in the military territory of the Niger by one Dr Sommerfeld, a German veterinarian and prisoner of war who had seen rinderpest in 1913 in German East Africa. Investigations showed that the disease probably spread from Chad in 1914 to northern Nigeria and from there to the Gaya region of the Niger. Various sanitary cordons were developed in an attempt to prevent further westwards spread and although these delayed the infection they could not prevent it happening. Benin was infected in 1916 as was Burkina Faso and Mali (then termed

Upper Senegal). Ghana was infected in 1916. Côte d'Ivoire, Mauritania, and Senegal were infected in 1917 along with Gambia and Guinea. Togo became infected in 1918. Essentially then, in West Africa the pandemic lasted around 25 years after which the virus was endemically entrenched throughout West and Equatorial Africa giving rise to a situation that national and international veterinary authorities contained using vaccination over the next 80 years.

The spread of the Great African Pandemic to southern Africa

Unlike the pattern of epidemics recounted by the Peulh, the Great Pandemic, uniquely as far as we know, also spread southwards into Ethiopia, through East Africa and to South Africa. Its passage through these territories is vividly described in Chapter 2.2.

Having crossed the Tanzanian–Zambian border, rinderpest's immediate southwards spread went unrecorded, although by virtue of its subsequent appearance in Zimbabwe it clearly happened, having transited Zambia (and possibly Malawi) in game species. The disease appeared on the northern bank of the Zambezi river in 1893 and, after a delay of some three years, crossed into Zimbabwe around February 1896. Shortly thereafter an infected cattle herd was marketed near Bulawayo with the result that the disease was confirmed there in March that year and also, almost simultaneously, in Harare (then known as Salisbury), inflicting a 97% mortality rate on infected stock and a general air of desolation and death on the area (5) where hitherto there had been a thriving livestock population.

Continuing its spread, likened to a destructive prairie fire, by March, rinderpest was also present in Botswana (erstwhile Bechuanaland) where the road from Gaborone to Bulawayo was lined with dead draught oxen and their supply wagons. By April, further east, it had also reached Transvaal. A conference in Mafeking (then in British Bechuanaland) endorsed a range of zoosanitary control measures to be taken to control the disease, and in August a second interstate conference was held at Vryburg to discuss further measures.

The final stages of the Great Pandemic were also famous for prompting research into remedies or cures for the disease. Building on contemporary Russian research, a team comprising Arnold Theiler, a Transvaal Government veterinarian, and Herbert Watkins-Pitchford, Chief Veterinary Surgeon, Natal, began work studying immune serum as a curative method and the simultaneous inoculation of the virus and immune serum as a prophylactic method. In early 1897, Dr Theiler's efforts were subsumed into another team led by Drs Bordet and Danysz, brought in from the Pasteur Institute, Paris; this team reported its results in June 1897. The use of serum to treat already infected animals considerably reduced mortality rates, although deaths might still occur. This was the so-called 'French method'. To protect unexposed animals, these were infected with blood from an ongoing case ('virulent blood'), monitored for a febrile reaction and then treated one or more times with immune serum.

In the midst of the search for a preventive method, the famous German bacteriologist, Robert Koch, arrived in Cape Town – at the beginning of December, 1896 – and began work at Kimberley with a team of local staff comprising Drs George Turner (Medical Officer of Health, Cape Colony) and Alexander Edington (Director of the Colonial Bacteriological Institute, Grahamstown). Koch was at pains to discover a means of 'attenuating' the virus, and in February 1897 he reported that bile from an infected ox could render the recipient immune to a challenge infection. Although the science of this method has never been fully explained, it would seem that bile from infected animals could behave as a partially inactivated rinderpest vaccine. However, it could sometimes contain more live virus than dead virus and set up a fulminating infection. Koch's stay in South Africa was abruptly halted when he was ordered to India to investigate plague; his technique was modified to the extent that any live virus present was inactivated by glycerine but the overriding opinion appeared to have been that the bile method could actually disseminate the disease and it never came into general use.

Vogel and Heyne (43) tell us that in the three and a half years after 1896, 2.5 million cattle died of rinderpest, including 66% of all cattle in Transvaal, 46% of all cattle in Natal and 90% of all cattle in Matabeleland. While it took seven years to fully eliminate rinderpest from South Africa, the appalling mortality rates must have taken their own toll on the virus's survivability. P.J. du Toit, former South Africa's Director of Veterinary Services, remarked that attempts to vaccinate had been useless and that the disappearance of the disease was largely due to an exhaustion of the supply of susceptible hosts.

The infection reached Lesotho in 1897 and spread to Namibia and Mozambique in 1898. For a fuller understanding of the history of the concluding stages of the Great Pandemic the reader is commended to the excellent and detailed accounts provided by Clive Spinage (5) and the illustrations provided by Vogel and Heyne (43). The dates of the last occurrence of pandemic rinderpest in the countries of southern Africa are shown in Table VII.

TABLE VII
THE YEAR OF LAST OCCURRENCE OF RINDERPEST IN SOUTHERN AFRICA

Country	Date of last occurrence
Botswana	1899
Lesotho	1896
Malawi	Never reported
Mozambique	1896
Namibia	1905
South Africa	1904
Swaziland	1898
Zambia	1896
Zimbabwe	1898

Postscript to the Great African Rinderpest Pandemic

The disease was eradicated from South Africa in 1905 and, as indicated above, was untraceable in Malawi in 1910 and Zambia in 1920. The final legacy of the great epidemic was to be a continent-wide belt of endemically infected countries stretching from Senegal in the west to Eritrea, Djibouti and Somalia in the east and with a southward extension through East Africa, which included Kenya, Uganda and Tanzania.

While eradication from these countries was still 90 years away, in the decades immediately following, Tanzania came to be seen as the country responsible for ensuring that another south African debacle was avoided. By 1912 the disease was endemic among cattle north of the central railway. This feature runs from Dar es Salaam to Kigoma following a line that effectively divides the country into northern and southern halves; in subsequent years the spread of rinderpest south of this line provided a performance indicator that control measures were becoming ineffectual. This happened during the First World War (1914–1918) when British and German forces fought a campaign down the eastern side of Tanzania and rinderpest spread from northern to southern Tanzania and into Zambia. In response to this unwelcome spread the South African Government sent a commission to Tanzania to create a 15–30 km cattle-free strip along the Malawi–Zambia border with Tanzania and, using the virus–serum simultaneous method, an additional belt of immune cattle positioned 50–65 km north of the border (44). At the same time the Tanzanian authorities undertook similar immunisation work in other areas south of the central railway so that by 1918 southern Tanzania was again rinderpest-free.

By 1936, rinderpest seemed to be moving steadily southwards again (though still north of the central railway), assisted by the movement of infected game animals. In fully susceptible herds mortality rates of up to 20% were recorded. In 1937, rinderpest moved south of the central railway, crossed the Great Ruaha river and reached the southern highlands. In the north of the country buffalo and eland were frequently implicated in the spread of infection, but in the south the greater kudu assisted in the process. At the onset of outbreaks, the disease was often mild and therefore unrecognised, but by 1938 the situation had become so grave that an attempt was made to create a 130 km immune barrier in the face of the disease. This did not stop the spread of the virus and when, in 1939, the newly constituted rinderpest intelligence service found rinderpest close to the international border, it was decided to create another belt along the border itself, from Lake Nyasa to Lake Tanganyika. Initially, in 1939, inactivated spleen vaccine was used (45) and over a million doses were produced before being superseded by the introduction of Kabete attenuated goat (KAG) vaccine. 1941 saw the start of the construction of a 2,400 km-long game-proof fence along the international border separating Tanzania from Malawi and Zambia (46); rinderpest did not cross this barrier. Meanwhile the Veterinary Department used KAG to carry the fight to the virus and by 1942, and over 2.7 million vaccinations later, rinderpest no longer occurred south of the central railway; at the same time good progress had also been made in disease control north of the railway line.

Rinderpest in Egypt

Egypt suffered limited introductions of rinderpest in 1841, 1863 and 1883, the virus being introduced with infected trade cattle from sources in southern Russia, southern Europe and Asia Minor. Fleming (11) confirms an outbreak beginning in 1841 and raging until 1844 that caused an estimated 665,000 deaths. Enquiry suggested that the disease arrived with Russian steppe cattle brought in through the Mediterranean ports of Adana and Tarsus. These outbreaks appear to have been confined to Egypt and eliminated after each incursion.

Early in the 20th century (1903) Egypt experienced a further well-documented incursion of rinderpest (28). Its origins lay with 'Bagdadlis' – imported cattle possibly carrying subclinical rinderpest and imported from Mesopotamia (the area of modern-day Iraq lying between the Tigris and Euphrates rivers). Such animals arrived in Egypt by boat either from Syria or from Iraq (having been shipped from Basra) and were fast-tracked into the slaughter house at Alexandria. By virtue of its low-grade pathogenicity, the virus apparently entered the slaughter house unnoticed, but subsequently escaped either as infected meat or on contaminated clothing, and an epidemic among local animals ensued. In the fully susceptible Egyptian stock, the virus apparently regained its virulence and caused some 354,647 deaths. The invading virus caused a two-year-long epidemic (1903–1904).

Over the succeeding 60 years Egypt recorded a further series of rinderpest epidemics interspersed with periods of freedom from overt clinical disease (see Table VIII). Neither the 1917 nor 1921–1923 epidemics were associated with fresh invasions from an external source but the 1945 to 1947 outbreaks arose as a result of the importation of live (infected) animals from a fresh source – Anglo-Egyptian Sudan (47). Each of the outbreaks was controlled and apparently eliminated but the interepidemic period was not investigated.

TABLE VIII
RINDERPEST MORTALITY LEVELS DURING EPIDEMIC PERIODS IN EGYPT

Year(s)	Rinderpest deaths in bovines
1903–1904	354,647
1917	500
1921–1923	697
1945–1947	831
1950–1953	800
1961–1963	315
1982–1986	11,423

During the 1953 outbreak it was noticed that the disease did not always appear in its classic form and that mild cases were occurring from which there could be recovery. During the final epidemic (in 1984) a virus was isolated from a sick steer in a feedlot near Cairo. In experimental cattle at the Pirbright Institute, United Kingdom, this virus (Egypt/84) behaved erratically inducing clinical infections that could be clinically silent or distinctly overt. In the event, it is now known that this virus relates to the descendants of the Great African Pandemic (and probably the Sudanese introduction) and therefore not to the 'Bagdadlis introduction' coming from Mesopotamia. Rinderpest was eradicated from Egypt within a period of intense vaccination that ended in 1996.

Final stages

Throughout the 1940s, 1950s and 1960s individual government Veterinary Services within Africa brought rinderpest under control through the widespread use of live attenuated vaccines in intensively farmed areas. As these campaigns generated levels of population immunity probably approaching 70% the virus became less frequently an epidemic problem and began to assume a lower level of virulence. In the Sudan, for instance, in the face of such control, the case fatality rate dropped from an initial 80% to a more commonplace 1.7% (Babiker El Hag Ali, personal communication).

In addition, the virus was able to adapt to survive within endemic foci in remote, poorly vaccinated populations. These viruses were occasionally identifiable by virtue of their pathogenicity in non-bovine hosts. Thus, Roeder *et al.* (17) deduced the existence of a lineage 1 endemic area in the 1970s and 1980s encompassing Egypt, Sudan, Ethiopia and parts of Kenya and Uganda (Box 1). These authors spoke of an outbreak in southern Ethiopia beginning in 1975 in giraffe and lesser kudu and spreading northwards in cattle along the (Ethiopian) Great Rift Valley and into the more northern Afar region of Ethiopia in 1976 and into Sudan in 1978. Latterly, in keeping with the lineage distribution map for the early 1970s (Fig. 2), this endemic focus was still present in northern Kenya in the 1980s and still present in the Afar region in 1994.

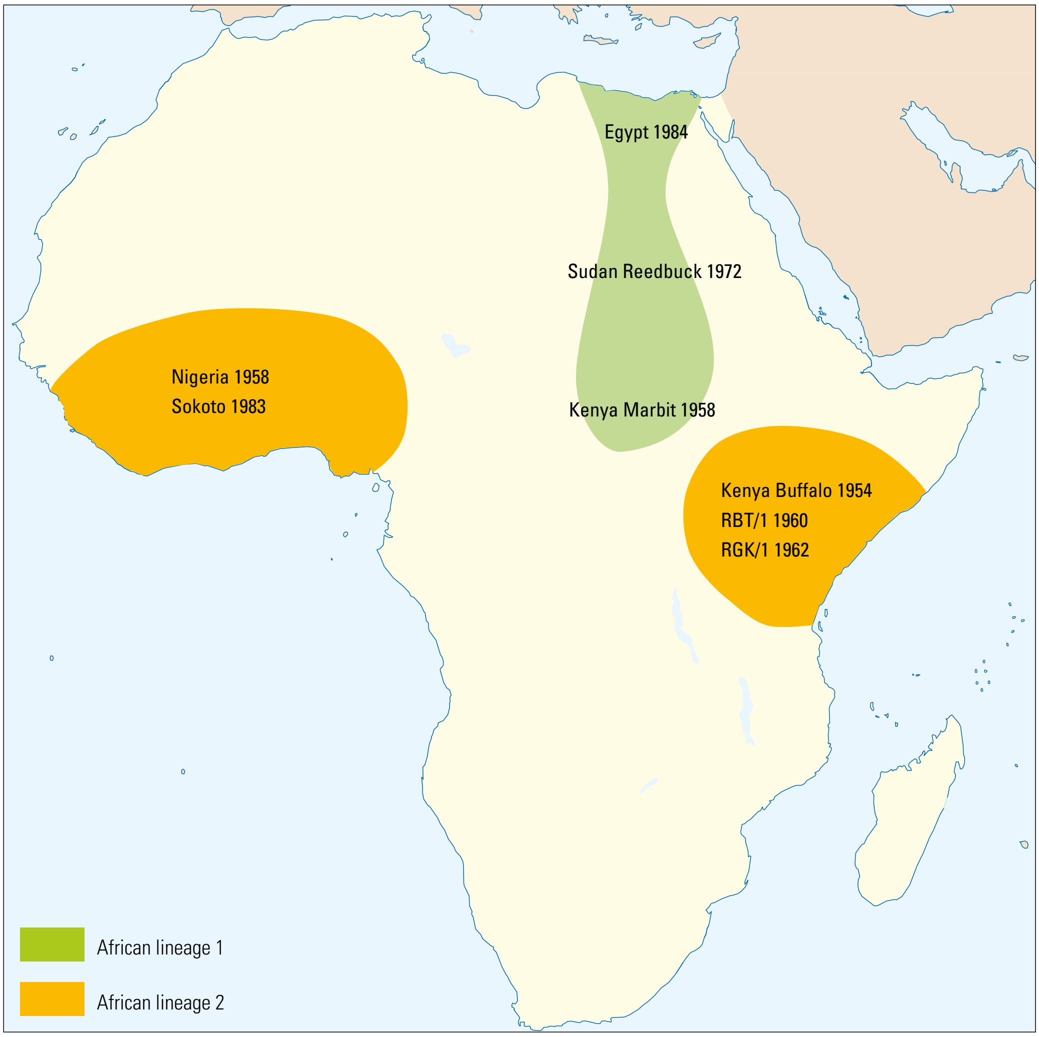
Somewhat exceptionally, epidemics did still happen, such as the three-year-long epidemic in Kenyan game animals and cattle described by Stewart (48). This epidemic had the additional significance of yielding a lineage 2 isolate (RGK/1) from a sick reticulated giraffe in a remote area of Kenya in 1962 (49). Again in 1962 a suite of lineage 2 viruses of a mildness (for cattle) as to be almost clinically unrecognisable were found within an endemic focus in the Arusha region of Tanzania (50). Subsequent studies by Mariner *et al.* indicated that lineage 2 virus (probably with a similar loss of virulence) had persisted for 30 more years in an ecosystem in the north of Kenya and the south of Somalia (51).

In the aftermath of the first international eradication effort based on mass vaccination (Joint Programme 15, or JP15) across sub-Saharan Africa, three significant foci of persistence remained, one due to lineage 1 in Sudan–Ethiopia, another due to lineage 2 in the so-called Somali ecosystem and the third also due to lineage 2 in Mali–Mauritania. In Mali rinderpest was regularly reported from the conclusion of JP15 (1969) onwards and by the early 1980s residual immunity levels were insufficient to constrain the virus. Thereafter a major epidemic ensued carrying this (lineage 2) Malian virus through Burkina Faso into the Niger and western Nigeria. On the other side of the continent, in 1982, Sudan reported a number of outbreaks involving North and South Kordofan, North Darfur and around Dongola. The 1982 outbreaks around Dongola were associated with motorised transport,

BOX 1
A STUDY OF THE AFRICAN RINDERPEST LINEAGES AIDS THE EPIDEMIOLOGICAL UNDERSTANDING OF THE VIRUS

Figure 3 of Chapter 1.1 outlines the relationships between all available strains of rinderpest based on a molecular phylogenetic analysis of F gene polymerase chain reaction fragments. This shows that field strains of rinderpest fall into three lineages, an Asian one and two African ones. It appears that within Africa during the 20th century a subgroup of viruses evolved in Sudan–Ethiopia–Kenya to represent lineage 1, while viruses from West and East Africa remained closely aligned with each other forming lineage 2. The distribution of available lineage 2 isolates corresponds to the eastern and western extremes of the sub-Saharan region of Africa where the virus became endemic following the Great Pandemic.
An attempt to show the relative disposition of the lineages during the second half of the 20th century is presented in Figure 2. When representatives of the two lineages overwhelmed Nigeria in the early 1980s the relatively mild lineage 2 virus coming from the west (Sokoto 83) contrasted with the highly virulent lineage 1 virus spreading out of Sudan (Yankari buffalo) – see Chapter 2.4.

FIG. 2
THE DISTRIBUTION OF NAMED VIRUSES SUGGESTING TERRAIN OCCUPIED BY AFRICAN LINEAGE DURING THE SECOND HALF OF THE 20TH CENTURY
Source: United Nations, 2018 (54), modified to indicate the distribution of named viruses



while the outbreaks in North Darfur were associated with nomadic movements. The outbreaks in North Kordofan were the first since 1971, although generally post-JP15 Sudan was regarded as being endemically infected and there were data to show a rising incidence of outbreaks between 1978 and 1984 (3 in 1978, 24 in 1979, 36 in 1980, 65 in 1981, 94 in 1982, 65 in 1982). There had been decreased annual vaccinations, and cattle nomadism was not under veterinary control. The further spread of rinderpest became part of an epidemic that spread through Kordofan, across Chad and northern Cameroon (in trade cattle) to reach the Dikwa control post in Borno state, eastern Nigeria, in 1982 (52). The infected herd was impounded, but within two weeks the disease had begun to disseminate within Borno state and neighbouring Gongola state and thereafter continued its rapid spread within the herds of the Fulani pastoralists. When the virus invading eastern Nigeria was shown to belong to lineage 1, there could be little doubt but that it originated in the Ethiopia–Sudan cryptic nidus. D.R. Nawathe describes the impact of these events in Nigeria (Chapter 2.4); they prompted calls for further international assistance ultimately leading to the reinstitution of mass vaccination and the eradication of rinderpest from Africa (the dates of the last occurrence of rinderpest in African countries are provided in Chapter 4.2, The Pan-African Rinderpest Campaign). In a final twist, rinderpest of lineage 2 appears to have lingered in East Africa beyond the reach of the mass vaccinators and to have resurfaced in wild buffaloes in both Tsavo and Meru National Parks, Kenya, where its ultimate burnout in 2001 was carefully monitored (53; Chapter 2.5).

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CHAPTER 2.2

THE GREAT AFRICAN RINDERPEST PANDEMIC, 1887–1900, AND ITS DRIVERS

R. KOCK [(1)*] **& M. RWEYEMAMU** [(1, 2)]

(1) The Royal Veterinary College, Hawkshead Lane, North Mymms, Hatfield, Hertfordshire AL9 7TA, United Kingdom
(2) Southern African Centre for Infectious Diseases, African Centre of Excellence for Infectious Diseases of Humans and Animals, Sokoine University of Agriculture, United Republic of Tanzania

*Corresponding author: rkock@rvc.ac.uk

SUMMARY **The Great African Rinderpest Pandemic is legendary for its impact and legacy at the end of the 19th century on indigenous communities, livestock and wildlife, on the colonial settlers, administrators and officers and on the natural ecology of the African savannahs. This was not the first time the disease had emerged, but it was the most dramatic and extensive event ever recorded. Prior epidemics were most probably caused by cattle being introduced from Europe and Asia, where the disease was prominent in the 17th and 18th centuries, but the disease remained relatively localised and subsequently burned out. Descriptions consistent with rinderpest in Egypt and a few other countries were recorded in the early 1800s, but the virus never spread so extensively and with such devastation as in the Great Pandemic. The conditions for this widespread invasion were clearly optimal by this time, and a significant disease introduction into the Horn of Africa in 1887 appears to have been the trigger. Military expeditions, colonial and indigenous livestock, and wildlife (mostly buffalo, eland and antelope) spread the virus throughout the continent. Sudan was a pivotal region, providing opportunity, through both nomadic livestock and trading patterns, to funnel the disease to the Atlantic coast. Meanwhile, the disease spread rapidly into East Africa up to the extensive ecological barrier of the Miombo woodlands in today's United Republic of Tanzania, where it paused, or so it seems, until exploding, most probably through wildlife that bridged the transmission across this tsetse-ridden region, into Zimbabwe and finally into South Africa, leaving desolation behind. The disease then became established in parts of Africa, with periodic epidemics in eastern, central and western Africa during the following decades, including epidemics in wildlife populations, the last of which occurred in Meru National Park, Kenya, in 2001. This event in Meru National Park heralded the final eradication of the virus from the region, from Africa and indeed from the world.**

KEYWORDS **Great African Rinderpest Pandemic –** ***Morbillivirus*** **– Rinderpest.**

INTRODUCTION

The global significance and the modern conception of rinderpest as a disease requiring control for the public good probably resulted from the experience and stories of the disease in Africa. Its emergence and control is as much a part of the evolution of African society as it was an example of an introduced pathogen. In the 19th century, before the great pandemic of 1887–1900, which is the focus of this chapter, there had been several rinderpest incursions into Africa. In 1805, rinderpest had ravaged the 'Soudan' and had been seen by Olivier, a veterinary artist, in Senegal in 1828, as reported by Curasson (1). Moreover, the Peulh people of West Africa related that the disease appeared every 25 years and always came from the east, information that Curasson felt coincided with West African epidemics known to have taken place in 1828 and 1865. He thought that the virus reaching West Africa was probably first introduced to East Africa by Indian and Persian cattle traders plying the East African seaboard and which occasionally spread through Central Africa to West Africa. Supporting evidence for this was provided by the restrictions on trek animal movements from the Horn of Africa to the interior (cited in Pankhurst [2] writing about the Earl of Mayo's expedition in 1876). Whatever the facts, these 'stuttering epidemics' were precursors to the Great African Rinderpest Pandemic, an event of such massive scale and impact as to be probably unprecedented in the history of animal disease.

THE EAST AFRICAN GATEWAY

In 1885 an Italian expeditionary force occupied the then Ethiopian port of Massawa. Pankhurst (2) ascribes the origin of the pandemic to the importation of infected cattle from India to provision these troops and even identified the Italian importing agent. Rowe (3) cites S. Sonnino, writing in *L'Africana italiana* (Rome, 1890), as noting the presence of rinderpest in Massawa at the end of 1887 when the military expedition of General San Manzano into the Ethiopian highlands was getting under way. Subsequently Pankhurst chronicles its spread southwards to Hamasien province (Asmera region) and in 1888 to Tigrey, Begemder (modern Gondar, Ethiopia), and Gojjam. The likelihood that Massawa could be contaminated with rinderpest from India is corroborated by Littlewood (4), referring to the Major Von Wiessmann expedition from German East Africa into the interior between 1888 and 1889 suffering a 'disease like plague' with cattle purchased from (not too distant) Aden and probably originating from Bombay (now known as Mumbai).

What came to distinguish this particular introduction from its predecessors was its extent and the rapidity with which it spread, the involvement of both cattle and wildlife species and the enormous losses it caused across the board, fully justifying the epithets of *great* and *pandemic*. To make the following narrative more easily understood Figure 1 provides a broad outline of the routes within Africa taken by the pandemic strain.

EMERGENCE OUT OF THE HORN OF AFRICA

By 1889 rinderpest was in Shewa province of Ethiopia (2) and spread east to Harar (Harai region) and had probably already spread to the coastal areas of the Danakil desert. This took the disease into Somalia, and there were reports of heavy losses of cattle in the Somali trading centre of Luuq and its further spread to Janale. By 1889, it had reached the north end of Lake Turkana. Rowe (3) quotes the PhD text of Paul Robinson indicating that the Gabbra-Oromo tribe of the region had heard of the disease's southwards march, devastating herds in the Galla lands of southern Ethiopia and north-eastern Kenya.

Pankhurst (2) also notes that the new introduction appeared to possess the novel features of both being highly virulent, causing peracute deaths (i.e. death before the full extent of clinical disease becomes apparent, as inferred from the epidemic being so violent that observers spoke of 500–1,000 deaths in a herd within 48 hours), and having the ability to spread very rapidly. The desolation was enormous, unique and memorable. Mortality rates of 90% were noted in cattle, while in wildlife there was also heavy mortality. It was clear that the epidemic had affected a variety of ruminant species and killed buffalo and antelopes to no lesser an extent than cattle, although certain gazelle species, most probably dorcas gazelles (*Gazella dorcas*), and sheep and goats had survived. It was suggested that the country (Ethiopia) had been transformed by the epidemic and that buffalo and hartebeest, which formerly roamed in their hundreds, were now almost extinct. The mobility of hosts seems to have been a crucial factor in the spread of the epidemic. Discussing the southward and westward spread, Rowe (4) indicates that buffalo and eland tended to wander long distances, spreading the disease in the process through watering points shared with cattle.

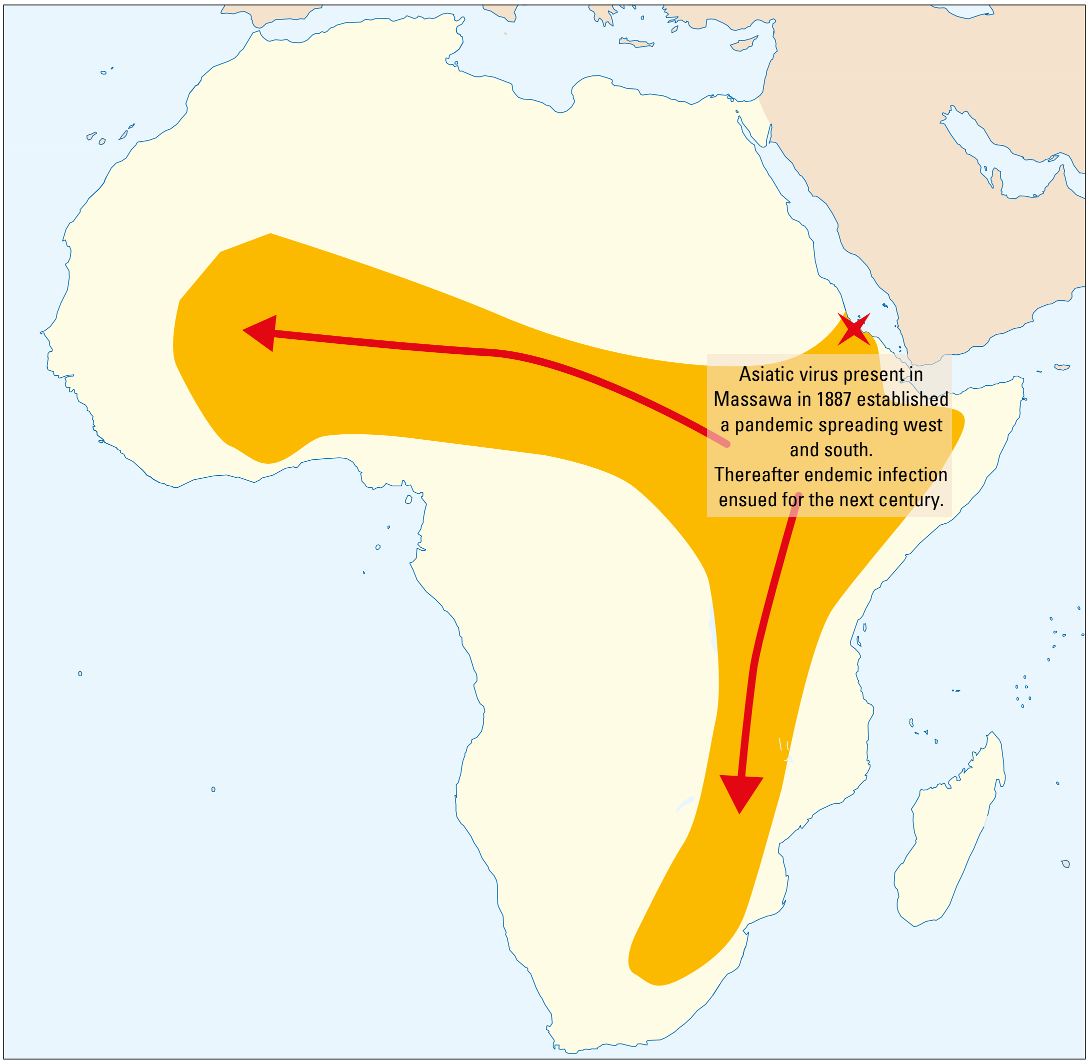
THE WESTWARD SPREAD OF THE VIRUS, A PIVOTAL ROLE FOR SUDAN

The infection spread from south-western Ethiopia westwards along the Sobat and Pibor rivers into

FIG. 1

SPREAD OF PANDEMIC RINDERPEST 1887–1900

Source: United Nations, 2018 (23), modified to indicate the spread of pandemic rinderpest



southern Sudan. Rowe (4) has looked for an account, similar to that in Ethiopia, of a major epidemic in Sudanese cattle populations in the immediate post-incursion period – say 1888 to 1891 – but found none. Indirect evidence explained below indicates, however, that such an epidemic did occur but was not recorded at the time. A report into rinderpest in Khartoum in 1900 by Professor W. Kolle of the Koch Institute in Berlin, reported by Hødnebø (5), contrasts the (contemporary) mortality rate of 10–40% with a 95% level in 'an epidemic north of Omdurman in 1888'. In this publication Hødnebø noted that cattle could be moved from Massawa to Omdurman in a few days. Recognising that the virus was present in Massawa in 1887, it seems probable that a major epidemic took place north of Omdurman in 1888 and that the epidemic strain involved had come directly from Massawa a year earlier. Twelve years later a less virulent, endemic infection was present in northern Sudan, no doubt resulting from the earlier epidemic (virulence levels appear to decline in endemic situations). Even so, cattle appear to have thrived, confirmed by the fact that after 1899, when Sudan came under Anglo-Egyptian administration, cattle were present in large numbers, suggesting that there had been no recent large-scale mortality.

THE EPIDEMIC REACHES THE ATLANTIC OCEAN

Yet in the absence of a massive epidemic, rinderpest successfully transited Sudan, probably following stock routes in the west of Sudan. de St. Croix (6) believed that it moved through Central Africa along a well-travelled route from Darfur via (Wadai) Chad and into the Fulani cattle of the West African Sahel. Rowe (4) considers the fact that rinderpest reached the Fulani and other West African pastoralists so quickly was suggestive of a fairly direct passage through the grazing lands of Kordofan and Darfur, although he could trace no account of this happening. Once the disease was in German Cameroon and French West Africa, contemporary cattle losses were said to be at the 98% level. There was a reliable account of it reaching Dori, in Burkina Faso, in 1891 and it reached Dakar, Senegal, in June 1892, five years after the epidemic began in Massawa (1).

THE VIRUS REACHES EAST AFRICA AS A LETHAL PANDEMIC

Having been recorded beside Kenya's Lake Turkana in 1889 (4) the epidemic continued to move south, west and east.

In November 1890, the English hunter–explorer, Captain F.D. Lugard, writing of the Kamasia range (Tugen hills) in Kenya (a year after rinderpest had been observed on the shore of Lake Turkana, some 200 km to the north), stated that:

> 'here for the first time we began to find carcasses of buffalo, recently dead of the plague, and, as we passed onwards, they daily became more numerous, and we found that this dreadful epidemic had swept off all the cattle and wild buffalo, and much of the other game beside. The vultures and hyenas were too surfeited to devour the putrid carcasses, which lay under almost every tree near water.'

From Lugard's writings (7), it is apparent that the epidemic was affecting a range of species and that its geographic spread from north-east to West and East Africa justified the description of a pandemic. Rinderpest reached the Kavirondo, Maasai and Kamba regions of Kenya in the second half of 1890 and reached Tanzania through the transnational Maasai ecosystem. A combination of rinderpest, smallpox, drought and an impoverished, weakened Maasai community, which had been driven by colonial forces from their extensive grazing lands and restricted to the Serengeti ecosystem, resulted in a devastation of cattle and wildlife that was described by a young Maasai man in the Engaruka Basin of Ngorongoro, Tanzania, as 'so many and so close that the vultures had forgotten to fly' (8). Spear (9) also wrote:

> 'Rinderpest devastated the herds of pastoral Maasai, driving them into the mountains to seek refuge; smallpox spread rapidly along the trade routes recently forged up the Pangani valley; and drought and killing famine blanketed the area, especially during the years 1883–1886, 1891–1892 and 1897–1900.'

Rinderpest was also being introduced independently into Tanzania in 1889–1891 west of Lake Victoria, spreading from Ankole-Bunyoro in south-west Uganda into Karagwe, Missenye and Kiziba in Tanzania. Here again the devastation due to rinderpest was exacerbated by drought, inter-clan fights in Ankole (Uganda) and Karagwe (Tanzania) and an epidemic of smallpox (10, 11).

The German expeditionary, Emin Pasha, encountered rinderpest in the west of Uganda (Mpororo) in 1891 (4) and Lugard identified the disease at Kavalli on the west side of Lake Albert, in the Democratic Republic of Congo, in September 1891. Here he found that it had 'swept off every ox only a few weeks before I arrived'.

By 1892, rinderpest had traversed Tanzania into Malawi and Zambia. Lugard cites the writing of Sharpe, a hunter, saying that

> 'Shortly before August 1892, the district at the north of Nyasa had been visited by the cattle-plague. The mortality was over 90 per cent, and practically all the cattle were cleared out. On my way across to Tanganyika (Tanzania) I found that parts of the country had been visited, and portions had escaped. I had no evidence that this disease had attacked the wild game till I arrived at the end of Lake Mweru. Here enormous quantities of game have died. At the time of my passing the Luapula river, in October 1892, the plague was at its height. Dead and dying beasts were all around. On the first day I counted over forty dead Pookoo [*Kobus vardani,* a marsh antelope of central Africa] within half a mile of my camp. Elephants do not appear to have been attacked by the plague.'

Lugard's comments on what he witnessed and had been told included the following:

> 'Not for thirty years has a plague like this been known in the country, and even then it was not to be compared in virulence to the present one. Never before in the memory of man, or by the voice of tradition, have the cattle died in such vast numbers; never before has the wild game suffered. Nearly all the buffalo and eland are gone. The giraffe suffered, and many of the small antelope – the bush-buck and reed-buck, I believe, especially. The nsunu (*Kobus kob*) was affected only partially, and very large herds were left both in Buddu and near Lake Albert; but Mr Sharpe reports this antelope as having been especially attacked in Nyasaland. The pig (wart-hog) seem to have nearly all died. The elephant, hippo and water-buck are exempt. It is noticeable that the animals nearest akin to the cattle have died – viz., the buffalo and the most bovine of the antelopes, the eland. It is

therefore extremely curious that the wildebeest has escaped.'

Deputy Commissioner F.J. Jackson, quoted by Simon (12), estimated that at least 90% of the buffalo population had succumbed and graphically described the effects of the disease as follows:

> 'On my way down from Uganda in July 1890, between lakes Baringo and Naivasha, I saw in one day's march as many as six herds of buffaloes, in varying number from one to six hundred head in a herd. In the same district in the following March my friend Mr Gedge, on his way down to the coast, saw nothing but carcasses… In 1892 the officers of the Mombasa and Victoria/Nyanza Railway Survey only saw on two different occasions the spoor of a single beast, although they traversed a great part of the country where buffaloes were once so plentiful.'

These explorers' notes are accurate in as much as they correctly identify the origin of the Great African Rinderpest Pandemic and its effects on wildlife and cattle populations of eastern Africa where the virus, for the first time as a known pathogen of cattle, was introduced to a vast array of species, some of which were discovered to be highly susceptible to rinderpest virus. By the turn of the century, there was a good understanding of the variable resistance of the different species of game animal, with buffalo and tragelaphine antelope (e.g. eland, bushbuck), giraffe and warthog being highly susceptible, while waterbuck, hippo and other ruminants were less so. As already noted in Ethiopia, Lugard found that goats and sheep had been spared the ravages of the disease.

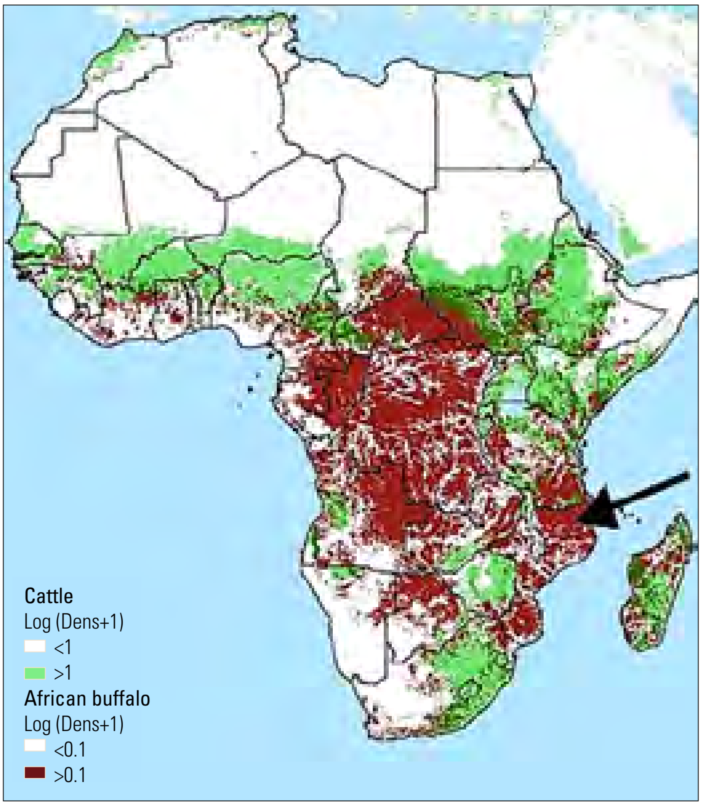
Having crossed the Tanzanian–Zambian border, rinderpest's immediate southwards spread went unrecorded, although, by virtue of its reappearance in Zimbabwe, it clearly happened, having been transmitted through Zambia (and possibly through Malawi), in game species.

Sharpe's sighting, as reported by Lugard, of sick game on the Luapula river well within the western borders of Zambia gives an inkling of what might have happened. At that time Zambia teemed with game but cattle numbers were low and were restricted to tsetse fly-free areas, with only limited movement between isolated populations. When Zambian livestock diseases were first investigated in the 1920s, no rinderpest was found and, more remarkably, no history of its having been present. In consequence, control measures never became a necessity in Zambia. Similarly, in Malawi where, when veterinary recording began in 1910, rinderpest was not present, there was no memory of rinderpest having passed through the country and no eradication efforts were ever needed. Therefore, the absence of evidence in cattle strongly suggests the virus traversed the region in wildlife, as discussed in the commentary to Figure 2.

FIG. 2
MAP OF AFRICA SHOWING THE CATTLE–BUFFALO INTERFACE

Green shading shows cattle and brown shows buffalo log density based on habitat suitability and population data. This simulates more or less the situation likely at the end of the 19th century showing how the north–south movement was dependent on wildlife to carry the virus through the Miombo woodland ecological barrier in southern United Republic of Tanzania, Zambia, Malawi and Mozambique (arrow). Buffalo were shown to be able to maintain and spread the virus over hundreds of kilometres and over several years (see Chapter 2.5) and, given its likely distribution at the time, this was probably a key factor in the disease reaching southern Africa.

Source: Robinson & Siembieda, 2011 (13), modifed to comply with United Nations (2020). Final boundary between the Sudan and South Sudan has not yet been determined



SPREAD IN SOUTHERN AFRICA

The final stages of the spread of rinderpest southwards in 1896–1897 (a decade after its entry to Massawa) are extensively chronicled by Edmonds (14). Writing in 1922 that author states that in southern Africa little was known of the contemporary disease events further north, and that the first indication of rinderpest's approach was the news of its presence in cattle on the north bank of the Zambezi river around 1893 (where it was held up for three years by the size of the obstacle in its path). Eventually, infected cattle and/or wildlife crossed the river into Zimbabwe and rinderpest reached Bulawayo in March 1896. Describing its subsequent spread Edmonds writes: 'leaving a never-to-be-forgotten stinking desolation. The country was full of cattle and big game both of which the disease decimated; it destroyed about 97% of the cattle.' Policies to limit the spread of the infection by the compulsory slaughter of trek oxen on the completion of their journeys southwards can only have added to the mayhem. In another attempt to prevent its southern spread, an east–west fence was constructed, but this too failed to halt transmission and the virus reached the extreme south of Zimbabwe in the same year (1896). At much the same time the disease spread westwards to Angola.

Rinderpest swept across the Bechuanaland Protectorate (now Botswana) in 1896, spreading along the transport routes towards Mafikeng. Knox, a British Member of Parliament (15), asked his Secretary of State for the Colonies:

> '... whether he is aware that the loss of cattle in the Bechuanaland Protectorate, owing to the ravages of the rinderpest, is causing very severe suffering to the natives, no less than 60,000 cattle having been lost in Khama's country alone ...'

Practically all trek oxen were killed in this outbreak and as a result a new railway line had to be built to maintain communications with South Africa with such urgency that the laying of 400 miles of line in 300 days constituted a world record.

Rinderpest reached South Africa within two months of crossing the Zambezi and by 1897 the Transvaal had lost 980,000 head of cattle. In 1897–1898 the Cape Colony lost 1.3 million head. The depth of the disaster led to the birth of international efforts to find prophylactic methods of control (see Chapter 3.4). The infection reached Lesotho in 1897 and spread to Namibia and Mozambique in 1898 and, according to Spinage (16), to Madagascar in 1890.

THE IMPACT OF THE PANDEMIC ON ANIMALS AND SOCIETY IN AFRICA

As mentioned in the introduction, rinderpest had caused small epidemics in Africa before the events of the Great African Rinderpest Pandemic. So why did the introduction of rinderpest to Massawa in 1887 cause a pandemic when previous introductions had not? There is no simple answer, but it is helpful to understand the social, political and biological context of the time. Rinderpest does not cause latent infections of epidemiological significance and cannot survive in the environment, requiring animal-to-animal aerosol contact for infection. It is likely that the host population and dynamics changed in Africa at or around this time, resulting in a robust chain of susceptible animals and thus supporting the pandemic. Settlers arriving in Africa from overcrowded European lands brought with them not only culture and agricultural tools but also significant numbers of domestic animals from Europe and Asia. The increase in animal populations, movement and trade, the invasion of wild lands, and the social disruption and conflict brought on by the colonial era were no doubt were contributory to the Great African Rinderpest Pandemic (17).

The devastation of the indigenous and immigrant livestock and wildlife population led to widespread hunger, social, political and livelihood impacts and reshaped the ecology of the African savannah. It is worth stating that rinderpest was not the only plague that benefited from these circumstances; in eastern and southern Africa there was a near-concurrent epidemic of smallpox pouring misery on misery (9, 12, 17). The Great African Rinderpest Pandemic was characterised by heavy cattle losses throughout eastern, western and southern Africa. It is not surprising that the Murle, Dinka, Shilluk and other peoples in southern Sudan regarded rinderpest in mythological terms: '... a monster that swallowed all their cattle' (18), and its presence fundamentally changed the livelihood of some tribes such as the Nuer, which shifted to more agropastoral systems (19). Rowe (4) cites various authors to suggest that recovery from the reverses sustained around 1890 to 1891 was not rapid. He also points out that a branch of the Nuer managed to preserve their cattle by sequestering them on isolated pastures and that the practice of splitting herds into smaller units was practised by the 1930s (19). In Uganda, the cattle of the Langi tribe were ravaged along with those of the Teso, Jie, Dodosi and Karamajong. The devastation was even greater in south and south-western Uganda and the cross-border areas of Rwanda and Tanzania (Karagwe), where the Ankole cattle were far more susceptible to rinderpest than the zebu cattle of northern Uganda. Cory (20) observed that the incursion of rinderpest into Karagwe at the end of 1889 transformed Karagwe from the richest pastoral area in the whole of Buhaya (west of Lake Victoria) into a poverty-stricken kingdom. Similarly, Rowe states that the loss of cattle brought about a shift in the balance of power, to the detriment of the Maasai in the Kenya–Tanzania transfrontier ecosystem, and that the descriptions of the explorers such as Lugard, presented earlier, are vivid. Branagan and Hammond (10) suggest that in East Africa the effect of the epidemic on the pastoral communities was to pave the way for the European settler community and the expansion of agriculturist tribes. This pattern continued into southern Africa where the epidemic of rinderpest is regarded to have contributed to the Shona–Ndebele uprising of 1896–1897 in Zimbabwe (21). In Nigeria, rinderpest decimated the herds of the cattle owners. According to de St. Croix (6):

> 'Fulani, having lost all, or nearly all their cattle became demented; many are said to have done away with themselves. Some roamed the bush calling imaginary cattle.'

In fact, similar reactions accompanied the losses they sustained in 1983 (Chapter 2.4).

Rinderpest was also characterised by heavy wildlife losses in eastern and southern Africa, and these have been described earlier. Nevertheless, it was observed even then that certain wildlife animals were not affected by rinderpest (e.g. see account by Sharpe in Lugard [9]). This effect of rinderpest on animals and plants, fundamentally shifting the ecologies with long-term consequences, was described by Holdo for the Serengeti ecosystem (22). There was also the suggestion that the disappearance of wild ungulates and cattle was followed by bush encroachment, favouring wildlife recovery and increased tsetse colonisation (10).

The impact of rinderpest was more than the heavy losses of cattle and wildlife. It had a considerable impact on livelihoods, culture and settlements. In eastern and southern Africa, the devastation by rinderpest was exacerbated by three other concurrent factors: these were a widespread drought, an epidemic of smallpox and conflicts either within clans or between white settlers and the indigenous populations (4, 21). In parts of eastern Africa and southern Africa the fear of rinderpest contributed to the segregation of white settler farmers from the indigenous population, as the latter had cattle herds that were regarded as a risk for the introduction of rinderpest (9).

FROM PANDEMIC RINDERPEST TO ENDEMIC RINDERPEST AND THE FINAL WHIMPER

Arguably, after the virus killed a large proportion of the available hosts, the reduced host populations resulted in the modification of the virus that caused the Great African Rinderpest Pandemic. Under these conditions the virus became endemic across large parts of its distribution range and remained so for the next century or so, surviving the inception of veterinary services and the advent of vaccines. It could not, however, withstand the effects of internationally organised vaccination programmes. On the basis of virus isolates held by laboratories around the world, it has been possible to place isolates of rinderpest virus into three distinct phylogenetic lineages. This aspect of rinderpest is discussed in more detail in Chapter 1.2. The virus that is believed to have been the cause of the Great African Rinderpest Pandemic, before lapsing into endemicity and leaving a scattering of contemporary viruses with a common heritage, has been classified as lineage 2 (see Chapter 1.2). The final epidemic whimper of this lineage occurred in the buffalo populations of Kenya, as described in Chapter 2.5.

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CHAPTER 2.3

NEAR EAST EPIDEMICS OF RINDERPEST, 1924–1928 AND 1969–1973

A. SHIMSHONY [(1)*] & M. HOPP [(2)]

(1) 44/41 Rabindranath Tagore Street, Tel-Aviv 6934102, Israel (Former Chief Veterinary Officer for Israel, Koret School of Veterinary Medicine, the Hebrew University of Jerusalem)

(2) 6 Hannah Senesh Street, Herzeliya 46446, Israel

*Corresponding author

SUMMARY **During the 1920s, two epidemics were recorded in the Near East: the 1924–1927 epidemic in Iran, introduced from the north-western border (Caucasus and Turkey), which affected five of Iran's northern provinces; and the 1925–1928 epidemic, introduced from Turkey, which affected Syria, Lebanon, northern Transjordan and Mandatory Palestine. A third epidemic, about 41 years later (1969–1973), was introduced from Afghanistan into Iran, spreading throughout Iran and further into Turkey, the Syrian Arab Republic, Lebanon and Jordan.**

KEYWORDS **Rinderpest – Iran – Israel – Jordan – Lebanon – Mandatory Palestine – Syrian Arab Republic – Turkey.**

TRANSBOUNDARY RINDERPEST IN THE NEAR EAST, 1924–1928

Introduction

Rinderpest was present in Ottoman Turkey before and during the First World War, with several recorded incursions of the disease into other Near Eastern parts of the Ottoman Empire. Rinderpest maintained its circulation in Asia Minor after the end of the war (1918), the disintegration of the Ottoman Empire and the 1923 proclamation of the Republic of Turkey. It was eventually eradicated in 1932 (1). The continued circulation of the virus throughout the 1920s within the Anatolian cattle population – which was (and still is) the Near East's largest – had a decisive impact upon the epidemiology of rinderpest in other Near-Eastern countries during this period.

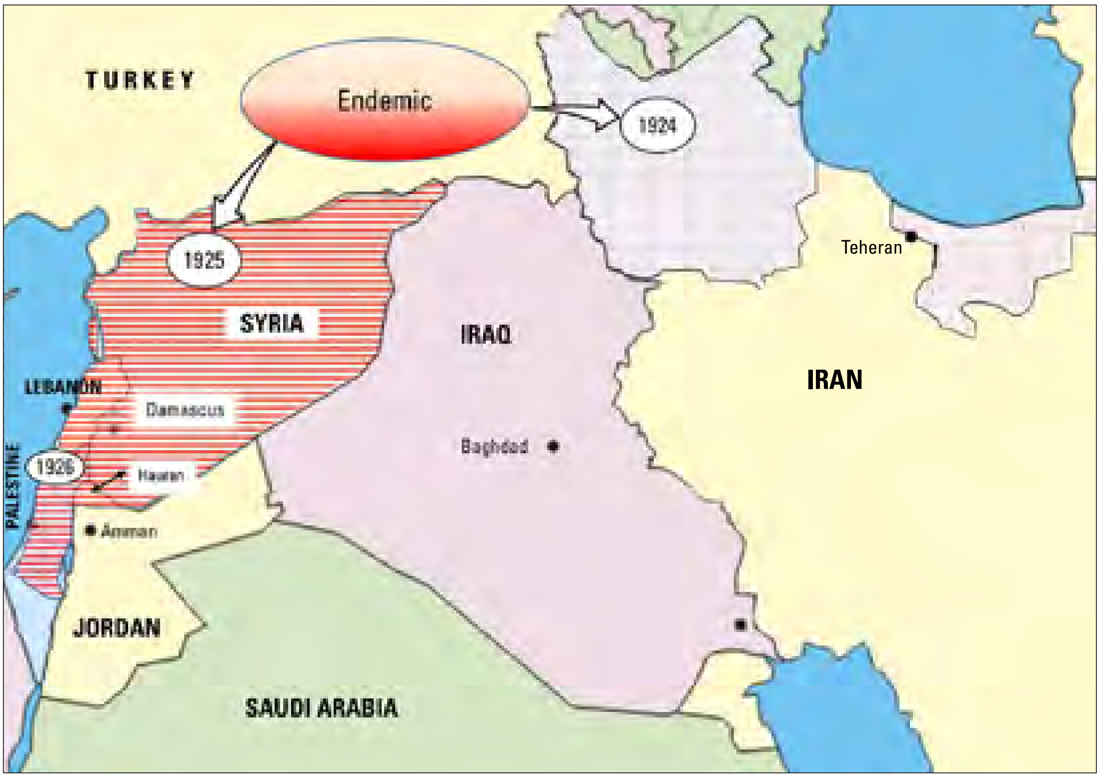
The 1924–1927 and 1931 epidemics in Iran

Iran (at that time called Persia) suffered a considerable outbreak of rinderpest that had been introduced in 1924 from the north-western border (between Caucasus and Turkey) (2). From Azerbaijan province, it spread into the Tehran region and thereafter affected Guilan, Mazandaran and Gorgan, resulting in extensive mortality and losses (Fig. 1). The epidemic was finally controlled with the aid of the then existing means of control, i.e. the serum–virus simultaneous method.

Notwithstanding its considerable damage and losses, this epidemic made a notable contribution to Iran's Veterinary Services by the creation, in 1925, of the Animal Disease Control and Serum Manufacturing Centre in Tehran, which undertook

FIG. 1
AN OVERVIEW OF THE EXTENT OF RINDERPEST INFECTION COMING FROM TURKEY TO NORTHERN IRAN (1924–1927) , SYRIA (1925–1928), LEBANON, NORTHERN TRANSJORDAN (1926–1928) AND PALESTINE (1926–1927) . IRAQ EXPERIENCED RINDERPEST BETWEEN 1918 AND 1923 (3)

Source: d-maps.com, 2020 (26), modified to show the extent of rinderpest infection. The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of FAO or the OIE concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement



the production of the antiserum. This epidemic lasted for three years and finally ended in 1927.

A second rinderpest outbreak took place in 1931 when the disease was again reported in north-western provinces. At that time, the laboratory moved to Hessarak, some 40 km west of Tehran, becoming later the Razi State Serum and Vaccine Institute (named after the famous Persian scientist and physician, abu-Bakr Muhammad-ibn-Zakariyd' al-Razi, b. 850). Initially assisted by French expertise, the Razi Institute produced a killed rinderpest vaccine that was used for preventive immunisation. Combined with the destruction of affected and in-contact susceptible animals, the 1931 outbreak was soon controlled and eradicated.

The 1925–1928 regional epidemic: Syria/Lebanon/Jordan/Palestine

Following the partitioning of the Ottoman Empire after the First World War, France obtained the status of mandate holder in Syria and Lebanon. The High Commissioner of the Levant, the highest-ranking authority, was based in Beirut. The political and military situation in Syria was unstable during the 1920s; most of the information on rinderpest in the French-controlled regions was published by British sources in Mandatory Palestine (in this chapter hereafter referred to as Palestine, the name applicable to the situation as it was between 1920 and 1948, when the entire territory west of the Jordan river was administered by the United Kingdom of Great Britain and Northern Ireland as a mandate).

In 1922, the British civil mandate administration was formalised under the auspices of the League of Nations. This included the establishment of government Veterinary Services, headed by a British Chief Veterinary Officer. The land west of the Jordan River, known as Palestine, was under direct British administration; the land east of the Jordan, similarly under the British mandate, was a semi-autonomous emirate known as Transjordan and was under the rule of the Hashemite family from the Hijaz.

In March 1925, the British (mandated) Government of Palestine published information about the prevalence of rinderpest in Asia Minor and Syria as background to their decision to 'prohibit importation of cattle from all ports of Asia

Minor and Syria, except Beyrut' (4). This indirect information on the presence of rinderpest in Syria (and its possible absence in Lebanon in 1925) was followed by another official, import ban-related, British notice that was published on 30 June 1926. It stated that rinderpest occurred in the Damascus and Busra-Sham Districts of Syria (5). Busra Ash Sham is a town in southern Syria, administratively belonging to the Daraa district and geographically part of the Hauran region, which is shared between Syria and Jordan. This notice was followed by a rule, signed by the High Commissioner of Palestine on 14 July 1926, which included the statement: 'Rinderpest, cattle plague or peste bovine occurs in certain parts of Syria and the Lebanon and Transjordan'.

Information on the deteriorating rinderpest situation in Syria followed when, on 29 July 1926, outbreaks were recorded in Palestine. The official notice attributed the source of infection to a rinderpest epidemic in the Damascus area 'of which no report was received in time to allow precautionary measures to be taken' (6).

According to later media reports, attempts by the French authorities to control rinderpest in the Hauran during 1926 had inconclusive results.

The continued circulation of rinderpest in Syria, Lebanon and the Hauran (Syria and north Transjordan) was discussed during a regional conference (Syria, Lebanon, Transjordan and Palestine), which met in Haifa in January 1927 (7). Details of the conference are included in the following section on rinderpest in Palestine.

According to information from Beirut, published on 29 June 1927, rinderpest was raging in Syria and Lebanon, with outbreaks reported in the regions of Damascus, Aleppo, Homs, Hama, Lebanon, Jebel Druze and the Hauran (Fig. 2).

Reportedly, 2,850 head of cattle were affected, of which 150 died and 300 were destroyed by order of the authorities (8). The control activities in Syria and Lebanon were hampered by political unrest and military operations, but eventually the disease was eradicated by the implementation of quarantine measures, the slaughter of infected animals and the inoculation of antiserum into contact cattle (9). The completed eradication in Syria and Lebanon and the absence of new cases in Transjordan allowed the Palestine government to withdraw its precautionary measures on 3 February 1928 (7). This date can be regarded as the end of the regional epidemic.

Rinderpest was present in Palestine when the region was conquered by Great Britain in 1917. The military authorities took measures to control

FIG. 2
AREAS OF SYRIA, LEBANON AND NORTH TRANSJORDAN AFFECTED BY RINDERPEST, 1925–1928

Source: d-maps.com, 2020 (26), modified to show areas affected by rinderpest. The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of FAO or the OIE concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement

recurrent localised outbreaks of disease; in 1920 it was completely eradicated (10).

The statutory legislative actions and precautionary measures undertaken by the British Mandate Government in Jerusalem between March 1925 and mid-July 1926, mentioned above, were designed to prevent the entry of the disease from Syria and Lebanon (Box 1).

In spite of these measures, on 29 July 1926, outbreaks of rinderpest were recorded simultaneously in villages in three of Palestine's subdistricts: Tiberias and Nablus in the northern district, and Ramleh

BOX 1
NOTICE BY PALESTINE'S BRITISH HIGH COMMISSIONER, PUBLISHED 6 AUGUST 1926 (11)

LORD PLUMER'S APPEAL ON CATTLE PLAGUE
(Officially Communicated.)

We are faced in Palestine and Transjordan with an outbreak of cattle plague, a disease which may, if it spreads, destroy practically all the cattle in the two countries.

The Government have issued certain emergency regulations by means of which it is hoped to keep the disease within limits.

It is fully recognised that these regulations will cause inconvenience and indeed hardship to many, but they are necessary in the public interest.

I earnestly hope that all in authority will take every opportunity to impress upon the people the importance of complying with these regulations in letter and in spirit, and I appeal to the people themselves to do all they can to assist the authorities in their efforts to prevent this outbreak becoming what it may be, a national calamity.

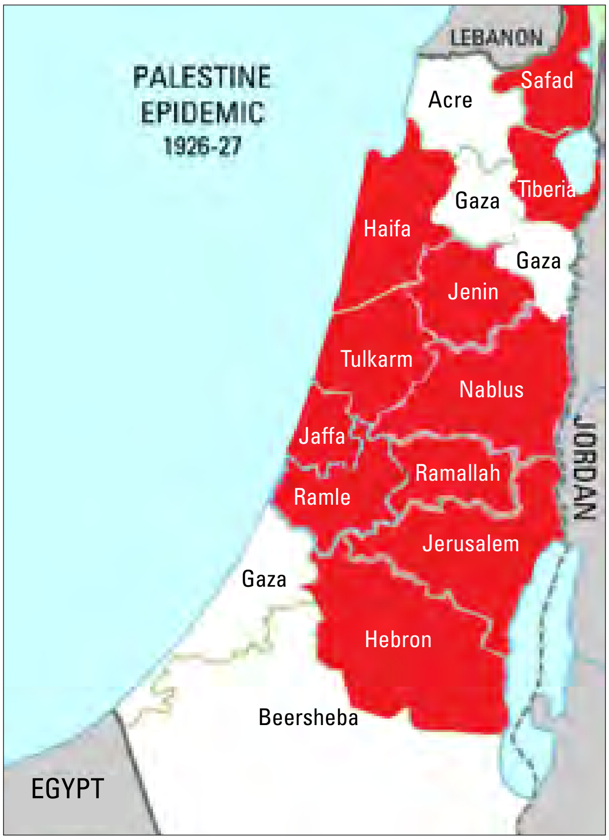
PLUMER, F. M.
6th August, 1926. **High Commissioner**

in the southern district. The source of infection was attributed to an (unpublished) epidemic of rinderpest in the Damascus area 'of which no report was received in time to permit precautionary measures to be taken' (6). The disease spread widely, eventually affecting 39 villages throughout Palestine (six subdistricts in the northern district and five in the southern district; see Fig. 3) before control measures could become effective. Emergency measures, including closures of animal markets and of slaughterhouses were immediately applied in both Palestine and Transjordan (6, 10).

The policy implemented in all affected holdings in Palestine included the slaughter of cattle presenting clinical signs and those exhibiting a temperature exceeding 39.5°C and inoculation of all exposed animals with antiserum. A single application of immune serum decreased the losses; repeated inoculations of the serum were found to effectively prevent further deaths and the need to cull animals. The total number of cattle subjected to infection in the 39 villages was 8,382; of these, 153 died and 266 were destroyed (because they showed disease signs) before inoculation of the herds with serum could be completed. The serum was imported from Cairo, Egypt; fresh quantities were supplied on a daily basis (12). The number of cattle inoculated was 8,031, of which 7,950 underwent a second inoculation. The total death toll, 419, represented 5% of the population exposed (6).

FIG. 3
SUBDISTRICTS OF PALESTINE AFFECTED BY RINDERPEST, JUNE 1926 TO JANUARY 1927

Source: d-maps.com, 2020 (26), modified to show subdistricts affected by rinderpest. The boundaries and names shown and the designations used on these map(s) do not imply the expression of any opinion whatsoever on the part of FAO or the OIE concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement



The disease was notified as resolved on 15 September 1926. However, on 20 December 1926, the disease recurred in northern Palestine through illicit introductions from Syria. The procedure for dealing with the new outbreaks was the same as that adopted after the original outbreak. In view of the fact that the number, distribution and location of the illicitly imported and infected cattle could not be ascertained, additional precautionary measures were introduced, including a total 'stand still' of cattle movements throughout the country and the establishment of cordons-sanitaires along the northern international borders with Lebanon and Syria, and along the demarcation lines between the Northern and Southern Palestinian Districts. The total number of cattle involved in this second event was 1,491, of which 19 died and 66 were preventively destroyed, representing a mortality rate of 5.7%. This brought the grand total of cattle deaths during both phases of the Palestinian epidemic to 504 (7).

The last rinderpest focus in Palestine, in the northern village of Yavne'el, was declared officially 'no longer infected' on 16 March 1927 (7), marking the epidemic's termination.

As rinderpest was still active in Syria and Lebanon, a conference of officials from Syria, Lebanon, Transjordan and Palestine was held at Haifa, Palestine, on 20 January 1927.

Its aims were:
a) to deal with any outbreaks occurring within the vicinity of the frontiers;
b) to establish a protective zone;
c) to secure cooperation and coordination of efforts of the governments at the four adjacent countries to prevent reinfection of Palestine and Transjordan (7).

The British and French High Commissioners ratified, on 30 March 1927, the mutually agreed measures to be implemented within the protective zones on both sides of the border in an emergency situation.

During the summer of 1927, rinderpest spread throughout the entire French-controlled areas, including the Hauran, and northern Transjordan (8). This led the Palestine authorities to implement, in early July 1927, the measures agreed upon earlier with their counterparts. This included the prohibition of all cattle movement within a defined zone adjacent to the borders with Lebanon, Syria and north-west Transjordan; the disease did not recur.

Eventually, the disease was eradicated in the Syrian Arab Republic, Lebanon and the Hauran and, as stated above, the final date of the Levant rinderpest epidemic was considered 3 February 1928 (7).

In 1948, Palestine became Israel, the West Bank and the Gaza Strip. The area remained free of rinderpest for the next 55 years, until it reappeared in early 1983 (13). The Syrian Arab Republic, Lebanon and Jordan remained disease-free until 1970.

NEAR EAST PANDEMIC 1969–1973

Iran

In June 1969, some scattered and unofficial information on a rinderpest outbreak in Afghanistan and West Pakistan was received in Tehran. The World Organisation for Animal Health (OIE) as well as the Iranian Embassy in Kabul were approached in order to get first-hand and reliable information on the matter. The news was not confirmed (2).

As reported by Afghanistan's delegate to the Food and Agriculture Organization of the United Nations (FAO)/OIE regional epidemics conference of October 1969 (14) and as further reported during a consultative meeting in Tehran, December 1969 (15), a considerable rinderpest outbreak did indeed occur in the middle of May 1969 in Afghanistan's western province Nimrose, bordering Iran's Sistan region (the northern part of the Iranian Sistan and Baluchestan province). Two veterinary delegations subsequently visited the affected Afghani region to investigate the event, eventually diagnosing rinderpest, which was confirmed in the laboratory. The primary outbreak was found to be a village near the Afghani town of Chakhansur. Reportedly, the disease spread from there south and west in the Nimrose province and it was known, in Afghanistan, to have reached, 'during that time', Iran's Zabol county. Zabol is situated in northern Sistan, about 25 km from the border with Afghanistan. After its introduction into Iran's territory, likely to have been in late May 1969, the disease spread all the way from Sistan to Tehran's environs, a distance of about 1,000 km, where it was eventually diagnosed on 24 June 1969. It was later suggested that the apparently delayed identification of the disease could be explained by the mildness of the disease and its atypical symptoms in the incubating, transported Sistani cattle when arriving in Tehran. These animals, relatively resistant to the disease, infected the fully susceptible and sensitive dairy cattle around Tehran, leading to a complete clinical picture of typical rinderpest, including high mortality, and allowing clinical and subsequent laboratory diagnoses, which were notified to the OIE. During the same time, similar cases were seen and reported from Esfahan (16).

During this time, shipments of cattle were transported along other routes from Sistan to Iran's various provinces, also spreading rinderpest. Because all highways of the country end up in Tehran, and the Tehran slaughterhouse is the largest livestock trading centre of the country, a number of incubating animals were sold and shipped, either by rail or truck, to the northern, central and western parts of the country, creating new disease foci. This disease dissemination route was, in fact, bidirectional, because the same vehicles transported infected animals from the periphery to Tehran's markets or slaughterhouse (2).

The routes of rinderpest spread in Iran are summarised in Figure 4 (2).

According to Iran's reports to the OIE, 21 outbreaks of the disease, in several parts of the country, were recorded during June 1969, and 109 outbreaks during July. The disease spread rapidly and by the middle of August 1969 it was circulating all over the country before sanitary measures could be implemented. The affected areas were officially declared 'infected', enabling the banning, by law, of the exit of cattle, buffaloes, sheep, goats and their products to unaffected regions. However, the historically prevailing nomadism and transhumance in vast parts of Iran virtually precluded efficient control of animal movements. Diseased animals were bought and destroyed by the government; more than 15,000 animals were destroyed this way, on top of several thousand animals that reportedly died, the total number of losses exceeding 20,000 dead cattle (Fig. 5).

The application of mass vaccination of cattle and buffaloes was found to be, by far, the most efficient mode of disease control (2, 17). During the first week of the event, cattle were vaccinated with stock tissue culture vaccine prepared by the Razi Institute, in Hessarek. When this was exhausted, an inactivated (formolised) tissue vaccine was used, prepared from lymph nodes and spleens of naturally infected animals that were purchased by the Razi Institute (Fig. 6).

About 5.2 million doses of this vaccine were produced and applied. This vaccine was soon replaced by the Plowright live virus vaccine, similarly produced by the Razi Institute; more than 11 million doses of this vaccine had been used by May 1970. Many owners of pure-bred or mixed breeds of

FIG. 4

ROUTES OF SPREAD OF RINDERPEST WITHIN IRAN, 1969–1970

Source: d-maps.com, 2020 (26), modified to show routes of spread of rinderpest. The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of FAO or the OIE concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement

cattle, which were initially vaccinated with the formolised vaccine, demanded revaccination with the Plowright tissue culture vaccine; therefore the final number of vaccinations exceeded the total number of the country's cattle and buffalo populations.

FIG. 5

SANITARY DISPOSAL OF CARCASSES

Source: P. Nicoletti/P. Gibbs

The vaccinations were performed by 618 (motorised and mounted) teams throughout Iran. The motorised teams each consisted of one experienced veterinary technician, one extension specialist and a driver. The mounted teams, operating in Iran's mountainous regions, each consisted of a technician and an extension specialist. Every four teams were supervised by a graduate veterinarian with responsibility for an area, and every four areas were under the supervision of a regional veterinary officer, reporting to district and provincial veterinary officers, respectively. The latter also oversaw the performance of 316 established quarantine stations and of the teams of investigating veterinarians that were moving among herds and flocks to detect the disease. Those activities, combined, led to a sharp decrease in the incidence of the disease and eventually to its complete eradication by October 1970 (17). Precautionary measures were maintained for longer (18).

This major epidemic virtually affected the entire territory of Iran (18, 19, 20, 21). Previous rinderpest events in Iran had remained restricted to several provinces. In this epidemic, Iranian sources underlined in particular the role that transport played in the widespread dissemination of rinderpest-infected animals. Prior to the 1960s, most long-distance movements of cattle had been by rail and boat and were controllable. This changed dramatically when trucks and vans became commonly available and the road network was improved and extended. This striking change allowed the further development of the pandemic throughout the entire region.

Turkey

From Iran, rinderpest spread to its north-western neighbour, Turkey. The first case was discovered in October 1969 in a town mill in Özalp (in Kurdish, Qerqelî), a district of Van province, situated virtually on the Iranian border (6, 7). Reportedly, the owner of a small herd of cattle in Özalp crossed the border into Iran to sell his animals and a few days later returned with some unsold cows. On 13 October the first case was observed in Özalp and was examined by a veterinarian who submitted samples to the laboratory that confirmed the preliminary diagnosis. In the meantime, cattle became infected in eight neighbouring villages that shared the mill. The disease started its rapid spread in Van and subsequently entered also the eastern province of Kars. From there, reportedly a truck carrying infected animals reached the village of Demirkent in the province of Artvin, but this incident was resolved without further spread. At the end of 1969, 20 villages were affected in the two provinces. In the province of Van, 349 animals had died and 934 were culled, for which compensation was paid. In the province of Kars, 7 animals had died and 66 were culled. There were no additional cases until spring 1970, when rinderpest was recorded again in a village in the province of Van. The disease gradually spread, mainly by illicitly transported animals, to other provinces, including the south-eastern province of Hakari, bordering both Iran and Iraq. From the eastern provinces, the disease spread westwards to Erzurum, Bayburt and Gumushane, reaching, by August 1970, as far to the west as Sivas, Amasya and, eventually, Ankara provinces, and as far north as Trabzon (Fig. 7). This dramatic development led Turkey's Minister of Agriculture to publish emergency rules, limiting and regulating all movements of animals in 42 provinces within a declared protection zone covering Anatolia's territory from Ankara eastwards (the total number of Turkey's provinces is 81). The regulations addressed animal movements, their compulsory vaccination, the operation of cattle markets and slaughterhouses, disinfection, etc. One of the requirements was the conditional veterinary movement permit, signed by a veterinarian, attesting the vaccination of the animal at least five days prior to movement.

FIG. 6
COLLECTION OF INFECTED TISSUES FROM CATTLE THAT HAD DIED OF RINDERPEST FOR PRODUCTION OF INACTIVATED VACCINE AT THE RAZI INSTITUTE
Source: P. Nicoletti/P. Gibbs

In 1969 a state vaccine-producing laboratory was established in Ankara for the production of a lyophilised rinderpest vaccine from the attenuated Kabete 'O' strain (Plowright), which was successfully applied both to cattle and water buffaloes. In view of the difficulties in controlling animal movements, vaccination became the prioritised control measure and massive efforts were invested in its performance. During 1969–1971, nearly 26 million animals, almost the entire national cattle and buffalo population of Turkey, were vaccinated.

During 1971, the disease was reported from several additional provinces in eastern Anatolia (Adana, Bingol, Diyarbakir), alarmingly extending its spread beyond the protection zone into south-west Anatolia. Until the end of 1971, it entered the provinces of Afyon, Burdur, Isparta, Konya and Kutahya, before eventually being fully eradicated.

A summary of the statistics for the 1969–1971 outbreaks is presented in Table I. Numbers vaccinated are presented in Table II.

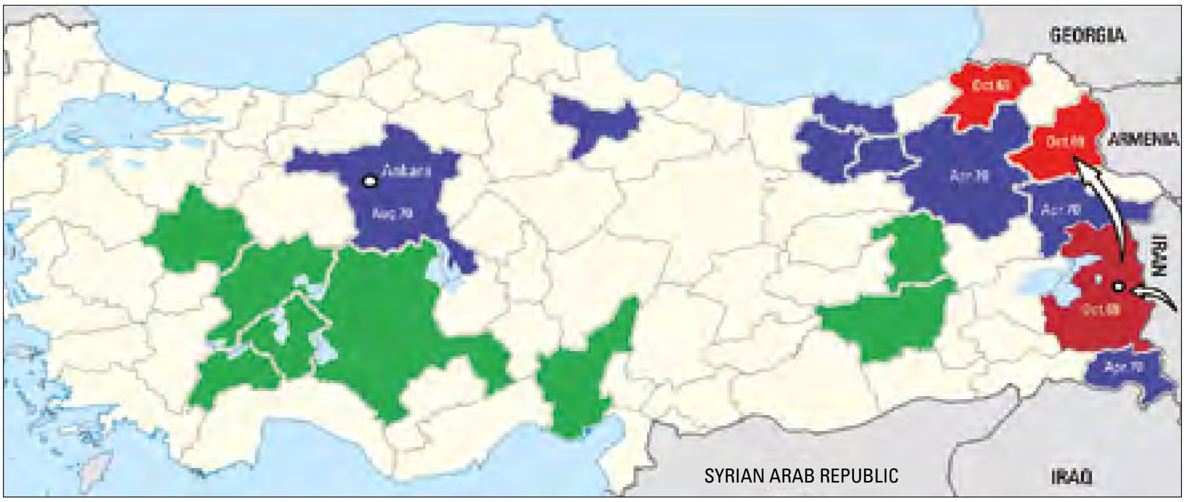
TABLE I
THE 1969–1971 OUTBREAK IN TURKEY. ANNUAL NUMBER OF LOCATIONS, DEATHS AND CULLING (22)

Year	Number of locations (outbreaks)	Number of deaths	Number of culled and compensated
1969	20	356	1,000
1970	294	1,302	8,462
1971	162	401	1,328
Total	**476**	**2,059**	**10,790**

FIG. 7

PROVINCES OF TURKEY AFFECTED BY RINDERPEST, 1969–1971

Source: d-maps.com, 2020 (26), modified to show provinces affected by rinderpest boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of FAO or the OIE concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement



From October 1969 — through 1970 — to December 1971

TABLE II

VACCINATIONS DURING THE 1969–1971 OUTBREAK IN TURKEY (22)

Year	Vaccinations (cattle and buffaloes)
1969	2,483,648
1970	11,686,347
1971	10,591,252
Total	**24,761,247**

The disease was declared eradicated from Turkey in 1972.

Lebanon 1970–1973

Lebanon reported its first suspected outbreak of rinderpest since 1927, near Beirut, in a telegram to the OIE dated 21 August 1970. In September, Lebanon reported that the preliminary diagnosis was confirmed by the Cairo laboratory and that general vaccination was being carried out. Within two months, 70,000 out of Lebanon's 86,000 cattle were reportedly vaccinated. It was also reported that 342 animals had already died but that the disease was 'almost under complete control' (23). However, outbreaks continued. During the subsequent period, Lebanon assiduously submitted regular reports. Until June 1971, 119 additional outbreaks were reported to the OIE. Mass vaccinations decreased the number of new outbreaks, although sporadic outbreaks continued to appear, with a flare-up in February–April 1973 (22 outbreaks). The last outbreak in Lebanon was reported in October 1973. The total number of outbreaks reported from Lebanon between August 1970 and October 1973 was 198. The applied tissue culture live vaccine was obtained from what was then the United Arab Republic and from Iran. Lebanon's lengthy epidemic would have reflected the unstable political situation there, combined with the country's dependence upon massive imports of live cattle for fattening and for immediate slaughter. This was a situation that was due to be repeated in June 1982, when rinderpest returned there, introduced by long-distance movements of cattle.

Syrian Arab Republic 1970

The Syrian Arab Republic reported its first outbreak of rinderpest since 1934 in a telegram to the OIE dated 24 August 1970. The diagnosis was confirmed by the Cairo laboratory. The disease was discovered in Aleppo, initially in two lots of cattle, one week and ten days, respectively, after their arrival from a neighbouring country. Some of these cattle were sent to the Damascus area and elsewhere, and further cases of the disease occurred (23). Additional outbreaks were reported in September and the first half of October 1970.

On 3 May 1971, the Syrian Arab Republic reported to the OIE that no new outbreaks had occurred since October 1970, concluding that the Syrian Arab Republic was considered free from the disease.

The disease was controlled in the Syrian Arab Republic predominantly by mass vaccinations with the Plowright vaccine, obtained from the Razi Institute, Iran. This was combined with various zoosanitary measures.

Jordan 1971

Jordan reported its first suspected rinderpest outbreak since 1927 to the OIE in a telegram dated 11 February 1971. The suspicion was confirmed by the Abbassia laboratory, Cairo. A vaccination programme for local and exotic breeds was introduced, in line with FAO recommendations, using vaccine batches obtained from the Razi Institute in Iran. In November 1971, another outbreak was officially reported. In April 1973 a consignment of cattle from Somalia, unloaded at Aqaba, was diagnosed with rinderpest.

Israel

Israel's situation during the 1969–1973 Near East rinderpest pandemic was summarised as follows (24):

'On August 23, 1970 information was received that rinderpest had broken out in Lebanon and Syria and, possibly, Jordan. At once precautionary measures were taken on the borders with these countries, and protective vaccination with live modified tissue culture vaccine flown in from Kenya was begun immediately. At first only beef herds were vaccinated, but later the campaign was extended to include all the cattle in the country. Vaccination operations were completed towards the end of the year, by which time 227,310 head of cattle had been inoculated. In the course of the campaign it was found necessary to shoot a number of animals from beef herds roaming along the northern border, which could not be rounded up for vaccination.'

Israel's decision to apply preventive mass vaccination with a live vaccine to fully susceptible dairy cattle, in spite of the absence of the disease for decades, was encouraged during a consultative meeting in May 1970, during which Israel confirmed that it remained free of the disease (25). The vaccinations were continued in the zone along Israel's northern frontiers until 1975 (14).

EPILOGUE

The striking long-distance spread of the 1969–1973 pandemic of rinderpest reflected the transport revolution. During the 1924–1928 event, the disease was spread predominantly by cattle on the hoof. International and long-distance transport was by rail and boats, which could readily be controlled by national authorities. By 1969, transport by van and truck had become common, potentially compromising the ability of authorities to control the movements of livestock over large distances. In sum, the 1969–1974 event was characterised by complacency and motorisation.

The establishment of international organisations, such as FAO and the OIE, and the development of an efficient, live, tissue culture vaccine, combined with the efforts of the affected countries, led to the eventual eradication of the pandemic.

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CHAPTER 2.4

RINDERPEST IN NIGERIA IN THE EARLY 1980S

D.R. NAWATHE

44-D Gillis Street, Nashua, New Hampshire 03060, United States of America

SUMMARY **After having participated in the first attempt to eradicate rinderpest from Africa (known as the JP15 programme) and having actually achieved freedom from the virus for six or so years, Nigeria's robust economy acted as a magnet for cattle traders who, in the early 1980s, reintroduced the disease from those parts of both western and eastern Africa where the JP15 programme had not been as successful. In 1980 a moderately virulent strain of the virus was introduced into Sokoto, western Nigeria, from the Niger, while in 1983 a highly virulent strain was introduced to Dikwa from Chad. While the Sokoto strain was relatively easily contained and combated, the Dikwa strain was much more invasive and caused a national crisis. Not only did the two strains differ clinically in cattle, but they turned out to be representatives of the two different phylogenetic lineages present at that time in sub-Saharan Africa.**

KEYWORDS **Fulani–Maiduguri epidemic–Rinderpest lineages–Sokoto epidemic – Yankari buffalo virus.**

INTRODUCTION

Along with much of the rest of West Africa, Nigeria first fell victim to the scourge of rinderpest around 1890 (Chapter 4.5.16) when the disease was first seen in Kukawa in the east of the country, which was then in Bornu Emirate and is now in Borno State. Subsequent waves of infection followed in 1914 and in 1919, spreading the disease as far west as Senegal. On each occasion the infection came from Sudan via Chad and destroyed 90% of the existing cattle. Thereafter, within the recovering Nigerian cattle population, the disease became endemic. In the late 1950s and early 1960s there were, on average, around 375 outbreaks annually. A similar picture of endemic rinderpest prevailed across most of West Africa until, between 1962 and 1969, the international Joint Programme 15 (JP15; Chapter 4.1) was launched in an attempt to break rinderpest's stranglehold through intensive regional vaccination of all cattle each year for three successive years, albeit in a series of discontinuous phases. In Nigeria, the programme ran for six years, during which time the number of outbreaks was reduced to an average of 7.5 per year between 1963 and 1968 and then, in the aftermath of JP15 between 1969 and 1975, to zero.

By 1982, it was realised that the original infecting virus in West Africa had not been eradicated by JP15 (1) but had continued to thrive in the Niger valley and was regaining momentum (see Table I). The disease had spread from Mali to Burkina Faso causing a number of outbreaks, and from there it had spread to the Niger, and finally, in 1980, to Sokoto in north-western Nigeria, sparking an epidemic that ran from 1980 to 1982. The number of outbreaks due to this incursion into Nigeria was small (around 80) and confined to the west of the country, where the disease was promptly diagnosed and dealt with by ring vaccination. The case survival rate indicated that the virus was only

TABLE I

EVOLUTION OF RINDERPEST OUTBREAKS IN SELECTED COUNTRIES OF AFRICA (1978–1985)

Compiled from data held by the Federal Livestock Department, Nigeria, 1987 and Cheneau, 1985

Country	1978	1979	1980	1981	1982	1983	1984	1985
Benin	0 (a)	0	2	4	+ (b)	3	2	1
Burkina Faso	0	0	10	11	10	3	+	8
Cameroon	0	0	0	0	+	84	1	2
Central African Republic	0	0	0	0	+	+	+	+
Chad	0	0	0	0	11	1	0	0
Côte d'Ivoire	0	0	0	0	0	4	2	3
Ghana	0	0	0	0	1	0	0	16
Mali	7	6	11	24	9	21	44	10
Mauritania	13	18	2	2	2	0	7	17
Niger	0	0	9	2	2	14	2	1
Senegal	8	1	0	0	0	0	0	0
Chad	0	0	0	0	11	1	0	0
Sudan	3	24	36	65	94	65	8	+
Nigeria	-	-	20 (c)	11 (c)	55(c)	11,081 (d)	329 (d)	39 (d)

(a) Numbers in the table are the number of disease outbreaks in a particular year
(b) + disease is present
(c) Outbreaks due to lineage 2 virus
(d) Outbreaks mostly due to lineage 1 virus

moderately virulent. At the National Veterinary Research Institute (NVRI) at Vom the virus was identified as Nigeria/Sokoto-1983 and was subsequently characterised as lineage 2 (2).

Thereafter, when things should have improved, they became more calamitous. In January 1983 rinderpest was recognised in cattle in Maiduguri, in the north-east of Nigeria. The disease spread from the cattle to Kyarimi zoo where a dozen eland died out of a population of 26. It was concluded that rinderpest virus had entered Nigeria from Chad (3). This happened at several points, most prominently at the Dikwa control post on the border between Chad and Borno State. The disease was spreading quickly because it was proving impossible to detain suspect animals at border check points. Within a month there were 20 large outbreaks and several smaller ones in Borno state. Importantly, this virus was behaving differently from the Sokoto strain. Prior to this incursion, the authorities in Nigeria had not appreciated that in Kordofan and Darfur provinces in western Sudan there were 91 rinderpest outbreaks during 1981 and 1982 (4). The virus entering eastern Nigeria in 1983 was highly virulent (Fig. 1) and represented a totally different threat to the country and one for which the country was unprepared, being already engaged with the Sokoto strain.

In March 1983 the disease reached Yankari Game Reserve in Bauchi State, where the warden reported the death of 252 wild buffaloes, 4 bush buck, 4 waterbuck and 20 warthogs. The virus was isolated in cell culture in a sample from a Yankari buffalo, confirmed as belonging to lineage 1 at the Pirbright Institute, United Kingdom of Great Britain and Northern Ireland, and listed as Nigeria/buffalo/83 by Barrett *et al.* (5). By the end of July over 950 outbreaks had been reported, involving half of the national herd (see Chapter 4.6).

At the National Livestock Development Committee meeting at Zaria, an NVRI officer, unaware of the situation in the north-east of the country, denied that it was rinderpest and stated that it could be a mucosal disease. There were others who said that it could be nothing other than rinderpest, because there were many outbreaks spreading throughout the country.

A CRISIS UNFOLDING

Once the presence of a second epidemic was understood, President Shehu Shagari immediately approved a special grant of 3 million naira (US$4 million) to cover the cost of emergency measures. The Federal Livestock Department (FLD) would do the fieldwork and the NVRI at Vom would diagnose and produce or procure the vaccines. By the time the disease was widely recognised, it had spread to large numbers of herds and reports had started pouring in from most of the cattle-rich states. The worst affected were the present-day states of Borno, Yobe, Gombe, Adamawa, Taraba, Benue, Nasarawa, Bauchi, Jigawa, Kano, Kaduna, Katsina, Plateau and Sokoto. By the end of 1983, 380,000 deaths had been reported (6).

In addition to the domestic cattle, sizeable numbers of wild animals were affected. The *Veterinary Record* in the United Kingdom published an editorial emphasising that the United Kingdom had suffered and fought to overcome the disease a century previously. It remarked that the price of freedom from disease is eternal vigilance. The Nigerian press was not far behind (Fig. 2).

The agony of the Fulani cattle keepers and the shortages of beef provided ample material for the media. Television and news media highlighted the sick cattle, heavy mortality and government measures trying to meet these challenges. Politicians questioned the government and concerned officials about how the disease had recurred and what action was planned to protect the national herd. The epidemiology of the disease was complex, including, but not limited to, differences in transmission, climate and animal nutrition. Severe drought led to animals travelling long distances for grazing and drinking water, thus contributing to the disaster.

THE RESPONSE TO RINDERPEST IN NIGERIA

In 1979, the NVRI, aware of a falling level of immunity to rinderpest, issued a circular making veterinarians aware of the situation and the need for vaccination but little action had been taken; now it was necessary to make all efforts to eradicate the disease. In 1983 the National Rinderpest Control Committee (NRCC) was created by the FLD to contact village leaders, pastoralists and news media. Groups were formed in the cities of Kaduna, Bauchi and Benin and they travelled to allocated states to organise vaccination programmes. They had cold storages equipped with generators, vehicles, vaccination supplies, drugs and material supplies. These groups met frequently and were supervised by a zonal coordinator based in Kaduna. The NRCC met regularly every quarter and discussed progress and problems.

The veterinary field workers who were directly involved with vaccinations were transferred to the local government areas (LGAs) in respective states. The LGAs had financial problems and therefore imposed taxes. An existing tax of US$10 per animal was abolished by the government, but the LGAs created a new tax imposed on cattle grazing in their areas. It was a heavy penalty for the pastoralists as

In 1984, a large number of Fulani cattle keepers marched to the office of Dr Abubakar Lamorde, Director of NVRI. They were desperate, as many of them had lost their cattle and become bankrupt. Some Fulani cattle keepers were reported to have committed suicide. There was no compensation given to their families. The Director sympathised with them and assured them that he would do his best. The calamity that befell the Fulani, on account of drought and disease coming together, was a national challenge.

FIG. 1
RINDERPEST DEATHS IN VILLAGE CATTLE, BORNU STATE, 1983
Courtesy of the author

FIG. 2
NEWSPAPER HEADLINES REPORTING THE NATIONAL RINDERPEST CRISIS
Courtesy of the author


CATTLE DIE IN THOUSANDS
800 MEN NEEDED TO VACCINATE CATTLE
NIGERIA'LL LOSE ₦9m ANNUALLY IF...
Rinderpest kills 700 cattle in Gongola
8,000 CATTLE DIE IN NIGER STATE
RINDERPEST: 50,000 CATTLE DEAD IN BAUCHI

There was a missionary in Jos working for a non-governmental organisation who was importing vaccines from Europe and selling them to local Fulanis at a small cost. He was arrested because importation without a valid permit was an offence. He was later released but he continued to do his work unofficially. There were many kinds of vaccines on the market, some even labelled in the Hausa language as Koffin Bushia – an allusion to the mouth lesions of rinderpest. Illegal trading in vaccines became quite common for over a year.

they passed from one LGA to another. In addition, the LGAs were a hindrance to Veterinary Officers and inoculators. There were many times when the FLD contributed to payment for vaccines and equipment.

When the programme to vaccinate cattle started in 1983, the demand for vaccine from NVRI skyrocketed to 20 million doses – four times the normal annual production. Although, initially met with some resistance, it was then agreed that importing the vaccine was the only way to meet the demand. Eight million doses of vaccine from India, Kenya, Senegal and the United Kingdom were imported and had to be cleared through customs.

Earlier batches of vaccines imported by the government worked well while others, imported later, failed miserably. Even the locally produced vaccine did not escape criticism. Despite the best efforts of the FLD, batches of vaccine were mishandled and probably ineffective.

Dr Yoshihiro Ozawa, Chief Animal Health Officer of the Food and Agriculture Organization of the United Nations (FAO), assisted the production of vaccines at NVRI by sending a specialist, Dr Pierre Bourdin, and US$250,000 in financial assistance. Dr Daouda Sylla, Director of the Central Veterinary Laboratory, Bamako, Mali, also visited NVRI on behalf of FAO and conducted training in vaccine quality assurance. Unfortunately, the unvaccinated cattle herd kept at NVRI for safety and for potency testing of vaccines became infected. All 65 animals became sick and showed typical clinical signs. This delayed further safety and potency testing of vaccines until a fresh set of susceptible animals was assembled. Professor Walter Plowright was invited to discuss the control of cattle diseases at a national conference at NVRI in 1984.

In the years 1983 and 1984, some 2.5 million cattle in Nigeria were infected, of which approximately 0.5 million died. Approximately, 27 million doses of vaccine were issued and 19 million cattle were vaccinated. This brought the disease under control (7). The losses caused by rinderpest were estimated at

FIG. 3
MAP OF WEST, CENTRAL AND EAST AFRICA
Final boundary between the Sudan and South Sudan has not yet been determined
Source: United Nations, 2018 (9), modified to indicate West, Central and East Africa

the time to be at least 1.5 billion naira (US$2 billion) (8). Nationally organised vaccinations continued for another five years, during which time the epidemic completely subsided, with only two outbreaks in Bauchi State in 1986, the last being in trade cattle in Oyo State in 1987. After 1989 Nigeria's continuing vaccination programme became part of the Pan-African Rinderpest Campaign (PARC) programme) (Chapter 4.2).

EPIDEMIOLOGY

Professor Tom Barrett at the Pirbright Institute used the unfolding epidemics in Nigeria to illustrate the value of the reverse transcriptase polymerase chain reaction (RT-PCR) technique for tracing phylogenic relationships through nucleotide sequencing. His team processed all available rinderpest viruses from field and laboratories. African rinderpest viruses were of two different biotypes or lineages and they also differed from Asiatic ones. The viruses isolated from outbreaks in cattle from Sokoto in 1958, 1964 and 1983 belonged to the lineage 2 biotype, presumably being descendants of the 1919 epidemic. The Yankari buffalo virus (1983) was found to be of lineage 1 and closely related to the Sudan reedbuck virus (1972) but was clearly distinct from the virus that first spread across Africa. Uniquely, two viruses of different lineages were co-circulating in Nigeria in 1983 (2).

In terms of the sequence in which outbreaks occurred, what happened in Nigeria also more or less happened throughout the region. Table I shows the buildup of outbreaks in countries to the west of Nigeria in the years up to 1980 (presumably due to lineage 2) and, similarly, the buildup of outbreaks in countries to the east of Nigeria (presumably due to lineage 1) in the years before 1983 (see also Fig. 3). The ability of the virus to travel eastwards and westwards at this time was symptomatic of the need to bring it back under control.

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CHAPTER 2.5

TSAVO WILDLIFE RINDERPEST EPIDEMIC, 1993–2001

R. KOCK [(1)*], J. MWANZIA [(2)], E. WAMBWA [(2)], J. WAMBUA [(3)], H. WAMWAYI [(4)], N. KOCK [(5)] & P. ROSSITER [(6)]

(1) Department of Pathobiology and Population Sciences, Royal Veterinary College, Hawkshead Lane, North Mymms, Hatfield, Hertfordshire AL9 7TA, United Kingdom
(2) Crown Prince Court Abu Dhabi, P.O. Box 124, Abu Dhabi, United Arab Emirates
(3) Division of Animal Resources, Yerkes National Primate Research Center, Emory University, 954 North Gatewood Road, Atlanta GA 30322, United States of America
(4) Kenindia Business Park, Museum Hill, Westlands Road, P.O. Box 30786-00100, Nairobi, Kenya
(5) Wake Forest School of Medicine, Department of Pathology/Comparative Medicine, Medical Center Boulevard, Winston-Salem, North Carolina 27157-1040, United States of America
(6) St Michael's House, Poughill, Devon EX17 4LA, United Kingdom

*Corresponding author: rkock@rvc.ac.uk

SUMMARY

In 1993, while the Pan-African Rinderpest Campaign (PARC) was in its final phase, with marked progress in the elimination of the virus from the continent, a disease event occurred in the Tsavo National Park in Kenya, which was to shift the strategy for eradication significantly. At the time, small foci of rinderpest virus of lineage 1 were believed to persist, only in the Sudanian grasslands, with the last vestiges of virus in Ethiopia being close to removal. Kenya had had only a few sporadic incursions of rinderpest from these foci in the North, with the main part of the country apparently free for three decades, and Maasailand in the south and the United Republic of Tanzania had been free since the early 1980s. The Tsavo epidemic of rinderpest involved a range of susceptible wildlife, mainly buffaloes, tragelaphine (bovine) antelopes and giraffes. The disease seemed to appear from nowhere, with no livestock cases of rinderpest being reported before or during the episode. The virus spread for four years through wildlife and across the ecosystem of some 96,000 km^2 and beyond, causing a 60% loss of the Tsavo's buffalo population, as confirmed by aerial survey. It is likely that the epidemic had similar impacts on lesser kudu and other species. As this event unravelled, epidemiological investigations exposed a cryptic focus of virus of lineage 2. This so-called mild virus had apparently persisted in pastoral cattle since the 1960s, in the eastern region of Kenya and in Somalia. Once attention shifted to deal with this problem, the goal of global eradication was achieved.

KEYWORDS

African buffalo – Rinderpest – Tsavo and Meru National Parks – Wildlife.

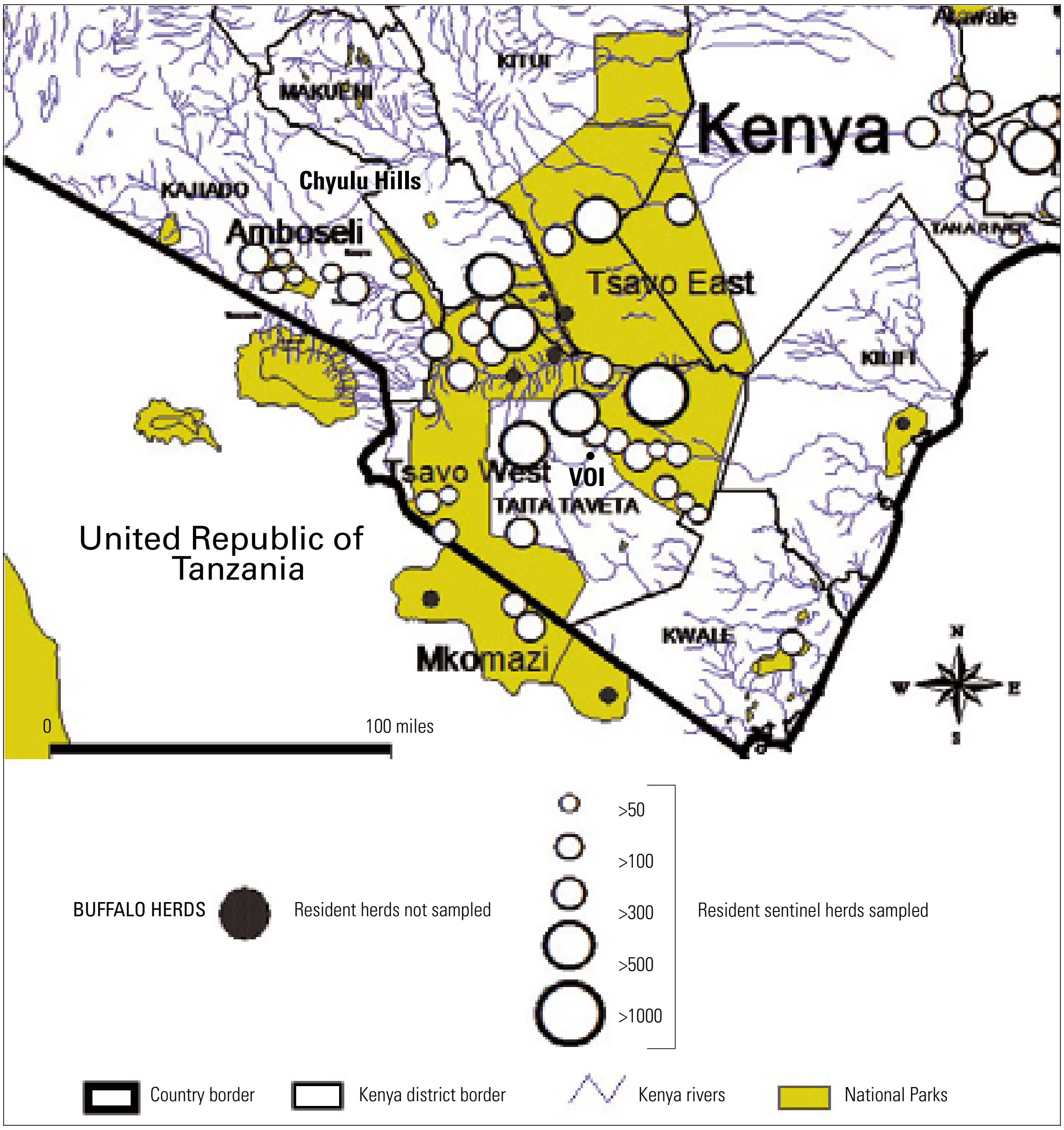
INTRODUCTION

The Tsavo–Meru ecosystem of Kenya was a hot spot for rinderpest re-emergence from the time of the Great African Rinderpest Pandemic of 1887 (1, 2) to the last recorded case of rinderpest in the world in 2001 (3). It was from the 1993–2001 wildlife epidemic in the dry and dense bushlands of the Tsavo–Meru ecosystem in the southern lowlands of Kenya that much of the impetus came to finally eradicate rinderpest. Wildlife rinderpest was a topic of interest in the region, and much of the current understanding was underpinned by work done by British, Kenyan and Tanzanian veterinarians between the 1930s and 1960s (4, 5, 6, 7, 8, 9) and later in the 1970s and 1980s (10, 11, 12) and 1990s (3). The Tsavo epidemic described here was probably the most studied epidemic of rinderpest in its history, given that the main affected population was unvaccinated African buffaloes (*Syncerus caffer*) and the disease followed its course to its natural extinction over a period of seven years. The monitoring was made possible because, for the first time in East Africa, a dedicated veterinary unit was established in 1990 as part of the Kenya Wildlife Services (KWS), which are mandated to conserve Kenya's wildlife.

FIG. 1
BUFFALO HERDS: TSAVO ECOSYSTEM

Map of southern Kenya showing African buffalo herds at the time of the outbreak in the Tsavo ecosystem, which includes two national parks – east and west, indicating sampled and non-sampled herds during serosurveillance and disease investigation

Source: Kock, 2008 (3)



THE EPIDEMIC

The story begins in March 1994, when sick buffalo close to Voi in Tsavo East National Park (TENP) (Fig. 1) were reported to the unit.

Although most animals observed were in good condition, four sick animals were immobilised, and one was so ill that it was euthanised for necropsy. Samples were submitted to the Kenya Government laboratories and rinderpest was included in the differential diagnoses but, when negative serology was reported, infection with rinderpest virus was ruled out. In June 1994, in the northern sector of TENP along the Tiva river and around Ithumba hill, many lesser kudu were reported dead or with blindness (Fig. 2), and samples were collected and resubmitted for testing, with reported negative results for rinderpest.

Kenya had not reported outbreaks of rinderpest to the then Office International des Epizooties (OIE; now the World Organisation for Animal Health) since the 1960s in wildlife and the 1980s in livestock and then only in northern districts. The country was in the last phase of the Pan-African Rinderpest Campaign (PARC) eradication programme, making it unlikely that the disease would have emerged in the middle of the country. In hindsight, these reports in wildlife were the first signs of the epidemic, and retrospective serology from the area and histopathology of sampled tissues confirmed this, but only after matters had significantly progressed.

On the 24 November 1994, the senior warden of Tsavo West National Park (TWNP), nearly 100 km to the south-west of Ithumba (Fig. 1) reported several buffalo deaths near the Taita Hills Hilton Wildlife Sanctuary, and 22 carcasses were examined the following day. On 27 November three markedly dehydrated animals with greenish-brown diarrhoea soiling their hind quarters were euthanised and necropsied, with samples submitted to the National Veterinary Research Centre at Muguga (NVRC). The NVRC failed to detect any virus and the disease remained undiagnosed. At the end of three weeks, 70 of approximately 100 buffaloes in the herd at the Salt Lick Lodge, Taita Hills, were dead. Within weeks of this outbreak, the disease spread explosively through the south of TWNP to the Chuyulu hills in the north. Groups of buffaloes became fragmented and distressed, and carcasses were observed in all areas of the park (R. Kock, personal observation, 1994) and outside in the Maasai ranches (Fig. 3).

Samples continued to be submitted, but despite all the evidence (clinical and pathological) throughout 1994, rinderpest remained officially unreported in Kenya. At this juncture Dr Walter Masiga, Director of the African Union Inter-African Bureau of Animal Resources (AU-IBAR), which was responsible for PARC, joined the team on the ground. He was convinced that the disease was rinderpest, pressure was put on the authorities and a preliminary diagnosis was accepted, as a result of which the Veterinary Services of Kenya reported suspected rinderpest to the OIE in January 1995 (13). Samples were submitted to the International Reference Laboratory at Pirbright, United Kingdom of Great Britain and Northern Ireland, for confirmation. In February 1995, morbillivirus ribonucleic acid (RNA) was detected by reverse transcriptase polymerase chain reaction (RT-PCR), using rinderpest-specific fusion protein (F gene primers) in a sample taken from the spleen of a buffalo acutely

FIG. 2
CLINICAL RINDERPEST IN A LESSER KUDU IN ITHUMBA, TSAVO EAST NATIONAL PARK, KENYA, JULY 1994

Adult female lesser kudu showing excessive lacrymation, conjunctivitis, corneal opacity, intraocular haemorrhage and possible uveitis

Source: Kock, 2008 (3)

FIG. 3
KUKU RANCH, JANUARY 1995

Odd buffalo carcasses were evident but densities were low outside the national parks and these were frequently overlooked by the Maasai
Dr Solomon Haile Miriam of the Pan-African Rinderpest Campaign looking on (white cap) with KWS rangers and Kuku ranch residents

Courtesy of the authors

affected. Nucleotide sequence analysis confirmed this as a rinderpest strain of Africa lineage 2 (14), and the outbreak was then officially reported a year later by the Government of Kenya to the international community (15). Over the following weeks and months, sporadic deaths in buffaloes, lesser kudu and eland were reported. Some of these were ongoing infection and acute cases while others were survivors that succumbed to the debilitating effects, even if surviving the initial challenge. In May 1995, the last case associated with the epidemic in the TWNP was examined, from which virus was finally isolated. The story did not end there, and the disease continued to be tracked, with dead buffaloes observed in the Kuku ranch west of Tsavo, where large numbers of apparently healthy (domestic) livestock were kept. Further searching towards Amboseli National Park (ANP) showed buffalo calves with acute severe diarrhoea in the Kimana swamp; these and more buffaloes within the ANP were sampled, and some were positive for antibody while others were negative. By 1996, serology showed that all herds in the protected areas had been infected. There was a brief lull in 1996, and then an outbreak occurred on 8 October 1996 in Nairobi National Park (NNP) (Fig. 4), within a few miles of the IBAR and PARC headquarters. The virus seemed to have moved with migrating antelope into the park from Kitengela, and most probably up through Kajiado district from ANP, over a period of a few months. The first cases observed were in eland, a wide-ranging species. This was a further rude awakening to the prevalence of rinderpest at the very end of the eradication campaign; the disease had spread despite extensive cattle vaccination around TWNP in 1995, suggesting that wildlife were acting as disease vectors threatening further cattle outbreaks in unvaccinated herds with cattle included as the target. Outbreaks were also detected in Meru National Park (MNP) in 1995 within the Greater Meru Conservation Area (see Fig. 5), but this epidemic was relatively short lived and the disease burned out quite rapidly. The source of this infection was at the time not entirely clear, but it was assumed to have been through wildlife vectoring of infection from Tsavo. With hindsight this may well have been an independent incursion of virus from the Somali regions, perhaps from cattle. Whatever their provenance, these events resulted in a recognition of the importance of monitoring wildlife in the Global Rinderpest Eradication Programme (GREP) strategy (see Chapter 4.3) and the introduction of wildlife surveillance in the OIE Pathway towards the end of PARC (16). Details of the epidemic and its pathology were reported (17, 18).

The last case in the TWNP lesser kudu marked the apparent disappearance of rinderpest from the Tsavo ecosystem, again based on observations and the apparent absence of any clinical evidence during the following four years. Serosurveillance of wildlife across Kenya continued annually to track fresh outbreaks of the disease, and some evidence of fresh viral infection was found in young buffaloes in Tsavo in 1998, but no disease was detected until 2001, when routine clinical surveillance and serosurveillance detected the virus in buffaloes in the MNP (Fig. 5) (19).

FIG. 4
AFRICAN BUFFALO WITH RINDERPEST, NAIROBI NATIONAL PARK, KENYA, IN OCTOBER 1996

Calf with tenesmus and watery diarrhoea and generally poor condition from the effects of dehydration

Courtesy of the authors

In the 2001 MNP outbreak there was no obvious clinical disease in the older buffaloes and only mild signs in young buffaloes, and without active surveillance this occurrence would not have been detected. The virus was confirmed at the Pirbright Institute, the same lineage 2 strain of rinderpest isolated earlier, and this resulted in a final push for eradication, with intensive surveillance of livestock in the eastern regions of Kenya and in the Somali ecosystem with further vaccination.

A combination of epidemic observation and serosurveillance provided evidence to support the delineation of an endemic zone for rinderpest in the eastern regions of Kenya. Figure 6 shows buffalo serology across the region, showing a wave of infection probably arising from the Tana river and Garissa districts (now counties) of Kenya passing most probably down the Tiva river and emerging in the area of Ithumba in the north of TENP.

A further incursion may have arisen from infected cattle or wildlife crossing the Galana ranch and entering TWNP around Voi, followed by a separate spread from the east to MNP. The TWNP outbreak extended into the Kuku cattle ranch to the west with a few scattered buffaloes dying (Fig. 3) and seemed to lose virulence with a more cryptic emergence of the disease in buffaloes in Amboseli, which was only detected by active searching (18). No reports or signs of disease in cattle were recorded until

FIG. 5
MAP OF BUFFALO HERDS IN THE GREATER MERU CONSERVATION AREA

Map of eastern Kenya showing African buffalo herds in the Greater Meru ecosystem at the time of the outbreak, indicating sampled and non-sampled herds during serosurveillance and disease investigation

Source: Kock, 2008 (3)

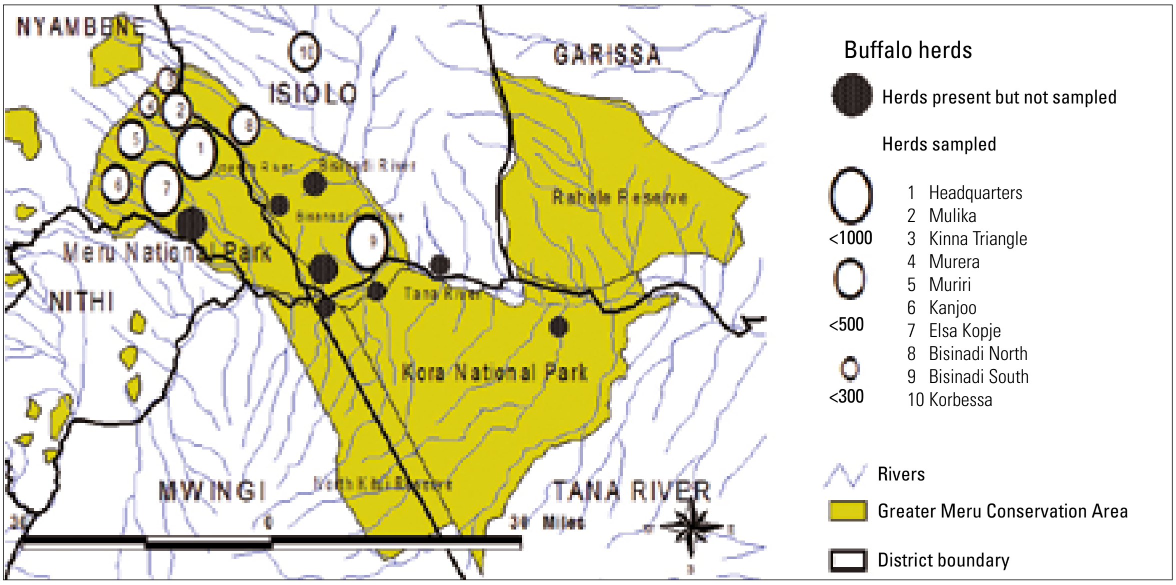
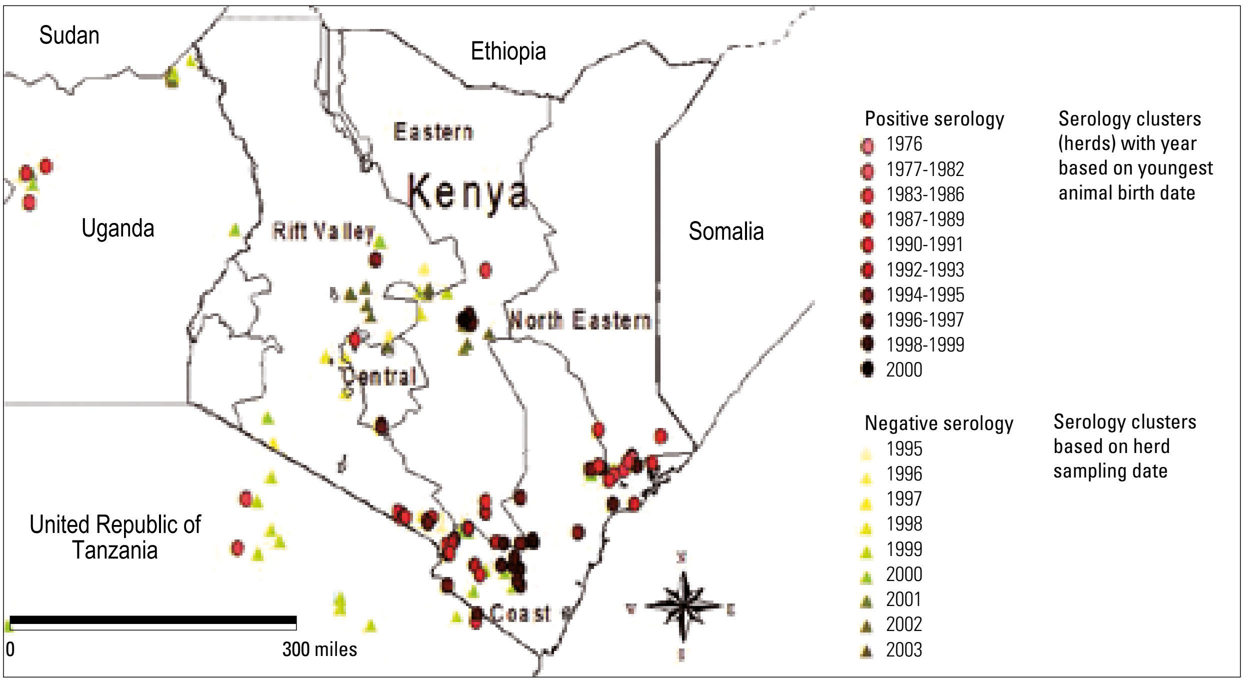


FIG. 6
SEROLOGY OF BUFFALO 1994–2004, KENYA

The map shows the earliest possible infections based on the earliest birth dates estimated from positive aged animal samples. The spatio-temporal pattern suggests the endemic area is in what was then described as North Eastern Province or the Somali region of Kenya, in the Tana delta region and around Boni and Dodori to the east, where large wildlife herds persisted in close association with ethnic Somali pastoral herds. The temporal aspect shows the later spread in the 1990s through to Tsavo and north to Nairobi and Meru. It is assumed that ethnic Somali livestock maintained the virus, and it spread endemically into these wildlife herds, periodically emerging as naive epidemics spreading west. It is possible that outbreaks in East Africa after the virus was eliminated from the Serengeti ecosystem in the 1950s were a result of the expansion of the virus's range over the 1960s, 1970s, 1980s and 1990s from this reservoir

Source: Kock, 2008 (3)



suspect cases were investigated in Kajiado district with agar-gel immunodiffusion (AGID) positive results, but these infections in cattle were not definitively or officially confirmed (3, 20). Thereon it spread probably up the wildlife gradient through Kajiado and the Kitengela to NNP. Retrospective serology showed that every buffalo herd that could be infected over this vast landscape succumbed. Unknown numbers of other wildlife were affected and died, but no accurate account could be made of these losses. During the entire time of the epidemic in wildlife, there was not a single case of rinderpest confirmed unequivocally in cattle.

CONCLUSIONS

From 1993 to 1996 rinderpest virus spread over an area of 96,000 km^2, affecting the more than 10,000 buffaloes and other wildlife in the Tsavo–Meru ecosystem, and it then expanded to Amboseli and Nairobi National Parks, despite the relatively low densities of wildlife between discrete buffalo herds. In Tsavo, the buffalo mortality was conservatively estimated at 60% (3), based on total aerial counts taken in 1993/1994 (21, 22, 23, 24, 25). A government survey was also consistent (26, 27) with an estimated population decrease of 65% during the epidemic. This was the first time that epidemiology and mortality data were accurately recorded for a rinderpest epidemic. The Tsavo epidemic is central to understanding the rinderpest virus circulation patterns in eastern Africa, which were largely unnoticed by the Veterinary Services from 1963 to 1995. The lack of clinical disease in cattle during the epidemic was surprising, although it was an area where outbreaks occurred historically in the 1930s, 1940s and 1960s. Earlier survey results suggested that infection, but not disease, occurred at least until 1987 in buffaloes in parts of the Serengeti National Park (28) and in a range of other species in Kenya and the United Republic of Tanzania, based on serological samples taken between 1982 and 1993 (12).

Despite a lack of evidence from livestock disease surveillance during the Tsavo epidemic, it was likely that the virus originated from the east of TENP, most probably from ethnic Somali and/or Orma cattle (or wildlife) (29), and not from the known persistent foci of infection at the time in southern Sudan, north-eastern Uganda and north-western Kenya (30).

The outbreak history and serology in wildlife suggested that there was a zone of endemicity in the Somali ecosystem, with cattle, the maintenance host, spilling virus into naive wildlife populations periodically as their immunity waned from earlier epidemics (3, 19). This pattern provided evidence that the wildlife populations were not maintaining the virus between these roughly decadal events. The natural extinction of rinderpest virus from wildlife populations despite repeated re-infection was a matter of considerable relief and most probably simply a product of the relatively small populations (19). The focus of the vaccination of cattle shifted as a result of the wildlife studies. In the final phase, the Somali Ecosystem Rinderpest Eradication Coordination Unit (SERECU) probably eliminated the virus within a few years through this intensive focal approach. This targeted thrust allowed the global declaration of freedom from rinderpest in 2011. The benefits of eradication are not only measured in livestock economic terms; the benefit to wildlife populations in the region is significant and has been demonstrated for the Serengeti ecosystem (31) by increases in the populations of buffaloes, kudu and other susceptible wildlife populations in the Tsavo–Meru ecosystem of Kenya and probably across a wide swathe of Africa.

ACKNOWLEDGEMENTS

The list of people who assisted in this work is too long to mention them individually. For this reason, we name the institutions and communities that were relevant to this episode and in so many ways contributed: the people of Kenya; the Kenya Wildlife Services; the Veterinary Department of the Government of Kenya; the National Veterinary Research Centre in Muguga; the African Union, Inter-African Bureau of Animal Resources in Nairobi and colleagues from the Pan-African Rinderpest Campaign; colleagues at the Global Rinderpest Eradication Programme and at the Food and Agriculture Organization of the United Nations and the Zoological Society of London; the British Government and the World Bank, which supported the emergence of the KWS veterinary department, which is central to this story; and the Directorate-General for International Cooperation and Development of the European Commission, which significantly contributed to the costs of the eradication campaign in Africa.

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CHAPTER 2.6

THE EPIDEMIC OF CATTLE PLAGUE IN NORTHERN PAKISTAN, 1993–1994

P. ROSSITER [(1)*] & M. HUSSAIN [(2)]

(1) St Michael's House, Poughill, Devon EX17 4LA, United Kingdom (Formerly staff member of the Food and Agriculture Organization of the United Nations [FAO] and rinderpest consultant)
(2) 128, Jinnah Colony, Faisalabad, Pakistan (Formerly Control of Transboundary Livestock Diseases Project, Food and Agriculture Organization of the United Nations, National Agricultural Research Centre, Islamabad, Pakistan)

*Corresponding author

SUMMARY **The former Northern Areas of Pakistan suffered a severe epidemic of rinderpest in 1993 and 1994. The source of the outbreak and some reasons behind the delay in recognising the disease and bringing it under control are described. Over 40,000 cattle and yaks were estimated to have died, inflicting severe negative socio-economic consequences on individual families and communities in this marginalised area of Pakistan. This was the last major outbreak of 'cattle plague' in the world before global eradication was confirmed in 2011 and a stark example of what might happen should rinderpest ever affect Earth's cattle again.**

KEYWORDS **Cattle plague – Epidemic rinderpest – Lack of preparedness for rinderpest – Severe negative socio-economic impact.**

GILGIT-BALTISTAN

With cobalt blue skies, soaring snow-capped mountains, and panoramic valleys that are full of blossoming fruit trees in spring, Gilgit-Baltistan (formerly the Northern Areas or Pakistan-controlled Kashmir) must be Pakistan's most beautiful destination (Fig. 1). The Himalayas, Hindu Kush and Pamirs meet just outside Gilgit, and jeep tracks cut along sheer cliffsides high above the headwaters of the iconic Indus river beginning its 2,500 km journey to the Arabian Sea near Karachi. Abundant springs flow down to the river, supporting oasis villages that hang almost vertically from steep hillsides or sit on the flood plains beside the roads that follow the river valleys. Many more villages remain hidden from sight in remote and almost inaccessible valleys. For historians, ancient kingdoms and customs abound, and Alexander the Great reputedly passed nearby on the way to defeat in Punjab.

FIG. 1
A TYPICAL VIEW FROM THE MAIN ROAD OUTSIDE GILGIT

Blue skies and snow-covered mountains tower above a stream-fed village and fields running down to the River Indus
Courtesy of the authors

In the 1990s the region was more geographically and politically isolated from the rest of the country than it is today and was one of the country's poorest regions. With very little tourism, despite the attractions of its physical beauty, rural income was almost entirely dependent upon crops such as apricots and apples, seed potatoes, wheat and vegetables grown for local consumption and for export to the rest of the country. Livestock production of sheep and goats, cattle, yaks (Fig. 2) and yak-mo (the cross between yak and cow) was limited to home markets and insufficient to meet local demand, especially for meat. More importantly, cattle and yak-mo were essential draught animals for ploughing small fields and hillside terraces (Fig. 3). With little fodder available, these vital assets roamed extensively across high-altitude, alpine pastures in summer, returning to their villages and the valley floors in winter. In the mid-1990s, this scenic but economically deprived community was disastrously infected with rinderpest and suffered the world's last major outbreak of 'cattle plague' (1).

The political and administrative isolation of the then Northern Areas extended to the semi-autonomous local veterinary service, and disease control was severely under-resourced. Rinderpest had not occurred there for over 50 years, and there had been no vaccination against it for perhaps 40 years. The local 'hill' cattle and yaks, both notoriously genetically susceptible to rinderpest, had no immunity against the virus; farmers did not know the disease and, more importantly, nor did the local veterinarians.

FIG. 2
BETWEEN GILGIT AND SKARDU, SENIOR VETERINARIAN DR ZABOOR KHAN OF THE DEPARTMENT OF ANIMAL HUSBANDRY AND VETERINARY SERVICE OF THE NORTHERN AREAS TEMPTS A YAK WITH SOME DRIED APRICOTS

Dr Khan played an important role with the joint Food and Agriculture Organization and Government of Pakistan team throughout its work with the epidemic of cattle plague in Gilgit-Baltistan

Courtesy of the authors

FIG. 3
YAK-MO PULL A PLOUGH NEAR SKARDU
Courtesy of the authors

RINDERPEST VIRUS IN PAKISTAN

Although rinderpest was not being reported from Pakistan it in fact persisted throughout the 1970s, 1980s and early 1990s in the huge dairy colonies in and around Karachi, especially the Landhi Dairy Colony (see Chapter 4.13.8). The colonies, composed of numerous small private farms, were effectively 'milk factories' rather than true farms that sustained their stock through animal husbandry (Fig. 4). New, freshly calved buffaloes were received into the colonies where they were milked until uneconomical (the costs of feed were high) and then slaughtered and replaced. With the average lifespan of a colony buffalo being about six months, maintaining the Landhi Dairy Colony's population of some 125,000 animals required a quarter of a million buffaloes throughout the year. To meet this demand around 100 truckloads of newly calved buffaloes from as far away as Punjab were imported to Karachi daily. Most, if not all, of the incoming stock were susceptible to the virus – providing the fuel for the virus,

FIG. 4
A TYPICAL BUFFALO DAIRY 'FARM' IN THE LANDHI DAIRY COLONY, KARACHI
Courtesy of the authors

which was burning like a fire in the colony. The fact that the disease frequently was not fatal in buffaloes and was milder still in the few lowland cattle, such as the Red Sindhi, kept in the colonies, may have contributed to some of the misunderstanding that led the veterinary authorities to consider the disease as 'rinderpest-like' rather than rinderpest itself. Local movements of buffaloes often transmitted the infection to other colonies in Karachi.

CHANGING PRACTICES

The 'businessmen' dairy farm owners in Karachi were concerned at the increasing cost of purchasing new animals, and the more progressive members were also starting to recognise that their practice of buying and then killing their animals could have a negative impact on the genetic potential of Pakistan's best milking buffalo populations. As a result, some 'farms' in the colonies were beginning to cover their cows with bulls while in the colonies and then send the higher-yielding animals back to the rural areas when they became uneconomical. Here they were allowed to 'recondition' and give birth, after which they returned to the colony for another lactation. This practice of sending animals from the hotbed of rinderpest in Karachi back to the rural areas provided opportunities to transmit the virus outside Karachi. Occasionally, outbreaks of rinderpest, known variously as Karachi disease or Landhi disease, occurred in the areas of Sindh and Punjab with close links to the Karachi dairy farms and were locally contained and controlled. As the practice of sending buffalo cows back to their origins increased, the amount of rinderpest in the 'homelands' also increased and became more persistent until the disease was finally eradicated completely from southern Pakistan.

POSSIBLE PUNJAB SOURCE

Buffaloes for slaughter in Gilgit-Baltistan were regularly purchased from Punjab and Northwest Frontier province and transported daily to butcheries there. Usually, from a lorryload of six buffaloes, only one or two would be slaughtered immediately, according to demand. The remaining live animals were then grazed nearby where they had the opportunity to meet local stock. In 1994 rinderpest occurred in Punjab, probably after introduction from the dairy colonies in Karachi, and in March 1994 an outbreak of severe enteritis with high rates of morbidity and mortality broke out just south-east of Gilgit, in a village where buffaloes had recently been imported for slaughter. Control of the severe 'infectious enteritis' proved difficult. It took until August, almost five months later, before the disease was confirmed by the national authorities in Lahore and vaccination with locally produced rinderpest vaccine was instituted with the expectation of bringing the disease under control. Unfortunately, despite vaccination the disease continued to spread. The Government of Pakistan (GoP) requested assistance from the Food and Agriculture Organization of the United Nations (FAO), which immediately responded with a series of projects covering improved disease investigation, diagnosis and control in the field, including vaccination, epidemiology, training of field and laboratory personnel, and vaccine improvement and production.

CATTLE PLAGUE

When we, the authors, set off to visit the affected region in August 1994, on the first of many missions to the region by FAO and GoP under joint project TCP/PAK/101, the epidemic had been spreading for five months and was widespread and prevalent. Even before reaching the veterinary office in Gilgit, the main town where the local veterinary service was based, we had investigated two separate cases of rinderpest at the side of the road, one being butchered beside its stall mate, which was then immediately milked with unwashed bloody hands.

In one valley alone, the farmers and veterinary extension staff estimated that nearly 8,000 of the 12,000 cattle and yak-mo there had died. When livestock owners realised that this was a disease that should have been recognised earlier and could have been prevented, their initial tolerance, or fatalism, regarding the failings of the veterinary services wore thin. In more than one village our vehicles were jeered at and, on one occasion, stoned. News of the disease and the mortality it caused spread widely. In newly infected villages where clinical disease was just starting to be seen farmers cried openly. One of us (PR) will never forget a yak in the early stages of the disease, staring with congested and lachrymating eyes, held on a halter by its owner, also with tears running down his face, knowing that he would almost certainly lose his animal. The concept of infection was virtually unknown. Sick and in-contact animals were being sold with little or no control; fresh meat from butchered animals was being sent to relatives and friends by bus and local taxis and sold by the side of the road. The sheer dependence on these animals for draught and milk meant that several farmers restocked too quickly before the disease had run its course in their villages and consequently were hit twice. Above the snow line infected meat was being stored frozen on the open roofs of the houses – including whole heads with classic mouth lesions and lymph nodes in which specific rinderpest virus antigen was found in later diagnostic tests.

Initially, control proved difficult – the disease had moved south to Chilas even before being confirmed – and it continued to spread north along the Karakoram highway until it was close to the border with China, and east up the Indus valley through Skardu almost to Ladakh and India.

It was very apparent that the locally sourced rinderpest vaccine was not working, and laboratory tests confirmed its poor quality. On top of this the cold chain was weak or absent, and veterinary staff had never used a live virus vaccine before. FAO immediately imported quality-assured vaccine together with items for the cold chain and provided training in vaccine handling and use. Very soon, vaccination was shown to be working well, and immunised villages were not affected by the plague.

When the disease had originally been confirmed in August, the height of summer, most of the region's cattle had already migrated to their mountain pastures. Many local veterinarians considered it very likely that some animals would have been infected and would have taken the virus with them to the high-altitude grazing land where they would have ample opportunity to mix with and infect animals from other valleys, regions and even countries. This 'alpine' transmission route was one reason suggested for the rapid early spread of infection from just outside Gilgit to Chilas much further south (although the transport of meat by road now seems equally likely). Informed opinion in Gilgit-Baltistan and Islamabad put the number of animals at risk in the surrounding areas at as high as three million, and a suitable amount of vaccine to cover these animals was provided to FAO and GoP by the European Union.

Finally, after a year with several false starts, correctly administered good-quality vaccine brought the disease under control in the Northern Areas, and the last case there was detected just over 18 months after the epidemic was thought to have started. It was estimated that at least 40,000, perhaps 50,000, cattle and yaks had died. Most local veterinary staff willingly threw themselves into the emergency programme, with some key personnel being prominent in making sure that surveillance and vaccination was carried out as thoroughly as possible. Very disappointingly, a small minority of veterinary staff put their own gain before the needs of their communities either by concentrating on other personal issues or by demanding payment from stock owners for what was free vaccination. Unimaginably, on one occasion, desperate stock owners requesting assistance were told by veterinary staff to go home and sharpen their knives.

FIG. 5

NOT FOR THE FAINT HEARTED

One of the authors, M. Hussain, crossing the Indus on a foot bridge to examine suspected cases. The other author, P. Rossiter, volunteered to remain behind to take the photograph

Courtesy of the authors

The one positive outcome of this outbreak of cattle plague in Gilgit-Baltistan was to sharpen the resolve of the national authorities to completely eradicate the virus from the whole country. If a devastating epidemic such as this could occur in what many would have considered the most unlikely of places, and some 2,000 km from the main foci of infection in Karachi, then clearly the whole country was at risk. Continuing surveillance showed that, fortunately, the virus had not spread beyond Gilgit-Baltistan into the millions of cattle in neighbouring regions as had been predicted by those with local expertise. Consequently, the balance of the vaccine that had been held in reserve for this eventuality was quickly moved to spearhead the fight against rinderpest virus in Karachi and Sindh, where it immediately proved successful, paving the way for the eventual eradication of rinderpest from Pakistan in 2000.

LASTING IMPRESSIONS AND MEMORIES

Apart from the technical challenges, working in Gilgit-Baltistan was an unforgettable adventure. The drive up the Karakoram highway from Islamabad to Gilgit was always scenically breathtaking, and enlivened by numerous unexpected experiences such as the automatic tracer fire arcing from hillside to hillside across the Indus during the overnight stop in Kohistan, the numerous gun shops already open at 8.00 a.m. (presumably to resupply what had been spent during the night). Climbing higher still, we needed burning braziers under the dining table in Skardu to keep us warm before heading to bed with hot water bottles and woollen night caps. We will never forget the swollen rivers crossed on small, swaying pedestrian suspension bridges (Fig. 5), climbing through the snow to reach affected villages, beautiful lakes and rivers filled with trout, tea laced with salt not sugar, oddly shaped polo grounds in the smallest and highest villages, a wolf on the road at night and even home-made wine.

More vivid still are the memories of the dreadful impact of the disease itself. For affected stock owners it was a hammer blow. Whole villages were left with hardly an animal. Many farmers lost all their large ruminants, and families already close to the breadline were forced to send their breadwinner away to distant cities. Ironically, some ended up working in Karachi, the ultimate source of their plague almost 2,000 km away. It is unlikely that the present generation of livestock owners in Gilgit-Baltistan will ever forget the outbreak. In today's rinderpest-susceptible world these outbreaks in Pakistan's Gilgit-Baltistan region are a stark reminder of what could go wrong if we forget rinderpest or if veterinary authorities are slow to recognise and react to it.

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CHAPTER 2.7

RINDERPEST IN GEORGIA, MONGOLIA AND THE RUSSIAN FEDERATION, 1989–1998

P. L. ROEDER

Hollyhedge Cottage, Spats Lane, Headley Down, Hampshire GU35 8SY, United Kingdom (Former Secretary of the Global Rinderpest Eradication Programme, Food and Agriculture Organization of the United Nations [FAO], Rome)

Corresponding author: peter.roeder@taurusah.com

SUMMARY **This chapter discusses three widely separated enigmatic instances of rinderpest, the locations of which are shown in the accompanying map. Although the evidence is largely circumstantial, there is a strong indication that all three disease events were linked to the use of the K37/70 live attenuated rinderpest vaccine, presumably as a result of reversion to virulence of the attenuated virus.**

KEYWORDS **China – Mongolia – Rinderpest – Russian Federation – Vaccine.**

HISTORY

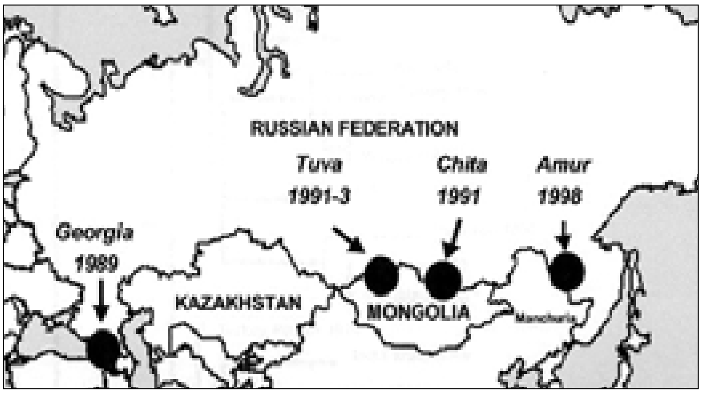
The small village of Simonovo lies close to the Chinese border in Amur region of the far east of the Russian Federation (Fig. 1). It is situated in a densely forested region, which has small villages that are widely separated.

In 1998, cattle, mainly a Simmental type originally derived by crossbreeding with local cattle, were grazed in summer on pastures close to the village and were housed in winter. On 17 June 1998, Dr Rosa Kuzmenko, chief of the veterinary station of Shimonovsk district in Amur region of the Russian Federation was called to attend to a sick ox with ocular and nasal discharges, diarrhoea and a fever. This animal died four days later. A second case was recognised on 22 June, and subsequently fresh clinical cases occurred virtually daily until August. Although too young to have ever seen rinderpest herself, Dr Kuzmenko was convinced that this was rinderpest. In all there were 70 clinical cases out of 164 cattle and 43 of these died. Samples from affected cattle were submitted to the Amur region diagnostic laboratory in June, but it was not until a team from the All Russia Research Institute for Animal Health (ARRIAH) in Vladimir visited in August that the disease was confirmed as rinderpest.

This diagnosis was understandably alarming for the authorities of the Russian Federation, for the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE), and for the neighbouring countries of China and Mongolia, because the disease had not been seen in the far east of the Russian Federation for many decades, not since 1946 in Amur region. The nearest known presence of rinderpest, then and subsequently, was in Pakistan, more than 5,000 km away.

This occurrence was an enigma that demanded an explanation to safeguard the advances being made in the eradication of rinderpest and the verification of freedom from rinderpest; a joint FAO/OIE investigation was mounted in mid-1999 (1). Working with veterinarians and scientists of the Russian Federation from ARRIAH, the team established that there had been no movements of cattle into the district in 1998 and that Simonovo was the only village that had been affected. Simonovo is situated in the border area of the former Soviet Union, where it had been customary to vaccinate annually or biannually with rinderpest vaccine in an attempt to prevent invasion by rinderpest from neighbouring countries. Vaccination had taken place in the village on 20 May 1998 and 58 of the then 164 cattle present were vaccinated; perhaps significantly, neither of the first two

FIG. 1
MAP OF THE RUSSIAN FEDERATION INDICATING LOCATION OF RINDERPEST EVENTS LINKED TO THE USE OF K37/70 VACCINE; EVENTS IN CHITA AND TUVA WERE PART OF THE SAME INSTANCE
Source: Roeder, Mariner & Kock, 2013 (2), modified to indicate location of rinderpest events linked to K37/70 vaccine



cattle affected had been vaccinated. Out of the 70 clinical cases only 6 had been vaccinated. The vaccine used was the K37/70 live attenuated vaccine, which had been in use since 1978. The vaccine virus was derived from the highly virulent Kabul (Afghanistan 1961) isolate attenuated by 37 passages in cattle and 70 passages in primary calf kidney cells. The vaccine was routinely produced in primary calf kidney cells and assayed for potency, but innocuity tests by animal inoculation were not routinely conducted. The vaccine had been rigorously tested in Kazakhstan where the attenuation work had been conducted. In the year following the Simonovo incident, veterinary scientists at ARRIAH conducted additional testing by passaging the vaccine virus in cattle, including immunosuppressed cattle, without being able to produce any adverse effects.

In response to the outbreak, the village was quarantined and all remaining cattle in the village (and neighbouring villages) were vaccinated; there were no further cases. Vaccination continued for another year before the vaccine was withdrawn from routine use. The Chinese veterinary authorities withdrew all susceptible species from the border with the Russian Federation to a distance of 100 km and commenced vaccination of cattle and yaks in China on the southern border with Pakistan, the nearest known area where rinderpest had occurred in the recent past.

POSSIBLE ORIGINS OF THE OUTBREAK IN AMUR

Possible means by which an outbreak could have been initiated were examined in some detail, and the most likely were considered the following.

Persistence within a cryptic focus of infection in cattle

It was considered unlikely that rinderpest virus could have persisted in a completely virulent form in the region. Given the low livestock density, the fenced border with China and the wide river, the low contact rate, the sparse, low density cattle populations in the region, the lack of cattle movements, the absence of trade and markets and the long winter housing period, long-term maintenance of the rinderpest virus in any form in domestic livestock is difficult to conceive. Subsequent serological studies undertaken to verify rinderpest freedom confirmed this to be the case (S. Starov, ARRIAH, personal communication).

Transmission from wildlife

Of the possibly susceptible species, forest-dwelling ungulate species are abundant in Amur region – elk (*Alces alces*), roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*). Two wild ungulate species present on the steppes of Central Asia are known to be highly susceptible to rinderpest and have been involved in rinderpest introductions across borders in the past – Saiga antelope (*Saiga tatarica*) and zeren or Mongolian gazelle (*Procapra gutturosa*). However, mortalities in these species have been studied intensively without any evidence of rinderpest infection being disclosed. Suroks and susliks, rodents of the genera *Marmuta* and *Citellus* respectively, abundant in Mongolia and neighbouring regions, have been proposed as potential hosts, because experimental infections are reported to have produced mild clinical disease in them. Extensive flooding had occurred in northern China at the time of the outbreak and this could have caused unusual migrations of what are termed locally as 'running species'; such migrations are not uncommon locally in response to forest fires and floods. Again, it is unlikely that these animals could have sustained rinderpest virus infection for 50 years without its presence being signalled in cattle. The cattle in the region are derived from introduced Simmental cattle and would have been highly susceptible to rinderpest. Further, there had been no evidence for the presence of rinderpest in the region for many years.

Escape of virus from scientific institutes

There were no known research institutes handling rinderpest virus in the region, even for diagnostic purposes.

These considerations raised a contentious issue: that the rinderpest outbreak could have been in some way related to the use of rinderpest vaccine. The timing of the onset of the outbreak very soon after partial vaccination of the village herd was suggestive of a causal connection. Surprisingly, however, it had been possible to isolate the virus from sick cattle some three months after vaccination had been applied in the village. Infection following vaccination, or even infection with field virus in an individual animal, is most unlikely to exceed 21 days, but it is not unknown for virus to persist for some weeks or months in small groups of cattle. Examples of this occurring are the long-term persistence of the virus in the grey steppe cattle used by Chinggis Khan (otherwise known as Genghis Khan) for transport from Mongolia to Europe over many centuries (2) and the movement of rinderpest from Belgium to Brazil in 1920.

The hypothesis of a causal relationship between the outbreak and vaccination is strengthened by three additional pieces of evidence.

Molecular characterisation of the Amur virus

Work conducted by ARRIAH scientists, supported by information from the Pirbright Institute, showed that the virus isolated from diseased cattle in Amur region was very closely related to the Russian vaccine virus (K37/70) and to the original Kabul 1961 isolate of the virus (less than 0.5% nucleotide difference over nucleotides 840 to 1161 of the F gene). The shared presence of a substitution at nucleotide 885 in the Amur and vaccine viruses, but not in Kabul 1961, is highly suggestive of the causal relationship hypothesis.

Enigmatic outbreaks possibly associated with vaccination in Georgia a decade earlier, in 1989

In October/November 1989 rinderpest appeared unexpectedly in three farms close to the Turkish border (Fig. 1). There is no clear account of the incident, but the affected border districts lay within the vaccine buffer belt, which had formerly been vigorously enforced. Introduction of infection from Turkey was suspected. The diagnosis was confirmed virologically. A virus designated as 'Russia 903', probably from the Georgia outbreak in the archive of the Pirbright Institute, bears a close phylogenetic relationship to Kabul 1961 and therefore to the K37/70 vaccine (T. Barrett, personal communication). It is clearly distinct from viruses isolated in the Islamic Republic of Iran (1989) as well as all other archived viruses from Turkey and the Islamic Republic of Iran.

Enigmatic outbreaks possibly associated with vaccination in Mongolia in 1992–1993

Russian cattle in the Chita region of the border of the Russian Federation with Mongolia were vaccinated with rinderpest vaccine K37/70 in April/May 1991 and they were then moved to summer grazing in Mongolia – a well-established system of transhumance (Fig. 1). Adverse reactions to vaccination were not observed in the Russian Federation. There was no morbidity or mortality in the Russian herd of origin, but deaths started to occur in the transhumant cattle in Mongolia; in a period of three weeks from 5 July 1991 some 174 of the 902 cattle developed clinical disease and of these 110 died. The signs of disease were highly suggestive of rinderpest, yet a team of investigators concluded that the disease observed was bovine viral diarrhoea/mucosal disease, although other investigators from Chita and the Kazakhstan rinderpest laboratory had confirmed rinderpest by a complement fixation test. After revaccination no further disease was seen. However, in October or December 1991 rinderpest was again seen in domesticated yaks in nearby Tuva region of Mongolia where they had been vaccinated following the earlier events (Fig. 1); predominantly unvaccinated yaks were affected. Recovered animals were found to be seropositive and rinderpest was confirmed by two independent institutes in the Russian Federation. The disease spread in yaks in Tuva and was observed in cattle only in the second half of 1992. Overall, mortality in Tuva and Chita (Russian Federation) amounted to some 2,500 yaks and 10,000 cattle. Tissues from yaks in Tuva, examined at the Pirbright Institute, were found to be positive for rinderpest precipitin and nucleic acid by hybridisation and reverse transcriptase polymerase chain reaction (RT-PCR). However, F gene sequencing gave sequence results that were interpreted to indicate the presence of two unrelated viruses, one being a virus of the Asian lineage and the other being the rinderpest bovine old Kabete (RBOK) rinderpest vaccine virus. Although only a 280 nucleotide sequence was available, it became clear from subsequent work that one sequence was virtually identical to the Kabul 1961 virus and therefore the K37/70 vaccine virus.

CONCLUSION

There is a strong indication that all these disease events were linked to the use of the K37/70 live attenuated rinderpest vaccine, presumably as a result of reversion to virulence of the attenuated virus. This interpretation was not fully accepted by the authorities of the Russian Federation at the time, but the use of rinderpest vaccine in the border belt was discontinued after the year 2000 and there was no recurrence of disease. Mongolian and Chinese authorities were eventually persuaded that all three countries – Russian Federation, China and Mongolia – were in fact free from rinderpest. This was subsequently, and unequivocally, demonstrated by surveillance, including serological studies, and the three countries achieved OIE accreditation of freedom from rinderpest in 2010, 2007 and 2005, respectively.

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CHAPTER 2.8

RINDERPEST IN DELHI AND GUJARAT, 1980–1988

P.K. UPPAL

H. No. 770, Sector 17A, Gurugram, Haryana 122001, India (Former National FAO Expert on Rinderpest, Government of Punjab, Department of Animal Husbandry, Dairying and Fisheries)

SUMMARY **By 1980 the Government of India (GoI) had spent nearly 25 years battling against rinderpest using mass vaccination. Between 1980 and 1990 the ongoing mass vaccination programme was reviewed and a reformulated programme was introduced within an international drive towards global eradication. The European Union supported the GoI's efforts to implement the revised control strategy. An outbreak of rinderpest in Delhi in 1981 triggered these changes, while an epidemic in Gujarat State in 1986 and 1987 was instrumental in bringing them to fruition.**

KEYWORDS **Control in Delhi – Control in Gujarat – Control strategy – Disease epidemiology – Disease incidence – Mass vaccination – Re-emergence 1980 – Rinderpest.**

DELHI

In 1981 the union territory of Delhi comprised 209 villages having a bovine population of 200,000 cattle and buffaloes, housed mostly in peri-urban dairy farms. The union territory of Delhi has a common border with the States of Haryana and Uttar Pradesh. At that time, the territory had sundry veterinary units designated for rinderpest vaccination under the old National Rinderpest Eradication Programme, which had begun in 1956. Significantly, it had no vigilance (active surveillance) unit – a mobilised team responsible for searching for rinderpest outbreaks. There had been 155,000 rinderpest vaccinations of cattle and buffaloes in 1981, 147,000 in 1982 and 92,000 in 1983; notionally then, this small population should have been well protected against rinderpest.

However, in 1981 there was a massive outbreak of rinderpest in Delhi involving 8,050 animals with 798 deaths (Table I). The disease mostly affected buffaloes in the dairies around Delhi as shown in Figure 1. The outbreak was attributed to the movement of infected cattle from the State of Uttar Pradesh as shown in Figure 1. The ensuing series of outbreaks lingered on until 1985.

This outbreak assumed a significance far beyond the level of the damage it actually caused. It came at a difficult time and place for the Government of India (GoI). Its National Committee on Animal Health (Rinderpest Sub-committee) had already noted an increasing number of outbreaks after 1979 (Table II) and it was about to review why its 25-year-long national mass vaccination campaign could not eliminate rinderpest. In the event, the Delhi outbreaks prompted the GoI to seek the advice of Dr Y. Ozawa, the Chief of the Food and Agriculture Organization of the United Nations (FAO) Animal Health Service, who visited Delhi in 1982. This resulted in an FAO expert consultation, which met at the Indian Veterinary Research Institute, Izatnagar (India), in December 1983 to discuss the

FIG. 1

EMERGENCE OF RINDERPEST IN DELHI, 1981–1985

Source: Google Maps (2018). – Map of Delhi. Available at: https://www.maps.google/com (accessed on 9 June 2021); modified to indicate emergence of rinderpest

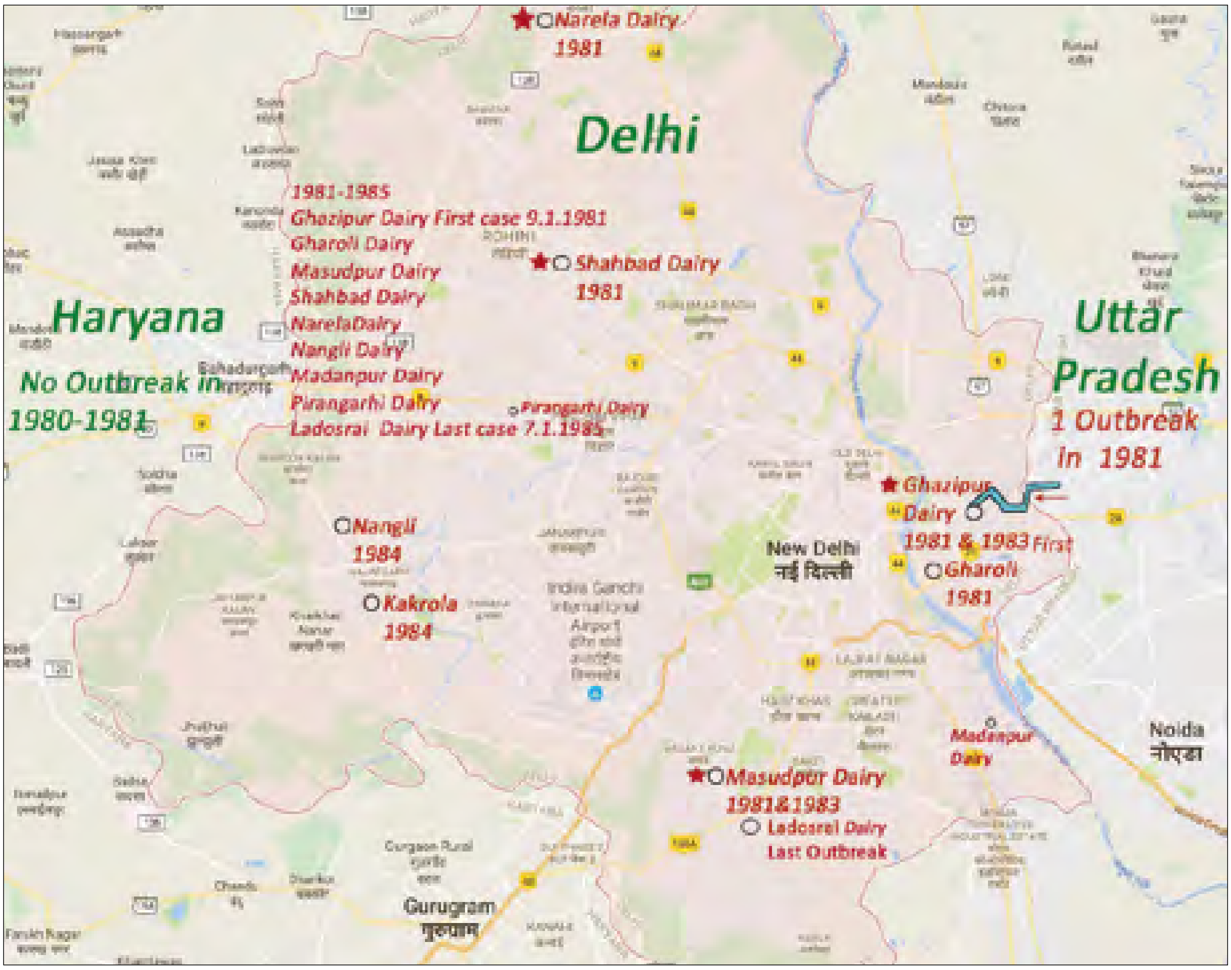

TABLE I

RINDERPEST OUTBREAKS, CASES AND DEATHS IN DELHI, 1980–1985

Year	Districts	Dairy farms	Number of rinderpest		
			Outbreaks	Cases	Deaths
1980			–	–	–
1981	East Delhi	Ghazipur [a], Gharoli	1	8,050	798
	South-west	Masudpur			
	North-West	Shahbad, Narela			
1982			–	–	–
1983	East Delhi	Ghazipur	1	340	288
	North-west	Nangli			
	North-west	Nangli			
1984	South-west	Masudpur, Pirangarhi	1	115	18
1985	West Delhi	Ladosarai	1	447	139
	South Delhi	Bhati			

[a] Disease was first reported at the largest dairy farm of Delhi–Ghazipur on 9 January 1981 and, in all, five dairy farms were involved

requirements for a rinderpest eradication campaign in South Asia. The consultation concluded that the regional campaign should include Bangladesh, Bhutan, India, Nepal and Pakistan. This project proposal was subsequently endorsed by FAO's Animal Production and Health Commission for Asia and

TABLE II
INCIDENCE OF RINDERPEST IN INDIA, 1979–1983

Year	Number of			Number per outbreak	
	Outbreaks	Cases	Deaths	Cases	Deaths
1979	120	2,619	1,296	22	11
1980	185	4,789	2,349	26	13
1981	209	12,667	2,243	61	11
1982	122	2,295	691	19	6
1983	88	1,916	905	21	10

the Pacific (APHCA) in 1984 and the Commission suggested the inclusion of Sri Lanka and Myanmar in the regional campaign. This was the start of the South Asia Rinderpest Eradication Campaign (SAREC) concept (see Chapter 4.13.1).

GUJARAT

In 1981 the State of Gujarat in the west of India comprised 25 districts and 18,509 villages with a bovine population of about 9.5 million head. The state was well-equipped with anti-rinderpest campaign personnel. Gujarat had a long history of excellent vaccination coverage and had not experienced the disease since 1971. Nevertheless, in line with the slight upwards trend in the number of outbreaks as noted above, Gujarat again experienced occasional outbreaks in the early and late 1980s. The incidence of outbreaks is shown in Table III. In Gujarat, the disease was first detected on 1 May 1981 in the village of Makakhad and the last case was detected at Changodhar in September 1983. Coincidentally, Gujarat's neighbouring states, namely Rajasthan, Madhya Pradesh and Maharashtra, were reporting the periodical occurrence of rinderpest in 1980–1981 (Fig. 2). It is considered that the outbreaks in Gujarat may have been due to the trading of animals, especially the movement of Gir bulls and cattle between Rajasthan and Gujarat (as shown in Figure 2 in blue).

In 1985, after completing an internal review, the GoI launched a fresh initiative against rinderpest, known as Operation Rinderpest Zero (ORZ). The review had identified several states where the virus was possibly endemic and called for intensified vaccination in those districts where this might be the case. In fact a second series of outbreaks, amounting to a mini-epidemic, began in 1986. The years

FIG. 2
EMERGENCE OF RINDERPEST IN GUJARAT, 1981–1983
Source: Google Maps (2018). – Map of Gujarat. Available at: https://www.maps.google/com (accessed on 9 June 2021); modified to indicate emergence of rinderpest

TABLE III
INCIDENCE OF RINDERPEST OUTBREAKS IN GUJARAT, 1980–1988

Year	Names of the districts	Village outbreaks	Cases	Deaths
1981	Mehsana	1	–	–
1982	Ahmedabad	4	275	128
1983	Ahmedabad	3	61	34
1986	Ahmedabad, Banaskantha, Baroda, Bharuch, Bhavanagar, Kheda, Mehasana, Surat, Valsad	24	3,931	1,541
1987	Ahmedabad, Banaskantha, Baroda, Bharuch, Bhavanagar, Kheda, Mehasana, Panchmahals, Surat, Valsad	62	5,476	1,772

No outbreaks were reported in 1980, 1984, 1985 and 1988

1986 to 1988 were drought years in Gujarat and saw large-scale cattle migration. A solitary outbreak in Bhavnagar city led to 24 outbreaks throughout the state. The intensified vaccination policy worked well. While 24 outbreaks were reported in 1986 and 62 in 1987, the disease was under control by 1988 and thereafter never reappeared.

CONCLUSION

Mindful of the fact that the ORZ programme was only funded until 1990, by 1988 the GoI forwarded a proposal to the European Union for bilateral assistance in promoting a new, time-bound eradication programme, as recommended in 1983 by the FAO expert group that met at Izatnagar, mentioned above. In the event that the ORZ programme was successful, the new programme would, it was hoped, introduce the World Organisation for Animal Health (OIE) Pathway and the proposition that, once the disease had been eliminated and intensive vaccination ended, intensive surveillance would begin. The importance of Gujarat lay in the fact that its earlier endemic status had been correctly identified and correctly rectified. Although similar achievements had occurred in Maharashtra and Orissa, it was Gujarat that the EU review mission of 1988 visited and, impressed by the professionalism with which Gujarat had dealt with its most recent crisis, recommended the adoption of a National Project for Rinderpest Eradication; this was launched as project ALA89/04 in May 1992. It lasted until 2005 when India was declared free from rinderpest (Chapter 4.13.5).

PART 3
THE PRINCIPLES UNDERLYING RINDERPEST CONTROL AND ERADICATION

CHAPTERS

CHAPTER 3.1

BASIC PRINCIPLES IN THE CONTROL OF VIRAL DISEASES SUCH AS RINDERPEST

B. TOMA [(1)*], F. MOUTOU [(2)] & B. DUFOUR [(3)]

(1) École vétérinaire d'Alfort, 94704 Maisons-Alfort, France
(2) 42 rue de l'Est, 92100 Boulogne-Billancourt, France
(3) École vétérinaire d'Alfort, EpiMAI, USC Anses, 94704 Maisons-Alfort, France

*Corresponding author: bernard.toma@vet-alfort.fr

SUMMARY **The technical possibility of eradicating a transmissible animal disease relies on both the properties of the pathogen (such as its epidemiological, pathological or immunological characteristics) and on the existence of tools for diagnosis and/or screening and vaccination. These conditions appear to have been met for rinderpest.**
The implementation of selected action plans, under international coordination, was of great importance. This was especially relevant in the last countries where rinderpest was still present. Significant economic, social and epidemiological difficulties were faced.
The worldwide eradication of rinderpest opened the way, although difficult, to try to eradicate other transmissible animal diseases.

KEYWORDS **Animal disease control – Eradication – Rinderpest.**

INTRODUCTION

In cattle and other animal species, as well as in humans, diseases with the highest lethality rates have been called 'pests'. Rinderpest has been, over several centuries, responsible for the death of billions of cattle. On account of its very high economic importance, the need to control rinderpest led to the creation of the first two veterinary schools in the world: Lyon, France, in 1761 and Alfort, France, in 1765 (1, 2).

One hundred and fifty years later, because of the continuing potential threat represented by rinderpest to uninfected countries, as illustrated by its arrival in Europe and in Brazil from India in 1920, 28 countries signed an international agreement on 25 January 1924 to create the Office International des Épizooties (OIE) (which became the 'World Organisation for Animal Health'), with the aim of coordinating the scientific knowledge devoted to the control of this disease (3).

After years of campaigning to control rinderpest, this very important cattle infection became the first animal disease to be eradicated worldwide. Was this transmissible animal disease specifically sensitive to the tools used against it? This chapter is an introduction to Part 3 entitled 'Rinderpest control' and recalls the principal tools that can be used against this type of transmitted viral disease and presents an assessment of the possibility of eradicating animal diseases and the complexity of organising regional eradication plans.

OBJECTIVES AND PRINCIPLES IN THE CONTROL OF TRANSMISSIBLE ANIMAL DISEASES

Fighting a disease may have various kinds of objectives associated with various levels of expected results.

The various levels of objectives and expected results of a control plan against a disease

Since the first definitions of the concept of 'eradication of a disease', as suggested by Soper in 1962 (4) and by Andrews and Langmuir in 1963 (5), the terminology has been improved (6) with the distinction being made between the various objectives, result levels and control steps, and a few differences have appeared (7). These discrepancies are associated with:

- the residual presence of the pathogen within some animals, for instance wildlife or the environment;
- the zone covered by the eradication plan, whether it is worldwide or a smaller area;
- maintaining a contingency plan in place after eradication in the event of re-emergence of the disease.

Regarding terminology, a few important ideas must first be clarified before explaining the various objectives and levels or steps taken towards the eradication of a disease (8):

In the case of a disease eradicated in some countries but not yet worldwide, it is useful to mention for how long these countries have been free of the disease. As it is difficult to confirm the actual disappearance of the pathogen, the longer the country remains disease free, the more likely it is that we have been successful in eradicating the pathogen.

The different degrees of controlling a disease and the steps used to succeed in its eradication worldwide are presented in Table I.

TABLE I

DEFINITIONS OF THE VARIOUS STEPS IN THE WORLDWIDE ERADICATION OF A DISEASE

Eradication step	Definition
Control of a disease	Reduction in the incidence and prevalence of a disease to a locally **acceptable** level, through the application of different measures
Elimination of a disease [(a)]	Reduction in the incidence of disease **cases/ outbreaks** to **zero** in a given geographical zone, through the application of different measures
Elimination of an infection [(a)]	Reduction to **zero** of the incidence of the **infection** caused by a given pathogen in a geographical zone, through the application of different measures
Eradication of a disease	All actions leading to the total elimination of a disease, through the **suppression** of its **cause**, in a country, a group of countries or worldwide, over a period of time
Extinction	The specific infectious agent no longer exists in nature or in the laboratory

[(a)] The distinction between two levels of elimination of a disease or infection focuses on the fact that the 'disease' has a clinical expression (through cases or outbreaks) while an 'infection' may occur without clinical signs

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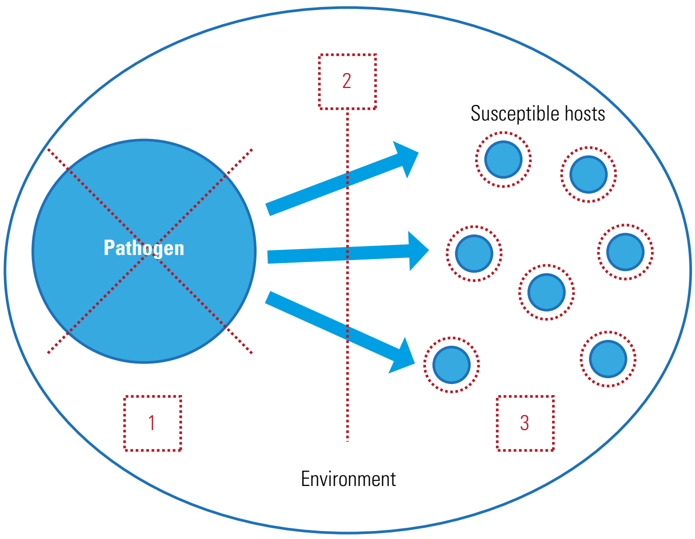
FIG. 1

REPRESENTATION OF THE FACTORS ACTING TOGETHER IN DISEASE: THE SOURCE OF THE PATHOGEN, THE SUSCEPTIBLE HOSTS AND THE ENVIRONMENT

Courtesy of the authors



The basic principles of the control of a transmissible disease are:

1. a limitation in the production of the pathogen
2. a decrease in exposure of susceptible hosts
3. vaccination of susceptible hosts

Basic principles when fighting transmissible animal diseases

At an epidemiological level, a transmissible disease is an entity in which a biological pathogen acts on susceptible hosts within their environment. This entity can be shown as a diagram (Fig. 1). Some important aspects of transmissible diseases are listed below:

- Many different kinds of *biological pathogens* (bacteria, viruses, parasites, prions, etc.) exist with very different properties, conditioning disease profiles and levels of difficulty in controlling them.
- In the same way, *susceptible hosts* may be quite different between diseases, in terms of

the host category (e.g. humans only, animals only, humans and animals, plants) and the number of susceptible species, such as domestic and wild animals, both of which lead to different levels of difficulty when trying to control these diseases.

– The *environment* may also act on the biological pathogen (by preserving it or inactivating it rapidly or slowly) as well as on the susceptible host populations, their physiology, their contacts, their movements, etc. Humans are included and are able, through their actions, to unknowingly encourage the transmission of biological pathogens, or, conversely, to actively try to prevent transmission or protect susceptible species.

The basic principles when fighting a transmissible disease are simple and have been known for years. They involve three main elements (Fig. 1).

1. *To limit, or even stop, the production of the biological pathogens*. For transmissible animal diseases, there is a tool that is not available for human diseases, i.e. the destruction of the pathogen by culling and destroying sick and contaminated individuals (action 1 in Fig. 1). This applies mainly to domestic livestock, at least in some countries. It does, however, sometimes raise technical and/or psychological difficulties in the case of pets. It can also be used for wildlife, but it is more difficult.
2. *To reduce the exposure of susceptible individuals to the biological pathogen.* All control measures are put in place in the event of a transmissible disease outbreak, for example a ban on the transport or on the introduction of animals, isolation of domestic stock and disinfection of vehicles (action 2 in Fig. 1).
3. *To make susceptible individuals resistant.* This action corresponds to preventive vaccination (action 3 in Fig. 1).

Depending on the situation, the use of the first two categories (i.e. 'sanitary approach') or a mix of the three ('medico-sanitary approach') can control many transmissible animal diseases (but not all) in countries that have a highly organised sanitary agency.

In general, within a given country, the probability of succeeding in the fight against one transmissible animal disease depends theoretically, firstly, on the disease's characteristics and, secondly, on the organisational capacity to implement practical measures and on the tools available.

A more detailed analysis will confirm the reasons for the success story of worldwide rinderpest eradication and will highlight the potential for additional successes in the fight against other transmissible animal diseases.

HOW TO CHOOSE WHICH DISEASES CAN BE ERADICATED AND DEVELOP A CONTINGENCY PLAN

Worldwide eradication of a transmissible animal disease always starts with small geographical steps, involving a country, region or continent.

Eradication can only be achieved for diseases that, for technical reasons, can be eliminated, without too many difficulties, in countries with an effective sanitary agency and when elimination can be justified at an economic level. For such diseases, it is becoming increasingly difficult in countries where the disease epidemiology is far from simple and where the sanitary agency is ineffective. Success will take longer to achieve. In addition, in these countries, at an economic level, the result of a cost–benefit analysis can be very different and less favourable than in a country where eradication of another disease has already been achieved. This is why the eradication of foot and mouth disease (FMD) (an animal disease with very low lethality) in countries where cattle breeding represents a capitalisation of goods (i.e. bloodstock) does not mean the same as in countries where cattle breeding is aimed at beef and dairy production and trade.

Therefore, worldwide eradication of a transmissible animal disease, if achievable, is linked to the implementation of a chosen contingency plan in the last countries where the disease is still present. This requires international organisation and financing. Even in countries with a good sanitary agency, it is not possible to ensure the eradication of a disease because there can be technical characteristics linked to eradication that are impossible to overcome (such as the existence of many wildlife species acting as reservoir), or because the cost–benefit analysis is unfavourable.

The process towards the worldwide eradication of a transmissible animal disease includes, firstly, the long and difficult weighing up of the decision to adopt (or not) such an objective, and, secondly, the organisation and the (long and difficult) implementation of the eradication plan.

Evaluation of the feasibility of an eradication process

The intellectual process to determine which transmissible animal diseases could be eradicated worldwide, as in the case of human diseases, involves:

– an evaluation of the feasibility of the eradication of a disease;
– a cost–benefit analysis, country by country;

– a cost–benefit analysis at an international level (will disease eradication offer a rapid economic improvement and have a positive effect in terms of international trade, for instance?).

Evaluation of the likely eradication level of a transmissible animal disease

For every transmissible animal disease, this evaluation relies on the study of the characteristics of the disease (epidemiology, pathogenicity and immunogenicity of the causative agent), as presented in Table II, and on the availability of tools for monitoring and/or diagnosis and vaccination, as presented in Table III.

TABLE II
CHARACTERISTICS OF A TRANSMISSIBLE ANIMAL DISEASE PROMOTING THE CHANCES OF SUCCESSFUL CONTROL

Epidemiology
Low number of susceptible animal species
No wildlife reservoir
No transmission through arthropods
No environmental reservoir
No long-time carriers
Pathogenicity
High frequency of clinical expression of the disease in susceptible animals
No pathogen excretion during incubation
Immunogenicity
Antigenic uniformity (no type diversity)

TABLE III
AVAILABILITY OF TOOLS THAT DICTATE THE SUCCESS OF MEASURES APPLIED AGAINST A TRANSMISSIBLE ANIMAL DISEASE

Epidemiological surveillance and diagnosis
Availability of sensitive and specific laboratory tests that are easy to use, cheap and rapid
Availability of laboratory tests able to differentiate vaccination from infection
Vaccination
Availability of a safe, cheap, thermostable and efficient vaccine
Long-lasting post-vaccination immunity

The basic principles of the control of a transmissible disease are:

1. a limitation in the production of the pathogen
2. a decrease in exposure of susceptible hosts
3. vaccination of susceptible hosts

The two tables bring together most of the factors that need to be taken into account in an evaluation of the likely achievable eradication level of a given disease. They are not exhaustive and minor details could be added. They consider criteria listed by Fenner in 1982 (9) for human smallpox eradication, those mentioned by Dowdle and Cochi in 2011 (6) for human diseases and those suggested by Thomson *et al*. in 2015 (10) for transboundary animal diseases. The last authors defined three groups of factors: seven epidemiological factors, five monitoring factors and five vaccination factors. They tested 26 animal diseases, which are or were present in South Africa, using a notation scale (from 1 to 5 for each factor, with a weight from 1 to 10 depending on the factor involved), and they developed a classification of the theoretical likelihood of eradicating these diseases, the most likely to be eradicated being rinderpest. The authors do agree that the scoring and weighting of each factor may be subjective and that other expert panels could have produced different results. However, their results appear logical on a biological basis, defining three groups: a group of diseases usually considered to be eradicable (rinderpest, dog rabies, peste des petits ruminants, FMD linked to Eurasian serotypes, etc.), a group of diseases less likely to be eradicated (anthrax, bovine tuberculosis, FMD linked to Southern African Territories serotypes, contagious bovine pleuropneumonia, etc.) and a group of diseases with vector transmission, which are certainly the most difficult to eradicate.

Cost–benefit analysis by country

To ensure that a majority of countries agree to engage in the process of eradication of a specific transmissible animal disease, all the countries that are still affected by the disease must be persuaded that there will be an economic improvement. This kind of analysis is not without difficulty and is still uncertain, but it appears to be sound. Many developed countries have succeeded in eliminating various major animal diseases by eradicating the associated pathogens in the domestic animal pool, sometimes in all pools (including wildlife), at the national or regional level, and sometimes for a very long time (in Europe, for instance, this has been done for rinderpest, glanders, contagious bovine pleuropneumonia, dourine, sheep pox, FMD, classical swine fever, Aujeszky's disease).

For this analysis it is necessary to estimate the costs of the disease (through direct and indirect losses) and to list the methods and tools available in the fight against the disease, as well as their cost. The costs and benefits must be evaluated for each stakeholder, for example farmers in the various production areas that are affected (also discussed in

Chapter 6.4). Will eliminating the disease result in financial losses due to the extra work they will have to perform during eradication?

The result of this analysis may be very different depending on the diversity in pathogenicity expression of the transmissible pathogen, on the country, on farming practices (family or more industrial farming) and on production objectives (trade or capitalisation). Indeed, the end result may not be a decision to control the disease in developing countries that may represent the last place where a disease, previously present worldwide, now exists.

Cost–benefit analysis at the international level

This is even harder to perform than the previous analysis, as it may bring together very different situations due to countries' levels of development. However, even if the results are also uncertain, it has to be done to prevent starting a long process, with unclear results, in many countries without reasonable assurance of a favourable eradication level and a globally positive economic impact.

Organisation and application of the eradication

Each country manages the control of transmissible animal diseases in its own territory depending on its priorities, its trade incentives and the tools and means that are available. It also follows the guidelines governing international regulations on animals and the trade in animal products.

An eradication objective on a larger scale means cooperation between Veterinary Services in the various countries in the region and the writing of a regional plan to cover very different epidemiological situations. It also needs to be able to indicate the sanitary risks for the leading countries, which are already free of the disease (see Chapter 5.1 for the role of Veterinary Services).

Worldwide eradication must be undertaken with the help of international agencies such as the Food and Agriculture Organization of the United Nations (FAO) and the OIE. They must make extensive plans and organise regional control campaigns, based on specific tools, such as vaccination (see Part 4). The permanent monitoring of the changing epidemiological situation allows control tools to be adjusted. In the few years after the disappearance of the disease case/outbreak, vigilance in the field must be very high to be able to show that there is no resurgence and to confirm that the disease has really disappeared. Eradication of the disease is more and more probable as the number of years without any clinical signs and without any positive screening test results increases.

The implementation of the plan and its proper functioning must be supported by international funding (Chapters 5.8 to 5.13). The rinderpest example, as presented in the chapters of this section, is a perfect illustration of the complexity and importance of contingency plans, especially during the last part of the eradication, and of the major role of international agencies.

RINDERPEST: THE EXAMPLE OF WORLDWIDE ERADICATION SUCCESS

It is both logical and 'miraculous' that rinderpest has been the first transmissible animal disease to be eradicated worldwide. It is, at present, the only one and will probably remain so for some time.

Logical

As the evaluation of its eradicability has shown, the control of rinderpest has been possible in developed countries, with the help of appropriate sanitary measures, and in infected developing countries, with the development of a vaccine that is safe, cheap, thermostable and has a high immunological response.

Europe has been free of this disease for years, following the application of sanitary measures suggested as early as 1715 by Lancisi (11).

The accidental reintroduction of rinderpest in rinderpest-free countries during the 20th century ended with its rapid elimination, again with only the use of sanitary measures. Jacotot and Mornet in 1967 (12) made it clear that sanitary measures are efficient in controlling rinderpest:

> 'When introduced by accident in a free country, rinderpest is certainly the easiest contagious disease to eradicate because of the very low resistance of the virus in the environment, of the rapidity of its evolution, of the very low occurrence of long lasting forms and of virus carriers.
>
> 'There is no example when, in the regions where it was possible to apply them strongly, classical sanitary measures: culling of sick and contaminated animals, destruction of dead animals, disinfection of stables and yards, isolation of the

infected zone, ban on ruminant movements, ban on beef and hides trade, did not succeed in stopping rinderpest expansion. But diagnosis must be done rapidly and legislation must be rapidly and fully applied. Usually, this is only possible in developed countries with a good administration and social network. Under such conditions the proof of the efficiency of just sanitary measures was brought during different situations: Brazil in 1921, Australia in 1923, Rome in 1949.' (12).

The systematic use of vaccination with the vaccine developed by Plowright and Ferris (13) in bovine populations of various African and Asian countries made the eradication of the rinderpest virus possible.

In 1995, Taylor *et al.* summarised the principles and the practice of rinderpest eradication (14).

Therefore, the effectiveness of the available tools, chosen depending on the region, in controlling this disease has been demonstrated on various occasions.

Miraculous

Rinderpest eradication is simple and efficient when the sanitary organisation is of first-class quality or in an easy to access area. However, it can become very complicated where the effectiveness of the sanitary organisation is unknown or the area is difficult to access or even dangerous.

In addition, the potential adaptability of any biological pathogen may mean that it can evolve very rapidly, in one or several steps, from high pathogenicity, with spectacular clinical signs (classic rinderpest), to low pathogenicity, associated with mild symptoms and clinical signs, which is much more difficult to recognise. This could have occurred during the last stages of rinderpest eradication.

It is also miraculous in that, even with quite a large spectrum of animals susceptible to rinderpest, both domestic and wild, in the latter stages of eradication, no other species (e.g. wild ruminants) other than domestic cattle appeared to be able to act as a reservoir for this virus.

The success of the eradication of the first transmissible animal disease shows that such a project is possible. It highlights the huge efforts that are needed to obtain such a result, but it does not say that the worldwide eradication of any other transmissible animal disease would be straightforward.

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CHAPTER 3.2

THE ROLE OF ZOOSANITARY MEASURES IN THE ERADICATION OF RINDERPEST

J. DOMENECH

La Fabrèguerie, 12170 Lédergues, France (Formerly at the World Organisation for Animal Health [OIE], 12 rue de Prony, 75017, Paris, France)

SUMMARY

Rinderpest caused massive losses in several continents of the world over many centuries. Giovanni Maria Lancisi's recommendations of 1715 listed the zoosanitary measures to control the spread of rinderpest, and even today they remain valid for many contagious diseases. These recommendations were continuously updated and are now reflected in official documents published by the World Organisation for Animal Health (OIE) and other international organisations, such as the Food and Agriculture Organization of the United Nations (FAO) and the European Commission.

In Italy, the Lancisi recommendations, complemented shortly thereafter by Thomas Bates in England, were based on zoosanitary measures of isolation of infected animals and stamping-out, combined with strong legal enforcement. Before the advent of the vaccines, these measures, when fully implemented, resulted in rinderpest's eradication in a number of European countries.

In this chapter, the history of zoosanitary measures and the implementation of zoosanitary legislation are presented with a focus on Europe, including Russia, in the 18th and 19th centuries.

After 1,500 years of living with rinderpest, the disease was eradicated from Europe, excluding Russia, by the end of the 19th century and from European Russia, west of the Ural mountains, by 1908. Following a resurgence of rinderpest in Russia, Lenin promulgated several decrees in 1920 that combined strong zoosanitary measures and vaccination (immune serum plus virulent material). These led to eradication in the European part of the Soviet Union in 1928, including the Caucasus region.

The part played by rinderpest in the establishment of the veterinary schools and profession, Veterinary Services and national and international bodies is also addressed in this chapter, and the conditions for successful implementation of the major sanitary measures are briefly presented.

In poorly resourced countries, where rinderpest was endemic, eradication was attained through the combination of zoosanitary and vaccination measures, as demonstrated in Africa and South Asia in the 20th century.

The lessons learnt from rinderpest's eradication are relevant for other animal diseases such as peste des petits ruminants.

KEYWORDS

Keywords – Eradication – Rinderpest – Veterinary legislation – Zoosanitary measures.

INTRODUCTION: THE IMPORTANCE OF RINDERPEST AND OF SANITARY MEASURES IN THE 18TH, 19TH AND EARLY 20TH CENTURIES AND THE CONCEPT OF GLOBAL PUBLIC GOOD

Rinderpest was a disastrous cattle disease for millennia, causing massive losses on several continents across the world. As a result of very high mortalities, this so-called 'cattle plague' provoked several famines in ancient times and caused the loss of draught animal power in agricultural communities in the 18th, 19th and 20th centuries. It was also a major barrier to livestock trade until its final eradication (1, 2, 3, 4).

Rinderpest probably evolved in the Central Asian steppes in the first millennium BC (5), and from its homeland around the Caspian Basin it spread westward towards Europe and eastward towards Asia as a result of successive invasions and military campaigns (5, 6).

Regarding Europe in the early 18th century, rinderpest spread throughout many countries from Russia, first to central and western Europe and then southwards to Italy, probably as a result of trade in cattle coming from eastern Europe). For example, herds of cattle in Venice and Lombardy were infected in 1711 through commerce in cattle across the Adriatic Sea. During the decade from 1745, a pandemic swept away nearly the whole race of horned cattle throughout Europe (2). It is estimated that 200 million cattle died in eastern and southern Europe between 1711 and 1769 (1).

Until the 18th century, spread was mainly due to army campaigns and the trade in animals for meat, or indirectly through the trade in corn transported by ox-drawn carts (2). In the mid-19th century the transmission routes changed. Rinderpest contaminated new countries through the shipment of live cattle by steam-powered trains (several railway lines crossed Russia to central and western Europe) and boats.

In the 19th century an important epidemic occurred in Great Britain (1865–1867) as a result of the shipment of cattle from Russia. Another occurred in France, when the Russian army brought rinderpest from the Central Asian steppes at the end of the first Napoleonic Empire (1804–1815), and in 1854 the Franco-English war against Russia in Crimea brought rinderpest to Hungary, Austria, Germany, the Netherlands and finally England. A large epidemic occurred in 1870–1872, related to the Franco-Prussian war, notably in Belgium and France (7).

Rinderpest had also been present for several centuries in regions other than Europe, particularly in the 19th and 20th centuries, such as the Middle East, including the Arabian Peninsula, because of the repeated introduction of infection in traded cattle from South Asia (see Chapter 2.3). At the end of the 19th century rinderpest was introduced from Asia into the Horn of Africa – by military provisioning – and it spread through western and southern parts of the continent. A major epidemic took place in South Africa in 1896–1897 and there was another, throughout western and eastern Africa, in the 1960s and 1980s (5, 8, and Chapter 2.2).

Rinderpest, a typically highly contagious disease of a transboundary nature, provided an example of applying zoosanitary measures for the public good and of the necessity for legislative backing. The concept of 'global public good' has emerged to affirm the need for public action. Public Veterinary Services are considered to be key players in preserving animal health and in so doing supporting animal resources and reducing poverty and hunger. The prevention and control of transmissible animal diseases and of the risk posed to humans are considered to be in the global public interest. The benefits are international and intergenerational in scope; countries are interdependent and the failure of one single country may endanger the entire planet (9, 10). This has important consequences with regard to the definition of national, regional and international control or eradication programmes to fight against such diseases and raises questions on the use of public funds to implement the programmes and on the share of costs between public and private sectors.

This chapter describes the history of sanitary measures in the eradication of rinderpest, with a focus on Europe, including Russia, in the 18th and 19th centuries (the eradication of rinderpest in regions other than Europe in the 20th and 21st centuries is addressed in other parts of the book). This chapter also describes how this history has progressively framed the current sanitary measures described in the OIE *Terrestrial Animal Health Code* (*Terrestrial Code*), including legislative backing, and how they can be implemented successfully and associated with medical measures (vaccination) in poorly resourced countries.

HISTORY OF CONTROLLING RINDERPEST IN THE 18TH, 19TH AND EARLY 20TH CENTURIES THROUGH ZOOSANITARY MEASURES IN EUROPE AND RUSSIA

The first scientific description of rinderpest was given by Bernardino Ramazzini of Padua University, Italy, in 1712 (1, 11, 12). The contagious nature of rinderpest was established in Prussia by Johann Kanold in 1711, but, actually, zoosanitary measures to control rinderpest were introduced centuries before the work of Maurice Nicolle and Mustafa Adil-Bey showed in 1902 that rinderpest was caused by a virus (1, 3). Recommendations regarding movement of cattle between countries and isolation of sick animals may have been proposed as early as in the fourth century (1), and they were more precisely described in 1599 when the cities of Venice and Padua prohibited the importation of cattle from Hungary and Dalmatia.

The ground-breaking recommendations of Giovanni Maria Lancisi (Italy, 1715)

A significant breakthrough was made by Giovanni Maria Lancisi (physician and *camerarius a secretis* of the Popes in Rome, Italy; see Fig. 1) in 1715, whose edicts provided comprehensive and sound recommendations (see Box 1) to control the disease (1, 13). These recommendations were based on two major elements: zoosanitary measures, including stamping-out; and strong legal enforcement of these measures.

The 1715 Lancisi's recommendations were implemented successfully in the Papal States despite the difficulty of the task. Lancisi's recommendations were thereafter adopted in many European countries, such as Austria, France, Prussia and Germany (7, 14). These countries succeeded in eradicating rinderpest through the application of these measures.

In England in 1718, Thomas Bates used Lancisi's recommendations and he added segregation of animals in small units and destocking for three months.

The majority of sanitary measures applicable today actually grew out of experience with rinderpest, and Lancisi's recommendations (13), which became the cornerstone for the control of rinderpest, were progressively updated as scientific knowledge accrued.

FIG. 1
GIOVANNI MARIA LANCISI, ITALIAN PHYSICIAN AND EPIDEMIOLOGIST AND *CAMERARIUS A SECRETIS* OF THE POPES IN ROME
Source: FAO/Alessia Pierdomenico

BOX 1
LANCISI'S RECOMMENDATIONS

1. Prohibition of the circulation of animals from infected areas. Kill and bury immediately any such animals that are found. Punish livestock owners and animal dealers from infected areas who take their animals too close to disease-free areas.
2. If the disease should occur, confine the sick animals in an isolated cowshed or if possible kill the animals with a lead ball without spilling blood.
3. Remove healthy cattle from exposed pasture to infection-free ones.
4. It would be better to kill sick animals. If not, the veterinarian should put on a waxed overall, which will be left in situ after and the veterinarian should wash his hands and face.
5. Infected cowsheds must be sealed and access authorised only to farmers and veterinarians until the animals recover or die. If they die, walls and floors be cleaned and all dirt and litter be burnt.
6. Containers and drinking troughs be washed with water with lime.
7. Herdsmen's clothing and bandages be disinfected by fumigation.
8. Cadavers be buried deeply.
9. Dairy cows to remain confined in the cowshed and the milk be buried. Offenders to be punished.
10. Animals that have recovered be confined for a further twelve days and then washed with water and vinegar and kept confined for four more days.
11. Movements of farmers and dogs between contaminated areas and disease-free areas be prohibited.

As testament to the relevance of Lancisi's insight, today the official documents of several international organisations responsible for the control of infectious diseases, i.e. particularly the OIE *Terrestrial Code* (15), FAO guidelines and European Commission regulations, reflect them.

The zoosanitary measures applied in the 18th century in Europe to control and ultimately eradicate rinderpest were complemented in the 19th century. They incorporated quarantines; import restrictions; restriction of movements; slaughtering of sick and in-contact animals; recommendations for destruction of virulent material through the incineration of cadavers; prohibition of sales and destruction of meat, milk products, skins and hides from rinderpest-affected animals; decontamination of clothes of people who had been in contact with sick animals; and disinfection of premises. Legislation and its enforcement with penalties for offenders were included.

Systems for notification and alert were described several centuries ago, but they started to become better regulated in the 18th century. At that time, declaration of rinderpest cases was compulsory, and there were severe penalties in the case of failure to report (fines, hard labour, imprisonment or even death). Incentives to declare the disease were decided in some countries, such as England and Austria in 1714, the Principality of Liège (Belgium) in 1746 and the south of France in 1776.

Compulsory culling of infected cattle, accompanied by compensation, was done for the first time in England during an epidemic that killed more than 5,000 head of cattle in 1714 (1, 2).

The rinderpest epidemic that occurred in England in 1865–1867, led to the establishment of Veterinary Services, which enabled the disease to be eliminated within two years.

During the epidemic that started in Europe in 1870, an international conference took place in Vienna in 1871 and eradication programmes were established for many countries.

Zoosanitary measures combined with strong legal enforcement were extremely effective and by 1908, after a history of plagues of over 1,500 years, rinderpest had been eradicated from the continent of Europe. (In fact, western Europe was free of rinderpest after the Franco-Prussian war in 1870–1871 [3, 7], but it was not until 1908 that rinderpest had been eradicated from European Russia west of the Ural mountains [16].)

Europe remained free of endemic rinderpest but experienced several incursions in the 20th century. Importation of infected animals from Asia and Africa occurred in Belgium in 1920 as a result of the importation of infected zebu cattle from India to Antwerp. It spread to local cattle but was eradicated within five months. In Italy there was an outbreak in the zoological gardens in Rome in 1949 (16) due to the importation of wild ruminants from Somalia. In Italy again, rinderpest cases in buffaloes occurred in 1954 (16) on board a ship docked at Trieste harbour that had embarked at Mombasa, Kenya. As a result of the implementation of strict sanitary measures, this incident in Trieste did not lead to further cases.

A timeline with some examples of zoosanitary measures being implemented in Europe, excluding Russia, through official regulations in the 18th and 19th centuries is given in Box 2.

In Russia, rinderpest was present for many centuries and epidemics were frequent in the 18th and 19th centuries. Many important measures were taken in Russia, and the promulgation of the 1879 act that imposed the slaughter of sick and in-contact animals (with compensation) led to a dramatic decrease in outbreaks from 1886 to 1896. Russia

BOX 2
TIMELINE OF SOME MEASURES TAKEN AND LEGISLATION INTRODUCED FOR THE ERADICATION OF RINDERPEST IN EUROPE, EXCLUDING RUSSIA, AND THEIR POSSIBLE IMPACT ON RINDERPEST

1604	**France**	Slaughter orders were issued in Lyon during the 1604 epidemic.
1665–1682	**Germany**	Frederick Willhem imposed burial of carcasses.
1711	**Germany**	Frederick I implemented stringent measures: no imports from Prussia and Silesia, carcasses were to be buried, infected herds were to be isolated and disinfection applied.
1714	**England**	Thomas Bates' recommendations of eradication, including culling, with compensation, were followed.
1714	**Germany and Netherlands**	No measures were taken and therefore no eradication occurred.
1714	**France**	The King's Council of State issued an edict to bury carcasses, to prohibit the sale of infected animals in markets and to isolate contaminated herds.
1714	**Austria**	Imported animals had to be accompanied by health certificates.
1714	**Belgium (rinderpest threat)**	The ordinance of King Charles VI allowed no import of animals without a health certificate.
1715	**Papal States**	Pope Clement VI implemented Lancisi's recommendations.
1716	**Germany**	Frederick Willhem I enforced branding 'FW' on cattle imported into Prussia, promoted closure of markets and imposed movement restrictions with the requirement for health certificates.
1718	**England**	Thomas Bates used Lancisi's recommendations and added segregation of animals into small units and destocking for three months.
1739	**France**	By royal order, imports from Hungary were prohibited, and imports from Germany required health certificates.
1740–1750	**Belgium**	Ordinances were enacted in the Principality of Liège to implement sanitary measures.
1745	**Germany**	Edicts of princes were issued to implement sanitary measures.
1746	**France**	Sick animals had to be branded ('M': malade).
1745–1758	**England (epidemic from Netherlands)**	Measures based on Bates' recommendations including compensation for culling were implemented.
1750, 1775, 1777, 1778	**Sweden and Denmark**	Laws and regulations were published to control rinderpest.
1769	**England (introduction from Netherlands)**	Stringent measures were applied and eradication was rapid. The same happened in 1770, 1774, 1781, 1783 and 1799.
1769	**Luxembourg**	Sanitary measures such as isolation of outbreaks and culling were introduced.
1770	**France**	The army was directed to enforce movement restrictions.
1775	**France**	In an epidemic in Gascogne, Bearn and Landes provinces, the army was again engaged in controlling animal movement, which generated strong civil resistance.
1769–1776	**Austria**	Culling sick and contaminated cattle was recommended as a new sanitary measure. The same occurred in Belgium and the Netherlands but not immediately in France (isolation of contaminated cattle only). Culling was introduced in France in 1776 by Felix Vic d'Azyr.
1815	**France**	King's ordinances (ordonnances) were issued to implement sanitary measures.
1850s–1860s	**Austria-Prussia**	Zoosanitary measures were taken to control herds along the Russian border. No rinderpest outbreaks occurred between 1850 and 1863 (one case only in Austria).
1865	**France**	A circular from the Ministry of Agriculture identified the enforcement of sanitary measures, such as culling, compulsory outbreak reporting, zoosanitary certificates, quarantines, disinfection, market closure and import restrictions to control rinderpest.
1865	**Britain**	The implementation of sanitary measures in response to the epidemic of rinderpest was low (isolation poorly applied, slaughter without compensation), allowing rinderpest to continue.
1866-1867-1869	**Britain**	Promulgation of appropriate acts, implementing eight measures, and the establishment of State Veterinary Services led to the eradication of rinderpest within two years.
1871	**Austria**	A conference was organised in Vienna. Measures, such as reporting, culling with compensation, disinfection and trade restrictions, were decided by the participating countries (Austria, Belgium, England, Germany, France, Hungary, Italy, Romania, Russia, Switzerland, Serbia, and Turkey), but it was difficult to implement them in countries such as Turkey, Russia and Hungary.
1880	**Austria**	Vigorous measures to combat rinderpest were imposed. Eradication was attained within five years.

eliminated rinderpest in 1908 from its European part, but following the 1917 Soviet revolution, rinderpest reappeared and spread through the Caucasus region and to Ukraine, Poland, Rumania, and Bulgaria.

After this resurgence of rinderpest, Lenin's decrees in 1920 were promulgated, with strong rules for the slaughter of sick animals, the banning of movement of cattle around infected zones and vaccination (by the serum–virus method – see Chapter 3.5), which led to its eradication in the European part of the Soviet Union by 1928, including the Caucasus region.

It is important to note that, in 1893, Professor E. Semmer recommended the injection of immune serum from sick animals to control rinderpest as was the practice in southern Africa during the Great African Rinderpest Pandemic. The use of immune serum remained popular but, as it provided only short-lived protection in the 1920s, virus inoculation was added to the serum inoculation.

Russia thus became a model for the future control of rinderpest by combining zoosanitary measures with vaccination.

THE PART PLAYED BY RINDERPEST IN THE ESTABLISHMENT OF THE VETERINARY PROFESSION AND NATIONAL AND INTERNATIONAL BODIES AND THEIR ROLE IN THE PROMULGATION OF ZOOSANITARY DISEASE CONTROL

Rinderpest has played an important role in the establishment of the veterinary profession and its organisation. Rinderpest was cited as a key reason for the establishment of the first veterinary school in Lyon, France, in 1761 by Claude Bourgelat, who also pioneered the concept of comparative pathobiology between humans and animals, which anticipated by more than two centuries, the 'One Health' concept. By the mid-18th century, 14 veterinary schools had been established in Europe (17).

From the early days, the veterinary curricula included courses on contagious diseases, including prevention and control of rinderpest through the implementation of relevant zoosanitary measures.

In addition to the establishment of veterinary schools, the need for countries to control rinderpest promoted the organisation of Veterinary Services within countries. The fight against rinderpest was at the core of their activities in Europe from their creation. Today, Veterinary Services of all countries occupy a central role in the enforcement of veterinary laws, which need a functional and effective chain of command (8, 18). These functions and activities as they relate to rinderpest are presented in Chapter 5.1.

As previously mentioned, rinderpest had been eradicated from western Europe by the end of the 19th century. So when it was reintroduced to Belgium in 1920 through the port of Antwerp by zebu cattle imported from India, there was alarm (see Chapter 5.2 for more detail). Concern over this incident led to an international conference of chief veterinary officers in Paris in 1921 who agreed to support concerted international efforts to fight the disease using the existing zoosanitary measures and the relevant legislation. To help organise the response to rinderpest and other important animal diseases, the Office International des Epizooties (OIE) (which later became the World Organisation for Animal Health, with headquarters in Paris) was created in 1924 by 28 countries as an intergovernmental institution with objectives that today are still at the core of the OIE missions (in 2020, the OIE had 182 Member Countries).

The OIE has a major responsibility in strengthening both national and international activities to fight against contagious diseases. This is done through many tools, particularly through publishing relevant measures in articles in the OIE *Codes* and *Manuals*, which are implemented by national Veterinary Services. Zoosanitary measures that need legislative backing to be implemented are described in the OIE *Codes*. All articles are adopted by OIE member countries, which are therefore committed to implementing them after their integration into national legislation in order to become enforceable. Regarding national veterinary legislation, the OIE *Terrestrial Animal Health Code* and the OIE *Aquatic Animal Health Code* define a list of relevant standards, and to support harmonisation of rules the OIE provides guidelines on veterinary legislation and a support programme to develop national legislations as well as a tool for the evaluation of the quality of veterinary legislation as part of the evaluation of the quality of Veterinary Services.

Soon after the creation of FAO in 1945, its Advisory Committee on Agriculture (1947) and a conference organised in Kenya (1948) by FAO and the Government of the United Kingdom of Great Britain and Northern Ireland, stated that rinderpest eradication was possible and gave FAO an important coordination role (11). This priority on rinderpest remained a focus of FAO until its global eradication.

The FAO, through its mandate, has operational capacity in the member countries of the United

Nations to assist in the control and eradication of diseases. The OIE supports its member countries in establishing freedom from disease status. This provided the rationale for the partnership of the OIE and FAO to assist countries and regional organisations, such as the African Bureau for Animal Resources (IBAR), in the eradication of rinderpest. Within this context in 1993, the OIE, in conjunction with FAO, developed an indispensable tool that consisted of a series of steps that countries must undertake to obtain official recognition by the OIE that they were free of rinderpest and its causative virus. This scheme was named the 'OIE Pathway' (12, 19) (see Chapter 3.5).

Many other institutions, research and training centres, and laboratories were created, strengthened or deeply influenced to address prevention and control of rinderpest all over the world, particularly in Europe, Africa and Asia, such as CIRAD in France (Centre de coopération internationale en recherche agronomique pour le développement) and the Pirbright Institute in the United Kingdom.

SANITARY MEASURES: LEGISLATIVE BACKING, COMPLIANCE WITH INTERNATIONAL STANDARDS AND CONDITIONS FOR SUCCESSFUL IMPLEMENTATION

Today's control of diseases of veterinary and zoonotic importance is based on the principles that were recognised in the long quest to first control and then eradicate rinderpest. The lessons learnt through the eradication of rinderpest underpin today's policies and actions of the OIE, FAO and Veterinary Services in the control and prevention of infectious disease.

The three principal methods used to control (reduction of incidence), eliminate (the disease does not exist any more, but the pathogen may persist within some species, for instance in wildlife species or within the environment) or eradicate (the virus has completely disappeared from all susceptible animal species and from the environment of the entire country, region or worldwide) (8) the virus are:

a) to stop the replication of the agent, particularly through the culling of sick and infected animals;
b) to reduce the contamination of new animals through the banning of animal movements, the isolation of domestic stock and the disinfection of all premises, materials and equipment; and
c) to increase the resistance of animals to infection through vaccination (20).

Regarding rinderpest, before vaccination became widely available in the 20th century, zoosanitary measures were the only means to prevent or control and eradicate the disease. Even with vaccination available, zoosanitary measures remained important in achieving the final eradication in infected countries and in preventing the introduction of the virus into rinderpest-free countries.

The current sanitary measures for a number of animal diseases are described in the OIE *Terrestrial Animal Health Code* (15), from which the list of measures presented in Box 3 is taken.

But zoosanitary measures require a legal and regulatory framework to achieve effective disease control and prevention. Legislation is necessary to make policy objectives enforceable and is a crucial element that gives Veterinary Services the necessary authority to implement measures related to the effective management of any animal disease.

The evaluation of the quality of veterinary legislation during eradication included the evaluation of the quality of Veterinary Services, and the OIE performance of the Veterinary Services (PVS) tool (21) comprised relevant critical competencies (e.g. preparation of legislation and regulations and their implementation and compliance thereof). The PVS principle is recommended to be a periodic evaluation according to prevailing standards and practices. Laws and regulations are usually written at the national level. It is important that all interested stakeholders from the public sector and from economic and civil society (22) are involved.

Today, veterinary legislation should be as much as possible in compliance and at least in coherence with the OIE standards. Under the framework of global governance architecture and according to the treaty that created the World Trade Organization (WTO) in 1995, the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) designates the OIE as responsible for standards, guidelines and recommendations on animal health including zoonosis.

OIE standards and methods of evaluation evolve. During the past ten years, the adoption of the concepts of zoning and compartmentalisation allows the recognition of production system-specific biosecurity practices. The introduction of commodity-based risk allows safe trade of specific commodities under precise conditions that enable trade that would previously have not been possible, particularly from developing countries (23). The OIE also introduced progressive changes in disease reporting obligations using an established set of epidemiological criteria. All these changes have made it possible for disease prevention and control policies to be more proportionate.

BOX 3
MAIN SANITARY MEASURES

- Regarding control of movements or in cases of outbreaks, sick and infected animals will be isolated before being eventually culled. Quarantines are also used to put animals coming from or leaving to other regions under isolation.
- When outbreaks occur, or in enzootic regions, several kinds of zones will be designed (infected zone, protection zone and containment zone). Animal movements from or to these zones will be forbidden or strictly regulated, and zoosanitary certificates will be used at border control posts. Closure of markets will prevent any contact between infected and non-infected animals.
- Identification and registration are the basis of the implementation of many sanitary measures, such as isolation, slaughtering and disinfection, zoning and, generally speaking, the control of movements of animals and animal products. Identification and registration are also indispensable for vaccination. Traceability of animals or products is needed particularly when an outbreak occurs.
- Surveillance and reporting are key elements of disease control policies. A system of surveillance for the listed diseases that are subject to surveillance has to be in place, and early detection and a clear chain of disease notification and reporting are crucial
- Killing, accompanied by compensation, of sick and infected or potentially infected animals will be followed by the destruction of the cadavers and the cleansing and disinfection of establishments. Killing methods are described precisely in the OIE *Terrestrial Code*.
- Many premises are subject to disinfection/decontamination or disinsectisation. These include farms, sales barns, stockyards, exhibition grounds, quarantine stations, zoological parks and abattoirs, as well as vehicles, equipment and other objects. Infected surfaces require thorough cleaning prior to the application of chemicals, and manure and litter are removed. In some cases fumigation can be used. After disinfection/decontamination is achieved, restocking is delayed for a period of time, which depends on the disease, and sentinel susceptible animals can be introduced first before restocking.
- Biosecurity can prevent the entry of infection to a population or premises (bioexclusion) or can prevent infection escaping from an infected location (biocontainment). Biosecurity focuses on segregation (isolation of new animals; isolation of sick animals; movement control of people, animals, vehicles and other equipment; and the cleaning and disinfection of farms, markets and transport).
- Biosecurity measures have to be adapted to the production system and the animal species involved, and a number of guidelines have been published on this topic.
- The application of biosecurity depends upon the private activities of large numbers of stakeholders, but the resulting reduction in animal disease should be a positive incentive for operators.
- The concept of compartmentalisation defines subpopulations with a common health status and has been created on the basis of a common biosecurity management system rather than geographic location.
- In laboratories handling pathogen products, specific biosecurity, biosafety and biocontainment measures have been issued by several organisations (FAO, European Union, OIE) or countries.

The improved availability and efficacy of vaccines have also impacted the veterinary health policies. In the end the standards have evolved into risk-based recommendations for trading in certain commodities even when disease is present, and they no longer focus only on the traditional unique option that was given for obtaining disease-free status for a country or zone.

Implementation of the sanitary measures

To set up sanitary measures, many conditions have to be fulfilled, and there are a number of limiting factors that can hamper smooth and effective implementation.

Some principles can be mentioned, such as the need for a strong political will to implement all animal health regulations, the necessity of allocating appropriate financing, the crucial importance of effective surveillance, a clear chain of command for notification and reporting, and the necessity of adapting sanitary measures to the contexts.

Risk analysis, made on the basis of available health information and scientific knowledge, will support regulations, which must be adapted to the epidemiological situations and to the levels of risk of disease and of impacts of the measures, in order not to be disproportionate.

The major conditions for the successful enforcement of policies and of the legal and regulatory frameworks are the following:

- Veterinary policies should be proportionate, which means that their implementation costs are commensurate with the impacts of the relevant disease and therefore these costs are justified.

- Good veterinary governance is needed, which means transparency, and the accountable management of human, natural, economic and financial resources. It should also be participatory and consensus oriented, effective and efficient, and should follow the rule of law (24).
- Strong Veterinary Services are needed that have appropriate powers for relevant legislation enforcement as well as adequate available budgets, which may be difficult particularly in developing countries.
- There should be a clear and effective chain of command.
- There should be public–private partnerships among all the private and public stakeholders.

CONCLUSIONS

Rinderpest control and eradication programmes have shown, particularly in Europe during the 18th and 19th centuries, that sanitary measures are very powerful tools. They remain valid in the 21st century for the control and eradication of major contagious diseases or to maintain an already officially recognised disease-free status.

It is also important to record that, in other parts of the world, rinderpest eradication was attained without implementing strict zoosanitary measures, such as rigorous movement control and culling of infected animals, as these could not be used for economic and social reasons.

A combination of sanitary measures and vaccination has proved to be a valid strategy, with levels of their respective use being adapted to the epidemiological and economic contexts as well as to the objectives of the programmes. The cases of India, where combined strategies used progressive zonation, and of Africa, where the eradication strategy was based primarily on surveillance and vaccination, demonstrate how effective sound, well-adapted strategies can be.

But it is very important to remind ourselves that vaccination cannot be considered to be a miraculous solution to replace sanitary measures when they appear to be too difficult to implement. An effective and efficient vaccination programme is not an easy task because it needs appropriate epidemiological intelligence to inform strategies, laws, regulations and financing; clear objectives; good programming; and technical quality assurance of the full vaccination chain (25).

Many other lessons can be learnt from the rinderpest eradication programmes. Among them are the need for long-term political commitment and funding, appropriate laws and regulations with enforcement capabilities, the use of international standards, international and regional cooperation, effective Veterinary Services, and animal health delivery systems that are adaptable and that ensure private stakeholders' participation. The credo that applied to the later stages of the eradication of rinderpest, namely 'surveillance–detection–warning–early reporting–early response', remains fundamental.

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CHAPTER 3.3

DIAGNOSTIC TECHNIQUES FOR RINDERPEST

G. LIBEAU [1], W.P. TAYLOR [2]* & P. ROEDER [3]

(1) Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), UMR ASTRE, and Université de Montpellier, F-34398 Montpellier, France
(2) 16 Mill Road, Angmering, Littlehampton, West Sussex BN16 4HT, United Kingdom
(3) Hollyhedge Cottage, Spats Lane, Headley Down, Bordon, Hampshire GU35 8SY, United Kingdom

*Corresponding author

SUMMARY **Classic rinderpest was an acute, viral disease of domestic cattle, yaks and wild African buffaloes (*Syncerus caffer*) and Asian water buffaloes (*Bubalus bubalis*). It was characterised by high morbidity and mortality rates. Sheep, goats, pigs and wild ungulates may also have been affected.**

Clinical recognition of classic rinderpest was based on the finding of an individual dead animal or small groups of extremely sick animals showing one or more of the following signs: pyrexia, inappetence, depression, emaciation, shallow erosions of the upper and lower lip and gum, erosions or blunting of the cheek papillae, serous or mucopurulent ocular discharges and/or nasal discharges, diarrhoea, and terminal recumbency. It is more than likely that the group would have contained a number of dead animals with such lesions.

Laboratory confirmation was based on demonstrating the presence of precipitating antigens in the ocular or nasal secretions of acutely infected animals or by isolating the virus from the spleen, lymph nodes or blood.

A competitive enzyme-linked immunosorbent assay (c-ELISA) could be used to determine the presence of rinderpest antibodies in animals that had been infected with field virus or had received rinderpest vaccine. The test used was sensitive, with respect to the lineage of virus likely to be present, and highly specific. Neutralising antibody estimations could be used for the same purpose. As with the virus, serum samples from rinderpest-suspected cases, and those that may contain the virus or viral sequences, could only be examined in World Organisation for Animal Health (OIE)-approved high-security laboratories.

KEYWORDS **Agar-gel immunodiffusion test – Clinical signs – Competitive ELISA – Differential IC-ELISA – Immunoperoxidase staining – Lineage identification by RT-PCR – Post-mortem changes – Rapid chromatography strip test – TaqMan PCR – Virus isolation – Virus neutralisation.**

INTRODUCTION

Classic rinderpest was an acute, viral disease of domestic cattle, yaks and wild African buffaloes (*Syncerus caffer*) and Asian water buffaloes (*Bubalus bubalis*). It was characterised by high morbidity and mortality rates. Sheep, goats, pigs and wild ungulates might also have been affected (1).

An important attribute of rinderpest was the ability of the virus to adjust its level of virulence in keeping with its environment. Although the classic disease generally occurred, at times the virus was able to transmit rapidly among highly susceptible cattle or buffaloes – circumstances that led to it behaving in a per-acute manner causing death before typical signs occurred, possibly in association with a particular genetic mutation. Latterly a suite of isolates from the Arabian Peninsula displayed such a characteristic. At the opposite extreme, in situations in which long-term endemicity in somewhat resistant breeds of cattle prevailed, a mild, non-fatal disease of cattle could arise and be recognised by communities that were aware of this characteristic of the virus.

However, levels of cattle virulence aside, all strains of the virus were able to infect wild animal species and, in African buffaloes, eland, giraffe, lesser kudu and warthog, to cause an acute infection associated with high mortality.

Rinderpest was not a zoonotic disease, but the virus or virus-containing materials had to be handled in accordance with strict biocontainment procedures.

The appearance of classic rinderpest – both clinical and at post-mortem examination – is described in Chapter 1.2 of this book. The present chapter provides information on the diagnostic tests that were in vogue from the 1960s until eradication was achieved, either to confirm the presence of rinderpest through viral genetic, antigenic material or, by isolating the virus in tissue culture, to confirm a clinical diagnosis or to attribute the virus to a particular lineage within an epidemiological context. In addition, the serological tests employed in seromonitoring and serosurveillance routines are described.

IDENTIFICATION OF THE AGENT

Although clinically diagnosed outbreaks were often subject to laboratory investigation, any fresh suspicion of a rinderpest-like disease had to be viewed as a potential threat to international biosecurity and had to be rapidly confirmed or differentiated. If confirmed, backtracing measures had to be immediately instigated but these were based on an understanding that the virus had been isolated, its lineage identified and its virulence in experimental cattle assessed (2). Samples with putative diagnostic value for virology were mostly collected from animals in the febrile stage of the disease and in the erosive-mucosal phase, as samples from animals that have recovered seldom, if ever, allow virus detection. Rinderpest virus, like other morbilliviruses located mainly in lymphoid tissue and the epithelial cells of the respiratory, digestive and lymphoid systems, could be detected from ocular and nasal swabs, blood and from biopsies of lungs, lymph nodes, small intestine and spleen as well as from post-mortem samples from fresh carcasses/cadavers. A variety of suitable tests were available, the simplest and most widely applied of which was the agar gel immunodiffusion (AGID) test.

Antigen detection by agar gel immunodiffusion

The AGID tests could be conducted in Petri dishes or on glass microscope slides (3). In either instance the surface was covered with agar to a depth of about 4 mm using a 1% aqueous solution of any high-quality agar or agarose. Wells were usually cut in a hexagonal pattern of six peripheral wells around a single central well (Fig. 1). For slides, wells were 3 mm in diameter and 2 mm apart. For Petri dishes, the wells could be increased to 4 mm in diameter and the distance between wells to 3 mm. The closer the wells were placed to each other, the shorter the reaction time.

Using a small volume pipette, rinderpest hyperimmune rabbit serum was placed in the central well. Similarly, control positive antigen, prepared from the macerated lymph nodes of rabbits infected with the Nakamura III lapinised strain of rinderpest, was placed in alternate peripheral wells (i.e. one, three and five). Negative control antigen was placed in well four. Test antigens were obtained as exudates from the cut surface of spleen or lymph nodes submitted for testing; if no exudate could be obtained, a small portion of the sample was ground with a minimal volume of saline. Ocular exudates (Fig. 2) could be squeezed directly from the swabs or, alternatively, by compression in a microtip (the cotton wool was cut off the swab and placed into the wide end of a plastic 50–250 µl pipette tip; the stem of the swab could then be used to compress the cotton wool and force a small volume of exudate out of the narrow end of the tip). Test samples were added to wells two and six (Fig. 3). Tests were best developed at 4°C or at low ambient temperatures. The reaction area had to be inspected from 2 hours onwards (Fig. 4) for the appearance of clean, sharp lines of precipitation between the wells, forming a line of identity with the controls (Fig. 5). Tests were discarded after 24 hours if no result had been

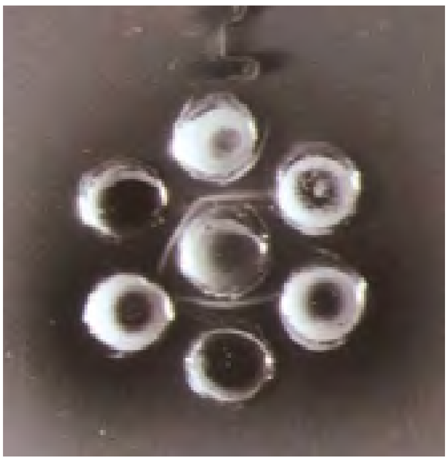
FIG. 1
PETRI DISH WITH AGAR WELLS CUT FOR AGID REAGENTS
Courtesy of the authors

FIG. 2
EYE SWAB BEING USED TO COLLECT OCULAR EXUDATE FOR TESTING BY AGID
Courtesy of the authors

FIG. 3
ADDITION OF EXUDATE SAMPLE TO WELL
Courtesy of the authors

FIG. 4
INSPECTING A PETRI DISH FOR RESULTS DURING A TRAINING COURSE IN PAKISTAN
Courtesy of the authors

FIG. 5
POSITIVE TEST RESULT: LINE OF IDENTITY BETWEEN TEST SAMPLE AND POSITIVE CONTROL
Source: A. Diallo



obtained. The result was not acceptable unless precipitation reactions were also obtained with the control positive antigen preparation.

Although the test was neither highly sensitive nor highly specific, it was robust and adaptable to field conditions. A positive reaction from a large domestic ruminant was treated as rinderpest. From a small ruminant, a positive result was treated as a case of rinderpest or peste des petits ruminants (PPR) requiring further differentiation.

Virus isolation

Rinderpest virus could be cultured from the leucocyte fraction of whole sterile blood that had been collected into heparin or ethylenediaminetetraacetic acid (EDTA) at final concentrations of 10 international units (IU)/ml and 0.5 mg/ml, respectively. Samples had to be thoroughly mixed and transferred to the laboratory on ice, but never frozen. On average, the onset of viraemia slightly preceded the onset of pyrexia, and could continue for one to two days after pyrexia began to wane. Consequently, animals showing pyrexia were probably viraemic and were therefore the best candidates with which to attempt virus isolation. However, as occasional febrile animals may no longer have been viraemic, samples from several febrile animals had to be collected for submission. It was important to ensure that there was adequate tissue available for at least two virus isolation attempts from the initial submission from a suspected outbreak. The other procedures described were attempted only if there was extra tissue available.

Virus could also be isolated from samples of the tonsil, the spleen, or prescapular or mesenteric lymph nodes of dead animals; these samples could be frozen for transport, which had to be under biosecure conditions, in compliance with international transport regulations described in Chapter 1.1.2 – Collection, submission and storage of diagnostic specimens – and Chapter 1.1.3 – Transport of specimens of animal origin – of the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (4) and with the OIE guidelines for rinderpest virus sequestration.

To isolate the virus from blood, uncoagulated blood was centrifuged at 2,500 g for 15 minutes to produce a buffy coat layer at the boundary between the plasma and the erythrocytes. This was removed as cleanly as possible, mixed with 20 ml physiological saline and recentrifuged as part of a washing procedure designed to remove any neutralising antibody present in the plasma. The resulting cell pellet was suspended in cell culture maintenance medium and 2 ml aliquots were distributed on to established roller tube monolayers of primary calf kidney cells, B95a marmoset lymphoblastoid *Theileria*-transformed bovine T lymphoblast or African green monkey kidney (Vero) cells.

Alternatively, 20% (w/v) suspensions of lymph node or spleen could be used. These were made by macerating the solid tissues in serum-free culture maintenance medium using standard grinding or shearing techniques and inoculating monolayers as before. The release of virus from solid tissue could be achieved in several ways. Perhaps the easiest was using a pestle and mortar, but this technique requires the use of sterile sand as an abrasive. Alternatively, tissue could be ground without an abrasive using all-glass grinders, for example a Tenbroeck tissue grinder. Shearing techniques were equally applicable, using, for example, Silverson or Waring blenders. Virus-containing suspensions were clarified by low-speed centrifugation. The volume of the inoculum was not critical; the working volume was between 1 ml and 2 ml. Commonly used antibiotics were penicillin and streptomycin in combination, each at a concentration of 100 IU/ml. A similar broad-spectrum cover could be obtained using neomycin at 50 µl/ml. Fungizone had to be included at 2.5 µg/ml.

The inoculum had to be removed after one to two hours and replaced with fresh medium. Thereafter, the culture maintenance medium had to be decanted and replaced every two to three days and the monolayer was observed under a microscope for the development of cytopathic effects (CPEs). These were characterised by refractility, cell rounding, cell retraction with elongated cytoplasmic bridges (stellate cells) and/or syncytial formation. The speed with which the CPEs developed varied with the substrate and probably by strain of virus also. Up to 12 days had to be allowed in primary cells, a week in Vero cells and two to four days in B95a cells. Blind passages could be attempted before declaring an important sample to be negative, but a preferable technique was to inoculate the cell suspension, and any residue of the original sample, intravenously into a rinderpest-susceptible ox and to attempt to reisolate the virus from its blood. Isolates of virus could be partially identified by the demonstration of morbillivirus-specific precipitinogens in infected cell debris, or completely identified by the demonstration of specific immunofluorescence using a conjugated monoclonal antibody (MAb).

Histopathology and immunohistochemistry

At post-mortem examination, tissues were collected and placed in 10% neutral buffered formalin for histopathology and immunohistochemistry; the base of the tongue, retropharyngeal lymph node and third eyelid were suitable tissues. Sections stained with haematoxylin and eosin were examined for the presence of syncytial cell formation and cells with intranuclear and intracytoplasmic viral inclusion bodies (5). The presence of rinderpest antigens could be demonstrated in the same formalin-fixed tissues by immunoperoxidase staining following the quenching of endogenous peroxidase activity. If a polyclonal antiserum had been used, this test would have failed to differentiate between rinderpest and PPR. However, this problem could be circumvented by using monoclonal antibodies specific for rinderpest and PPR in duplicate tests (6).

Lineage identification using the reverse-transcription polymerase chain reaction

The reverse-transcription polymerase chain reaction (RT-PCR) (7) produces DNA suitable for gene sequence analysis. Rinderpest viral RNA could be purified from spleen (not ideal because of its high blood content), lymph node and tonsil (ideal) tissue, peripheral blood lymphocytes (PBLs), or swabs from tears or mouth lesions (contingent). Solid tissues (0.5–1.0 g) were minced and homogenised with 4.0 ml cell lysis buffer solution – eye and mouth swabs were treated with 1.0 ml, and purified PBLs (from 5–10 ml whole blood) were treated with 0.4 ml – according to the published procedure. Solution D (disruption solution): the procedure for making cell lysis buffer solution (solution D) was carried out in a chemical safety hood with minimal handling of guanidium thiocyanate, which is poisonous and extremely hazardous. To prepare a 250 g bottle, the guanidium thiocyanate was dissolved in the manufacturer's bottle by adding 293 ml sterile distilled water, 17.6 ml 0.75 M sodium citrate, pH 7.0, and 26.4 ml 10% sarcosyl, and then heated to 65°C in a water bath to dissolve.

This solution could be kept for several months in the dark at room temperature in a chemical safety cabinet. The final solution D was made by the addition of 0.36 ml 2-mercaptoethanol to 50 ml of the stock solution. This solution was not to be kept for more than one month.

In the last few years of the eradication campaign, RNA extraction spin columns had become widely used for the fast purification of high-quality RNA (RNeasy kit, Qiagen). The resulting RNA was precipitated with 2.5 volumes of ethanol, washed in 70% ethanol, dissolved in sterile water, or TE buffer (10 mM Tris/EDTA, pH 7.5, 1 mM EDTA) and stored at –70°C or –20°C until required. The complementary DNA (cDNA) synthesis was carried out using random hexanucleotide primers to enable several different specific primer sets to be used in the PCR amplification step. Aliquots of the resulting cDNA were amplified using at least three primer sets that could detect and differentiate between PPR and rinderpest. These primer sets included two 'universal' sets, based on highly conserved regions in the phosphoprotein and nucleoprotein genes that should detect all morbilliviruses, and rinderpest virus-specific sets, based on sequences in the fusion protein genes of the virus. The PCR products were analysed on a 1.5% (w/v) agarose gel along with a suitable DNA marker to identify the specific DNA product. A positive control, such as measles or canine distemper virus RNA, and a negative control using sterile distilled water instead of RNA, had to be included in each RT-PCR. Positive reactions were confirmed either by using 'nested' primer sets based on the F-gene sequences or by sequence analysis of the DNA product. It was important to use more than one set of primers for the PCR step when testing for the presence of RNA viruses, as their nucleotide sequences could vary significantly and one change at the 3′-end of the primer sequence may result in the failure of the primers to amplify the DNA. The World Reference Laboratory in the United Kingdom of Great Britain and Northern Ireland, which was also an OIE Reference Laboratory for rinderpest, could advise on the use of the technique for field sample analysis.

In addition, a simple TaqMan real-time RT-PCR assay for rinderpest virus diagnosis had recently been described. This real-time RT-PCR assay for rinderpest virus had been validated as being highly sensitive in tests of infected tissue culture supernatant and in clinical samples from experimentally infected cattle. The assay had been proven to be able to detect isolates that represented all known phylogenetic lineages of the virus and to clearly differentiate rinderpest virus from PPR virus and other lookalike diseases (foot-and-mouth disease virus, bovine viral diarrhoea virus, bovine herpesvirus, vesicular stomatitis virus). The analytical sensitivity of the L10 primer–probe system exceeded 1–100 $TCID_{50}$ (50% tissue culture infective dose)/ml, depending on the rinderpest virus strain. Comparison of samples from experimentally infected animals showed that white blood cells and conjunctival swabs were the sample of choice for epidemiological surveillance of the disease, allowing the preclinical detection of the disease in two to four days. In the event of a rinderpest virus outbreak, this portable, single-tube format, real-time RT-PCR could provide a preclinical diagnosis, thus aiding efforts to prevent further transmission of disease.

Differential immunocapture enzyme-linked immunosorbent assay (ic-ELISA)

Neither clinical observations nor AGID tests could differentiate between rinderpest and PPR; consequently, if either disease was suspected in sheep or goats in countries where both diseases occurred, other tests such as the real-time RT-PCR had to be used. Rapid differentiation could be achieved using a differential immunocapture ELISA test (8). This test used MAbs directed against the nucleocapsid protein (N protein) of the two viruses. One MAb, with a reactivity against both viruses, was used as a capture antibody, while a second biotinylated MAb specific for a non-overlapping antigenic N protein site, and specific against either rinderpest or PPR, was used to determine which N protein had been captured.

High-protein-binding ELISA plates (or strips) were coated with 100 µl/well of capture antibody. After three washes, the wells were loaded with 50 µl of test sample diluted 1/10 in a lysis buffer, 25 µl of the manufacturer's recommended dilution of the virus-specific MAb and 25 µl of streptavidin peroxidase at a final dilution of 1/3,000. The wells were then placed on an orbital shaker for 1 hour at 37°C, after which they were again washed. Following the addition of 100 µl of ortho-phenylenediamine (OPD), the wells were reincubated at room temperature for 10 minutes. Reactions were halted by the addition of 100 µl of 1 N sulphuric acid, and an automated ELISA reader was used to measure the absorbance of each well at 492 nm.

Chromatographic strip test

A rapid chromatographic strip test (9) was developed for assisting field personnel in investigating suspected outbreaks of rinderpest. Any positive result indicated a highly suspicious rinderpest case that had to be immediately subjected to a thorough investigation. The test strip itself was sent to the appropriate FAO/OIE Reference Laboratory along with other samples, as viral nucleic acid could be harvested from used strips for characterisation (10).

SEROLOGICAL TESTS

Virus neutralisation

Diagnosis of rinderpest virus was also achieved indirectly by detection of specific antibodies. The 'gold standard' virus neutralisation test (VNT) was performed in roller tube or culture flask cultures of primary calf kidney cells, following the method of Plowright & Ferris (11), or in 96-well microplates (12); both tests have been validated in experimentally infected cattle. In the roller tube procedure, sera that had not been heat inactivated were serially diluted at intervals of 1 in 10 and then, starting with undiluted serum, mixed with an equal volume of $10^{3.0}$ $TCID_{50}$ per ml of the attenuated Kabete 'O' vaccine strain virus. Mixtures were held overnight at 4°C, after which 0.2 ml volumes were inoculated into each of five roller tubes, immediately followed by 1 ml of dispersed indicator cells suspended in growth medium at a rate of 2×10^5 cells/ml. Tubes were incubated at 37°C, sloped for the first three days, after which they were replenished with maintenance medium and placed on a roller apparatus. They were examined regularly for virus-specific cytopathology and positive tubes were recorded and discarded; the final examination took place on day 10.

For calculating end-points, the virus dose was regarded as satisfactory if the final dilution fell within the range $10^{1.8}$ to $10^{2.8}$ $TCID_{50}$/tube. This test was used to examine the sera of ELISA reactors during national serosurveillance programmes designed to demonstrate freedom from infection, or to qualify susceptible cattle for vaccine testing. Under these circumstances, the presence of any detectable antibody in the 1/2 final serum dilution was considered to indicate previous infection with rinderpest virus. VNT was the test of choice to confirm or rule out ELISA-positive wildlife serum samples, as ELISA was designed for domestic animals while being used for wildlife.

In the microplate method sera were heat-inactivated for 30 minutes at 56°C before use. An initial serum dilution of 1/5 was further diluted at two-fold intervals. Thereafter, 50 µl volumes of serum were incubated with 50 µl volumes of virus diluted to contain between $10^{1.8}$ and $10^{2.8}$ $TCID_{50}$ (12). Following a 45-minute to overnight incubation, 50 µl rinderpest virus-susceptible cells (between 1 and 2×10^5 primary calf or lamb kidney cells or 5×10^3 Vero cells were added as indicators. Tests were terminated after six to seven days. Such tests might have given indications of non-specific neutralisation at high serum concentrations. There appeared to be factors in some normal (with respect to prior rinderpest exposure) sera that brought about the failure of the virus to penetrate and replicate in indicator cells. In the tube test, these factors were probably removed during changes in maintenance medium; in the microplate method, they remained present the whole time. If the most concentrated final serum dilution was limited to 1/10, the effect disappeared. Although specific, VNT was laborious and required 7–14 days for completion.

The competitive enzyme-linked immunosorbent assay (c-ELISA)

Efforts have been made to develop ELISAs to ease large-scale surveys. A competitive rinderpest ELISA based on the use of an anti-haemagglutinin protein MAb was available for the specific detection of antibodies in the serum of animals of any species previously exposed to the virus. The test was based on the ability of positive test sera to compete with the MAb for binding to rinderpest antigen. The presence of such antibodies in the test sample blocked the binding of the MAb, producing a reduction in the expected colour reaction following the addition of enzyme-labelled anti-mouse immunoglobulin G conjugate and a substrate/chromogen solution. As this was a solid-phase assay, wash steps were required to ensure the removal of unbound reagents.

The rinderpest antigen was prepared from Madin–Darby bovine kidney cell cultures infected with the attenuated Kabete 'O' strain of rinderpest virus and was inactivated at 56°C for 2 hours. The viral antigen was extracted from the infected cells by repeated cycles of sonication and centrifugation. The MAb was obtained by fusing the splenocytes of hyperimmunised mice with the NSO myeloma cell line, and was then shown to be rinderpest H-protein specific (13); this MAb was designated as C1.

Both C1 and standardised rinderpest antigen were directly available from the OIE Reference Laboratory for rinderpest in the United Kingdom. Kits were available commercially until the manufacturing of the antigen, although it was based on vaccine, was stopped because of the moratorium on using live rinderpest virus.

Test instructions

1. Reconstitute the freeze-dried rinderpest antigen in 1 ml of sterile water and further dilute it to the manufacturer's recommended working dilution using 0.01 M phosphate buffered saline (PBS), pH 7.4.
2. Immediately dispense 50 µl volumes of the diluted antigen into an appropriate number of wells of a flat-bottomed, high-protein-binding ELISA microplate using two wells per test serum. Tap the sides of the microplate to ensure that the antigen is evenly distributed over the bottom of each well and, having sealed the plate, incubate it on an orbital shaker for 1 hour at 37° C. Wash the wells three times with 0.002 M PBS, pH 7.4.
3. Add 40 µl of blocking buffer (0.01 M PBS, 0.1% [v/v] Tween 20 and 0.3% [v/v] normal bovine serum) to the test wells, followed by 10 µl volumes of all test sera.
4. Follow the manufacturer's recommendations to prepare a working dilution of the MAb in blocking buffer, and add 50 µl of this to each test well. Seal the plates and reincubate them on an orbital shaker for 1 hour at 37° C.
5. Follow the manufacturer's recommendations to prepare a working dilution of rabbit anti-mouse immunoglobulin horseradish peroxidase conjugate in blocking buffer and add 50 µl to each test well. Seal the plates and reincubate them on an orbital shaker for 1 hour at 37° C.
6. At the end of this period wash the plates as before and immediately refill them with 50 µl volumes of substrate/chromogen mixture (1 part 3% H_2O_2 to 250 parts OPD) and incubate at room temperature for 10 minutes without shaking. Then add 50 µl of a stopping solution consisting of 1 M sulphuric acid.
7. The test system must include known rinderpest-positive and -negative serum samples, a MAb control and a conjugate control.
8. Measure the resulting absorbance values on an ELISA reader with a 492 nm interference filter and express the test results as percentage inhibition values compared with the value obtained using the MAb control. Inhibition values of 50% or more were considered to be positive, and values below 50% were considered to be negative.

Lowering the positive/negative threshold to 40% or less increased the sensitivity of the test, but inevitably affected specificity by increasing the proportion of false-positive test results encountered. In practice, the 50% value was recommended by the Global Rinderpest Eradication Programme, at which level the sensitivity was at least 70% and the specificity exceeded 99%. The sensitivity needed to be taken into account when designing sampling frames for serosurveillance.

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CHAPTER 3.4

THE DEVELOPMENT OF IMMUNISING TECHNIQUES AS A MEANS FOR THE CONTROL OF RINDERPEST

K. YAMANOUCHI [(1)], J. MARINER [(2)] & W. TAYLOR [(3)*]

(1) 2-38-1 Kitayamacho, Fuchu-city, Tokyo 138-0041, Japan
(2) Cummings School of Veterinary Medicine at Tufts University, 200 Westboro Road, North Grafton MA 01536, United States of America
(3) 16 Mill Road, Angmering, Littlehampton BN16 4HT, United Kingdom

*Corresponding author

SUMMARY

This chapter traces the history of immunisation methods against rinderpest as well as the scientists who contributed to it. Starting out in 18th century Europe, cattle were artificially infected in the knowledge that, although a dangerous procedure, survivors would have gained an enduring 'resistance', i.e. immunity. At the end of the 19th century, in Constantinople, it was shown that the serum of a 'resistant' animal could be used to passively protect (or cure) other animals but only for a relatively short period. With this understanding grew the practice of simultaneously inoculating cattle with the virus and the immune serum, the technique being popular in South Africa and Korea. The early 20th century saw the adoption of inactivated rinderpest as a safer means of inducing an immunity that, although short lived, could be manipulated to create immune belt populations through which infection could not be transmitted by contact. In the early 20th century it became clear that continually passaging rinderpest virus in aberrant hosts, such as goats, rabbits, eggs and ultimately cell cultures, selected a virus population that had become attenuated in virulence for bovine hosts and conferred a long-lived immunity. Live attenuated vaccines could be made in sizeable quantities thereby paving the way initially for control but ultimately for eradication. The ability to conserve and distribute attenuated vaccines in the required quantities owed a great deal to the development of freeze-drying techniques, ultimately modified to produce a vaccine capable of being distributed without depending on a cold chain.

The role of international assistance in promoting an understanding of developments in vaccine technology is acknowledged along with the role of the scientific community in the development of contingent vaccines based on advances in molecular biology.

KEYWORDS

Edwards' GTV in India – Inactivated vaccine – KAG in Africa – Kakizaki – Mariner's thermostable TCRV – Nakamura's lapinised vaccine and its derivatives – Plowright's tissue culture rinderpest vaccine – Provost's Bisec vaccine – Recombinant pox-vector vaccines – Virus–serum simultaneous method.

CONTROL METHODS FROM THE 18TH TO THE EARLY 20TH CENTURY

The immunological background

In the following pages we will try to outline how an animal could be temporarily, transiently or permanently protected against rinderpest and how such protection could be used to cure it of an infection and/or protect it against further attacks of the disease. Hopefully we will have shown how those responsible for controlling rinderpest came to an understanding of the different protective mechanisms available (see Box 1) and, over the course of a century or so, used them to eradicate the virus.

BOX 1
THE RATIONALE FOR PROVIDING ANIMALS WITH AN IMMUNITY TO RINDERPEST

a) Passive immunisation could be conferred by the transfusion of antibody-containing serum or by ingesting antibody-containing milk; in either case protection was short lived, as the antibody quickly disappeared from the recipient's circulation.

b) Short-lived (about half a year) active immunity could be conferred by exposure to non-replicating (inactivated) rinderpest virus. When the immunity waned, the animal could be re-infected. When such material is inoculated as a vaccine, it induces a B cell response that produces antibody. As live virus is absent, this method is safe except for some mild local reactions. However, the duration of immunity is short, generally for several months. To enhance immunogenicity, an adjuvant is required. An adjuvant traps the antigen at the inoculated sites allowing only slow release, thus maintaining a longer antigenic stimulus. An adjuvant also induces inflammation, which enhances immune reactions.

c) Primitive active immunisation is a modified natural infection created by the simultaneous inoculation of live virus and immune serum; the virus-induced disease is modified by the presence of immune serum in the circulation of the host, but occasional severe or fatal outcomes may arise. This method provides lifelong immunity.

d) Active immunisation by an attenuated virus vaccine induces both cytotoxic T and B cell responses. Cytotoxic T cells attack virus-infected cells as targets and B cell-induced antibody neutralises invading virus. Because live virus is used, systemic side reactions sometimes occur. Immunisation of highly susceptible cattle with the classic rinderpest vaccine, which did not have a satisfactory attenuation level, was carried out with the simultaneous inoculation of immune serum. A long duration of immunity was acquired.

The inoculation method

At the start of the 18th century, rinderpest-specific protective or curative measures were unavailable. Treatment was constantly attempted through the application of non-specific remedies, such as purging, bleeding or even placing the root of a stinking hellebore plant in the ears of sick animals. In this respect, veterinary medicine lagged behind human medicine, where – over the three preceding millennia – smallpox, a universally feared and highly fatal disease, was known to be preventable by a specific process known as variolation – the cutaneous introduction of variola virus (possibly from cases of variola minor, a mild type of smallpox). Although a generalised smallpox rash usually occurred, and could be severe and sometimes fatal, a specific acquired immunity nonetheless resulted. In 1754 an Englishman, Mr Dobson, applied this process to the control of rinderpest by subcutaneously inoculating ten cattle with rinderpest-infected material, of which nine survived. Mr Dobson had in fact artificially infected his experimental animals, as a result of which they would have had a long-lived, acquired immunity.

For the next half century or so 'Dobson's inoculation method' was the subject of ongoing trials that either endorsed or repudiated the method. In 1769 Camper lectured in favour of inoculation and showed that there could be a 40% survival rate (considered preferable to the higher mortality rate that often followed field infection) and by 1777 it was possible to purchase branded 'resistant' animals. The work of Spinage provides an excellent review of the various experiments and experimenters of the period (1). There did not appear to be any understanding of differences in virulence between different 'strains' of the virus, such as the mild field strains that came to attention in the 20th century and which would surely have improved recovery rates had they been available.

In 1798, an English country doctor, Edward Jenner, published *An Inquiry Into the Causes and Effects of the Variolæ Vaccinæ, or Cow-Pox* (2) demonstrating that infection with cowpox could render humans immune to smallpox. (At the present time, Jenner's cowpox is considered to be vaccinia virus.) This was a seminal discovery that ultimately sealed the fate of that virus, but attempts to protect cattle against rinderpest failed (1). This process to protect humans against infection with smallpox became known as vaccination. Nearly a century later and in honour of Jenner's discovery, Louis Pasteur broadened the term 'vaccination' to denote protection against other infectious agents.

At the start of the 19th century the eradication of rinderpest from the Russian steppes became an issue for the Russian Government. In 1852, a Russian

Rinderpest Commission was appointed to 'inquire into the best means of extinguishing the Cattle Plague' (1). For a time inoculation was seen as the way forward, zoosanitary controls being viewed as unenforceable. Experimentation followed, drawing the conclusion that there was no way to reduce the virulence of the inocula and that the losses to be expected were relatively high. In addition, it was considered that, on the steppes, secondary infections would result. On the other hand, steppe cattle possessed a high degree of innate resistance and were viewed as candidates for inoculation and then for export to Europe. Towards the end of the century opinion seems to have gradually polarised in favour of eradication by the slaughter of infected animals and that a less dangerous inoculation process was needed. The last voice in favour of mass inoculation was that of Semmer (3), who persisted with the view that the method was appropriate for the steppes; his view did not prevail in spite of the fact that in the course of his research he had made a number of pioneering discoveries, among them that heat-inactivated rinderpest virus worked as a vaccine and that a passive immunity could be conferred with either milk or serum from a recovered animal. His findings were extended by demonstrating that animals could be immunised by the co-inoculation of the virus and immune serum, and a number of dedicated immunisation stations were set up (4). Imperfect though this technique was (a 1–2% death rate resulted), it was a contributing factor to freeing Russia from rinderpest in 1928. However, as Laktionov points out, in the final analysis success came as a result of a combination of techniques including the inoculation of healthy (in-contact) animals with immune serum (giving them temporary protection) together with the slaughter of infected animals and a ban on livestock movements within the infected area (4).

The immune serum method

In 1893 Maurice Nicolle, a staff member of the Institut Pasteur, Paris, went to Constantinople (Istanbul) at the request of the Sultan of the Ottoman Empire, Abdulhamid II, where he founded the Imperial Institute of Bacteriology (for human and animal diseases), becoming its first director. He was joined by Mustafa Adil Bey, a Turkish veterinarian and a graduate of the École Nationale Vétérinaire d'Alfort. In 1894 there had been an announcement in Paris concerning the therapeutic value of anti-diphtheria antiserum, which had caused worldwide interest, following which Nicolle and Adil Bey were trained in the production of this antiserum and transferred the technology to their institute in Istanbul. Thereafter, it was but a small step to start producing rinderpest antiserum for a similar purpose, which they began to do in 1899, publishing results that showed that rinderpest immune serum could be used to either prevent or cure cases of rinderpest – an outcome that they indicated was already public knowledge but which they had proven experimentally (5). It is probably safe to assume that Nicolle and Adil-Bey were aware of Eugene Semmer's work in Russia, and they were certainly aware of the similar contemporary developments taking place in South Africa (see 'The bile method' below). Scientifically more ground breaking were their companion studies that showed rinderpest to be a member of a new emerging class of pathogens – the viruses – infectious organisms that could be distinguished from bacteria by virtue of their small size, this being demonstrated by an ability to pass through filters that would retain bacteria.

Other institutions in Turkey started producing rinderpest serum, which was used in Turkey and in other parts of the Ottoman empire affected by rinderpest. In Palestine, Dr Yossef Shemtov became well known for his ability, through the use of immune serum, to cure cattle that were sick with rinderpest (see Box 2). Within three years he had stopped an epidemic, although it must be noted that zoosanitary procedures such as market closures and quarantines were complementary measures (Fig. 1).

FIG. 1.
DR SHEMTOV ADMINISTERING IMMUNE SERUM
Source: Dr Yaacov Neriya's collection

In Turkey, the use of immune serum was included in the Animal Disease Prevention Bill, published in 1893 by the Sultan (Abdulhamid), with general instructions for rinderpest control (quarantine measures, slaughter of infected stock, ring inoculation with immune serum). The bill became a Code of Law in 1913 but was short of powers to enable the implementation of an effective control regime. In 1928, all the measures and necessary rules were enacted in law, and by 1929, rinderpest had been restricted to sporadic outbreaks in regions bordering the Islamic Republic of Iran. In 1932 there were no cases, and subsequently Turkey remained free from rinderpest for 37 years.

BOX 2
'THE RINDERPEST AND ITS ANTISERUM, BY THE DOCTOR OF VETERINARY MEDICINE, MR SHEMTOV YOSSEF FROM MAGNEZIA (MANISA), ANATOLIA'

Translated by Arnon Shimshony from the publication Hashkafa of 30 August 1904. Available at: https://tinyurl.com/y92jnzxg

During a visit to the small village of Machali 24 km from Manisa, on 15 Dec 1902, I discovered cases of rinderpest in the village's cattle. The disease had started 8 days earlier. Until my visit, 34 cases were already reported, of which 19 died; the total cattle population of the village was 350. In spite of severe quarantine and biosecurity measures applied, until 3 January 1903 the number of cases rose to 130, of which 45 died, 11 were still sick and 74 recovered. Recovery of infected animals is attributed to the antiserum treatment, particularly when high doses were injected. According to a close observation in a group of 13 sick cattle which were presented for treatment, 3 of the animals which did not respond to the initial, standard treatment, had to undergo a second and even a third treatment with higher doses of the anti-virus than officially prescribed. Eventually, only 2 animals of the 13 died.

Writing in 1930, Edwards noted the advantages of serum protection when used as an adjunct to 'standstill' conditions but with limited overall applicability to Indian conditions (6).

The bile method

Towards the end of the 19th century a rinderpest epidemic raged down the East African seaboard, reaching South Africa in 1897. Slightly ahead of events, Robert Koch was invited to South Africa to help avert the impending disaster. He stayed from December 1896 until March 1897 and immediately launched the idea of using bile from rinderpest-infected animals as an immunising antigen.

At that time, the antitoxic activity of bile had been used as an antidote to snake venom. According to Duncan Hutcheon, Chief Veterinary Officer, Cape Colony, Koch said,

> 'Bile when injected into the cellular tissue is very gradually absorbed into the system of the animal, the minute dose of the poison the system resists forming a chemical protecting substance, which confers a weak immunity, which is increased as the further absorption of the remaining bile goes on, until on or before the tenth day of gall inoculation, the animal can withstand the enormous dose of 10 cc. of virulent blood without contracting the disease' (7).

In reality, rinderpest would have been present in the mucous membrane of the gall bladder or bile duct of an infected animal, and bile harvested from such an animal would specifically immunise by virtue of its live virus content or, more probably, because of its inactivated viral content, assuming that bile salts had destroyed the virus's lipid outer coat.

In 1903 the first Pan-African Veterinary Conference recommended that the best way of stamping out rinderpest was the liberal use of immune serum but, if this was unobtainable, pure bile inoculation was the next best thing. However, both recommendations were rapidly surpassed by the virus–serum simultaneous method (see below), partly because Koch's method could actually spread the disease while serum alone gave only short-lived protection.

The virus–serum simultaneous method

Developments in southern Africa

An 1897 editorial article in *Nature* (8) reviewed the results of a conference between the Minister for Agriculture of the Cape of Good Hope and those engaged in seeking methods of protecting cattle against the disease. The conference noted that, while the passive immunity conferred by serum is transient, a long-lived protective immunity could be stimulated by the simultaneous inoculation of virus-containing blood on one side of the animal and immune serum on the other.

Although Arnold Theiler and Herbert Watkins-Pitchford had demonstrated the effectiveness of this method, they had not published their results. Researching the technique, Koch's former assistants, W. Kolle and G. Turner (with whose work Nicolle and Adil Bey were familiar), now examined this method in detail. Initially they injected immune serum followed by rinderpest-infected blood a few days later. Then they injected rinderpest-infected blood followed by serum one or two days later, but in both instances the results were variable. Finally, they came up with the idea of simultaneous inoculation of rinderpest blood and immune serum into the same animal at places in the body sufficiently far apart to prevent the two fluids immediately mixing together; the results proved 'very satisfactory'. In December 1897, the first field trial of the virus–serum simultaneous method was conducted on Robben Island, Cape Town, on a total of 52 animals. Each was injected behind one shoulder with 0.5 ml of rinderpest blood and with an average of 25 ml of immune serum behind the other shoulder, the dose of immune serum being varied according to the size of the animal. In order to prevent the possibility of too great a fatality rate, 25 animals received a second dose of immune serum. Of the 52 cattle used, fever developed in only eight animals. No other clinical signs indicative of rinderpest were observed. A second series of inoculations gave similar results. Of 39 animals simultaneously inoculated, no deaths occurred, but 29 showed clinical signs of rinderpest. The ten animals that had shown no signs of fever resisted challenge ten days later with injections of 10 ml of virulent blood, sufficient to kill 10,000 fully grown oxen. They survived without any visible disease. Field trials followed: in Matabeleland, 3,141 cattle were inoculated, and the resulting mortality rate was less than 1% (9). Kolle and Turner reported that simultaneous inoculation of 9,007 cattle resulted in the death of only 1.4% (10).

Developments in Southeast Asia

In Japan, the oldest record of rinderpest is the description of *Tachi*, the old Japanese name for rinderpest, in *Vocabvlario da Lingoa de Iapan* (Japanese–Portuguese dictionary), published by the Japanese Society of Jesus in 1603 (Fig. 2). Sakae Miki, a Japanese medical historian, recognised six large outbreaks of rinderpest in Korea from old records, i.e. 1541–1542, 1577–1578, 1636–1637, 1644–1645, 1668–1671 and 1680–1684. These outbreaks probably originated in China where rinderpest had long been endemic. In Japan, extensive outbreaks occurred in the periods 1638–1642 and 1672–1673. These outbreaks correlated with outbreaks in Korea, suggesting that this country was the source of the infection (11). In 1869, the feudal government of the Shoguns ended, and the Meiji government was installed. Rinderpest was the first exotic disease that the new government was forced to deal with (Fig. 3).

When Japan annexed Korea in 1910, control of rinderpest was considered an urgent task for both Japanese and Korean agriculture. Accordingly, the Japanese government built the Rinderpest Serum Production Station in an isolated area totalling 720,000 square metres in Pusan in Korea (now the Republic of Korea) in 1911 (Fig. 4). Immunisation of cattle was carried out by Kolle's virus–serum simultaneous method, with some modifications devised by Hatsukuma Tokishige, a professor of the University of Tokyo, who had learnt the method from Kolle

FIG. 2

TACHI: OLD JAPANESE ILLUSTRATION OF RINDERPEST-INFECTED CATTLE WITH EXPLANATION OF CLINICAL SIGNS

In *Gyuuka Satsuyo (Handbook of Cattle Diseases)* published in 1720, taken from the Portuguese text of 1603

Source: K. Yamanouchi's collection

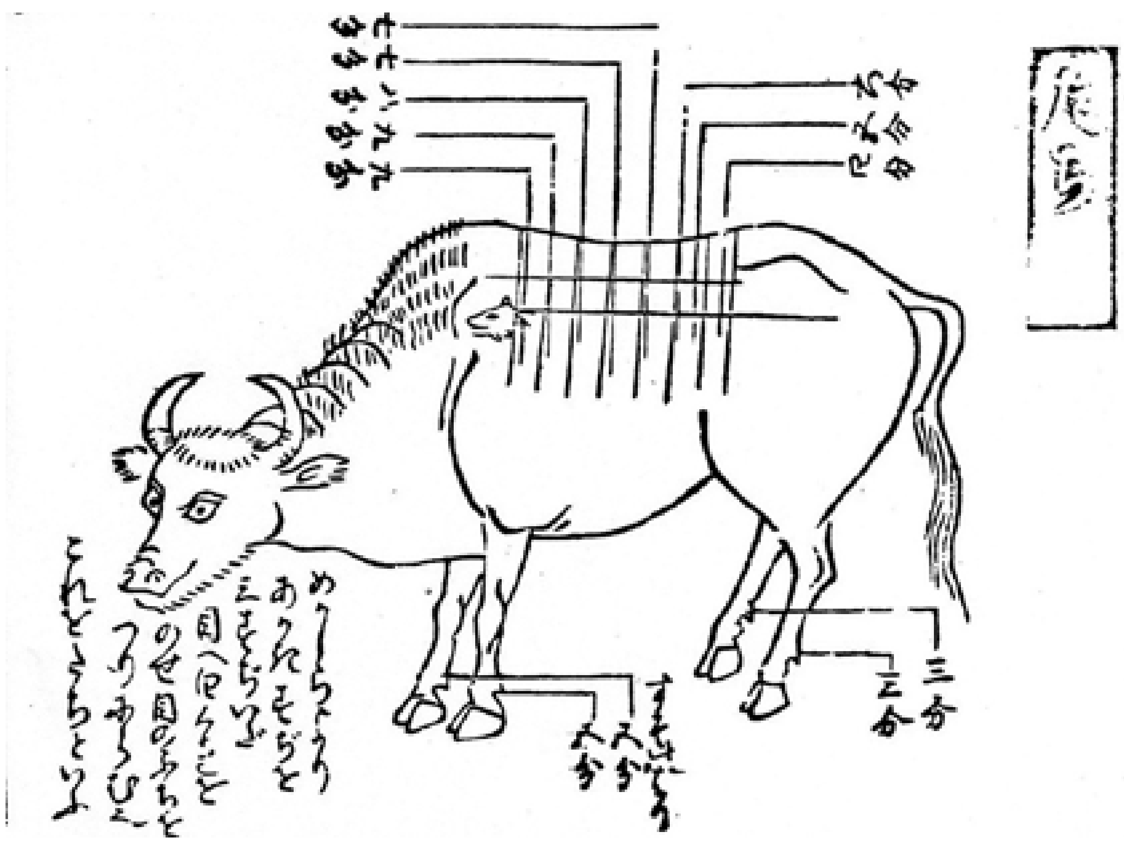

FIG. 3
POSTER EXPLAINING EXOTIC ANIMAL INFECTIOUS DISEASE PREVENTION LAW: RINDERPEST, 1871

Illustration shows the measures taken in Europe

Source: K. Yamanouchi's collection

FIG. 4
VETERINARY SERUM PRODUCTION STATION, PUSAN, 1935

Source: K. Yamanouchi's collection

in Berlin. Chiharu Kakizaki, assistant to Tokishige, was appointed as a senior scientist at the serum production station. Immune serum for the simultaneous inoculation was produced in the following way. Cattle were first inoculated simultaneously with rinderpest blood on the left shoulder and immune serum on the right shoulder. Some cattle developed fever, but they recovered. The cattle were then hyperimmunised by inoculating them successively at intervals of about one week with an increasing volume of rinderpest blood until the total volume of rinderpest blood inoculated had reached between 800 and 1,000 ml. Two weeks after the series of inoculations had been completed, blood was collected, from which the immune serum was produced (12, 13).

To prevent the introduction of rinderpest from China into Korea, a 20 km wide belt of immune cattle was established by the virus–serum simultaneous

FIG. 5
MAP INDICATING THE IMMUNE BELT AT THE BORDER BETWEEN CHINA AND THE PENINSULA OF THE DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA AND THE REPUBLIC OF KOREA

Source: Clyde H. Mapping, 2020 (80), modified to indicate geographical points

inoculation method along the 1,200 km border between the two countries (Fig. 5). Vaccination was conducted mainly from September to October, to maintain an immunity over the winter period when smugglers could bring cattle on foot across the frozen Tumen and Yalu rivers from China (14).

Conclusions regarding the simultaneous inoculation method

The simultaneous inoculation method had the following drawbacks: occasional fatal cases were inevitable, virulent blood could not be stored for long periods and the inoculation protocol was complicated. Nevertheless, the technique played an important part in controlling the virus. It was the first effective prevention method and was widely used in Africa, Russia and India. In South Africa, Arnold Theiler eventually abandoned this method because of the mortality caused by the use of virulent blood contaminated with other pathogens, such as piroplasms, trypanosoma and babesia (1).

Inactivated vaccines

The work of Kakizaki

In 1896, Almroth Wright, working with David Semple in London, inoculated himself and volunteers with a heated (and therefore inert) culture of typhoid bacteria and demonstrated antibody production. This was the first inactivated vaccine. This experience led Semple to develop an inactivated rabies vaccine, using phenol as the inactivant. This vaccine had the advantages of safety and a long storage life (15). At that time several chemical compounds, including phenol, glycerine, ether, chloroform and toluene, were known to inactivate microbes. Some of them were tested on rinderpest. Alexander Edington in South Africa noticed that the blood of rinderpest-infected cattle had entirely lost virulence when mixed with glycerine for eight days (16); in Russia, Semmer had used heat – see above.

In 1914, Chiharu Kakizaki (Fig. 6), at the Veterinary Serum Production Station (former Rinderpest Serum Production Station) in Pusan in Korea, started research to develop a vaccine that lacked infectivity and could be stored for a long period. Among several inactivants tested, he chose glycerine. He developed his vaccine by immersing slices of diseased cattle spleen in 10% glycerine for about two months and published the results in Japanese in the station's annual report in 1917 and in English the following year (17). This was the first inactivated rinderpest vaccine. By two inoculations at an interval of two weeks, nine out of ten cattle were protected against a challenge of 1,000 minimal infectious dose units of rinderpest virus. The method was improved gradually, and in 1922 the

FIG. 6
CHIHARU KAKIZAKI

Source: K. Yamanouchi's collection

addition of 10% toluene instead of glycerine to the spleen emulsion, followed by incubation at 37 °C for seven days, became the standard protocol. The toluene vaccine could be stored for a longer period than the glycerine vaccine (18). In 1922, the cattle in the immune belt on the border with China were vaccinated with inactivated vaccines.

In 1924, in Gando district in south-east China, 1,079 cattle were vaccinated with Kakizaki's toluene vaccine. About nine months later an outbreak of rinderpest occurred and lasted for six months, resulting in the death of more than 800 cattle. Of about 1,000 cattle vaccinated that could be followed, all cattle except two, which were incompletely vaccinated, were protected from the disease. Similar results were obtained during outbreaks in North Pyongan and North Hamgyong in Korea.

Inactivated vaccines in general use

In France, the first positive results of a formalin-inactivated foot-and-mouth disease vaccine were reported by H. Vallée, H. Carré and P. Rinjard in 1926 (19). Inspired by this success, Georges Curasson and L.P. Delpy inactivated the spleen pulp prepared from rinderpest-infected cattle with formalin. The idea of adjuvant was proposed for diphtheria toxoid by Gaston Ramon in 1925. In 1931 in Iran, where the use of immune serum had given poor results, a formalinised rinderpest vaccine was developed at the Razi Institute, and for the next 15 years the country was rinderpest free. By using the formalinised vaccine with a saponin adjuvant on 300,000 head of cattle, they succeeded in controlling a very severe outbreak of rinderpest in 1949 (20). Around 1930, Turkey also discarded the virus–serum simultaneous method in favour of an inactivated vaccine prepared at the Pendik Laboratory, which gave 12–15 months' protection (21).

In the Philippines, William Boynton developed an inactivated vaccine in 1928. The principle of the method was practically the same as that of Kakizaki except for the inclusion of the liver, heart, kidneys and testicles in addition to the spleen and lymph glands. Boynton claimed that the addition of these tissues, which contain an abundance of virus, ensured uniform consistency of the vaccine. To the emulsion of the tissues, phenol was added to make a 0.5% suspension and then glycerine was added, equivalent to one-third the weight of the tissue, followed by heating at 42–42.5 °C for three hours. Vaccination was carried out by the inoculation of 20 ml over the ribs, and seven days later 3–4 ml on the opposite side of the body. In an infected area the combination of vaccine and quarantine successfully smothered the disease on numerous occasions (22).

Until 1934, outbreaks of rinderpest were annual events in Sri Lanka, its constant reintroduction being blamed on live animal imports from India. By combining a ban on all such imports with the use of a formalinised rinderpest vaccine, the disease was eradicated until its reintroduction much later through the same route of incursion (see Chapter 4.13.4). In Tanzania, a field-manufactured formalin-inactivated vaccine was used in the 1940s (see Chapter 3.5), while in Afghanistan there was a severe rinderpest episode in 1944, during which Soviet experts produced 55,000 doses of a formalinised vaccine that was used for the following three years, and which was succeeded in 1950 by the introduction of live attenuated goat vaccine when the United Nations (UN) became involved (see next section on the vaccines of the 20th century).

Conclusions concerning inactivated vaccines

Inactivated vaccines worked well and were instrumental in achieving control over rinderpest on a number of occasions. Inactivated vaccine had the advantages of safety and efficacy, but it was expensive. Vaccine for only 50 cattle could be obtained from one infected calf. Around 1925, the annual vaccine production at Pusan reached only 50,000 doses (18). At a meeting held in Nairobi in 1948, inactivated vaccines were deemed too expensive and were not recommended for further development (23).

THE TISSUE-HARVESTED LIVE ATTENUATED VACCINES OF THE 20TH CENTURY

Attenuation in goats

India's goat tissue vaccine (GTV) (Edwards' vaccine)

In South Africa, Koch inoculated rinderpest virus into sheep and goats between December 1896 and January 1897. Over several passages, the virulence of the virus appeared to increase in sheep, whereas a slow attenuation was noticed in goats (24). In 1919, in Indo-China, H. Schein, who was interested in Koch's essay on the influence of repeated virus passages in goats, reported that after 148 passages of rinderpest virus in goats, the virus was attenuated for buffaloes (25).

In 1922, J.T. Edwards was working at Mukteswar in India and using the virus–serum simultaneous method to vaccinate cattle. He began a search for a virus inoculum that was free of bovine piroplasms by attempting to adapt a virulent rinderpest strain (hill bull virus) to rabbits. When an epidemic of rabbit septicaemia killed all the rabbits on the station, he examined the suitability of goats because of their ready availability and hardier nature. He was unaware of Schein's earlier work. In November 1926, he intended to vaccinate cattle by the simultaneous inoculation of goat-passaged virus with immune serum using a group of zebu cattle (*Bos indicus*). Although the cattle were inoculated with the virus, they were not given the immune serum, as the container was found to be broken. Nevertheless, the cattle survived the infection, as the virus had become attenuated. During the following months, the new virus, continuously passaged either directly through goats or alternately through goats and cattle, showed marked attenuation for cattle, including hill bulls (*Bos taurus*) that were known to be highly susceptible to rinderpest. Although still developing some clinical signs of rinderpest from vaccination, most of them recovered. The more resistant zebu cattle showed only febrile reactions without other clinical signs.

In the field, the goat-adapted virus was initially used for simultaneous inoculation with immune serum but, in 1931, several Indian States discovered that the goat-adapted virus could be used without immune serum to safely immunise the local breeds (26), effectively introducing the first live attenuated rinderpest vaccine (see Box 3).

In Madras, India, P. Saunders and K. Ayyar started experiments in 1932 to confirm that successive passages of the virus through goats would alter the virus enough to make it safe for use as a vaccine without using immune serum. Over a series of 150 unbroken passages in goats and by referring each passage to cattle, based on the resulting decreases in mortality, they concluded that attenuation was completed by the 80th passage. Their experiment supported Edwards' fortuitous findings of the attenuation of his goat-passaged virus (27, 28). By 1934, virus suspension was replaced by desiccated powdered spleen.

In Punjab state, large-scale immunisation with Edwards vaccine was carried out on 73,018 animals in 1934–1935 and 90,668 animals in 1935–1936. The results raised hope that rinderpest could be effectively controlled at a very low cost with the vaccine. However, deaths from rinderpest still accounted for 56% of the national bovine mortality in 1938. One of the chief causes of outbreaks was said to be due to incessant movement of cattle by dealers (29). Unfortunately, the use of goat-adapted virus did not have any immediate impact on the overall death rate in India because of the heavy burden of rinderpest in the country.

BOX 3
FIRST DEVELOPMENT OF AN ATTENUATED VIRUS VACCINE

Eventually the Edwards vaccine became the first artificially attenuated virus vaccine, different from the two virus vaccines (smallpox and rabies) that preceded it. Jenner's smallpox vaccine was vaccinia virus that had been naturally extant, and Pasteur's rabies vaccine cannot be considered an attenuated vaccine, being prepared by drying the spinal cord of fixed rabies virus-infected rabbits for varying periods of from 15 days to one day.
Several years after the introduction of Edwards' vaccine, Max Theiler, the son of Arnold Theiler, succeeded in attenuating the 17D strain of yellow fever virus by passages firstly in mice and then in chicken embryo cells. After field trials in 1936, this was accepted as the first attenuated vaccine for human use (31).

Writing from England in 1942, Edwards was at pains to point out that removing the cost of the serum production from the equation had made rinderpest vaccination very much cheaper and his conclusion was that 'with proper organisation and the application of improved technical methods of preparation and distribution, rinderpest ought to be no longer a limiting factor in livestock improvement in India, for it can be wiped out' (30).

Africa's goat tissue vaccine (KAG)

According to Daubney (32), the work of Saunders and Ayyar in Madras prompted the establishment of a goat attenuated vaccine in Kenya. After 1936, four separate strains were passaged, but the only one to pass into general field use was that derived from Kabete 'O', a laboratory-maintained virulent strain isolated in 1911. Early passages were associated with a mortality of about 90% in cattle, but from the 80th passage onwards the virus underwent rapid attenuation. At passage level 250 the virus was judged sufficiently safe for field release and became known as Kabete attenuated goat (KAG). The KAG vaccine was considered acceptable for zebu cattle, causing a mortality of less than 2%. In the course of his account, Daubney describes the relatively high mortality rates experienced when the Edwards virus was tested in grade and native cattle in Kenya. In grade cattle (cross-breeds between *B. taurus indicus* and *B. taurus taurus*) housed at the Kabete laboratory, the vaccine caused a mortality of roughly 16%, while in large-scale field trials on zebu cattle the mortality was 18%. In consequence, all substrains used in Africa reportedly consisted of the Kabete 'O' virus attenuated for goats.

Between 1942 and 1943, some 2.5 million cattle in central Kenya were immunised with this vaccine, resulting in a reduction in the incidence of infection in the known endemic area and leading to freedom from infection for up to two years. In Egypt widespread rinderpest occurred in 1945 through the importation of live animals from the Anglo-Egyptian Sudan. Mass immunisation with KAG vaccine of over 300,000 cattle successfully controlled the outbreak (32). Further detail regarding the deployment of these vaccines can be found in Chapter 3.5.

Attenuation in rabbits – Nakamura's lapinised vaccine

In 1926, Junji Nakamura (Fig. 7) started research on rinderpest in the laboratory of Kakizaki at the Veterinary Serum Production Station of the Government-General of Chosen (renamed as the Institute of Animal Health in 1942) in Pusan, Korea. In 1934, he visited the Imperial Veterinary Research Institute at Mukteswar, India, on his way to the laboratory of William Elford in London. At that time, the Edwards goat-adapted vaccine was gradually becoming accepted. After his return from London, Nakamura started to passage the virulent Fusan strain of rinderpest virus in rabbits. The purpose of Nakamura's experiments was to develop a rabbit model of rinderpest for the study of the pathogenesis and immunology of rinderpest in small animals,

FIG. 7
J. NAKAMURA (LEFT) AT THE PASTEUR INSTITUTE, PARIS, 1935
Source: K. Yamanouchi's collection

thus avoiding the use of expensive cattle. The susceptibility of rabbits to rinderpest virus had been suggested by Hatsukuma Tokishige in 1910, who had successfully passaged rinderpest in rabbits three times (33).

Six series of passages in rabbits by subcutaneous inoculation of the virus were carried out at an interval of seven days, except the third series, which was after a five-day interval. At the 100th passage level there was increased virulence for rabbits. But, unexpectedly, a decrease in virulence for calves was noted, most markedly with strain III (34). During subsequent passages of strain III, the virulence for calves progressively decreased until the 300th passage level, after which it did not change (i.e. it had become 'fixed').

Seigo Isogai, a former assistant to Nakamura, conducted field testing of strain III of the rabbit-adapted virus, at passage level 330 and higher, between 1941 and 1943, during which 17,547 Mongolian cattle were inoculated. Severe or fatal reactions were not observed. Several outbreaks of rinderpest occurred in nearby areas, but rinderpest was not observed in areas where cattle had been vaccinated (35). At that time, Mongolian cattle were known to be more resistant to rinderpest than other breeds of cattle, probably because of their frequent exposure to rinderpest virus in endemic areas. To vaccinate highly susceptible Korean cattle with the rabbit-adapted vaccine (the so-called Nakamura III vaccine, lapinised vaccine or L vaccine) simultaneous administration of a small amount of immune serum was necessary. Vaccination of cattle against rinderpest along the Korea–China border using the Kakizaki vaccine (as mentioned earlier) was changed to using the L vaccine in 1944 but terminated in 1945 when the Second World War was over.

The post-war attenuated vaccine revolution

In the aftermath of the Second World War, protecting and promoting food production was a major commitment of the UN.

In his introductory remarks to a 1948 Food and Agriculture Organization of the United Nations (FAO) meeting in Nairobi on the use of rinderpest vaccines, R.W. Phillips, acting Director of the Agriculture Division of FAO (then Washington based), recalled that FAO had first recorded an interest in rinderpest at an *ad hoc* committee meeting in London in 1946 that had emphasised the need for international action to eradicate the major plagues, noting that rinderpest was responsible for the annual loss of two million head of cattle.

Aware of the availability of both goat and rabbit attenuated variants of rinderpest, the meeting concluded that:

- The virus–serum simultaneous method carried a danger of disseminating the virus and should be abandoned.
- Inactivated tissue vaccines should not be further recommended because of the short-term immunity conferred, the high cost of production, the danger of spreading the disease as the short-term immunity wanes, and the transport issues involved because of the bulkiness of the product.
- The goat vaccine appeared to be the ideal product for animals with a degree of natural resistance, although it could result in a slight mortality if given to animals not in good health; most importantly it induced a long-lived immunity.
- For lapinised vaccine it was noted (from experience in China) that this vaccine was less virulent than goat vaccine and could be used on highly susceptible animals with minimum reaction – and that its value elsewhere should be investigated (23).

The era of attenuated vaccines for the control of rinderpest had begun.

Lapinised vaccine disseminated

After the Second World War, the Pusan Institute of Animal Health was transferred to the United Nations Relief and Rehabilitation Administration (UNRRA) and Kim Chon Hui became director. In 1946 he sent lapinised rinderpest (L) vaccine to North Korea (now the Democratic People's Republic of Korea) at the request of Kim Il Sung, without the permission of UNRRA. As a result of his action, however, rinderpest was eradicated from North Korea in 1948. (On a historical note, Kim Chon Hui was exiled to North Korea and became a professor at Kim Il Sung University [36, 37].)

Because of the Second World War, the existence of the lapinised rinderpest vaccine was not widely known until the Nairobi FAO meeting in 1948, where S.C. Chen of China and F. Fishman of FAO reported their experience in the use of L vaccine in China. Japan was not invited to the meeting because the country was under occupation. Subsequently, FAO distributed L vaccine seed to Egypt, Thailand, India, Kenya, Pakistan and Ethiopia (38).

At Mukden in Manchuria (currently north-east China), the South Manchuria Institute for Infectious Diseases of Animals (established in 1925 at the time of the Japanese administration) had been engaged

FIG. 8
SOUTH MANCHURIA INSTITUTE FOR INFECTIOUS DISEASES OF ANIMALS

Source: K. Yamanouchi's collection

in production of the Kakizaki vaccine along with rinderpest research until the end of the war in 1945 (Fig. 8). Several Japanese scientists were asked to remain by the Chinese Red Army (former People's Liberation Army) to assist in animal health control. In December 1948, after the end of Chinese civil war, the North-East Veterinary Science Institute (later renamed the Harbin Veterinary Research Institute) was established. The Japanese rinderpest experts, with Hachiro Ujiie as their leader and in collaboration with Chinese scientists, obtained lapinised rinderpest vaccine that had been kept in Beijing. As rabbits were not readily available, they started to adapt the vaccine to goats at the 400th passage (39). After 200 passages in goats, the vaccine still showed severe side effects in Korean cattle and yaks, but after a further 150 passages in sheep an attenuated vaccine was developed in 1953. This vaccine was used for the eradication thrust in China (26).

Nakamura's L vaccine is adapted to eggs – and then back to rabbits – and disseminated

In 1942, Nakamura started to passage his Nakamura III virus (L vaccine) into chicken embryos for further attenuation. After the end of the war he founded the Nippon Institute of Biological Science and continued the adaptation of L vaccine to chicken embryos. By initially alternating intravenous passages in chicken embryos and rabbits and later using intravenous passages only in chicken embryos, he succeeded in developing an attenuated virus. This vaccine was known as lapinised avianised (LA) vaccine and was used to vaccinate highly susceptible Japanese calves without any simultaneous use of immune serum (40).

In 1952, LA vaccine was sent to the National Institute for Veterinary Research, Pusan, Korea. However, the institute had no experience in the chicken embryo technique. Therefore, R. Reisinger (of the United Nations Korean Reconstruction Agency) advised producing the LA strain in rabbits, as the production of L strain had been continued there. After over 200 passages in rabbits, pathogenicity for calves remained unchanged. The safety of rabbit-passaged LA vaccine was confirmed in a field trial on 181 cattle. Subsequently 30,000 cattle in the area immediately south of the 38th parallel were vaccinated with this vaccine in 1952–1953, with no case of adverse reaction (41). Rabbit-passaged LA vaccine was also successfully used on 350,000 cattle in Viet Nam (42).

In Thailand, a vaccine of relatively low virulence was required for water buffaloes, which were highly susceptible to rinderpest. Although L vaccine was provided by FAO in 1949 and considered suitable for this purpose, the most important limitation was the small supply of rabbits. Field tests of L vaccine indicated that local Thai pigs were susceptible to L vaccine, developing fever and diarrhoea. Accordingly, L vaccine was passaged from pig to pig for 17 passages and also alternately in pigs and rabbits. Passage in pigs did not enhance the virulence of the vaccine for buffaloes. Minced pig tissues were freeze dried and ground to a powder for use as vaccine. About 1,200 doses of the vaccine were obtained from one pig. As the powdered vaccine was much cheaper to prepare than a vaccine using rabbits, this vaccine was used for buffaloes (43).

However, the powdered vaccine was still unsafe for immunisation of pigs in the field. Accordingly, LA vaccine was introduced through Nakamura from the Nippon Institute for Biological Science in 1958. LA vaccine produced at Pakchong Veterinary Laboratory was used on pigs without adverse reactions (44, 45).

In Taiwan, at the time of the Japanese administration, rinderpest had been controlled by immune serum; a stone tablet to commemorate the eradication of rinderpest was erected in 1920. However, rinderpest was inadvertently imported again in 1949. The Chinese–American Joint Commission on Rural Reconstruction obtained L vaccine from FAO and vaccinated 62,876 cattle, which represented nearly 90% of all cattle in the area. By the end of February 1950, the outbreak was over (46).

The history of measles prevention paralleled that of rinderpest

In 1916, Charles Nicolle, director of Pasteur Institute at Tunis, reported transient immunisation against measles by injection of human convalescent measles serum (47). In 1920 he applied the virus–serum simultaneous method, as the duration of immunity was only for two to three weeks, and succeeded in obtaining long-term immunisation (48). Nicolle was familiar with the rinderpest campaign using immune serum produced by his brother, Maurice Nicolle (as mentioned earlier).

In 1963 the Enders measles vaccine was developed. Because of side effects such as fever and convulsion, the vaccine was inoculated simultaneously with an injection of human immunoglobulin. Two years later, the Schwarz vaccine, using highly attenuated measles virus, was developed, and could be used without immunoglobulin (49). Thus, the history of measles prevention (immune serum, virus–serum inoculation, vaccination with immune serum and vaccination without immune serum) paralleled that of rinderpest.

Goat vaccine for India and Africa's National Rinderpest Eradication Projects

In 1951, FAO briefly sent its vaccine manufacturing expert, R. Daubney, to assist the Government of India with the introduction of the large-scale manufacture of freeze-dried rinderpest (goat) vaccine for use in the field. His report recommended the use of the Mukteswar W strain of rinderpest virus, with manufacture to be based at the Izatnagar campus of the Indian Veterinary Research Institute allied to a large-scale freeze-drying plant supplied by FAO (such as that shown in Fig. 9). He also recommended the production of vaccine at a number of individual state vaccine-manufacturing centres. Daubney suggested that a pilot vaccination scheme with goat vaccine be conducted in southern India (Madras and Mysore) ahead of the introduction of a National Rinderpest Eradication Programme in 1954. In the first year of the pilot scheme, around 5.5 million animals were vaccinated, and with this experience it was possible to manufacture and administer some 25 million doses annually. Rinderpest outbreak numbers subsided commensurately (50, see also Chapter 4.13.1.1).

Although the use of the goat-adapted rinderpest vaccine was widely distributed across sub-Saharan Africa in the 1940s, Africa was slow to introduce a mass vaccination plan designed to eradicate rinderpest, and it was not until 1962 that Joint

Programme 15 began (see Chapter 4.1). At the 1948 Nairobi meeting mentioned earlier, Daubney wrote,

> 'During the last seven years goat virus vaccines derived from a single parent strain developed at Kabete have been used in the immunisation of at least 15 million head of cattle in East, West Central and North Africa. With zebu cattle the results on the whole have been eminently satisfactory and the incidental mortality reasonably low, ranging from 0.2 to 2%.'

He pointed out that for non-humped cattle a higher mortality rate was expected – for which breeds Nakamura's lapinised virus became available. The goat-adapted rinderpest vaccine made with attenuated Kabete 'O' virus was to remain the mainstay of rinderpest vaccine manufacture in Africa for the next decade.

TISSUE CULTURE RINDERPEST VACCINES

Plowright's tissue culture rinderpest vaccine

Tissue culture rinderpest vaccine (TCRV) was first described by Walter Plowright in 1962 (52) (Fig. 10). The vaccine utilises the attenuated 'Muguga modification of the Kabete 'O' strain.' The attenuated strain was produced by adapting the virulent Kabete 'O' strain of rinderpest virus to cell culture though 92 passages in primary bovine kidney cells. The vaccine induced immunity against all forms of rinderpest that was essentially lifelong (53). A single $TCID_{50}$ (50% tissue culture infectious dose) induced immunity, and no adverse reactions were ever recorded. The vaccine was widely used throughout Asia and Africa with very little evidence of reversion to virulence. In one instance, vaccine virus was detected in clinical cases during an outbreak in northern Kenya, but it is not clear to what extent vaccination had been carried out and this may account for the presence of the vaccine virus (54). It has been said that the Plowright rinderpest vaccine was one of the finest vaccines ever developed for man or beast – cheap, safe and enormously effective. Its only shortcoming was the requirement for a cold chain (55), but the product could be stored for periods measured in years. It had tremendous impact on the well-being of livestock owners, national economies and food security across Asia and Africa. Walter Plowright was awarded the World Food Prize for this contribution in 1999 (56).

FIG. 9
DR Y.P. NANDA DISCUSSING LARGE-SCALE VACCINE FREEZE-DRYING WITH DR YVES CHENEAU, IZATNAGAR, 1988
Courtesy of the authors

FIG. 10
WALTER PLOWRIGHT, 1994, TOKYO
Source: K. Yamanouchi's collection

FIG. 11
ALAIN PROVOST, 1992
Courtesy of the authors

Provost's bivalent contagious bovine pleuropneumonia and tissue culture rinderpest vaccine

In the late 1960s, Provost (Fig. 11) developed a bivalent lyophilised vaccine, utilising a combination of TCRV and a contagious bovine pleuropneumonia (CBPP) vaccine based on the T1-44 strain (57). As streptomycin was used in the large-scale tissue culture production of TCRV, the T1-44 strain had to be rendered streptomycin resistant. This was accomplished, and the new strain, T1-44SR, became the dominant CBPP strain used in vaccine production (58). The new bivalent vaccine 'Bisec' was used throughout West Africa and in parts of East Africa in annual campaigns. As the duration of immunity of CBPP is short lived, at least annual revaccination was required. During the era of the bivalent vaccine's development, rinderpest vaccination was carried out as institutionalised mass vaccination to suppress disease. Logistically, the ease of administration and reduced delivery costs per animal made Bisec a major contribution to disease control.

The use of the bivalent vaccine was discontinued as the eradication of rinderpest progressed in the 1990s. As control strategies evolved away from mass vaccination to epidemiologically focused campaigns, conflicts arose between the vaccination strategies for the two diseases. Furthermore, it was imperative that countries that had apparently eradicated rinderpest cease rinderpest vaccination as the first step in the accreditation of eradication. For a brief moment in history, Bisec became an impediment to rinderpest eradication because of the policy issues around its use. The experience suggests an important lesson: multivalent vaccines make sense only if and when their control strategies can be aligned. At about the same time, CBPP resurged across large parts of Africa for a variety of reasons (59), one which was undoubtedly a decrease in vaccination.

Russian tissue culture rinderpest vaccine

Russia developed its own tissue culture rinderpest vaccine based on the K37/70 strain of rinderpest virus. This strain was derived from a virulent isolate obtained in Kabul, Afghanistan, in 1961. The seed virus was passaged 37 times in cattle and 70 times in primary calf kidney cells. The vaccine was introduced in 1978 and utilised to maintain vaccination barriers along the borders of the Soviet Union. It was associated with at least three outbreaks of clinical rinderpest that occurred in or near the vaccination zones. The available evidence suggests that the attenuation was based on a limited number of base substitutions, which would be consistent with a propensity to revert to virulence. Roeder reports that the All-Russian Research Institute for Animal Health in Vladimir found only one base difference in the F gene region between bases 840 and 1,161 as well as a close relationship between field isolates from the outbreak sites and the vaccine virus (60).

The Japanese LA-AKO tissue culture rinderpest vaccine

In 1957, Takeshi Furutani at the National Institute of Animal Health in Japan developed another LA virus using Nakamura's L vaccine and named it the AKO strain. In 1967, Kazuya Yamanouchi at the National Institute of Health in Japan reported high susceptibility of Vero cells (an established cell line of African green monkey kidney) to the LA strain of rinderpest virus (61). Subsequently, in 1970 Akiro Sonoda reported the development of a Vero cell-adapted rinderpest vaccine using the AKO strain of LA virus and demonstrated its efficacy for cattle. (62). (The Vero cell-grown LA-AKO vaccine is currently produced and held for emergency use at the category B facility of the National Institute of Animal Health (63, 64; see also Chapter 8.2).

Mariner's thermostable variant of tissue culture rinderpest vaccine

In 1990, an enhanced method for the production of Plowright's TCRV resulted in a lyophilised vaccine that maintained the required minimum dose for up to eight months at 37 °C as a 50 dose vial (65). The improvements included adapting production to the Vero continuous cell line and enhancements to the freeze-drying protocol (Box 4). Thermostability was made an integral part of the quality assurance process. An abbreviated test of the thermostability of the final product was required both in-house and independently at the African Union Pan African Veterinary Vaccine Center. In the final test, two vials were stored at 45 °C for two weeks and shown to maintain the minimum titre per dose.

The vaccine was approved for use without a cold chain for up to 30 days. Thus, field vaccinators were freed from the cold chain and could now work for extended periods (66) without the need for motorised transport. As a result, representatives of several African pastoral communities were trained and equipped to carry out vaccinations

BOX 4
A BRIEF HISTORY OF VACCINE DISTRIBUTION AND HOW FREEZE DRYING IMPROVES STABILITY AND COLD CHAIN HANDLING

Historically, many vaccines were produced for immediate use as wet cultures that were difficult to transport. It has been said that one of the advantages of the goat-adapted vaccine was that the infected goat could be transported to the field and the vaccine produced on the spot. But for most vaccines, strict systems of refrigeration and transport on ice were necessary, which greatly added to transport and delivery costs. Not only was 'cold chain' equipment necessary, but an expensive fleet of vehicles was also required to transport the vaccines. This cold chain requirement also limited the reach of vaccination programmes in rural and remote areas.

Biological materials degrade through reactions that depend on the presence of water and oxygen. In the process of freeze drying, free water is removed from the material while it is in a frozen state and in a vacuum. The result is a product that has the same stable structure as the frozen material but lacks water. The product is generally dispensed into vials or ampoules that can be finally sealed under vacuum or backfilled with inert dry nitrogen gas. Thus, the two principal reactants, water and oxygen, have been removed and degradative reaction rates have been greatly slowed.

The introduction of freeze drying greatly extends the shelf-life of products. Liquid vaccines with shelf-lives that are measured in days or weeks on ice can be stored for a year or more at refrigeration temperatures. Refinements to the basic approach have resulted in vaccines that can be handled without a cold chain for periods of up to a month.

The stability of the biological material can be enhanced further by the addition of chemical stabilisers. These are usually some combination of a protein and sugar, especially disaccharides such as sucrose and trehalose. These materials integrate with the biological agent and stabilise chemical bonds. In order to do this, the constituents of the product must not be allowed to crystallise and separate during freezing. Crystals are relatively pure structures, and if the stabilisers crystallise they are not available to stabilise the biological agent. The preferred structure of the frozen product to be dried is referred to as an amorphous glass – that is, a solid that lacks regular structure. The structure of the frozen product is determined by the rate of freezing, and rapid freezing generally favours the formation of glasses.

When amorphous glasses are warmed, they enter a rubber state and can be deformed or can flow. The material appears solid, but it slowly changes shape over hours or days, or if touched or pressed by an object. In the rubber state, components of the amorphous solid are able to move and can form crystals. An amorphous glass that is allowed to enter the rubber state and is then fully refrozen will suffer some degree of separation of the components and crystal formation. The temperature at which an amorphous glass transitions to the rubber state is called the eutectic point, and it is dependent on the composition of the frozen solution.

Ice cream is a familiar example of an amorphous solid. Good-quality ice cream is an amorphous solid with well-blended components giving a desirable flavour and texture. If allowed to warm, the ice becomes soft (a rubber state) and changes shape. If leftover rubbery ice cream is refrozen, ice crystals form and the ice cream is icy the next time it is opened.

Today, more stable freeze-dried vaccines can be produced by rapidly freezing an appropriate solution of the biological agent and chemical stabilisers to a temperature below the solution's eutectic point and removing the majority of the water present while maintaining the temperature of the frozen solution below this point. Once most of the water is removed (~95%), the material can be warmed to temperatures of 25 °C or more without transitioning into the rubber state. At these higher temperatures, the last of the free water is extracted, leaving a product with about 1% moisture. This water is actually in the structure of the organism and should not be removed (51).

against rinderpest. This was done in the context of community-based animal health programmes that addressed the principal problems of livestock in each community, including rinderpest. This approach was utilised in most of the remote and insecure regions of East Africa (e.g. in Karamoja in Uganda, South Sudan and the Afar region of Ethiopia) to complete the final elimination of rinderpest. The local knowledge of the communities in terms of identifying the last foci of infection was also essential and allowed targeting of the last vaccination efforts in the final eradication (67, 68). Further discussion of the advantages of the thermostable vaccine and the operation of the community-based animal health programmes is presented in Chapter 3.8.

CONTINGENT VACCINES DID NOT NECESSARILY CONTRIBUTE TO CONTROL OR ERADICATION

Vaccines developed at Grosse Isle, Canada

In 1942 during the Second World War, a joint team of American and Canadian scientists was organised on Grosse Isle, an isolated island in the Saint Lawrence River, and instructed to prepare, as rapidly as possible, 100,000 doses of rinderpest vaccine to protect cattle against possible attack by Japan using rinderpest as a biological weapon. At first, they developed inactivated vaccine by treating with chloroform the spleen, lymph nodes and lung of calves inoculated with the Kabete 'O' strain of rinderpest virus. Although the vaccine was effective, its production required large amounts of animal housing (69).

As a second approach, the scientists attempted to develop a chick embryo vaccine that could be produced more economically and without requiring the use of large numbers of animals. The Kabete 'O' strain could be adapted to grow on the chorioallantoic membranes of embryonated eggs, but the speed of attenuation was slow. Subsequently, the virus at the 26th membrane passage was passaged by yolk sac inoculation. After approximately 40 passages through the yolk sac, the virus was found to be attenuated and to protect cattle against the challenge with virulent rinderpest virus (70).

In 1946, after the Second World War was over, one million doses of the chicken embryo-adapted vaccine were flown from Grosse Isle to Shanghai, China. After establishing that the vaccine was immunogenic and safe in Chinese yellow cattle, a total of approximately 200,000 cattle in the provinces of Kiangsi, Kwantung and Hupeh were vaccinated under the UNRRA programme. All cattle survived the vaccination. In January 1949, more than a year and a half after the vaccination programme had been completed, not a single outbreak of rinderpest had been reported in the area (71). As an additional supply of vaccine was not made, use of this vaccine in the field was terminated.

Recombinant vaccines using poxviruses as vectors

Development of a heat-stable smallpox vaccine contributed greatly to the effectiveness of the smallpox eradication campaign in regions where a cold chain was not available. Because of the inherent fragility of paramyxoviruses, recombinant rinderpest vaccines (RRVs) were developed in the 1980s using the more stable poxviruses as vectors, which, upon injection into cattle, delivered rinderpest antigens that induced a protective antibody response.

In the United States, in 1988 Tilahun Yilma developed several types of RRV by inserting either the haemagglutinin (H) or fusion (F) gene of the virulent Kabete 'O' strain of rinderpest virus into the Western Reserve (WR) strain of vaccinia virus (72). However, an expert consultation committee of the World Organisation for Animal Health (OIE) considered the WR strain to be unsuitable for field use because of the potential health risk for humans (73). Subsequently, Yilma's group constructed a double recombinant vaccine by inserting the rinderpest F gene and the H gene into the Wyeth strain of vaccinia virus that had been used during the smallpox eradication programme. The double recombinant vaccine was tested at the National Veterinary Institute in Ethiopia. At 3, 8, 11, and 16 months after vaccination, all the animals were completely protected from challenge with virulent rinderpest virus (74) (Fig. 12).

FIG. 12
THOMAS BARRETT, P.N. BHAT (IVRI), TILAHUN YILMA, KAZUYA YAMANOUCHI

FAO biotechnology workshop, Beijing, October 1989

Source: FAO Biotechnology

In the United Kingdom of Great Britain and Northern Ireland, Thomas Barrett and colleagues also developed a RRV by inserting the F gene of TCRV into the WR strain of vaccinia virus. Efficacy was first examined in rabbits and later in cattle and pigs. This RRV completely protected cattle and pigs against a highly virulent rinderpest virus after either one or two vaccinations (75, 76). As this RRV also used the WR strain as a vector, efforts were then switched to the development of RRVs using capripoxviruses as vectors.

Capripoxviruses are not infectious to humans, having host ranges restricted to cattle, sheep and goats. Two capripoxvirus–rinderpest recombinant vaccines, one expressing the rinderpest H protein and the other the rinderpest F protein were constructed. The efficacy of the vaccine was tested at the National Veterinary Research Centre in Kenya. One month after vaccination, cattle were fully protected against challenge with lumpy skin disease virus (a capripoxvirus) and virulent rinderpest virus. Challenge with virulent rinderpest virus at 6 months or 12 months' post-vaccination showed a mixed response, over half being fully protected and the remainder showing mild signs of disease (77).

In Japan, Kazuya Yamanouchi developed a RRV by inserting the H gene of the lapinised (L) strain of rinderpest virus into the haemagglutinin region of the attenuated vaccinia virus (LC16mO strain). This vaccinia virus is a derivative of the Lister strain, which was further attenuated for humans. Its derivative (LC16m8 strain) is currently stockpiled as the third-generation smallpox vaccine. This RRV was highly heat-stable and could be maintained for one month at 37°C or 45°C without a decrease in titre (78). The efficacy of this RRV was demonstrated first in rabbits and subsequently in cattle. The duration of immunity was tested at the Pirbright Institute, United Kingdom. Two small groups of cattle were vaccinated and then kept for two (group I) or three (group II) years before being challenged with a highly virulent strain of RPV. Four out of five vaccinated cattle in group I and all six cattle in group II survived the challenge, some showing solid immunity without any clinical signs of rinderpest (79).

These RRVs had several advantages, including high heat stability and genetic stability. Importantly, they allowed the differentiation of naturally infected animals from vaccinated animals (DIVA) through the use of an assay designed to detect the presence or absence of antibodies to the nuclear protein of rinderpest virus. These vaccines were developed at a time when the global control of rinderpest was progressing well using TCRV. There was no enthusiasm for a manufacturing revolution; improved handling, cold chains, thermostable production methods and standard procedures were more or less in place, and vaccine uptake was already slowing in order to develop unvaccinated populations ready for surveillance routines. Consequently, none of the recombinant vaccines underwent a field trial.

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CHAPTER 3.5

THE INTRODUCTION, PRODUCTION AND QUALITY CONTROL OF RINDERPEST VACCINES

M.M. RWEYEMAMU [(1)*], W. JINGFEI [(2)], (KOOS) J.A.W. COETZER [(3)], L.W. ROWE [(4)], H. WAMWAYI [(5)], N. NWANKPA [(6)], P. ROSSITER [(7)], J. DOMENECH [(8)], S.K. BANDYOPADHYAY [(9)] & W.P. TAYLOR [(10)]

(1) Southern African Centre for Infectious Diseases (SACIDS) Foundation for One Health, Sokoine University of Agriculture, United Republic of Tanzania and the Royal Veterinary College, University of London, United Kingdom
(2) State Key Laboratory of Veterinary Biotechnology, Harbin Veterinary Research Institute, Chinese Academy of Agricultural Sciences, Harbin 150069, China
(3) Emeritus Professor, Faculty of Veterinary Science, University of Pretoria, South Africa
(4) 20 Kingfisher Drive, Westacott Road, Barnstaple, North Devon EX32 8QW, United Kingdom
(5) African Union Interafrican Bureau for Animal Resources (AU-IBAR), Nairobi, Kenya
(6) Pan-African Veterinary Vaccine Centre (PANVAC), Debre Zeit, Ethiopia
(7) St Michael's House, Poughill, Devon, United Kingdom (Formerly staff member of the Food and Agriculture Organization of the United Nations (FAO) and rinderpest consultant)
(8) La Fabrèguerie, 12170 Lédergues, France (Formerly at the World Organisation for Animal Health [OIE], 12 rue de Prony, 75017, Paris, France)
(9) 9/B Bangur Avenue, Kolkata 700055, India
(10) 16 Mill Road, Angmering, Littlehampton, West Sussex BN16 4HT, United Kingdom (Former Head, Department of Bluetongue and other Exotic Diseases, Animal Virus Research Institute, Pirbright [now the Pirbright Institute], United Kingdom)

*Corresponding author

SUMMARY

Rinderpest (cattle plague), first recognised in Europe, became a pandemic that affected practically most of the 'Old World' of Europe, Africa and Asia. Wherever it occurred, rinderpest caused havoc in the cattle population and untold socio-economic devastation of communities, beyond those whose livelihoods depended on cattle. Therefore, there was always a great incentive for the eradication of rinderpest. The 'stamping out' strategy that worked in Europe was not feasible for the rest of the world, so immunisation became the most practical and cost-effective option.

This chapter traces the development, production and field application of vaccines in coordinated rinderpest control programmes over a 100-year span. This has included serum therapy, serum–virus simultaneous vaccinations and the use of live vaccines for which the virus had been attenuated through serial passage in heterologous animal species, especially goats, rabbits and fertile chicken eggs. The advent of cell culture technology in the 1950s revolutionised the outlook for wide spread vaccination. The vaccines produced through this technology were relatively cheap to produce in large quantities, induced lifelong immunity in cattle, were safe to use in all cattle breeds and were of diverse susceptibility to rinderpest. This led to their wide use in international campaigns in Africa, Asia-Minor, the Middle East and South Asia.

KEYWORDS

Attenuation – Caprinised – Freeze-dry – Rinderpest vaccine – TCRV – Tissue culture rinderpest vaccine – Vaccine standard.

INTRODUCTION

By the late 19th century, apart from a few lingering pockets of disease in parts of southern and eastern Europe, the use of 'stamping out' had led to most of western Europe being free of rinderpest. Elsewhere in the 'Old World', the situation was not as favourable; rinderpest was widespread, covering practically the whole of Asia and Africa, (1, 2, 3, 4, and Chapter 2.1). The search for less drastic measures to control, rather than eliminate, rinderpest disease/infection among affected herds became a priority.

Chapter 3.4 describes the scientific advances in methods of immunising livestock and the development of a number of different vaccines suitable for the control of rinderpest. The present chapter focuses on the introduction of several of these vaccines for field use and the methods of production and quality control, culminating in their employment for mass vaccination, with the objective of national or regional disease elimination and eventual global eradication.

RINDERPEST CONTROL: VACCINES FOR NATIONAL AND REGIONAL CONTROL FROM THE LATE 19TH TO MID 20TH CENTURY

Production, quality control and use of serum–virus 'vaccine' in Africa

As discussed in Chapters 2.1 and 3.4, the arrival of rinderpest in South Africa in 1896 resulted in a huge effort to find curative treatments or the means of preventing its transmission. Briefly preceded by Robert Koch's technique of provoking an immune response by inoculating animals with bile from an infected animal, the serum–virus simultaneous method developed by Kolle and Turner (5, 6, 7) and amplified by the Transvaal team of Theiler (8, 9) became the method of choice in South Africa, despite its safety shortcomings. Verney (10), a member of the Theiler team, described the process of calibrating the immune serum as follows:

'The "strength" of each batch of serum produced had to be tested before it could be used in the "serum simultaneous method", as "overdosing" would have led to complete suppression of the disease process and, therefore, active immunity would not have developed. Serum had 0.5% carbolic acid added as preservative and was bottled and sold in doses for cattle of 600 lbs (272 kg) body mass.'

The vaccination method consisted of the injection of standardised serum on one side of the body and of a small quantity of blood from a viraemic animal on the other side. Active immunity was induced as a result of a mild post-vaccinal reaction to such *in vivo* 'virus attenuation'. The greatest drawback for this vaccine was more the risk of transmitting haemoparasitic protozoal infections than sub-optimal rinderpest virus 'attenuation' (11). One shortcoming of the technique was that it was unreliable in untrained hands, and it certainly could not be given to farmers to use. Nevertheless, the serum–virus simultaneous method, at that time, offered a new tool to protect cattle from rinderpest. Starting with limited activity at an experimental camp near Marico river, Theiler had moved operations to Daspoort (near Pretoria), where, as the government veterinary bacteriologist, he set up a rinderpest camp and the Daspoort Laboratory, which could produce large quantities (over 1,000 litres) of serum in six months (9). By 1897, this method of immunisation was adopted all over the country, and by the end of 1898 more than two million head of cattle had been successfully inoculated. By the end of 1898, rinderpest was under control and had almost disappeared from South Africa (12).

The serum–virus immunisation method continued to be the method of choice for controlling such localised outbreaks. The 'technology' was also adopted beyond South Africa, for example in Kenya (Fig. 1).

In Kenya, in 1924 and 1925, the government system for producing cattle that were immune (salted) to the rinderpest virus broke down. Numerous

FIG. 1
AN IMMUNE DONOR OX AT KABETE VETERINARY LABORATORIES, KENYA, BEING HYPERIMMUNISED WITH RINDERPEST-INFECTED BLOOD FOR THE PRODUCTION OF THE SERUM USED IN THE SERUM–VIRUS IMMUNISATION CAMPAIGN
Source: P. Rossiter's collection

outbreaks of rinderpest occurred in cattle that were believed to be immune to the disease after serum–virus 'double inoculation'. The affected cattle were in herds owned by European settlers and 'squatters' near Eldoret and Kitale in western Kenya. The overall losses of more than 400 cattle were significant enough for the Governor of Kenya to order an official inquiry (13). While recognising the overwhelming amount of work that had been given to the veterinary officer responsible at that time, including dealing with an outbreak of contagious bovine pleuropneumonia, the inquiry's conclusion was that he had not followed the immunisation schedule in the correct manner. On at least one farm, the live virus component of the procedure (see below) was collected from what later turned out to be immune animals.

The report illustrates the general technical difficulty in carrying out the double inoculation method and the demands placed on the Veterinary Services at that time by influential stock owners. The outcome of the governor's inquiry into the Veterinary Services was the establishment of a separate 'Rinderpest Service' charged solely with the control of this disease, thus allowing the Veterinary Services to concentrate on all other diseases. The outcome for the veterinary officer himself is not recorded.

Production, quality control and use of serum–virus 'vaccine' in South Asia

During Koch's time in South Africa, it had been observed that serum from rinderpest-recovered animals could confer protection from rinderpest infection. The protection thus induced was found to be of short duration (i.e. less than two weeks). Its role was largely restricted to arresting the spread of disease, the so-called 'serum therapy' (10). Nevertheless, at the turn of the 19th century, the serum-alone method was pursued in Asia, especially in the Philippines and India. Several experiments were undertaken at the Mukteswar Laboratories and in the field in India in doses of 30 ml, 60 ml and 90 ml, respectively, per 600 lb body weight. Although five times the standard dose could confer immunity for up to 44 days, the overall conclusion from the various experiences in India was that a single dose of anti-rinderpest serum could confer immunity for only nine days and that, although increased doses of serum could prolong immunity, the improvement was not proportional to the dosage increase. Thus, in 1922, the advent of the serum–virus simultaneous vaccination was heralded by Pool and Doyle (14) as the method par excellence for a country such as India, where the disease was endemic. The only concern was that the method involved the inoculation of cattle with virulent virus, which could spread.

Accordingly, in South Asia, the work of Edwards (15) at the Mukteswar Laboratory (at that time, the Imperial Institute of Veterinary Research) in India focused particularly on 'virus production' by pursuing two alternative routes for the serum–virus vaccine, i.e. cattle-infected blood and goat-infected blood.

For the *cattle* virus, the method adopted was:

> 'to withdraw blood at the height of the thermal reaction from infected, very highly susceptible cattle, with strictly sterile precautions, defibrinate it quickly, and then distribute it in sterile bottles (filled up nearly completely), which are then hermetically sealed (by impregnating the cotton-wool plugs with paraffin wax) as soon as possible. The consignments of virus are then despatched by parcel post to the consumers, who are advised telegraphically of the despatch. A considerable experience at the laboratory and in the field, now extending over three years, has shown that virus can be despatched readily in this manner to reach consumers in an active condition for periods extending to 8 days after leaving the laboratory.'

Nevertheless, Edwards and veterinary officials in India considered the serum-cattle virus vaccine to carry a high risk of transmitting piroplasms. Having become aware of attempts by German scientists, either in German East Africa (now United Republic of Tanzania) or in Germany, to infect goats with either rinderpest or contagious bovine pleuropneumonia, Edwards devised an ingenious method of adapting the rinderpest virus to goats, 'by careful surgical operation, on the foetal side of the foetal envelopes in a pregnant small ruminant'. After ten such passages, either goat to goat or alternating between goat and cattle, he had achieved adequate adaptation for vaccine production.

Apart from adapting the rinderpest virus to a heterologous species, Edwards introduced the concept of 'seed vaccine virus', by which small quantities of vaccine seed material were produced at Mukteswar, to be amplified for field use through final vaccine production near the point of use. Briefly, this method involved the following steps:

- '[Take] blood, withdrawn from infected goats at the height of an attack, in sterile glass ampoules, which will then be despatched by post to their proper destination. No more than three ampoules need be sent in any consignment.
- 'On arrival, the field operator should then inoculate the mixed contents of the ampoules immediately into two or more goats, and await in them the development of a temperature reaction, with the outwardly distinct

clinical symptoms of rinderpest, which may be expected as early as the third day.

– 'On the fourth day, the goats should be bled from the jugular vein, and the blood obtained from the two more goats inoculated mixed together to furnish the material for the virulent infection in the serum-simultaneous inoculation.'

The same goat-adapted 'seed virus' was used for the production of buffalo serum at the Mukteswar plains substation, Izatnagar. Edwards (16) advocated the following four advantages of the goat serum–virus vaccine over the cattle serum-virus vaccine:

'1. Freedom from concomitant risk of infection with piroplasms likely to set up serious complications.
2. Predictability of infectivity, because "when the goats show a decided observable reaction, the operator may rest assured that this virus will be fully effective". He further remarked that the goat virus possessed a "somewhat fixed virulence, often lower than that of virus obtained from cattle".
3. Acceptability: the use of blood from goats as a medium for the virus injection will not arouse the same antipathy in the minds of Hindu owners as the use of ox blood.
4. Cost-effectiveness: in the scheme of natural outbreaks of rinderpest, in which a considerable number of cattle have had to be protected by inoculation with serum alone, it is accepted that, when an adequate quantity of good serum has been given, the passive immunity of the protected cattle can be transformed readily and safely at almost negligible additional expense into an active, durable immunity by inoculation with a very small quantity of the goat blood containing the virus, before the effects of the serum have worn off. The generally lower virulence of the goat virus acts as a safety factor.'

Production of an inactivated vaccine for field manufacture in Africa

Despite its shortcomings, the serum–virus simultaneous method of immunising cattle was, for up to three decades, in some areas of Africa, the only technique available for inducing full protection against infection. Usually reliable in practised hands, it continued to be widely applied until newer immunising techniques became available. However, the necessity of using virulent virus in both the serum–virus simultaneous method and the vaccine–virus double inoculation method made them unpopular among cattle owners in areas where rinderpest had been eliminated.

In the 1930s and 1940s, the serum–virus simultaneous method began to be replaced across the continent by a killed vaccine. This newer product, referred to then as 'vaccine', came in a variety of killed forms and was used either on its own or with live virulent virus (the vaccine–virus double inoculation technique). Curasson (17) provides a very comprehensive review of the immunisation techniques and the different 'vaccines' used during this period.

Although inactivated vaccine was considered much easier, safer and cheaper to administer than the double inoculation method using immune serum and virulent virus, it induced only temporary immunity (accepted to be about one year) and was also cumbersome and expensive to produce. Although it was not the tool needed for eradication or for control in highly endemic pastoral areas, inactivated tissue vaccine was widely used from the 1920s onwards until it was progressively replaced with live attenuated vaccines in the 1940s in East Africa. Inactivated vaccines remained in use in the 1950s in various countries such as the Philippines and Iran and in much of West Africa (18).

With its high safety margins, inactivated vaccine could be used in disease-free areas but was also widely used in the control of rinderpest in pastoral cattle in endemic areas of Kenya, Tanganyika (United Republic of Tanzania) and Sudan (19) and in other countries. The inactivation also removed the risk of other pathogens for cattle, and a widely appreciated virtue was that it could be administered by trained farmers.

A detailed account of the establishment and operation of an emergency field laboratory for formalin-inactivated rinderpest vaccine was provided by Mitchell and Peevie (20) when the southern African states, still with vivid memories of their experiences some 40 years earlier, felt compelled to assist Tanganyika to control rinderpest in the south of the country during the Second World War. The sheer scale and industry of the work in which 3,500 cattle were used to produce just 1.1 million doses of vaccine and the meat from all donor animals was cooked as a non-infectious product to barter and exchange for much-needed firewood and fodder, and vaccine bottles returned from the field were constantly being boiled and sterilised for reuse was, to use an overused word, heroic! An altogether more amusing account of the production and use of formalin-inactivated vaccine in the field in 1931 is that by Hammond (21), who reminisces about his earliest days in Kenya at the start of a career culminating in Chief Veterinary Officer. Nowadays, we pay to enjoy the safaris that he and others 'endured'!

EARLY STEPS TOWARDS ROUTINE PRODUCTION BASED ON VACCINES ATTENUATED THROUGH ANIMAL PASSAGE

The 1948 Expert Consultation of the Food and Agriculture Organization of the United Nations (FAO), which was held in Nairobi, considered and evaluated rinderpest vaccines that could be applied widely in national or regional campaigns (22). The meeting concluded that:

'It is the considered opinion of this meeting that, with the prophylactics now available being effective and cheap to produce, the eradication of rinderpest is a practical possibility and should be carried without further delay.'

The meeting recommended the use of only:

a) the goat-adapted vaccine, which was already being applied in Africa, the Middle East and South Asia;
b) the avianised vaccine – which was being used in China to protect highly susceptible cattle – while noting some shortcomings of the vaccine;
c) the lapinised vaccine of Nakamura, which was still in a developmental stage but had generated some promising results in China.

Production, quality control and use of goat-adapted vaccine in South Asia

The first systematic development and use of goat-adapted rinderpest vaccine (GTV) for mass inoculation of cattle is credited to J.T. Edwards (23) (Fig. 2) but began with empirical observation by several veterinary officials in India who reported successful immunisation of cattle with his caprinised virus without the concurrent injection of immune serum (24, 25). Edwards (26) observed thus:

'It would exceed the limits of this paper to describe how, independently and almost simultaneously, in 1931, in Mysore State (Simpson and Achar), Bengal (Kerr), Central Provinces (James and Stirling) came to discover that the caprinised virus issued from Muktesar could be used alone, without simultaneous serum, safely to immunise the local breeds, the finding being confirmed by direct experiment on a large scale at Muktesar (Cooper) and how, somewhat later, in Madras (Saunders and Kylsamier) the limitations of the method as applied to the local breeds became apparent, but inoculated simultaneously with a small dose of anti-serum this moderately caprinised strain proved 'an excellent outbreak-stopper.'

Accordingly, Edwards and his team at Mukteswar set about serially passaging rinderpest virus in goats, with an attenuation target of limiting vaccine-associated cattle deaths to less than 4% of Indian zebu cattle vaccinated (27). During the same period, Saunders and Ayyar (28) in Madras used a local strain that they had passaged serially some 150 times in goats. Thus, the Madras and Mukteswar strains, which were independently developed, became the 'reference' vaccine strains in India.

Facilities for production, lyophilisation, quality control and distribution of GTV were created in most of the major states of the country through assistance from the central government or through the state's own financial resources. The state Veterinary Services carried out vaccination in the field. The Mukteswar Laboratory maintained the seed virus (Edwards' strain) and used to supply/sell the seed virus on demand to the state biological production centres for mass production. Apart from its own in-house quality control of the seed virus at the Mukteswar Laboratory, the state biological production centres conducted their own quality control of each mass-produced batch, which remained confined mainly to potency testing. Batches were occasionally sent to the Mukteswar Laboratory for verification. The challenge tests for potency testing were carried out using a 'bull' virus, a reference virulent rinderpest virus also supplied/sold by the Mukteswar Laboratory to the states.

FIG. 2
J.T. EDWARDS, WHO CHAMPIONED THE CAPRINISED RINDERPEST VACCINE AT MUKTESWAR, INDIA
Source: Indian Veterinary Research Institute (IVRI), courtesy of the Director

In India, caprinised vaccine was extensively used between 1955 and 1970, following implementation of the first National Rinderpest Eradication Programme (NREP; Chapter 4.13.4). Severe vaccine reactions (similar to those in Africa – see below) were recorded, although Datta (29) stated that the original goat-adapted Edwards strain of rinderpest virus had been extensively used in India for the control of rinderpest since 1931. He then went on to state:

'The Mukteswar strain has, no doubt, stood the test of time and has been experimentally proved to confer a solid and life-long immunity (so far tested up to 14 years at Mukteswar). The majority of cattle met with in the plains in India react only mildly to it and can be very safely immunized with this product and in these, this would naturally be the product of choice. It must be admitted, however, that the product produces more severe reactions in certain types of cattle such as the hill cattle, the European and the European-graded stock as well as in buffaloes and even in the last named species, which is comparatively more resistant that the other mentioned here, a marked reduction in milk yield and abortions in certain proportion of animals in advanced pregnancy is not uncommon.'

Caprinised rinderpest virus, popularly known in India as Edwards' goat-tissue vaccine (GTV), was extensively used to protect the cattle population in the first national, coordinated rinderpest control programme in the period 1956–1957. However, it soon became apparent, as noted earlier by Datta, that the GTV, while absolutely perfect for protecting the indigenous cattle on the plains, created some thermal and other reactions among the hill cattle and certain cattle breeds of European origin maintained in India. FAO assisted the Government of India in procuring both Nakamura's lapinised and lapinised-avianised vaccines. Following a satisfactory vaccine trial at the Indian Veterinary Research Institute (IVRI) with the Nakamura strain, the Government of India took a decision to use GTV for all of the indigenous cattle population on the plains in India and the lapinised vaccine exclusively for the hill and European breeds of cattle. A small amount of lapinised-avianised vaccine was also produced at the IVRI and used on an 'as required' basis. Considering that the IVRI alone could not produce enough doses of GTV for an organised rinderpest control programme in the country, production facilities for GTV were set up in several states of India, through training and establishing production and freeze-drying facilities.

The caprinised rinderpest vaccine was gradually withdrawn from the national campaign in India after 1970 and replaced by the tissue culture rinderpest vaccine (TCRV). The reputation of the goat-adapted vaccine had been such that many field veterinarians often lamented the withdrawal of this vaccine from the field, which they still thought was superior to TCRV for indigenous cattle and buffalo breeds on the northern plain. Their observations, if true, could be attributed to the fact that the goat-adapted vaccine was a crude tissue extract compared with the cell-free supernatant of TCRV and therefore the former could provide a little better virus stability in field conditions, even if the cold chain had been inadequate.

Production, quality control and use of goat-adapted vaccine in Africa

Developments in India stimulated Daubney (30, 31) and his research team in Kenya to serially passage the Kabete 'O' strain virus in goats for 250 to 400 passages, at which passage level the mortality in vaccinated zebu cattle was less than 2%. Although five strains, including the Mukteswar goat vaccine virus imported to Kenya in 1937, had been tried for goat passage, it was the Kabete 'O' strain that was selected for vaccine development. The Kabete 'O' strain was favoured because this virus was already well characterised in the laboratory. It was also known to have limited capacity for cattle-to-cattle transmission. The Mukteswar strain appeared to be too virulent in Kenyan cattle.

The Kabete 'O' attenuated goat (KAG) vaccine was used for wide-scale vaccination in East Africa, although it was contraindicated for use in highly susceptible cattle, such as the Ankole and the European breeds together with their crosses, in which it could result in up to 50% mortality. This strain was supplied to Vom, Nigeria, where it was further serially passaged, and from there it was sent to Cairo, where it was put to use in suppressing a widely disseminated outbreak (23). Eventually, when the original KAG vaccine was lost in Kenya, it was replaced with KAG vaccine from Cairo.

Although Edwards (26) and Daubney (23) carried out comparative pathogenicity experiments at Pirbright and in Egypt, the results were inconsistent. Daubney (23) reported that the Vom variant that had been passaged a further 90 times in goats from the master Kabete 'O' strain from Kenya was milder than the master strain. The Egyptian strain, which had been derived from Vom and passaged in Egypt a further 25 times, was milder still. Nevertheless, he cautioned that the three variants would need to be assessed in comparative tests in an established laboratory, such as the Kabete Laboratory in Kenya. Edwards (26) compared the virulence of the Mukteswar (Indian) and KAG vaccine strains and concluded the following: 'In our experiments at Pirbright, an East African (Kabete) caprinised strain received at the outset of our work was distinctly less pathogenic for British cattle than the Indian (Muktesar) strain received at the same time; though later, in Egypt, the converse was exhibited'.

Interestingly, the results of genetic sequencing have revealed that the KAG strain of rinderpest virus has an Asian rather than an African lineage (Chapter 1.1) (32).

Effectively, the simultaneous techniques and killed vaccines were progressively replaced by the attenuated caprinised live vaccine from 1940 in East Africa, 1941 in Nigeria, 1947 in Egypt (22) and 1956 in French West Africa (33). During the 1950s, goat-adapted rinderpest vaccine was the standard in campaigns in East and West Africa, Egypt and South Asia (34). For the first time, it was possible to produce a vaccine on a relatively large scale. The vaccine production procedures in Kenya (initially Kabete and later Muguga), Nigeria (Vom), Egypt (Abbasia) and India (Mukteswar and Madras) were relatively similar and based on the method developed by Hudson and described by Daubney (24), Macleod *et al.* (35) and Johnson *et al.* (36).

In Kenya, the process comprised the following key steps:

1. Healthy goats were carefully selected for virus production.
2. Virus-infected spleens were harvested, when the majority of inoculated goats were at peak temperature, homogenised and titrated in susceptible cattle.
3. The harvest was aliquoted in either bottles or ampoules for respectively single cycle desiccation (rubber stoppered vials) or double desiccated vials (for high vacuum), when vaccine was to be shipped long distances or destined for long-term storage.
4. The vaccine was subjected to quality control testing, which comprised testing for sterility, safety and potency in four susceptible cattle. Potency testing in Kenya was undertaken using the Kabete 'O' virus strain of low transmissibility in cattle, thereby allowing cattle challenge experiments to be undertaken in an open shed, where infected and uninfected controls could be housed together.

The KAG strain and other strains of the goat-adapted vaccine were known to induce a temperature reaction in about 90% of vaccinated *Bos indicus*/zebu cattle. However, in *Bos taurus*/European cattle and several Asian and African cattle breeds that are highly susceptible to rinderpest, the goat-adapted vaccine not only induced high temperatures but also could result in mortality of 5% to 18% for vaccinated animals. Therefore, the wide-scale use of goat-adapted vaccine was restricted to the relatively resistant zebu (*B. indicus*) breeds.

Pastoral communities had to be prepared for a reaction to vaccination, as summarised eloquently by Purchase (37), a field veterinary officer who had been given responsibility for field testing the vaccine in Kenya's Maasailand:

> 'The properties of the virus, together with the results of the experimental work, were fully described to the administrative officer in charge of the province. ... The proposals were agreed upon in a meeting of responsible Maasai elders. The Administrative and Veterinary Officers, then explained in detail to all assembled the benefits and possible pitfalls which could be expected to follow the use of KAG.'

The benefits of the vaccine were so considerable that these risks were mostly accepted. The Maasai of Kenya and Tanzania, who had large herds, accepted the vaccine. For the Maasai, the loss of a few animals after vaccination was of no consequence. Furthermore, the Maasai had observed that, when their herds became exposed to rinderpest-affected eland herds, the cattle only acquired mild disease, whereas exposure to infected buffalo tended to result in severe disease (37). They considered the transient thermal reaction after KAG vaccination was more tolerable than the mild disease acquired from exposure to diseased elands.

Even in the more resistant *B. indicus* cattle, goat vaccines usually caused fever and recumbency for about 24 to 72 hours occurring three or four days after inoculation. Many cattle owners and veterinary staff welcomed this as a sign that the vaccine had worked or 'taken'. However, on some occasions, reactions could be more severe, especially in younger stock or stock weakened by drought or other disease, and deaths could and did occur (38). The fallout from these severe vaccine reactions often led to serious misunderstandings between the cattle owners and the authorities and even deaths of veterinary and other government staff (see the story in Box 1), which naturally made the task of controlling rinderpest more difficult.

The lack of any laboratory test that could distinguish live vaccines from virulent rinderpest virus brought inherent risks. Several times, rinderpest virus that was pathogenic for cattle was mistakenly distributed and used in the field instead of the much safer KAG. The most notorious of these incidents occurred in 1950. While waiting to move to laboratories being built in Muguga, the newly established East African Veterinary Research Organisation (EAVRO) was hosted at the Veterinary Research Laboratory (VRL) in Kabete, Kenya. EAVRO had taken over from VRL the responsibility for producing and distributing KAG in the field. A batch of KAG vaccine was sent for use in Meru and Embu districts in Kenya, and within days the inoculated cattle developed signs

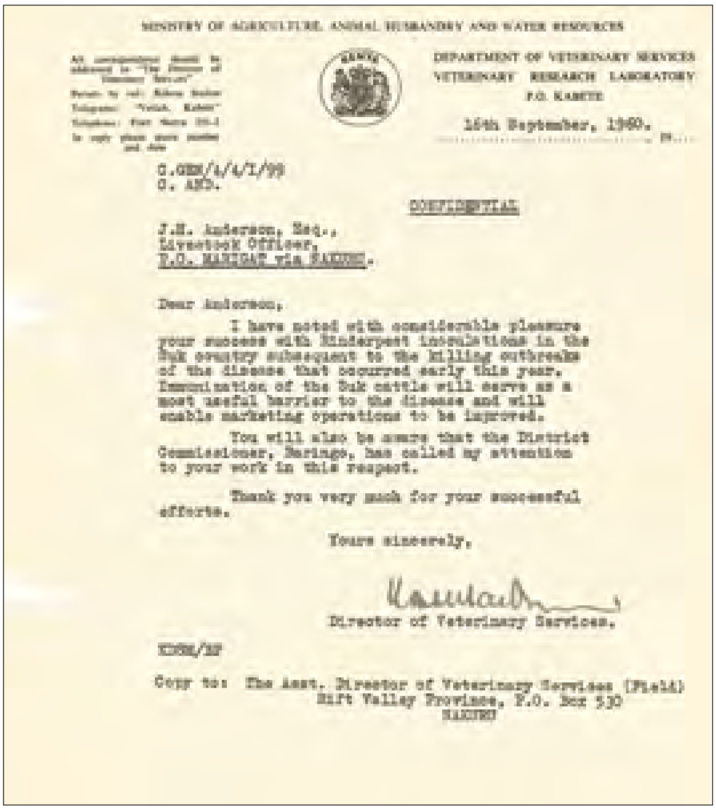
BOX 1
VACCINATING WITH KABETE ATTENUATED GOAT VACCINE – A TRUE STORY

In early 1960, rinderpest was affecting cattle belonging to herders in the Pokot area of Kenya (in those days the Pokot were more frequently called the Suk which is no longer the case) but vaccination with the KAG vaccine was itself causing disease and losses of cattle. A meeting to discuss the situation flared into a violent disagreement in which two officials were killed. Because of this, rinderpest persisted in the area, threatening neighbouring cattle populations and preventing marketing. Something needed to be done and the only option was more vaccination.
As the livestock officer based at Marigat in the Baringo district of Kenya's Rift Valley, J.H. 'Jock' Anderson, 24 years of age, was detailed to proceed north and inoculate all the cattle in the infected area as soon as possible. Knowing the history of what had happened previously and just how easily things could go wrong again, Anderson and a team of four staff proceeded to set up a vaccination camp with great caution and tact. The work lasted three weeks, and, after weekends spent back in Marigat, each Monday morning's return to the vaccination site was an occasion for considerable trepidation: what might have happened with the vaccinated cattle and what kind of mood were their owners in? Fortunately, all went well; reactions to the vaccine were not serious and rinderpest was controlled. Anderson, who now lives in Nairobi, says this was because 'mixing the vaccine before inoculation was taken very seriously by me'.

FIG. 3
LETTER OF APPRECIATION TO J.H. ANDERSON

The significance of a job well done under unusually testing circumstances was recognised in a personal letter of thanks to Anderson from the Director of Veterinary Services (Fig. 3) – something that not all livestock officers received for doing their job.

Courtesy of the authors



MINISTRY OF AGRICULTURE, ANIMAL HUSBANDRY AND WATER RESOURCES

DEPARTMENT OF VETERINARY SERVICES
VETERINARY RESEARCH LABORATORY
P.O. KABETE

16th September, 1960.

C.GEN/4/4/I/99
C. AND.

CONFIDENTIAL

J.H. Anderson, Esq.,
Livestock Officer,
P.O. MARIGAT via NAKURU.

Dear Anderson,

I have noted with considerable pleasure your success with Rinderpest inoculations in the Suk country subsequent to the killing outbreaks of the disease that occurred early this year. Immunization of the Suk cattle will serve as a most useful barrier to the disease and will enable marketing operations to be improved.

You will also be aware that the District Commissioner, Baringo, has called my attention to your work in this respect.

Thank you very much for your successful efforts.

Yours sincerely,

Director of Veterinary Services.

Copy to: The Asst. Director of Veterinary Services (Field)
Rift Valley Province, P.O. Box 530
NAKURU

of classic rinderpest with high mortality rates. Several hundred cattle died. Once again, Government House ordered an official inquiry. Its conclusion was that insufficient care and attention had been paid to the procedures for preparing vaccines (presumably, though it was never completely ascertained, rinderpest virus rather than stored KAG virus had been inoculated into the goats that were harvested to make this batch of vaccine). The newly appointed director of EAVRO lost his position and returned to the United Kingdom of Great Britain and Northern Ireland. Additional safety controls were put in place for vaccine production at EAVRO.

Caprinised rinderpest vaccine was the vaccine most widely used in the campaigns in Africa and South Asia up until the mid- to late 1960s, when TCRV was phased in. In West Africa, caprinised rinderpest vaccine was produced at Vom, Nigeria, primarily for anglophone West Africa, and at the Institut d'Élevage et de Médecine Vétérinaire Tropicale (IEMVT) laboratories in Farcha (Ndjamena, Chad) and Dakar-Hann (Senegal), primarily for francophone West and Central Africa, and was produced from various attenuated seeds, particularly the KAG vaccine strain. This vaccine continued to be produced and distributed for field use, alongside the newly introduced TCRV, as demonstrated in Table I below, compiled from unpublished records at Vom.

In summary, despite its great usefulness in *B. indicus* 'zebu' cattle throughout Africa and South Asia, caprinised attenuated rinderpest vaccine was still sufficiently virulent to cause mild clinical signs, including fever and inappetence, in this stock and occasionally low rates of mortality. More detrimentally, it caused severe disease with high levels of mortality in pure *B. taurus* cattle, especially imported European breeds, Sanga breeds such as the Ankole and Watutsi, commonly found to the west of Lake Victoria, and breeds such as the N'Dama in the moist tropical zones of West Africa, and therefore could not be used in these animals (38).

BOX 2
CHINESE HISTORY

Historically, albeit without veterinary records, from legends circulating among Chinese farmers, we know that rinderpest was first recognised by Chinese people more than 1,000 years ago, and immune methods were also developed and used to fight against rinderpest outbreaks. About 500 years ago, farmers began to use blood collected from rinderpest virus-infected cattle to prevent the infection in some areas of China, such as Sichuan, Qinghai and Tibet, by administering it intraorally to healthy cattle. About 300 years ago, some farmers noticed that rinderpest-infected wild goats showed mild clinical signs in contrast to the severe reactions seen in cattle and could recover from the infection. They therefore collected blood from these recovered wild goats and inoculated the blood intraorally into cattle. Continuous passages in cattle were conducted and yielded a cattle-adapted rinderpest virus strain named 'Yabo'. To preserve the strain once the outbreaks had been controlled, blood from inoculated cattle was smeared on the inside of a fresh sheepskin, dried in a cold place (about 4–6 °C in areas of Tibet), and then the sheepskin was wrapped and buried underground for long-term preservation. In the family of a farmer named Yangcuo, a strain had been kept and passed on from one generation to the next for more than 300 years. This strain had been distributed to many areas in Qinghai, Gansu and Sichuan and contributed greatly to the control of rinderpest in the region.

TABLE I
TOTAL NUMBERS OF RINDERPEST VACCINE DOSES PRODUCED AND ISSUED BY THE FEDERAL DEPARTMENT OF VETERINARY RESEARCH, VOM, NIGERIA

Vaccine		1960/1961	1961/1962	1962/1963	1963/1964	1964/1965
Lapinised	Produced	385,860	222,180	–	–	–
	Total	246,855	214,860	5,820	–	–
	JP15 (I) alone [(a)]	25,380	50,820	–	–	–
Tissue culture	Produced	–	No record	2,609,800	5,266,600	4,450,000
	Total issued	–	398,700	2,549,500	4,304,350	3,994,900
	JP15 (I) alone	–	363,900	2,109,100	2,903,950	2,127,000
Caprinised	Produced	4,684,500	10,018,000	4,859,000	5,070,250	2,511,500
	Total issued	2,781,685	3,654,495	7,607,925	5,748,075	6,470,000
	JP15 (I) alone [(a)]	2,112,610	2,433,575	5,036,825	4,780,250	4,755,200

[(a)] JP15 (I), Joint Programme 15, phase I (see Chapter 4.1)

It was this character of the goat-adapted rinderpest vaccine that led to the FAO consultative meeting in 1948 concluding that there was not a single vaccine strain and preparation that could be used for rinderpest control in all breeds and farming systems in all the areas of the world where the disease was endemic at that time (21). This conclusion remained true through most of the 1950s. In 1970, an international standard method for the production and control of caprinised and lapinised rinderpest vaccines was described in the 22nd report of the World Health Organization (WHO) Expert Committee on Biological Standardisation (39).

The Chinese experience with goat-adapted rinderpest virus (40) is described in Box 2.

Introduction of lapinised virus: lapinised–caprinised and lapinised–caprinised–ovinised vaccines in China

The development, recognition and post-war distribution of Nakamura's rabbit-attenuated variant of the Fusan strain of rinderpest (Nakamura III) is described in Chapter 3.4, together with its application in rinderpest control in Southeast Asia. The vaccine production method related by Cheng and Fischman (41) describes the intravenous inoculation of seed virus present in the blood or lymph node suspension of a donor rabbit. Three or four days later, when the temperature reaction reached 40–41 °C, the animals were bled out, and their spleens and intestinal lymph tissues were collected. Only animals with the appropriate temperature reaction and characteristic lesions on the Peyer's patches and lymphoid tissues were used for vaccine. Such tissue was ground to a 1:100 suspension with infected blood and normal saline and after filtration was ready for use. A 200 g rabbit was expected to yield 300 to 600 doses.

Lapinised rinderpest virus was not universally avirulent and was variously adapted to grow in fertile hen's eggs or in pigs in attempts to reduce its virulence for different breeds of cattle or buffaloes. Chinese adaptations leading to the eradication of rinderpest from that country to goats and sheep are described below.

Lapinised–caprinised vaccine

In 1949, a rinderpest eradication campaign was launched across China by the government. Initially, lapinised rinderpest strain (Nakamura III) was the only widely used vaccine (22). However, the low production of the vaccine and the high death rate of rabbits during transport (~50%) prevented its widespread use in remote pastures. Another shortcoming of the vaccine was the strong adverse reactions seen in several breeds of cattle (notably those originating from Korea), yak and Chuandong buffalo (42). In yaks, nearly two-thirds of vaccinated animals showed neurological signs, along with typical signs of rinderpest and a 10% fatality rate (43, 44).

In January 1950, a team of virologists at Harbin Veterinary Research Institute – Lingfeng Chen, Qingzhi Yuan, Rongxian Shen, Baliang Shijia and Baorong Li – began developing a goat-adapted strain using the lapinised virus. The first passage was by intravenous inoculation of goats with 5–10 ml of the Nakamura III strain, which had undergone 888 rabbit passages. The percentage of inoculated goats showing a high temperature reaction increased steadily with the increase in passages from about 40% before the 10th passage to 100% after the 120th passage. The virulence and immunity of the goat-passaged virus was studied in Mongolian cattle, Donghue yellow cattle and Korean cattle. Although the lapinised virus when adapted to goats caused elevated temperatures in most animals and even a mild form of rinderpest in some Korean cattle, the virus was safer than the lapinised vaccine for susceptible breeds of cattle. After being challenged with virulent rinderpest virus, all the inoculated cattle showed no clinical signs, indicating good immunity induced by the inoculation of the lapinised–caprinised rinderpest strain (45).

Lapinised–caprinised–ovinised vaccine

While these studies indicated that the lapinised–caprinised vaccine was safer than the lapinised strain alone for certain cattle breeds, it still caused severe clinical reactions, even fatal ones, in yaks and pian niu (half-breed yaks) (46). Therefore, the team launched another study to further decrease the virulence of the lapinised–caprinised strain by continuously passaging it in sheep (47). Sheep were intravenously inoculated with 10 ml of the lapinised–caprinised strain, as a lymph node emulsion obtained from goats at the 100th passage level. At the 190th passage, yellow and Korean cattle were inoculated with the blood or spleen–lymph mixed emulsion obtained from the inoculated sheep. Apart from elevated temperatures, no other clinical signs were observed in either the yellow cattle or the Korean cattle, and they subsequently withstood a challenge from rinderpest virus (47). By 1955, the strain had been passaged in sheep 398 times, and at this passage level it was safe to use the strain in cattle, yaks and pian niu.

Between 1949 and 1952, more than eight million cattle were vaccinated with lapinised or lapinised–caprinised strains of rinderpest virus. By 1952, through the use of these vaccines, rinderpest had been controlled in China, and there were no large-scale outbreaks thereafter. Indeed, rinderpest had been eliminated from most regions except for some small pastoral areas in Tibet, Qinghai, Sichuan and Gansu (40). A lapinised–caprinised–ovinised vaccine was used in 1955 to vaccinate 1.5 million cattle, yaks and pian niu in areas where rinderpest persisted (48, 40). In 1956, the last rinderpest outbreak occurred in Nangqian county in Qinghai province, and the disease never reappeared in China.

Production, quality control and use of lapinised rinderpest vaccine in Africa

In 1948, ampoules of the rabbit-attenuated or 'lapinised' vaccine were sent to various laboratories in Africa, including Kabete in Kenya and Cairo in Egypt.

Initial work in Kenya confirmed the positive findings for this virus in East Asia (41), and lapinised vaccine was produced routinely at the VRL in Kabete and subsequently at EAVRO in Muguga, Kenya (49), until the mid-1960s. It was widely and successfully used in European breeds of cattle in Kenya, Tanganyika and Uganda; in Sanga cattle in Tanganyika, Uganda, Rwanda and Belgian Congo (now Democratic Republic of the Congo); and in N'Dama cattle in Sierra Leone, Gambia and Ghana (50). Although the size of rabbits – compared with goats – meant that yields of vaccine per donor animal were lower (up to 600 immunising doses per rabbit (49), as opposed to some 3,000 doses per goat (35)), Kenya was able to produce over 2.5 million doses from 1951 to 1956 (51). Generally, the vaccine was supplied as a lyophilised product, but in countries without freeze-drying facilities it was used successfully in the 'wet form' (52).

Initially, partly as a result of the absence of a clinical reaction in vaccinated cattle, there was debate about the length of the immunity conferred by the vaccine. Estimates varied from one to two years, but subsequent work proved that the immunity was at least four years, and the lapinised vaccine was successfully used to bring the 1949 epidemic of rinderpest in Sierra Leone under control (52). It was safe to use in sick and weak animals (40) and could be used to stop outbreaks by inoculating infected herds (53). Nevertheless, lapinised virus was still not the perfect vaccine. It was more time-consuming and expensive to produce than caprinised vaccine and, consequently, not so economic for the mass vaccination of zebu cattle, the key species needing to be vaccinated to control rinderpest in Africa and South Asia. Annual reports of the veterinary department of Kenya record that, between 1950 and 1960, the number of doses of KAG vaccine issued to the field was about five to ten times the number of doses of lapinised vaccine issued during the same period. Moreover, like caprinised vaccine, the lapinised vaccine produced in Kenya was not completely attenuated, causing occasional outbreaks of typical rinderpest in some breeds of cattle, especially Channel Island dairy animals.

Eventually, lapinised rinderpest vaccine was superseded, but it remained a useful laboratory tool, especially for producing rabbit hyperimmune serum, which was widely used in diagnostic tests (53).

Avianised rinderpest vaccine

In response to continuing the search for an attenuated vaccine that could be readily used to protect the highly susceptible Korean and Japanese breeds, Shope and colleagues (54) successfully cultured the Kabete 'O' strain in fertile chicken eggs and achieved its attenuation. This vaccine was safe to use in cattle species highly susceptible to rinderpest. Although the original authors successfully produced some 200,000 doses of this vaccine for field testing in East Asia, laboratories in Asia and Africa could not reproduce a product of predictable attenuation, as apparently over-passaging could lead to reduced immunogenicity for some cattle. So, there were some technological modifications in the form of back-passaging between rabbits and chicken eggs (lapinised–avianised–lapinised). All in all, this vaccine had relatively limited field use, and the advent of the universally applicable attenuated cell culture vaccine obviated the necessity for the avianised or avianised–lapinised vaccines (55, 56).

Development of cell culture attenuated vaccine in East Africa and West Africa

With the advent of cell culture technology in the early 1950s, it was soon taken up for the culture of rinderpest virus. Following a visit to the United States in early 1954, R.D. Ferris developed a new Tissue Culture Section at EAVRO in Muguga, with the goal of producing rinderpest vaccine (56). In 1956, Walter Plowright assumed scientific leadership of this section (57, 58, 59) and thereby the means to indulge his personal passion for cultivating rinderpest virus in this new medium.

The partnership between Walter Plowright and the lead laboratory technologists that he inherited at EAVRO – Ron Ferris and Colin Rampton, who were later joined by Ken Herniman, Les Rowe and a team of laboratory assistants led by Francis Ngugi – was highly productive. Within a year, the team had succeeded in culturing the Kabete 'O' strain of the rinderpest virus in calf kidney monolayer cultures (60, 61). This led to an explosion of methodical studies on different aspects of rinderpest virus (61, 62) that included the serial passage of the Kabete 'O' strain in calf kidney monolayer cells. They noted that, between four and ten passages, the virus gained in virulence in cattle and could readily be transmitted from infected animals to contact animals. However, beyond seven to ten cell culture passages, the virus progressively became attenuated. By passage 45, the virus hardly resulted in a temperature rise in inoculated rinderpest-susceptible cattle, which were nevertheless resistant to the challenge. By the 75th passage, the virus did not cause a thermal reaction in either zebu or European cattle breeds. At last, the 'perfect' rinderpest vaccine that could be applied to all breeds of cattle had been developed! It would be known as TCRV (63).

To replace KAG vaccine with a product ultimately much easier to produce but lacking the inbuilt quality assurance of a thermal reaction, Plowright and his team had to develop extensive experimental evidence in its favour. They demonstrated that the immunity induced by TCRV matched that of the KAG vaccine, while its safety for all breeds of cattle exceeded any vaccine developed previously. In controlled laboratory and field experiments in Kenya and Uganda, starting in 1957, using experimental vaccines from virus aliquots at the 40th, 70th and 90th passage levels in calf kidney monolayer culture, Plowright and his team (64, 65) established the following:

1. All three passage levels induced a protective immunity in zebu, European–zebu cross and Ankole cattle, without clinical disease in vaccinated or contact cattle.
2. Only the 40th passage virus caused a transient temperature rise in some vaccinated animals.
3. For all three passage levels, there was no transmission of virus from vaccinated to in-contact cattle.
4. Back-passaging in cattle of the 70th and 90th cell culture passage virus stocks did not cause the virus to revert to virulence in cattle.
5. The immunity lasted for the periods tested, i.e. four years for the 40th passage virus and at least two to three years for the 90th passage.

Meanwhile, in 1959, Bob Johnson, who had established a cell culture facility at Vom, Nigeria, obtained a sample of attenuated Kabete 'O' virus at the 65th passage level in calf kidney monolayer cells from Walter Plowright at EAVRO in Muguga (66). Johnson successfully cultured the virus in cell culture and produced an experimental vaccine at the 66th to 70th virus passage level, which he freeze-dried into a finished product, using the facilities that he had used for the caprinised vaccine (36). This experimental vaccine was employed in large-scale trials in Nigeria (66, 67, 68). Thus, Johnson's preparation was the first cell culture rinderpest vaccine to be used in a national campaign. Spectacular results from Nigeria, plus evidence from continued experiments by the Plowright team, led the East African veterinary authorities to adopt the TCRV vaccine.

Later, Taylor and Plowright (69) concluded, from a series of pathogenicity experiments with TCRV, that its lack of pathogenicity was due primarily to:

a) its ability to confer solid immunity on account of its 'lymphotropic' characteristic;
b) its failure to replicate in the mucosae of the gastro-intestinal and respiratory tracts;
c) its inability to spread by contact among susceptible cattle as a result of the absence of virus in mucosae or parenchymatous organs and hence in excretions.

During the period 1960–1970, most of the rinderpest research work by the Plowright team at EAVRO, Muguga, continued to focus on the standardisation of the TCRV production parameter, including virus production titres, potency assay and vaccine thermostability (70, 71). Plowright *et al.* (72) showed that the addition of 2.5% lactalbumin hydrolysate and 5% sucrose to the virus suspension before freeze-drying resulted in a freeze-dried product that maintained its titre for six years at –20 °C and up to four years at +4 °C. The mean half-life of five different batches of the lyophilised product was 14.3 weeks at 20 °C to 22 °C and 3.2 weeks at 37 °C. By contrast, at 56 °C the half-life was only 2.5 to 3.6 hours.

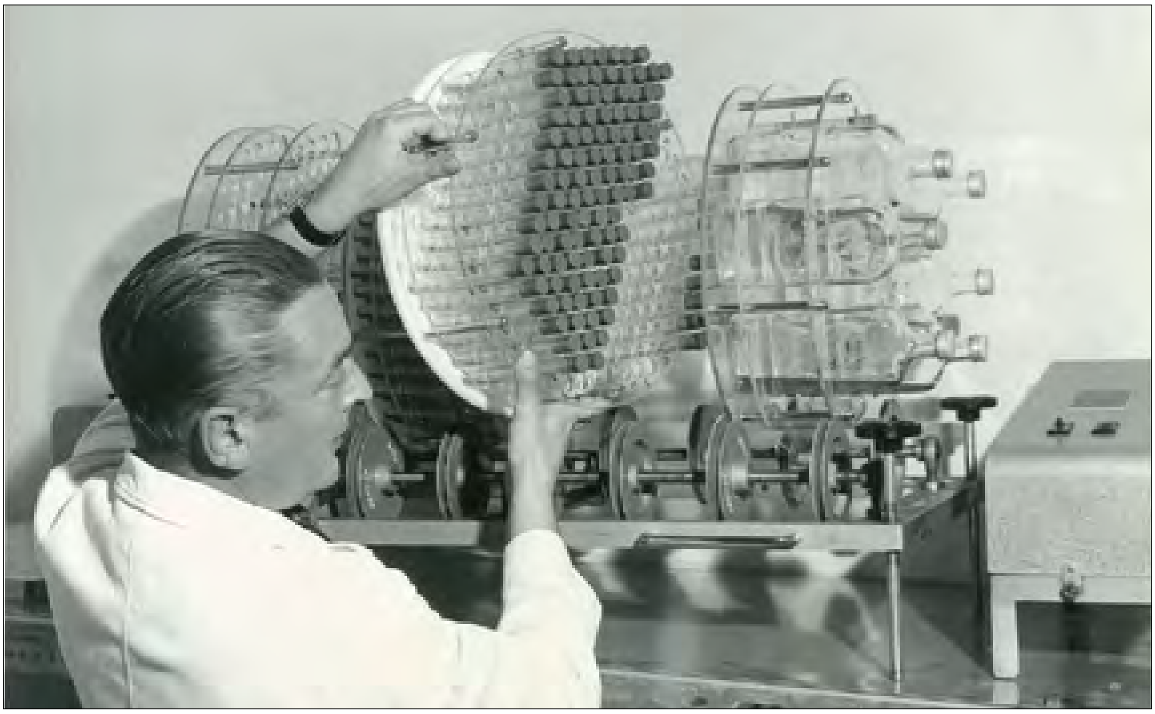
Plowright *et al.* (73) found that the reconstituted vaccine was highly labile between 37 °C and 40 °C, especially when diluted in water and/or exposed to diffused daylight or artificial light. At 25 °C, a temperature that can be considered closer to that experienced when reconstituted vaccine is in use in the field, the half-life of the virus was between seven and eight hours. An addition of either physiological saline (0.85% NaCl) or 1% $MgCl_2$ improved the stability of the reconstituted vaccine at 22 °C to 25 °C for about one hour.

TCRV was produced in roller cultures of primary calf kidney cells or Vero cells (Fig. 4). Infected supernate was mixed with a cryoprotectant, and the mixture was freeze-dried and sealed under vacuum in either ampoules or vials. National authorities were responsible for quality control, but this was usually ceded to the production laboratory. In Muguga,

FIG. 4

COLIN RAMPTON, A SENIOR TECHNOLOGIST AT EAVRO, MUGUGA, KABETE, INCUBATING ROLLER TUBE AND BOTTLE CELL CULTURES INOCULATED WITH RINDERPEST VIRUS

Source: East African Common Services Organisation, courtesy of J. Rampton



each batch was titrated three times to obtain a mean titre per freeze-dried ampoule and to calculate the number of doses per ampoule on the basis that 100 (later 300) $TCID_{50}$ (median tissue culture infectious doses) represented one cattle dose. Animal testing consisted of inoculating two cattle with 100 field doses, another two with one-tenth of a field dose and keeping an in-contact control along with the inoculated animals. After three weeks, all animals were challenged with virulent virus. Provided that the vaccinated animals remained healthy while the control animal reacted to the virus, the batch of vaccine was passed.

The work on cell culture rinderpest vaccine development and production in Muguga in East Africa and in Vom in Nigeria (West Africa) was complemented by similar collaborative work in francophone West and Central Africa through the IEMVT (74), which in 1984 was amalgamated with other French agronomic institutes to form the Centre International de Recherche Agronomique en Développement (CIRAD).

From the early 1960s, the rinderpest team led by Alain Provost (Fig. 5) at Farcha, Ndjamena, Chad (Christian Borredon, Remy Queval), and the team in Dakar-Hann, Senegal (Paul Mornet, Jean Orue, Michel Doutre, Jacques Chambron and Pierre Bourdin), undertook extensive research on cell culture vaccines. They developed a virus strain from the Kabete 'O' strain (obtained from Plowright at its 32nd passage level in cell culture), from which a seed bank was produced at the 35th passage and used for vaccine production at the 38th passage (75). This rinderpest vaccine was named PESTOSEC. Apart from some transient thermal reaction in vaccinates, for all practical purposes this vaccine was considered safe, and such a mild reaction was negligible compared with that experienced with caprinised vaccine. Between 1962 and 1965, the team produced two million doses of TCRV. Subsequent work produced a 'thermo-resistant' clone (clone 16b-1009), which corresponded to the 48th passage of the virus (76). This was used as the vaccine strain from 1968 onwards. The team also investigated ways to better produce and stabilise TCRV, including the use of molar $MgSO_4$ as a thermo-protective diluent when freeze-drying (77). The rinderpest teams at Farcha and Dakar-Hann and the contagious bovine pleuropneumonia (CBPP) team led by Pierre Perreau at the IEMVT Maisons-Alfort, France, Farcha and Dakar-Hann developed a combined vaccine against rinderpest and CBPP that mixed TCRV and the CBPP vaccine strain KH3J-SR (streptomycin resistant) to give a product named BISEC (76). The rinderpest bovine old Kabete (RBOK) strain 16b-1009 and the KH3J-SR culture yield were mixed before freeze-drying. This BISEC vaccine was first produced and used in Chad. Because of the short-lived CBPP immunity induced by the KH3J-SR valency, annual revaccination of cattle was essential. From 1966 to 1969, there were five and a half million BISEC vaccinations undertaken in Chad, which resulted in a dramatic decline in CBPP outbreaks (from 200 to around 10 per year in Chad).

The TCRV-RBOK vaccine and BISEC produced by the Farcha, Dakar and Bamako laboratories were widely used during Joint Programme 15 (JP15) in Central and West Africa (mainly in French-speaking countries) during the period 1965–1970. A similar RP-CBPP vaccine produced in the Debre Zeit laboratory was used in Ethiopia during JP15, the Pan-African Rinderpest Campaign (PARC) and the Programme for Control of Epizootics (PACE).

From 1970, the CBPP vaccine strain T1SR replaced the KH3J SR one (77). Initially, there was concern that the rinderpest component in the vaccine could be immunosuppressive. This was ruled out by the work of Doutre *et al.* in Dakar-Hann (78), who demonstrated that the rinderpest component had no measurable negative effect on immunity to CBPP induced by T1SR (this result was later confirmed by the Pirbright Laboratory in the United Kingdom, through research funded by the PARC programme) (79). This T1SR-RBOK vaccine, named NEOBISEC in Farcha and BISSEC in Dakar-Hann, was widely used in West and Central Africa.

During the pan-African rinderpest campaigns of the late 1990s and early 2000s (PARC and PACE), West and Central African laboratories (Bamako, Mali, Dakar, Senegal, LANAVET – a new laboratory established in Garoua, Cameroon and Vom, Nigeria) produced vaccines using passage levels of between 90 and 122 – see below.

TCRV introduced to India

The advent and the success of Plowright's TCRV in Africa in the early 1960s caught the attention of the Indian authorities because of its universal applicability and ease of production, although some initial investment was needed to create tissue culture facilities in the biological production centres. Here, again, FAO assisted the IVRI in Mukteswar to procure the Plowright vaccine strain in 1966 from Cairo, Egypt, and arranged to impart training at the Mukteswar Laboratory on production of TCRV in calf kidney primary monolayer culture. Following the production and testing of two experimental batches of TCRV at Mukteswar Laboratory, the first large-scale batch comprising about two million doses was produced and introduced into the field in 1969. Thereafter, the technology for TCRV production was transferred from the Mukteswar Laboratory to the Biological Production Division of the IVRI in Izatnagar, Uttar Pradesh. The production capacity was enhanced by the assistance of FAO through the procurement of additional freeze-drying equipment. By 1974, this facility at the IVRI, Izatnagar, had been producing almost ten million doses of TCRV a year, which was still inadequate to cover the entire country's vaccination programme with TCRV alone (see Chapter 4.13.4). To enhance TCRV production capacity in the country, the biological production centres under several state Veterinary Services were gradually upgraded to produce TCRV only.

Facilities for the production of TCRV were created under support provided by the fourth to fifth five-year plan programme of the Government of India,

FIG. 5
ALAIN PROVOST (SPECTACLES IN HAND) AND HIS RINDERPEST TEAM IN FARCHA, CHAD
Courtesy of the authors

covering the period 1970–1980. The major hurdle in transferring the TCRV technology to the state biological production centres came in the form of using calf kidney primary cell culture for production. As cattle (calf) slaughter was legally banned in most Indian states, TCRV could not have been produced in calf kidney primary culture. The Mukteswar Laboratory of the IVRI explored the use of lamb kidney primary culture as a possible replacement for calf kidney culture for the production of TCRV, and the standards were re-optimised (80). The technology was then successfully disseminated to the states. There were some hiccups in converting a GTV production facility into one for TCRV production, as the latter required more stringent biosecure conditions. Older equipment items were also slowly replaced with new ones with the assistance of the government budget or, later (1990–1995), with the assistance of the European Union through the revitalised National Project on Rinderpest Eradication (NPRE). The stock seed virus of TCRV, as with GTV previously, was being maintained at the Mukteswar Laboratory and supplied on demand to the state production centres against a nominal charge. The IVRI, either through the Mukteswar Laboratory or its Standardisation Division in Izatnagar, provided the quality control of representative vaccine batches produced by the states and used in the field.

The quality control at this stage included an assessment of antibody response by the serum neutralisation test, apart from potency testing by animal challenge. However, batch or vaccine failures were occasionally reported, which could be attributed to the following factors:

1. Compared to GTV, the TCRV required a more stringent cold-chain, which in the field was not always possible to maintain adequately. This may have caused the failure of an otherwise potent vaccine batch at the production centre.
2. The batch failure may have resulted from failure to maintain the seed virus at the production centre (4-6 further passages were recommended of the seed virus supplied by the Mukteswar Laboratory).
3. Inadequate or deficient lyophilisation of the vaccine at the production centre.
4. Low-level extraneous contaminant of the primary culture resulting in incorrect interpretation of the virus-induced cytopathogenic effect in virus-infected cell culture, resulting in low-titre (or no-titre) virus harvest.
5. A poor vaccine batch may have been released by a production centre without subjecting it to quality control tests.

VIRUS PRESERVATION

Chryochem

Rinderpest virus is relatively heat labile when suspended in liquid, but in the desiccated state it is far more robust (see above). Accordingly, to distribute vaccines to end users, methods of preserving the contents were developed. The first of these was the Chryochem.

Desiccation of rinderpest vaccine was introduced in the late 1930s. In Burma, Pfaff (81, 82) described his method as follows:

'The spleens are removed aseptically, finely ground in a Latapie pulper and dried in vacuo over calcium chloride, which is the method that was introduced at Kabete [Kenya] at the beginning of 1938. Since at the outset the vaccine was largely produced for immediate or early use it was issued in rubber-stoppered evacuated containers. If, however, it is desired to improve the keeping qualities of the product to allow of transport over greater distances, some form of supplementary or secondary desiccation had to be practised, and the vaccine was dispensed in sealed glass containers. Reduced temperatures improved keeping quality and in the laboratory storage was at minus 15 °C to minus 25 °C, this latter consideration applied during distribution and the need for a cold chain relying on ice or dry ice while in transit kerosene-operated refrigerators in the field.'

Freeze-drying

The Chryochem method was superseded by the introduction of centrifugal freeze-driers. However, it was the work of Daubney and Hudson in Kabete, Kenya, that is associated with introducing freeze-drying into the production of standardised vaccine lots in glass ampoules. Their major breakthrough was the introduction of the secondary desiccation step and a vacuum-sealed product. This was the beginning of batch producing quality-controlled lots, which could be shipped beyond borders. Indeed, in 1945 such a vaccine was shipped to Egypt before local production was set up. Daubney (23) described this milestone as follows:

'The opportunity to put the matter to practical test was offered in Egypt, which was infected in April 1945 by the importation of live animals from the Anglo-Egyptian Sudan. By the end of 1945 infection was widely disseminated throughout Upper and Lower Egypt. Attempts to control the spread by quarantine measures. the suppression of outbreaks by double inoculation, mass immunisation with wet goat virus (327,600 head), and mass immunisation with formalised tissue vaccine (626,784 head) failed.

In January 1947 at the peak of the invasion, as indicated by the highest monthly number of fresh outbreaks, mass immunisation with desiccated goat virus was begun. Just over 1,100,000 head were vaccinated by this method in 1947, but by August that year the last connected outbreaks had been registered. Two small outbreaks occurred, one in the last week of November, and the other in the first week of December. One was confined to imported cattle in the Suez Quarantine Station, and the other occurred in the Cairo district where large numbers of imported Sudanese cattle are slaughtered, although a connection could not be definitely established. Since then, for a period of roughly twelve months at the time of writing, the country has been completely free of infection.'

Accordingly, the KAG vaccine became the first mass-produced rinderpest vaccine product for international use, thanks to the freeze-drying process that was developed initially in Kabete and later introduced to EAVRO, Muguga, by Colin Rampton and Les Rowe (Fig 6). This technology was to prove pivotal when cell culture vaccine was introduced later. TCRV followed suit. Production levels were limited by access to freeze-drying capacity, which was only ultimately boosted by the introduction of shelf freeze-dryers in place of the centrifugal models (Fig. 7).

VACCINE PRODUCTION FOR INTERNATIONAL RINDERPEST CONTROL

Production, quality control and use of cell culture vaccine in Africa, the Middle East and South Asia

The introduction of a cell culture rinderpest vaccine (i.e. TCRV) that could be used for all breeds of cattle rekindled the drive for global rinderpest

FIG. 6

RINDERPEST VACCINE AMPOULES IN EDWARDS PRIMARY AND SECONDARY FREEZE-DRYERS, USED IN MASS PRODUCTION OF RINDERPEST CELL CULTURE VACCINE UP UNTIL THE 1980S IN AFRICA AND ASIA

Photos taken in Muguga, East Africa (Mr Les Rowe and a trainee), and in Izatnagar, India (Dr Singh)
Source: East African Common Services Organisation, and Indian Veterinary Research Institute

FIG. 7
SHELF FREEZE-DRYER AT THE PIRBRIGHT INSTITUTE, 1984
Source: Pirbright Institute

BOX 3
THE EXPERT COMMITTEE'S ENDORSEMENT OF PLOWRIGHT'S MODIFICATION OF THE KABETE 'O' STRAIN OF RINDERPEST

'A suitable cell culture strain is the Muguga modification of the Kabete 'O' strain developed by the East African Veterinary Research Organisation. It has been shown that this strain was avirulent and had maintained its immunogenicity for cattle between the 90th and 122nd passage under controlled cultural conditions.'

eradication. In 1970, the production methods that were developed in East Africa by Plowright were incorporated by the WHO Expert Committee on Biological Standardisation (83) into a text entitled *Requirements for Rinderpest Cell Culture Vaccine (Live)*, with the Muguga modification of the Kabete 'O' strain as a suitable candidate – see Box 3. These production norms were adopted wherever TCRV was manufactured.

To meet the increased demand for vaccine for JP15 (see Chapter 4.1), the number of rinderpest vaccine production laboratories increased from the original two laboratories in Muguga (Kenya) and Vom (Nigeria) to include Farcha, N'Djamena (Chad), Dakar (Senegal), Bamako (Mali), Niamey (Niger), Soba (Sudan) and Debre Zeit (Ethiopia). While the original laboratories had used a two-stage freeze-drying process that used ampoules, some of the new facilities introduced flatbed large-scale freeze-dryers with stoppered vials.

As already discussed, the fragility of the virus was always a major consideration when producing and distributing a vaccine, and the advent of freeze-drying for rinderpest vaccine production ushered in a new era for international vaccination because of the enhanced stability of the freeze-dried product. This meant that vaccine could be produced in one place and shipped to distant places for storage and use when required with little loss in infectivity. Nevertheless, this enhanced stability needed to be supported by a cold chain running between the manufacturer and the end user. In due course, standard requirements for a monitored cold-chain system were developed by FAO and the World Organisation for Animal Health (OIE) as part of standard operating practices (84, 85, 86). (As observed later, a variation in these requirements was introduced for a thermotolerant lyophilised product that could be used even by community animal health workers (CAHWs) in remote areas with poor or no cold chains [87].)

During the 1970s, rinderpest vaccine production laboratories throughout the world adopted the Kabete 'O' strain as the standard vaccine master seed. By the mid-1970s, rinderpest outbreaks worldwide were limited to a few isolated incidents. This generated international confidence that the widespread vaccination campaigns with TCRV had reduced disease incidence to such a low and sporadic level in Africa, the Middle East and South Asia that the final elimination of such pockets could be left to be accomplished locally by national governments. The continuous Vero cell line was also adopted by most vaccine producers as the standard vaccine production substrate, as was the adoption of large-scale flatbed freeze-drying processes (87, 88, 89, 90, 91). In terms of vaccine production capacity, the emphasis was on upgrading the government laboratories that had participated in the production of vaccine for the 1970s campaigns. Remarkably, there was only one commercial enterprise (i.e. the Botswana Vaccine Institute) that included rinderpest vaccine production in its portfolio. A programme supported by the United States Agency for International Development in the Niger

FIG. 8
HOT-IRON BRANDING OF RINDERPEST VACCINATED CATTLE, IN THE UNITED REPUBLIC OF TANZANIA, 1983, DURING EMERGENCY VACCINATION WITH TCRV, AS A SINGLE TCRV INJECTION CONFERRED LIFE-LONG IMMUNITY
Source: W. Taylor

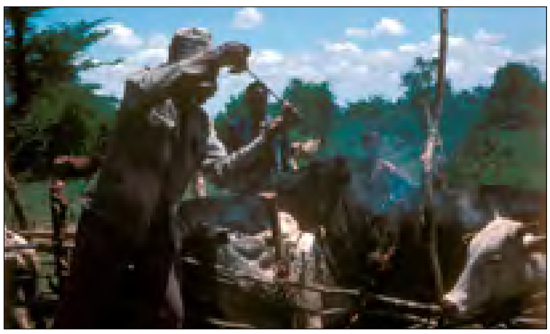


FIG. 9

WALTER PLOWRIGHT AT THE EAST AFRICAN VETERINARY ORGANISATION LABORATORIES, MUGUGA, KENYA, WHERE HE AND HIS TEAM DEVELOPED TCRV, WHICH WOULD PROVE TO BE THE UNIVERSALLY ACCEPTED VACCINE EMPLOYED IN THE RINDERPEST CONTROL CAMPAIGNS IN AFRICA AND ASIA. SITTING ON WALTER'S LEFT IS FRANCIS NGUGI, HEAD LABORATORY ASSISTANT

Photograph provided by Dorothy Plowright. © 2010 The Royal Society, doi:10.1098/rsbm.2010.0018 343

worked on improving the freeze-drying process that enhanced the thermostability of the freeze-dried product (87, 92). This was to prove vitally important, especially in the final stages of introducing vaccination to either remote areas or those under civil strife, as in both cases the involvement of CAHWs in vaccination proved to be the link that had been missed during the earlier campaigns. It was the involvement of CAHWs that enabled programmes such as PARC to reach all such pockets of virus endemicity (79, 93, 94, 95, 96, 97, 98, 99,100).

TCRV was used extensively during JP15 in Africa and the NREP in India and exclusively during PARC and India's second programme, NPRE. It was also extensively used by FAO during emergency vaccination campaigns (Fig. 8) It is probably correct to number the times it was used in billions and to conclude that it played a major role in rinderpest eradication.

In Africa, PARC, managed by the African Union Interafrican Bureau for Animal Resources (AU-IBAR), required that all vaccines to be used in the campaign in Africa had to be tested either by one of the two FAO–AU-IBAR units set up in Dakar and Debre Zeit - subsequently incorporated in the Pan-African Veterinary Vaccine Centre (PANVAC; see Chapter 5.6) in Debre Zeit, - or by the FAO–OIE World Reference Laboratory at Pirbright (101). That PANVAC ensured a quality certification process of all rinderpest vaccines to be used in Africa was a key to the success of eradication in the continent.

The OIE standard for rinderpest freedom from infection required cessation of vaccination, followed by rigorous clinical and serological surveillance to demonstrate lack of antibodies in yearling stock born after cessation of vaccination. This so-called OIE Pathway for rinderpest eradication was pursued rigorously with each Member of the OIE and/or FAO being individually certified by the OIE.

The results of such a standards-based rigour enabled the Director-General of FAO to declare on World Food Day, in October 2010, the cessation of all field rinderpest control activities. On 25 May 2011, the General Assembly of the OIE announced that rinderpest eradication had been achieved (102). On 28 June 2011, during the 37th FAO Conference, FAO and the OIE made a joint declaration of a 'World Free of Rinderpest', with verified cessation of vaccination and country-by-country freedom from infection (103, 104).

In recognition of his contribution to global rinderpest eradication

Dr Walter Plowright (Fig. 9) was recognised by the 1999 World Food Prize for his development of TCRV, the key element in the quest to eliminate rinderpest or cattle plague from farms and herds worldwide.

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CHAPTER 3.6

INTRODUCTION TO RINDERPEST SURVEILLANCE

A. JAMES

University of Reading, School of Agriculture, Policy and Development, Veterinary Epidemiology & Economics Research Unit, P.O. Box 237, Reading RG6 6AR, United Kingdom

Corresponding author: andrew.james@panveeru.net

SUMMARY **The role of epidemiological surveillance in supporting and confirming the global eradication of rinderpest is described. This included seromonitoring of vaccination campaigns and seromonitoring and active clinical surveillance after cessation of vaccination to detect any continuing virus activity. It is argued that these surveillance programmes gave countries the confidence to cease vaccination and proceed towards eradication.**

KEYWORDS **Clinical surveillance – OIE Pathway – Rinderpest – Sampling methods – Seromonitoring – Serosurveillance – World Organisation for Animal Health.**

INTRODUCTION

Epidemiological surveillance was an essential feature of the Global Rinderpest Eradication Programme (GREP; see Chapter 6.1). It not only provided assurance that the steps towards eradication in the World Organisation for Animal Health (OIE) Pathway (see Chapters 5.2 & 7.1) had in fact been achieved but also gave decision-makers the confidence to proceed to the next steps that, had the objectives not in fact been achieved, would have led to an increasing risk of serious outbreaks or even epidemics.

It could be claimed that it is this that distinguished GREP from earlier national or regional rinderpest eradication programmes. In these programmes, many counties would have continued vaccination indefinitely because they were not confident of the disease status of neighbouring countries. However, in situations of limited resources and competing demands on finances, it is difficult to maintain in the long-term sufficient levels of vaccination to prevent the reintroduction of disease. Furthermore, continued vaccination can mask the existence of residual foci of infection, especially if these are due to mild strains of the disease. The OIE Pathway and GREP provided a way for countries to avoid the need for continuing vaccination while managing the risk that the remaining infection could cause serious outbreaks in an increasingly susceptible population.

A prerequisite for the control of any disease is a passive disease reporting system that would detect disease if it occurred. In the case of rinderpest, this is not very demanding: the results of an outbreak could hardly be missed. Passive disease reporting can be seen as a 'fire alarm'. It does not provide quantitative information suitable for epidemiological analysis, but in the event of disease occurrence it should allow a rapid response to contain an outbreak. To be effective, it is important that veterinary services, livestock owners and the public are informed of disease signs. Moreover, there must be no disincentives to report suspicions of disease.

However, the challenge is to detect cryptic foci of infection early enough to prevent an outbreak, and to provide statistical evidence that disease is not present in populations to confirm freedom from disease. This demands active disease surveillance.

SAMPLING METHODS

Active surveillance seeks to estimate the prevalence of a disease agent or immunity in the population. To determine these exactly would require testing of the entire population using a perfectly sensitive and specific (no false-positive or false-negative results) diagnostic procedure. In practice this is impossible, so active surveillance is invariably conducted on samples of the population. If these samples are selected randomly, then it is possible to obtain unbiased estimates of prevalence or of the probability that the condition does not exist in the population if no positive results are found.

Animal populations are always clustered into groups such as herds or village populations. So a two-stage sample selection process is required, unless all of the animals in each selected cluster are to be tested. The techniques used in GREP for selecting random samples in active surveillance are described in detail by James (1).

For objectivity and international recognition of the results of surveillance, it was essential to use proper random sampling procedures. While it might have seemed logical to focus the surveillance on populations considered most likely to be maintaining the disease, judgements about the location of residual infection are very unreliable. The residual endemic focus of rinderpest, which is the target of active surveillance, is unlikely to be found where it is expected: otherwise it would have been eliminated in the disease control programme. However, it was acceptable to undertake additional surveillance in populations considered at greater risk, or to sample additional herds if suspicion of disease arose during surveillance work. However, those herds had to be in addition to those in the random sample, and not substitutes.

Random samples are typically less evenly spread through the population than is the case with a sample selected to be 'representative'. Sometimes, having selected a random sample of herds, it will be apparent that some part of the population considered to be important has been missed or under-represented by chance. In this situation it is not permissible to abandon the sample and select another. It is, however, acceptable to add herds to the random sample. This could never decrease the probability of detecting the disease below the level achieved by the random sample alone. It will increase the probability of detection (but by an unspecified amount).

SEROMONITORING OF VACCINATION PROGRAMMES

While the seromonitoring of vaccination programmes was not part of the OIE Pathway to verification of freedom from disease and freedom from infection, it was an essential component of GREP. It allowed the national Veterinary Services to be confident that a sufficiently high level of population immunity existed to ensure that any remaining foci of infection would be limited and unlikely to spread to cause widespread outbreaks of disease.

The development of automated enzyme-linked immunosorbent assay (ELISA) antibody detection systems during GREP greatly increased the capacity of Veterinary Services to undertake seromonitoring of vaccination programmes.

If a herd or other population cluster had been vaccinated, it would be expected that most, if not all, of the animals would be immune shortly after the vaccination, unless there had been problems of vaccine quality at the point of administration or poor field work by the vaccination team.

In most situations it would be impossible to cover all of the herds in a population in a vaccination campaign. Coverage of 70% of herds was often cited as a reasonable expectation in a rinderpest vaccination campaign, leaving 30% of herds unvaccinated. However, if the campaign were repeated with the same efficiency in the following year, the percentage of herds that had been vaccinated within one year would rise to 91%. This calculation assumes that there is no tendency for the same herds to be missed each year. This assumption seems reasonable in the case of rinderpest vaccination, as livestock owners had no incentive to try to avoid vaccination. The only reason for failure of the assumption would be if some herds were in areas that were inaccessible because of terrain or conflict.

On average, countries tested ~5,000 samples during each seromonitoring study. The seromonitoring results gave Veterinary Services the opportunity to intensify vaccination campaigns in areas or sections of the population where coverage was deemed to be unsatisfactory.

ACTIVE CLINICAL SURVEILLANCE

The first step on the OIE Pathway was to declare *provisional freedom from disease*. The preconditions for this were that:

- No rinderpest had been detected for at least two years.

- Vaccination had been discontinued.
- Any risk of reintroduction of rinderpest had been controlled.

The declaration of provisional freedom from disease was followed by a three-year programme of active clinical surveillance. This had to provide 95% probability of detecting any clinical signs if they were present in 1% of herds or other sampling units in each of the three years. Any suspicious signs of disease had to be followed up with an investigation to confirm or refute a diagnosis of rinderpest.

It was suspected that in a residual focus of rinderpest infection clinical signs of disease would be very mild and would be largely confined to calves with waning passive immunity. These might comprise only a few per cent of the population (2, 3). Therefore, the clinical examination of sampled herds had to be very thorough. Signs suggestive of mild rinderpest could also be the result of many other conditions, so the disease investigation procedures had to be rigorous and documented to support the OIE verification process.

While it was the purpose of clinical surveillance to search for signs of disease, it was also hoped that no rinderpest would be found. This situation could easily have affected the motivation of the staff conducting the surveillance. However, the consequences of failing to detect rinderpest in a population with increasing numbers of unvaccinated animals would have been disastrous. This, and the fact that they were participants in a global eradication programme, seems to have ensured that the clinical surveillance work was thorough.

At first glance the standard of a 95% probability of detection might seem to be inadequate. It suggests a 5% probability of failing to detect the disease if it were present, which would be unacceptable to many decision-makers. However, the fact that the process was to be applied three times meant that, by the end of three years, the probability of failing to detect the disease would be reduced to a small fraction of 1%. Moreover, by the third year after the cessation of vaccination a considerable proportion of the population would have become susceptible. This would mean that any remaining disease would become progressively easier to detect (and more dangerous). The OIE Pathway was designed not only as a process to demonstrate that eradication had been achieved, but also to manage the risks resulting from the withdrawal of vaccination.

SEROSURVEILLANCE FOR EVIDENCE OF INFECTION

This phase was intended to confirm by serological methods that rinderpest virus was not circulating. Serosurveillance was commenced at least two years after the declaration of *provisional freedom from disease* (one year before declaration of *freedom from disease*) and continued for at least two years.

These methods of detection of virus activity should be more sensitive than searching for clinical signs of the disease. They are subject, however, to confusion caused by vaccine-related and non-specific reactions, the frequency of which depend on the sampling and antibody detection procedures. No animal born since the cessation of vaccination should have had rinderpest antibody, unless it had maternal antibody, which should not normally be present after the first year of life. This defined the animals eligible for serosurveillance as those born after the cessation of vaccination and that were more than one year old. Any animal in the eligible age group that had rinderpest antibody would have provided evidence of circulation of rinderpest virus or of the continued use of vaccine.

The sampling and testing procedures were designed to give a 95% probability each year of detecting seropositive animals in the relevant age group if any were present in 1% of the herds or other sampling units in any stratum of the eligible population. Cattle and any other susceptible domestic animals had to be included in the serosurveillance programme. Wild susceptible species had to be sampled where possible, and domestic stock (including small ruminants) in contact with them had to be sampled intensively. If no evidence of virus activity was found, and subject to review of the serosurveillance programme and certain other requirements, the OIE was able to declare *freedom from rinderpest infection*.

The timing and duration of these stages of the OIE Pathway was as important in controlling risk as the detection probability and prevalence standards. It would not in general be possible to compensate for a reduction in the duration of the surveillance programme by increasing sample sizes. This is because the design of the standards takes into account the fact that the susceptible population will steadily increase after the cessation of vaccination, and with it the probability of detecting unsuspected foci of infection. Thus, as the risk of disease increases over time, so does the probability of detecting it. To reduce the duration of the surveillance programme would compromise the likelihood of detecting any residual disease foci before the declarations of freedom from disease and infection.

DISCUSSION

The fact that GREP, following the OIE Pathway, was successful in achieving and demonstrating the global eradication of rinderpest is testament to the value of using epidemiological surveillance to manage the process of regionally and globally eradicating a major animal disease.

Earlier regional rinderpest eradication programmes lacked this epidemiological surveillance dimension. Even where eradication had been achieved in a country or region, it was necessary to continue vaccination indefinitely because the risk of reintroduction of the disease remained. Inevitably, in the absence of an immediate threat, continuing vaccination was implemented less efficiently or even stopped altogether. The result was periodic serious outbreaks and epidemics of rinderpest, followed by more vaccination. This represented a major and ongoing economic loss due to both the direct losses caused by the disease and the cost of vaccination.

It must be doubted that the epidemiological standards were always applied in GREP exactly as specified by the OIE Pathway. Practical constraints such as difficult terrain and civil unrest can make it difficult to take truly random samples of populations. However, the success of the programme shows the robustness of the basic design and the fact that the participants in the programme were committed to the principles of GREP.

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CHAPTER 3.7

IMPLEMENTATION OF RINDERPEST SURVEILLANCE

F. NJEUMI [(1)*], P. ROSSITER [(2)], S. TEMPIA [(3)], J. MARINER [(4)] & C. SQUARZONI [(5)]

(1) Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, Rome, Italy
(2) St Michael's House, Poughill, Devon EX17 4LA, United Kingdom (Formerly staff member at the Food and Agriculture Organization of the United Nations and rinderpest consultant)
(3) Centers for Disease Control and Prevention (CDC); National Institute for Communicable Diseases, Private Bag X4, Sandringham, Johannesburg 2131, South Africa
(4) Cummings School of Veterinary Medicine at Tufts University; 200 Westboro Rd., North Grafton, MA, USA
(5) Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), TA A-15/G Campus Int. Baillarguet, 34398 Montpellier Cedex 5, France

*Corresponding author: felix.njeumi@fao.org

SUMMARY **Surveillance systems consisting of several components were used during the eradication of rinderpest. The efficiency of animal disease surveillance systems in detecting rinderpest in countries was measured through evaluation criteria, also called performance indicators. The assessment showed that countries were at various levels of performance. The surveillance system was essential for developing a cost-effective animal disease eradication programme. A good surveillance system can provide such information and make it possible to plan selective low-cost interventions, as opposed to blind interventions using mass vaccination.**

KEYWORDS **Active surveillance – Passive surveillance – Performance indicators – Rinderpest – Surveillance systems.**

INTRODUCTION

Rinderpest has been globally eradicated as a viral disease of livestock and wildlife. To achieve this, different surveillance systems were developed to both detect the presence or absence of rinderpest virus circulation, while gaining an epidemiological understanding of the disease transmission dynamics and maintenance so as to apply the appropriate eradication interventions, and gain assurance of the disappearance or eradication of the disease. This chapter describes the development of several conventional surveillance systems and how they were applied and adapted to account for the different situations and needs of countries as they progressed through the stages of global eradication.

ENHANCEMENT OF NATIONAL SURVEILLANCE SYSTEM CAPACITIES

To meet the objectives for the enhancement of national capacities for the delivery of animal health services, eradication of rinderpest and assistance to Member Nations in the control of major epidemic diseases, the Food and Agriculture Organization of the United Nations (FAO) Global Rinderpest Eradication Programme (GREP; see Chapter 6.1) considered its first priority to be the strengthening of national disease surveillance systems. This was achieved by utilising the existing animal health delivery systems in each country for reporting disease information. It was recognised that the delivery of Veterinary Services varied from country to country, but, at field level, key stakeholders comprised mostly government/private veterinary staff in stations/districts or auxiliaries at veterinary posts. Disease information, collected through the national system, was reported through a communication chain to regional and eventually central veterinary authorities.

The capacity-building process was implemented through extensive training and focused on four key areas:

a) epidemio-surveillance;
b) laboratory diagnostics;
c) communication;
d) database and data analysis for information collection and sharing through the use of software developed by FAO and other partners (e.g. African Union Interafrican Bureau for Animal Resources, AU-IBAR).

Communication campaigns were extensively implemented, particularly during the deployment of regional programmes, and were of great assistance in achieving good outbreak reporting and vaccination coverage (1, 2, 3, 4, 5, 6, 7). Figure 1 shows the major components of the surveillance system for rinderpest detection.

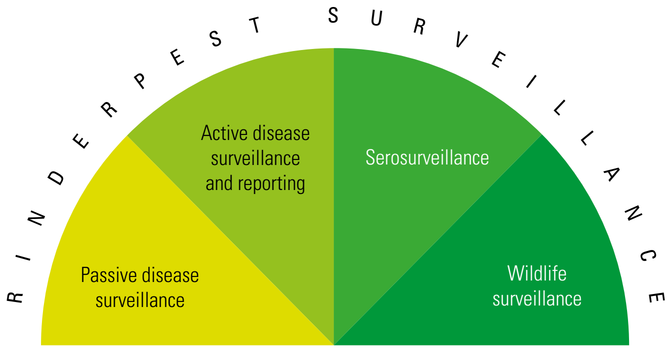
Of particular importance was the establishment of a national epidemio-surveillance system that involved the reporting of all notifiable priority diseases. The system worked at a number of different but interrelated levels. These included passive or routine reporting from the field, targeted searching for clinical rinderpest in cattle in suspected high-risk areas using participatory techniques, monitoring of livestock markets and slaughterhouses, and serological surveillance of cattle and wildlife to detect the presence or confirm the absence of rinderpest infection (1, 5, 7).

PASSIVE DISEASE SURVEILLANCE

Disease reporting

Disease reporting is the backbone of passive surveillance systems, and a well-coordinated disease reporting network was perhaps the single most important component of disease surveillance applied. In an ideal situation, passive surveillance revolves around the herdsman or herd owner's willingness to report a disease event to the local veterinary officer. The veterinary officer must in turn be able to identify the specific disease entities and then be willing to report such diagnosis to the relevant central authorities (5). The success

FIG. 1
COMPONENTS OF THE SURVEILLANCE SYSTEM
Courtesy of the authors



of passive surveillance further depends on the ability (or willingness) of the central authorities to allocate the necessary resources for gathering, analysing and distributing the information, and to do all this with the necessary urgency to make the information useful. However, under-reporting was the most serious problem encountered by passive surveillance systems and was particularly marked in developing countries where the basic communication networks required for efficient reporting either did not exist or were poorly developed (1, 5, 8). As many GREP countries appeared not to have the resources to set up efficient disease reporting networks, as they lacked the necessary communications and computing hardware and motivated staff, performance indicators for passive rinderpest surveillance were developed to monitor and measure the reliability, timeliness, accuracy and completeness of routine disease reports sent from field veterinary officers to headquarters. It was expected that the reports would contain evidence of endemic infectious diseases, including cases characterised by clinical signs of stomatitis–enteritis, as these should occur at a measurable rate (9).

An improvement in passive disease reporting capacity was observed in a few countries, where the system attained up to 75% of districts reporting notifiable diseases, using a GIS-compatible format, within 30 days of the end of each month to the chief veterinary officer and later to the OIE. An enhanced early warning system was put in place that shortened the time taken to report selected disease events to the epidemiology unit. A multilevel data management system was set up at provincial level to collect and analyse data from district level and below and to forward the same to the national Animal Health Information System (5). The Animal Resource Information System (ARIS), which was developed for use by all Pan-African Programme for the Control of Epizootics (PACE) participating countries, had operational problems, which affected uploading reports from lower user levels to higher levels. Spatial and temporal data up to village level (90%) was availed for planning and determining the cost-effectiveness of disease control strategies (10, 11, 12). This aided decision-making and policy formulation with regard to disease control strategies.

The use of community animal health workers (CAHWs) appeared to be an extremely effective strategy to reach cattle owners in difficult areas for both vaccination and reporting purposes (13, 14). In the process of establishing CAHW programmes, participatory rural appraisal methods were used to conduct needs assessments and to understand the knowledge base upon which the community animal health training programmes would be built (4, 5, 13, 14, 15).

A system of activated syndrome reporting of stomatitis–enteritis became well established in the few countries supported by a network of non-governmental organisations and international organisations. In Sudan, for example, a reward of US$500 (later increased to US$1,000) for any stomatitis–enteritis report that led to a laboratory-confirmed rinderpest outbreak was established. All suspicious outbreaks were notified and followed up for more information and for full laboratory confirmation. A substantial number of stomatitis–enteritis cases were reported in several countries but none confirmed as rinderpest.

Zero reporting

An apparent lack of a disease (rinderpest) could be due to either the absence of rinderpest or ineffective disease surveillance. Zero reporting distinguishes the two categories by ensuring an active reporting system within which negative reports or reports of the absence of rinderpest-compatible outbreaks are documented. A zero report would imply that a search was conducted but no evidence of rinderpest was found. During the eradication stage, zero reports were difficult to interpret, as they could imply either absence of the disease or the inability of the system to detect sporadic cases. Under such circumstances, the ability to detect an alternative (infectious) disease, preferably one that exhibits similar clinical signs, was used as a gauge of the efficacy of surveillance (5, 8). Knowledge of the baseline prevalence of the chosen alternative indicator disease (or disease complex) and capacity to confirm through laboratory procedure was required for quantitative and qualitative assessment of the efficiency of the system.

Abattoir samples

Abattoir (slaughter slab) samples and other grab samples were collected for other purposes. Unless trace-back facilities were available, abattoir samples were not found to be useful in the final phase of eradication programmes.

ACTIVE DISEASE SURVEILLANCE

FAO and partners introduced and supported active surveillance, to be conducted by Veterinary Services, whereby disease searching methodologies were developed using participatory techniques and random sample surveys. This was achieved through the development of mobile teams, which travelled from headquarters, regional offices and veterinary laboratories right into the field. In addition, with varying degrees of commitment and successes between countries, collection of animal disease data was undertaken from veterinary laboratories, abattoirs and markets (5, 10, 12). To assist and harmonise surveillance activities in the different countries, GREP undertook considerable training and communication in disease surveillance. To the epidemiologists, a set of performance indicators tailored to each country's requirements were introduced, which allowed them to monitor their surveillance activities (6). GREP also designed a set of evaluation criteria that were applied for the assessment and comparison of the surveillance systems of the different countries. National Veterinary Services were assisted in conforming to the OIE surveillance guidelines for declaring freedom from disease and infection (5). Apart from an effective strategy for the prevention or response to the re-introduction of rinderpest virus being articulated, emphasis was also laid on the development of effective national/regional emergency plans. This included a rehearsed action programme in the event of an outbreak and vaccination campaigns leading to a verifiable elimination of persistent endemicity.

Serosurveillance

Serosurveillance detects evidence of new or increased activity of the infectious agent of interest, usually through detecting agent-specific antibodies. The objective of rinderpest serosurveillance was to confirm the absence of rinderpest virus in a population or to confirm the emergence of new virus infection by detecting antibodies in unvaccinated animals. In the final stage of the OIE Pathway (towards freedom from rinderpest infection), a statistically valid serosurveillance programme was applied in establishing the final rinderpest eradication status.

Samples for serosurveillance were normally collected in a statistically defensible (random) manner, to increase the confidence that the result represented the real status of the disease in the country.

The absence of rinderpest-specific antibodies or an antibody prevalence of < 3–5% in an unvaccinated animal bled at least two years from the cessation of vaccination interventions for three consecutive years was considered evidence of absence of infection. In some instances, targeting areas that had an increased probability of harbouring infected animals (purposive sampling) was recommended, such as border regions that have frequent contact with cattle from other regions or countries, herds along cattle trade routes and major cattle markets, and parts of the country that had poor track records for regular disease reporting (1, 2, 5, 7, 10). The major cost of surveillance was often in getting to the herd. Therefore, combining serosurveillance with active disease searching reduced the costs considerably. Serosurvey teams examined the herds targeted for sample collection for signs of the disease and, where feasible, examined other herds within the same area. Performance indicators for serosurveillance measured the quantity of serum samples collected and tested, with results reported to headquarters within a specified period. Table I provides examples of the number of samples collected/tested in the last phase of eradication. Serosurveillance figures demonstrating the absence of rinderpest circulation were a crucial component of the final acceptance that a country was rinderpest-free.

In several cases, clusters of positive samples were backtraced in an attempt to resolve the significance. In the case of the Islamic Republic of Iran (7,538 and 9,258 collected in 2006 and 2007, respectively), a follow-up investigation of samples collected in 2007, for example, showed that 238 samples were in the 'ineligible' age group, 214 were seronegative upon resampling the same animals, and 43 animals had been sold/slaughtered. No seropositive case was confirmed in the eligible animal age groups. Hence, no evidence of the presence of rinderpest virus circulation was detected. Follow-up investigation was also undertaken in the Syrian Arab Republic with similar results.

Participatory disease searching as a special application of the participatory epidemiology method

Participatory approaches to epidemiology evolved throughout the 1990s as part of the rinderpest eradication effort. As thermostable rinderpest vaccine became available and the rinderpest programme gained experience with community-based vaccination programmes, it rapidly became apparent that the pastoral communities could provide very valuable insight into the historical and current distribution of

TABLE I
NUMBER OF SAMPLES COLLECTED PER YEAR AND RINDERPEST SEROPREVALENCE IN SELECTED COUNTRIES

Country (chapter cross-reference)	Collected samples	Year(s)	Rinderpest antibody prevalence (%)
Afghanistan (4.13.2)	6,700	2006	0.00
	6,005	2007	0.00
Benin (4.5.1)	2,611	2003	0.76
	2,004	2004	0.16
Cameroon (4.5.3)	5,393	2004–2005	0.20
	982	2006	0.00
Côte d'Ivoire (4.5.6)	2,133	2004	0.66
	3,046	2005	0.10
Guinea (4.5.11)	3,790	1999–2002	0.00
	538	2002–2004	0.00
Islamic Republic of Iran (4.11.2)	7,538	2006	0.06
	9,258	2007	0.05
Kazakhstan (4.17.1)	2,200	2009–2010	0.50
Kenya (4.5.12)	13,500	2002	–
	5,130	2004	1.20
	14,990	2006	1.11
	4,500	2008	0.14
	24,190	2009	0.01
Kuwait (4.11.5)	3,009	2005	0.00
	1,049	2006	0.00
	1,753	2008–2009	0.10
Mali (4.5.13)	5,313	2003	0.00
	3,692	2005	0.04
Mongolia (4.17.2)	12,463	2000	5.90
	4,676	2002	0,01
	11,052	2004	0,02
	66 (wildlife)	2004	0.00
Nigeria (4.5.16)	2,487	2007	0,00
	729	2008	0.00
	5,100	2009	0.00
Oman (4.11.6)	996	2005	0.00
	844	2006	0.00
	893	2007	0.00
Pakistan (4.13.8)	8,589	2003	0.40
	29,416	2004	0.30
	35,865	2006	0.10
Saudi Arabia (4.11.8)	4,080	2009	0.00
Senegal (4.5.17)	3,547	2005	0.25
	1,135	2006	0.00
	1,351	2007	0.01
	1,744	2008	0.01
	1,286	2009	0.00
Sri Lanka (4.13.9)	4,500	2009–2010	0.00
Syrian Arab Republic (4.11.9)	1,500	2006	13.80
	4,400	2008	0.68
Tajikistan (4.17.4)	6,000	2006	0.00
	6,050	2007	0.00

TABLE I (CONT.)

Country (chapter cross-reference)	Collected samples	Year(s)	Rinderpest antibody prevalence (%)
Togo (4.5.21)	4,222	2003–2004	2.70
Turkmenistan (4.17.5)	6,000	2005	0.00
	6,060	2006	0.00
United Arab Emirates (4.11.11)	3,475	2009–2010	0.00
Uzbekistan (4.17.6)	6,600	2005 and 2007	≤ 0.01
	6,000		
Yemen (4.11.12)	3,771	2001 and 2003	13.30
	1,992	2007	7.34
	3,834	March 2009	3.26
	893	December 2009	0.11

rinderpest as well as the risk factors that shaped these epidemiological patterns. Traditional knowledge often included clinical descriptions, species affected, timelines of cases and outbreaks, prominent pathological features and epidemiological information that were equivalent to detailed case definitions linked using traditional names in local language. The techniques of participatory rural appraisal (PRA) were used to conduct animal health needs assessments to design community-based vaccination programmes. Later, the techniques of PRA were used to conduct epidemiological investigations directly targeting rinderpest (16, 17). This was developed as participatory disease searching (PDS) and successfully used for the detection of mild rinderpest in the Somali ecosystem (17) as well as the endemic eco-zone in Africa and Asia. Its application in Pakistan is described in Chapter 3.8.

In a PDS assessment, open-ended, flexible methods were used based on semi-structured interviews and participatory exercises such as mapping, proportional piling, seasonal calendars and timelines. First, the assessment team reviewed the available information to develop a qualitative risk map of rinderpest to purposively site field interviews. Key informants, or those who were likely to have an important perspective on rinderpest in the area, were interviewed using a checklist of topics related to livestock and disease. In the early stages of the interview, the team explored animal health problems in general and did not mention rinderpest (13, 14, 15). If the community raised a disease consistent with rinderpest as a topic of interest, then the interview team encouraged the community to elaborate on the topic and documented the name, description and epidemiological features of the disease. Multiple independent interviews were conducted and the results examined for synergies and inconsistencies. A scenario was constructed from the aggregated information and was used as a working hypothesis to plan interventions. Often, trails of information led to active clinical cases that were sampled for laboratory testing to rule rinderpest in or out.

Good training of PDS practitioners and trainers was essential for the quality of the programme. A two-week training and certification process for practitioners was developed and later a one-week training process for trainers was added. Certification was done after the completion of field projects or presentation of training programmes under the supervision of a master trainer.

PDS was used to conduct epidemiological investigations in countries such as South Sudan (Chapter 3.9), Sudan, Kenya (Chapter 4.5.12), Uganda, Somalia (Chapter 4.5.18), and Ethiopia (Chapter 4.5.9). Subsequently, PDS was utilised as a tool to help validate rinderpest absence in Afghanistan (Chapter 4.13.2), Pakistan (Chapter 4.13.8), Tajikistan (Chapter 4.17.4), Turkmenistan (Chapter 4.17.6) and Uzbekistan (Chapter 4.17.6). The investigations contributed directly to the identification of the last foci of rinderpest in Uganda, Ethiopia, South Sudan and the Somali ecosystem and the targeting of final eradication interventions. In addition, the pastoralists perceptions of the behaviour of rinderpest were used to inform disease models that were instrumental in the refinement of eradication strategy. PDS contributed important data on the absence of disease in the preparation of dossiers for recognition of freedom. The technique was recognised in the rinderpest chapter of the OIE *Terrestrial Animal Health Code* as an important approach to surveillance for rinderpest and other diseases. The PDS approach was one of the factors that contributed to rinderpest eradication (Chapters 6.1 and 8.1) and an important lesson and legacy of rinderpest eradication.

Wildlife surveillance

Susceptible wildlife species served as sensitive indicators of rinderpest infection, especially during or after vaccination of domestic livestock. In countries with large populations of wildlife species susceptible to rinderpest, wildlife surveillance programmes were established to monitor outbreaks, unexpected deaths and other signs of infection. Where feasible, serosurveillance of susceptible wildlife species was implemented (11) as described in Chapter 2.5. A wildlife capture exercise was conducted at the Kainji Lake National Park (Nigeria) in February 2003, where serum samples were collected from seven western kobs and one buffalo and analysed for rinderpest. The techniques for undertaking wildlife surveillance are well described in Chapter 2.5. The results of the analysis indicated absence of rinderpest antibodies. None of the 66 wildlife species sampled in Mongolia were positive (11, 18).

Risk-based surveillance

In several pastoral areas of Africa and central Asia, where preliminary investigations did not show a wide distribution of the disease, identifying high-risk populations and mobilising interventions for control and eradication was cost-effective. Given the transboundary nature of the disease and considering that in several regions human and livestock populations move freely across borders, an ecosystem approach with enhanced coordination and harmonisation between the Veterinary Services of neighbouring countries proved critical for the final eradication of rinderpest. In these countries/ecosystems, the performance indicators for evaluating the surveillance system were established and found to be useful (6). One very relevant realisation was that the communities often had much better intelligence on the geographical distribution of rinderpest risk and the history of disease in their area than national Veterinary Services (3, 10, 12). They could often provide information that, if or when analysed from a risk-based perspective, led to the detection of active outbreaks of rinderpest.

FACTORS INFLUENCING PROBABILITY OF DETECTION

The factors influencing the probability of detecting infected animals depend on the specific surveillance component being studied. The most complex process for the detection of infection was in the passive disease reporting components. The factors influencing detection for each component are listed in Table II.

TABLE II
FACTORS INFLUENCING PROBABILITY OF DETECTION OF DISEASE IN DIFFERENT SURVEILLANCE SYSTEMS

Surveillance system	Factor
Passive livestock disease reporting	Animal shows clinical signs
Passive wildlife disease reporting	Reporter notices signs
	Reporter contacts Veterinary Services
	Veterinarian takes sample
	Sample tested for rinderpest
	Initial test positive
	Follow-up investigation positive
Livestock serosurvey	Initial test positive
Wildlife serosurvey	Follow-up investigation positive
Participatory disease surveillance	Animal shows clinical signs
Zero reporting	Reporter notices signs
	Initial test positive
	Follow-up investigation positive
Market surveillance	Animal shows clinical signs
	Initial test positive
	Follow-up investigation positive

STRUCTURE AND PERFORMANCE OF THE SURVEILLANCE NETWORKS

To monitor the vaccination coverage, FAO identified a number of regional reference laboratories that had sufficient technical expertise in the diagnosis and surveillance of rinderpest to be able to offer regional services to neighbouring countries. The network contributed to a dramatic improvement in laboratory proficiency, surveillance for disease, and monitoring of vaccination efficacy and coverage. The network became a valuable forum for information gathering on rinderpest disease status and the dissemination of such information, as the available data could then be assessed by national Veterinary Services and other stakeholders nationally, regionally and globally (3, 4, 5, 11; see also Chapter 6.3).

PERFORMANCE INDICATORS

Performance indicators comprise a set of questions and measures drawn up to assist heads of Veterinary Services and decision-makers to monitor and assess the effectiveness of programmes or epidemiological surveillance systems. In both human and animal health, indicators are usually based on the evaluation of the capacity of a surveillance system to detect, at an early stage, the introduction of a specific disease in a country. In fact, they allow the assessment of the epidemio-surveillance system's reliability or functionality (9, 19).

It was crucial to evaluate the performance of the system and undertake the necessary corrective intervention if the system was not found to be performing to the desired level (5, 6). Performance indicators were therefore developed to provide assurance that a surveillance system, consisting of both active and passive surveillance and including diagnostic capacity, would be able to detect diseases or infections if these were present in a population or a country. Performance indicators, according to several reports (3, 6, 7, 9, 19), are a management tool to assist Veterinary Services to:

- evaluate the present system of disease surveillance;
- identify deficiencies in the system (diagnostic indicators);
- determine the needs and requirements to meet a predetermined level of surveillance (checklists);
- provide information for making OIE declarations and applications;
- provide transparency for trading partners.

Performance indicators were specifically designed to measure the sensitivity and specificity of the surveillance systems. These comprised time-delimited and denominator-based statistics. Performance indicators for rinderpest surveillance were based on the ability of the surveillance system to detect at 1% prevalence with 95% confidence (7).

In order to achieve this:

- 80% of reporting units (districts, villages, etc.) in the country had to file regular (monthly) reports on time.
- Active surveillance had to evaluate annually at least 300 sample units (herds, villages, etc.) selected in a statistically valid (usually random) manner; sometimes random map coordinates were generated.
- All suspected cases of rinderpest (i.e. cases compatible with the stomatitis–enteritis case definition) had to be fully investigated (clinically, epidemiologically, and laboratory confirmed) within two weeks.
- A serological surveillance system had to examine annually at least 4,500 serum samples from unvaccinated animals in at least 300 randomly selected sample units (herds or villages).
- Cases of stomatitis–enteritis or disease complex (malignant catarrhal fever, bovine virus diarrhoea/mucosal disease, infectious bovine rhinotracheitis, foot-and-mouth disease, etc.) needed to be detected. The ability to detect cases of stomatitis–enteritis was considered a good indicator that the system would be able to detect rinderpest should it occur.

Performance indicators for active surveillance included the number (and distribution) of districts surveyed and the number of stomatitis–enteritis disease complex incidents discovered and reported within a given period. The laboratory component of active surveillance also measured the number of cases of stomatitis–enteritis reports investigated, appropriately sampled and definitively diagnosed in a given time period. The quality (training/experience) of the survey teams and laboratory personnel also contributed to the level of confidence in active surveillance activities and findings. When the performance indicators highlighted a poorly functioning component of surveillance, corrective actions were undertaken.

Diagnostic indicators were developed with the aim of providing a systematic pathway to resolve poor performances in each component of surveillance. A list of diagnostic indicators was provided to assist the national Veterinary Services in identifying the likely reason for the poor performance in each of the performance indicators. The diagnostic indicators were specifically designed to identify gaps in the availability of a trained workforce, equipment (vehicles, cold boxes, etc.) and consumable items (cotton swabs, blood tubes), which are the basic tools of surveillance (19).

SUSTAINABILITY OF THE SURVEILLANCE SYSTEM

Under PACE, 100% of Members established or revitalised their national epidemio-surveillance systems, and at its end all disease surveillance systems were operational, except in Equatorial Guinea. In general, the surveillance systems set up have a good organisational structure that rests on supervisory bodies (steering committee and technical committee), a central unit and the actual field network composed of livestock agents working under the supervision of heads of departmental and regional services. When this whole arrangement was placed under the supervision of the Directorate of Veterinary Services, one considered that there was a genuine line of command facilitating the flow of animal health information. But this was not always the case, as in certain countries the field agents were working under regional directorates that reported to the Ministry of Agriculture. This configuration created command problems when implementing actions, mostly when handling rapid outbreak interventions. It must also be pointed out that the organisation of surveillance systems was formalised in many cases by regulatory texts (ministerial order, for example). PACE contributed to improving agents' equipment by funding the acquisition of vehicles, motorcycles, cold chain material, laboratory equipment and various other pieces of equipment (3, 19).

This led to the improvements noted in the flow of animal health information between the field and the central veterinary administration and from the latter to the laboratories. The reporting used forms in line with the OIE requirements and was managed in a centralised computerised system, based on the ARIS software, developed by PACE. Apart from the traditional data transmission channels (monthly reports, warning bulletin), certain countries had set up an interconnected network that made the instant flow of recorded information possible (19).

In an effort to make the surveillance systems more sustainable and provide an incentive to improve and adapt existing surveillance systems, the PACE Epidemiological Unit developed ideas that would increase the justification for an epidemio-surveillance system. The unit strived to help Veterinary Services officials raise national decision-makers' awareness of countries' interest and the economic benefits of further investment, in a sustainable manner, in animal health in general and animal disease epidemiological surveillance in particular. To achieve this, they put at their disposal any relevant information that could serve as a selling point for total ownership of epidemiological surveillance activities at the end of the programme (6, 7, 19).

Studies conducted by PACE (1999–2006) showed that an epidemio-surveillance system is essential for developing a cost-effective animal disease eradication programme. A good epidemio-surveillance system can provide such information and make it possible to plan a selective low-cost intervention, as opposed to a blind intervention using mass vaccination. Several of those PACE studies have clearly shown that investment in animal disease control is beneficial from both an economic and a social standpoint. For example, for each euro invested in rinderpest control in ten African countries considered in a study, there was a return of €1.83 and a net present value of €29.0 million (18).

The good operation of a field network is mostly related to training, motivating, developing and coaching staff, and quality control through the use of performance indicators, a job that mainly rests on the central unit. The units are composed of epidemiologists entrusted with managing the database. This team, which constitutes the mainspring of the surveillance arrangement, does not always have adequate means to successfully conduct the work entrusted to it, which is generally huge: development of surveillance protocols for diseases and survey forms, training and retraining of agents, field surveys in cases of suspected outbreaks, animal health data recording and analysis, editing information bulletins, etc. In the course of evaluating surveillance systems, it turned out that maintaining the momentum could constitute a weak point that countries need to improve on.

CONCLUSIONS

Rinderpest disease and serosurveillance were integral to enabling eradication and the preparation of country dossiers of evidence for recognition of freedom by the OIE Pathway. There is no doubt that appropriate control of animal diseases and in particular effective veterinary epidemiological surveillance, covering all priority diseases (from an economic standpoint), are very beneficial to countries, their populations and their public expenditure (19). When one adds to this equation the possibilities or opportunities of exporting livestock products (thanks to a better health status, recognised by the international community) or the impact of certain diseases on public health (rabies, brucellosis, tuberculosis, Rift Valley fever), the return or benefit–cost ratio becomes even more positive, as there will be social and humanitarian considerations in addition to the economic considerations.

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CHAPTER 3.8

PARTICIPATORY DISEASE SURVEILLANCE OF RINDERPEST IN PAKISTAN

M. HUSSAIN [(1)*] & M. RASHEED [(2)]

(1) Foot-and-Mouth Disease Project, Food and Agriculture Organization, National Agricultural Research Center, Islamabad, Pakistan

(2) Solve Agri Pak (Private) Limited, Lahore, Pakistan

*Corresponding author: manzoor.hussain@fao.org

SUMMARY **Tools of participatory disease surveillance (PDS) were employed from 2002 to 2006 by trained veterinary staff to understand better the dynamics of important animal diseases, particularly rinderpest, foot-and-mouth disease and peste des petits ruminants, in Pakistan. For this purpose, 51 veterinary officers trained by a PDS expert were formed into 17 teams. In each province, one data manager and a transboundary animal disease (TAD) officer were also designated to facilitate and guide the work assigned to each team. These teams worked in their allotted areas and used various PDS tools. A total of 11,852 villages, spread throughout the four provinces of Pakistan, the autonomous territories of Azad Jammu and Kashmir, and Gilgit-Baltistan, and the federally administered tribal areas were searched for the footprints and other aspects of important animal diseases especially TADs. Data generated by the PDS activity was a vital part of the rinderpest freedom accreditation dossier submitted to the World Organisation for Animal Health, and Pakistan was declared free from rinderpest infection during 2007.**

KEYWORDS **Participatory disease surveillance – Participatory disease surveillance – PDS teams – PDS tools – Rinderpest – TADs – Transboundary animal diseases – Vaccination.**

After the concerted and well-planned efforts of all livestock departments in Pakistan, the last case of rinderpest was diagnosed in Karachi in September 2000 using a rapid pen-side test. This country-wide activity was mainly supported by various projects implemented by the Food and Agriculture Organization of the United Nations (FAO) and the European Commission. Although after 2000 there was no report of any rinderpest case in the country, in the presence of an under-performing surveillance system there was always the possibility of an outbreak of rinderpest, particularly in remote areas with minimal veterinary services in place. Against this scenario, the chief veterinary officer of the Animal Husbandry Commissioner's Office decided to officially prohibit the use of rinderpest vaccine anywhere in Pakistan from December 2000. This was done in a deliberate attempt to uncover any residual foci of infection that existed – which would then be dealt with by small-scale ring vaccination. During the following six years, and with an increasingly susceptible population, active disease surveillance results were needed for dossier formulation. It was considered useful to introduce a comparatively new approach, well-appreciated in Africa, of 'participatory disease surveillance'

(PDS), which utilises participatory methods to learn from livestock owner knowledge and epidemiological intelligence to guide disease control and eradication.

In 2002 under an FAO project (GCP/PAK/088-EC), Dr Jeffery Mariner, an international epidemiologist and PDS expert, conducted training courses on PDS, first in Punjab province and later in Sindh province, in which about 79 veterinary staff, nominated by all the livestock departments, participated. These veterinarians were trained in innovative techniques for gaining information from livestock farmers. At the end of each training course, and keeping in view the aptitude of the participants, a total of 51 from 79 veterinary staff were selected and assigned to undertake PDS in their allotted areas. By the end of 2002, PDS work had commenced in Punjab and Khyber Pakhtunkhawa provinces and the regions of Azad Jammu and Kashmir (AJK), and Gilgit-Baltistan. Early in 2003, this activity was extended to the entire country. Besides PDS teams, in each province or region, a data manager and transboundary animal disease (TAD) officer were also nominated by each livestock department and were an integral part of the PDS activity. Data managers assisted in the collection and analysis of data being generated by the PDS teams. Under the direct supervision of the national consultant, TAD officers took on the important role of properly monitoring and facilitating PDS teams in their respective province or region.

FIG. 1
PARTICIPATORY DISEASE SURVEILLANCE TOOLS: A PROPORTIONAL PILING EXERCISE WITH FARMERS
Courtesy of the authors

Seventeen PDS teams were constituted and the task was to search 10,352 villages for the prevalence and perceived importance of animal diseases, particularly TADs (i.e. rinderpest, foot-and-mouth disease [FMD] and peste des petits ruminants [PPR]). These teams collected data about important livestock diseases by using a range of PDS tools such as proportional piling, area/village mapping, disease scoring, seasonal calendar, visual observation and semi-structured interviewing, with the participation of local livestock farmers, livestock traders, butchers and veterinary field staff (Figs 1–4). These PDS data were also presented as a success story at an international symposium (1). Several cases showing signs similar to rinderpest were reported by the farmers and investigated, but there was no evidence of the occurrence of rinderpest in the area. A summary of villages searched in various parts of the country is given in Table I and illustrates the incorporation of PDS as the active rinderpest surveillance tool across Pakistan.

FIG. 2
PARTICIPATORY DISEASE SURVEILLANCE TOOLS: AN AREA/VILLAGE MAPPING EXERCISE WITH A FARMER DURING A PDS MEETING
Courtesy of the authors

FIG. 3
PARTICIPATORY DISEASE SURVEILLANCE TOOLS: DISEASE SCORING
Courtesy of the authors

FIG. 4
PARTICIPATORY DISEASE SURVEILLANCE TOOLS: FARMERS GATHERING TO SEARCH FOR DISEASE PREVALENCE IN THE AREA
(Faisalabad district, Punjab, Pakistan)
Courtesy of the authors

TABLE I
A SUMMARY OF PARTICIPATORY DISEASE SURVEILLANCE TOOLS EMPLOYED TO SEARCH FOR IMPORTANT ANIMAL DISEASES IN DIFFERENT VILLAGES IN PAKISTAN

Village interviews	Punjab	Sindh	NWFP	Bal	AJK	NAs	ICT	Total
No. of villages covered	2,973	3,142	1,328	888	1,088	823	110	**10,352**
No. of meetings conducted	3,468	4,166	3,945	892	1,087	756	174	**14,488**
No. farmers participating	27,704	45,397	23,051	6,162	2,803	5,224	1,555	**111,896**
No. key informants met	1,424	2,817	1,268	1,002	956	897	83	**8,447**

NWFP, North-West Frontier province; Bal, Baluchistan; AJK, Azad Jammu and Kashmir; Nas, Northern Areas; ICT, Islamabad Capital Territory

As the PDS had harvested valuable data, it was proposed to continue the programme, and six master trainers were trained to conduct further courses on PDS. Apart from working towards the eradication of rinderpest in Pakistan, four of these master trainers also served as national consultants in FAO and EU projects as well as employing their skills in other projects located in Afghanistan (see Chapter 4.13.2), Tajikistan (see Chapter 4.17.4), Turkmenistan (see Chapter 4.17.5) and Uzbekistan (see Chapter 4.17.6).

In June 2005 the PDS project funded by FAO was succeeded by the EU-funded 'Strengthening of Livestock Services Project', which continued until the final acceptance of Pakistan by the World Organisation for Animal Health (OIE) as being free from rinderpest infection in May 2007. Before submission of the rinderpest freedom accreditation dossier to the OIE, a work plan to search another 1,500 villages of Pakistan for rinderpest was launched in April 2006. Under this programme, 18 PDS teams worked in the randomly selected villages and the data generated by the teams were incorporated into the dossier.

The data generated by the PDS teams, particularly about rinderpest, FMD and PPR, were appreciated by all livestock departments. The information about important animal diseases in the country, from the perspective of livestock farmers, was analysed and published (2). Researchers also utilised the PDS data to study the prevalence of PPR and FMD in the country. For instance, Zahur *et al.* (3) used the data to select and target 24 villages from across Pakistan, from where the PDS teams then reported 526 suspected outbreaks of PPR (affecting 8,321 goats and sheep) during the period from 2002 to 2005. Serum samples collected from sheep and goats in selected villages showed that 1,096 of 1,463 (74.9%) serum samples tested were positive for the presence of antibodies against PPR virus (at a time when the use of PPR vaccine was minimal in the country). Zahur *et al.* (4) also studied the pattern of FMD and PPR in the country based upon the PDS information (Figs 5 and 6) and recommended the regular use of PDS tools to study a range of animal diseases in the country.

It was an interesting observation that, in the beginning, most members of PDS teams were not very enthusiastic and only half-heartedly employed various PDS tools in the field. However, as the time passed, the participation and interest of livestock farmers during scheduled meetings had a positive impact and proved that these tools were very effective in collecting real information from the farmers about the prevalence and importance of TADs. The project managers also realised the hard work of the PDS teams that were working and staying in villages

FIG. 5

PREVALENCE OF FOOT AND MOUTH DISEASE IN PAKISTAN (PARTICIPATORY DISEASE SEARCH 2002–2005)

Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan.
The final status of Jammu and Kashmir has not yet been agreed upon by the parties
Source: Schajee, 2010 (5), modified to indicate the prevalence of FMD in Pakistan

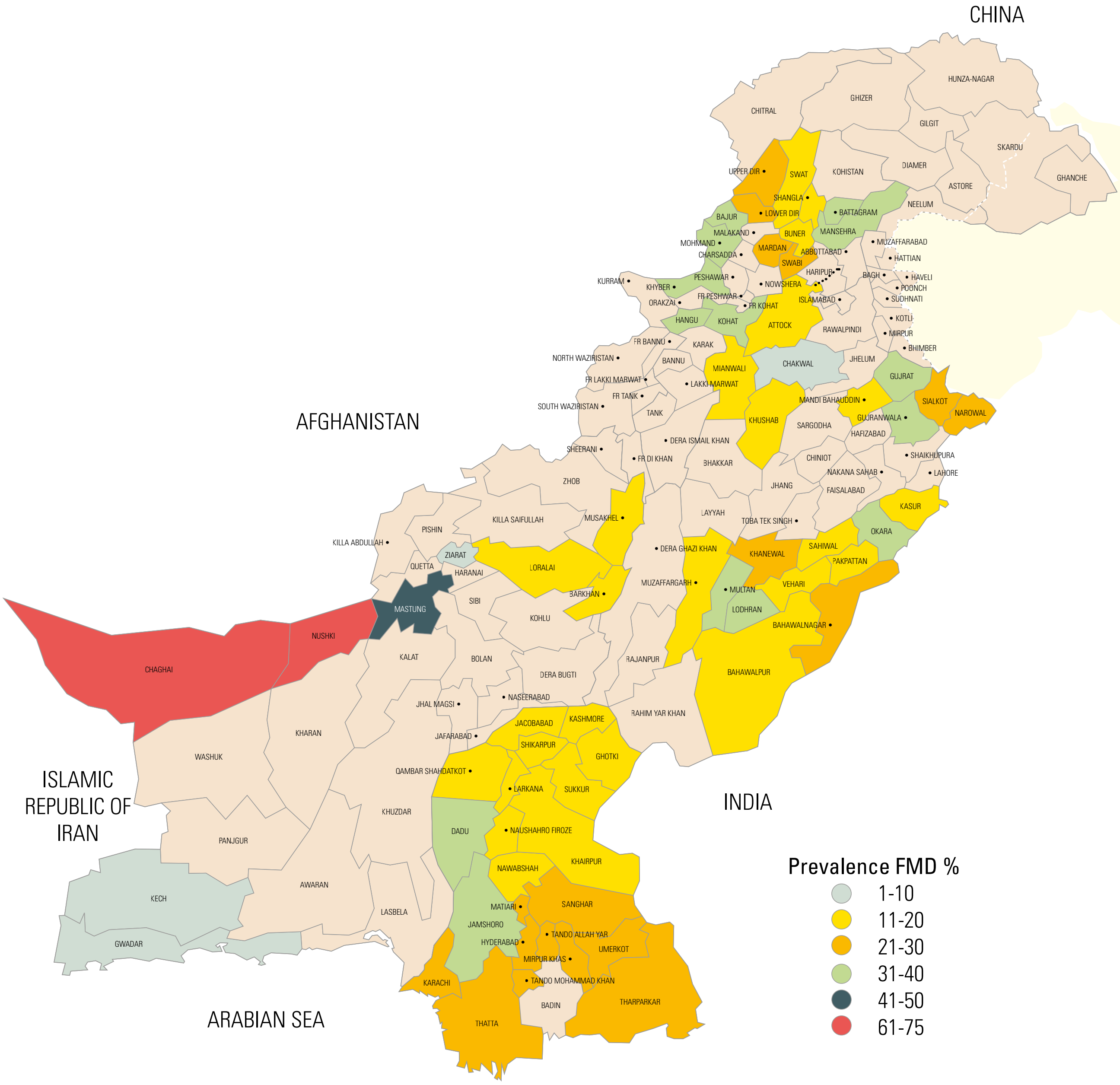


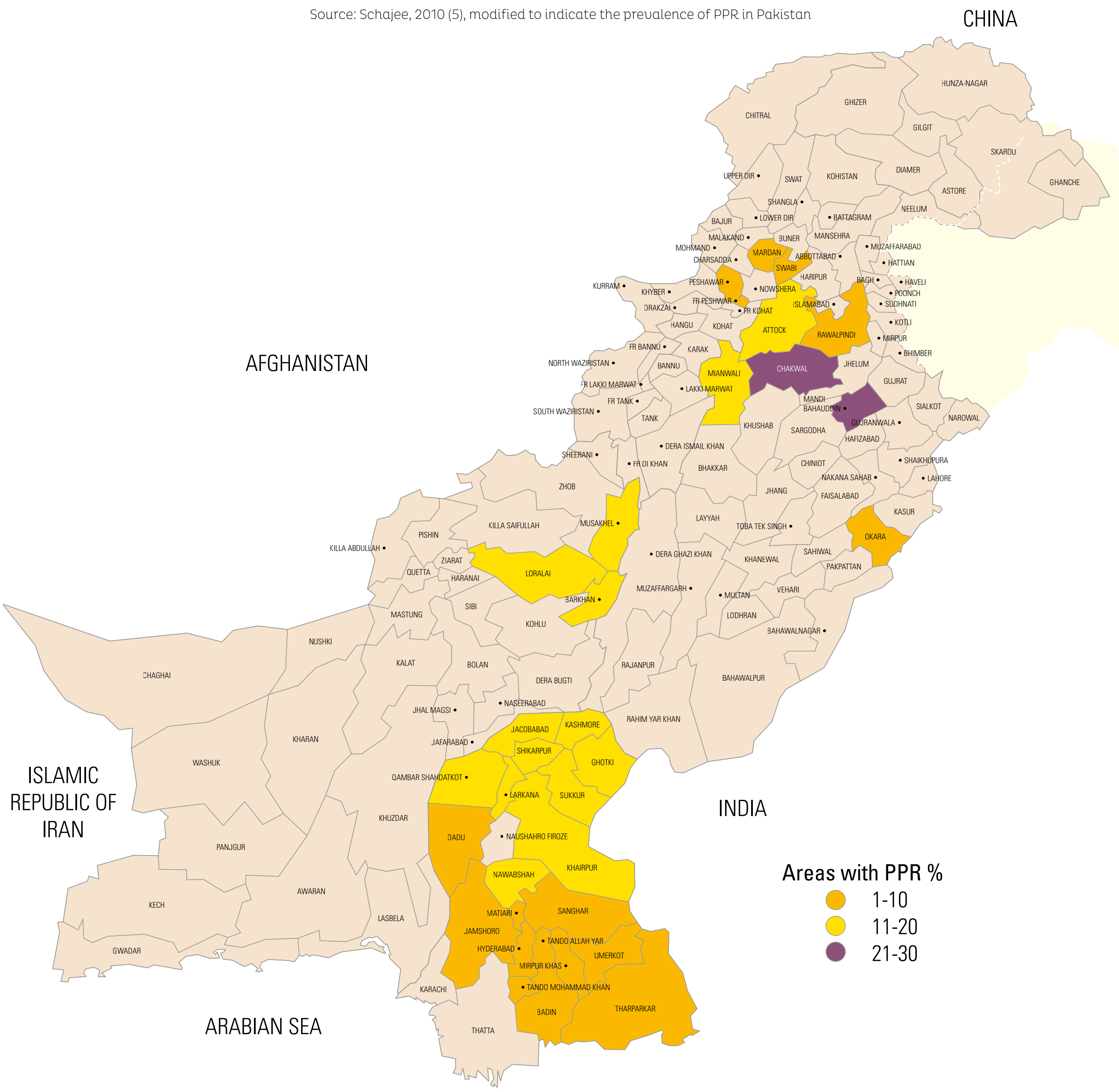
FIG. 6

PREVALENCE OF PESTE DES PETITS RUMINANTS IN PAKISTAN (PARTICIPATORY DISEASE SEARCH 2002–2005)

Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan.

The final status of Jammu and Kashmir has not yet been agreed upon by the parties

Source: Schajee, 2010 (5), modified to indicate the prevalence of PPR in Pakistan



while collecting data. To make their stay comfortable, every member of the PDS teams was paid US$26 (PKR 1,400) per day (for 7–14 days). This PDS activity quickly became so popular that many veterinary officers approached the management to become part of the PDS activity. Some of them did get a chance to work in additional PDS teams, but as the time was short they could not fully utilise their skills in this activity. Every three months, in the presence of senior veterinary officials, all the PDS teams were given the opportunity to present their data. This regular interaction and sharing of data created a friendly relationship among the PDS teams and they are still known as the 'PDS family' in the country.

Introducing the concept of PDS into the existing surveillance system was considered a milestone that yielded useful information about various aspects (prevalence and importance) of animal diseases and played a vital role in proving that rinderpest virus no longer existed in the country.

ACKNOWLEDGEMENTS

Participatory disease surveillance was supported by a trust fund project funded by the European Union and implemented by FAO, GCP/PAK/088-EC, 'Support for Emergency Prevention and Control of

Main Transboundary Diseases in Pakistan (rinderpest, foot and mouth disease and peste des petits ruminants)', and the EU project, 'Strengthening of Livestock Services Project'. The authors also acknowledge the assistance of Dr M. Abubakar (National Veterinary Laboratory, Islamabad) and Dr A. Mehmood (FAO-FMD Project, Islamabad) for providing photographs and improving the document.

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CHAPTER 3.9

COMMUNITY-BASED RINDERPEST CONTROL AND SURVEILLANCE IN SOUTH SUDAN

B.A. JONES [(1)*], A.A. AMERI [(2)], N.K. MOGGA [(3)], S.P. LETEREUWA [(4)] & T.J. LEYLAND [(5)]

(1) Department of Epidemiological Sciences, Animal and Plant Health Agency (APHA), APHA – Weybridge, Woodham Lane, New Haw, Addlestone, Surrey KT15 3NB, United Kingdom
(2) Directorate of Veterinary Services, Ministry of Livestock and Fisheries Industries, P.O. Box 126, Gudele, Juba, Republic of South Sudan
(3) Food and Agriculture Organization of the United Nations (FAO), UN House, Yei Road, Juba, Republic of South Sudan
(4) Department of Agriculture, Livestock, Veterinary and Fisheries, Samburu County Government, P.O. Box 3, 20600 Kenya
(5) Lifestock Inc. Ltd, Kohatu Streams, 315 Old School Road, RD 2, Nelson 7072, New Zealand – Aotearoa

*Corresponding author: bryony.jones@apha.gov.uk

SUMMARY

During the 1980s South Sudan experienced widespread outbreaks of rinderpest in the pastoralist and agropastoralist areas covering most of the country, threatening the food security of the conflict-affected people. A community-based animal health programme was set up by the United Nations Children's Fund (UNICEF) with the aim of improving household food security through the control of rinderpest and other major diseases. Between 1992 and 2000, major rinderpest vaccination campaigns using thermostable vaccine were conducted by community-based animal health workers (CAHWs), trained and supported by UNICEF and non-governmental organisations (NGOs). The incidence of rinderpest outbreaks decreased dramatically and the last confirmed outbreak was in Eastern Equatoria in 1998. The last vaccinations were carried out in 2002, and the surveillance system was strengthened to detect any subsequent outbreaks and demonstrate freedom from infection. During five years of surveillance, livestock keepers, CAHWs, animal health auxiliaries (AHAs) and veterinarians participated in outbreak reporting and investigation, clinical surveillance in cattle camps and markets, participatory disease surveillance, and two serological surveys to demonstrate the absence of infection. In 2007 the surveillance data were compiled for inclusion in Sudan's successful application to the World Organisation for Animal Health (OIE) for recognition of freedom from rinderpest infection. Key to the successful eradication of rinderpest from South Sudan were the network of CAHWs and AHAs that played an important role in vaccination and surveillance and that was the link between livestock keepers and veterinarians; the availability of thermostable vaccine allowing good coverage in remote areas; and the coordination of all partners in the programme including between United Nations agencies, NGOs and local administration, and between the northern and southern Sudan governments.

KEYWORDS

CAHWs – Community-based animal health workers – Disease eradication – Epidemiology – Participatory – Rinderpest – South Sudan – Surveillance – Vaccination.

INTRODUCTION

The Republic of South Sudan covers an area of about 650,000 km² and is bordered by the Sudan, Central African Republic, Democratic Republic of the Congo, Uganda, Kenya and Ethiopia. It has a variety of ecological zones ranging from the flat savannah and flood plains around the Nile and its tributaries to the rocky semi-arid region of the south-east to the rainforest of the hilly ironstone plateau of the west and south-west. The climate varies from extremely hot and dry in the dry season to hot and humid in the long rainy season when the low-lying areas are flooded. Every few years there are climatic extremes causing severe drought or floods.

The people of South Sudan are made up of many different ethnic groups. The two largest agropastoralist groups, keeping cattle, sheep, goats and chickens, are the Dinka and Nuer, who inhabit much of the Bahr el Ghazal, Lakes, Upper Nile and Jonglei regions (Figs 1–3). The major pastoralists include the Karamajong-related groups of Toposa, Jie, Nyangatom, Didinga, Buya and Murle in Eastern Equatoria and Jonglei regions. All of these groups have very strong livestock-based livelihoods and traditional cultures in which cattle are a source of food as milk, meat and sometimes blood, an indicator of status, an asset that can be stored or exchanged for cereals and other items and used as social capital to strengthen kinship ties through bride price and support in times of hardship. The husbandry systems of these groups are predominantly transhumant. In the sedentary mixed farming communities of western Bahr el Ghazal and Western Equatoria, which lie in tsetse-fly habitats, cattle-keeping is less commonly practised.

There was civil war between northern and southern Sudan during the periods 1956–1972 and 1983–2005: in the south millions of people were killed, displaced or became refugees, there was no development, infrastructure was destroyed, trade was disrupted, and administrative structures were minimal. Animal health services were very limited and livestock diseases, in particular rinderpest, were widespread. Early efforts to control rinderpest through mass vaccination were supported by Joint Programme 15 (see Chapter 4.1) in the mid-1960s and by the German Agency for Technical Cooperation in the 1970s, but rinderpest continued to cause outbreaks because vaccination coverage was low (1). When civil war restarted in 1983 large areas of the south were under rebel control (until the peace agreement in 2005) and responsibility for animal

FIG. 1
REGIONS IN FORMER SOUTHERN SUDAN (PRE-2005)

The various political groups used different administrative areas at different times. This paper uses the six regions that were used by the Operation Lifeline Sudan (OLS) southern sector for the period up to 2005. The Nile and its tributaries are shown in blue

Source: Jones, 2001 (4), modified courtesy of data from Unicef Operation Lifeline Sudan, and to comply with the United Nations, 2020. Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined

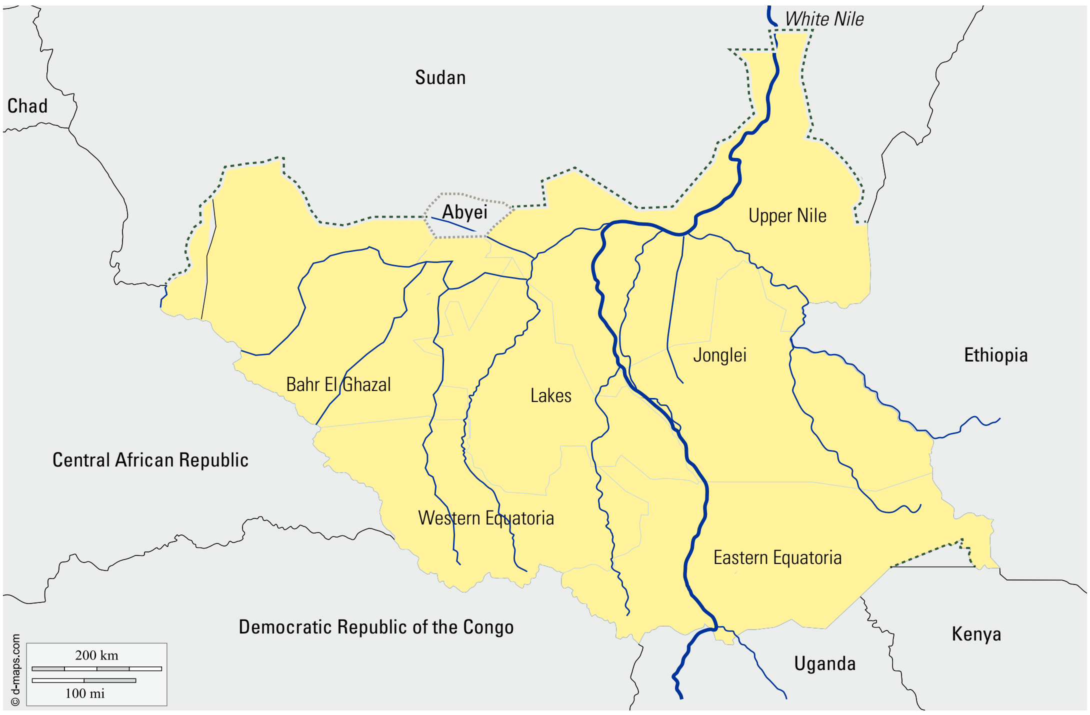


FIG. 2
COUNTIES AND STATES IN FORMER SOUTHERN SUDAN (PRE-2005)

The six regions were sub-divided into counties and, for parts of Jonglei and Upper Nile, states. The red circles indicate the approximate locations of the final confirmed rinderpest outbreak in Torit county in 1998 and the last suspected rinderpest outbreak in Pibor in 2001. The Nile and its tributaries are shown in blue

Source: Jones, 2001 (4), modified courtesy of data from Unicef Operation Lifeline Sudan and modified to comply with the United Nations, 2020. Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined

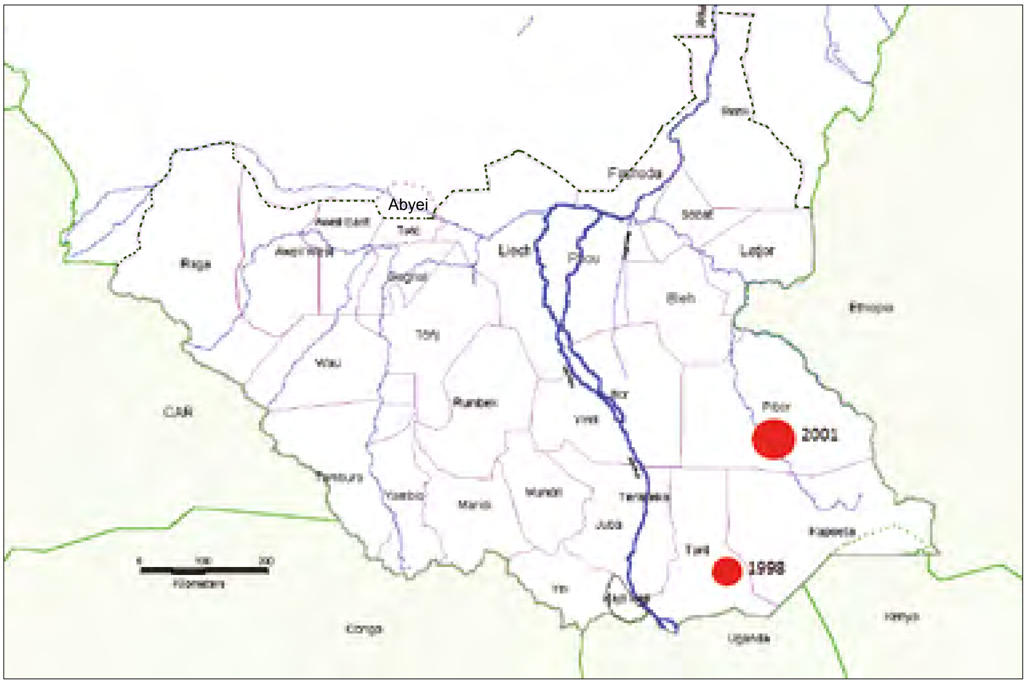
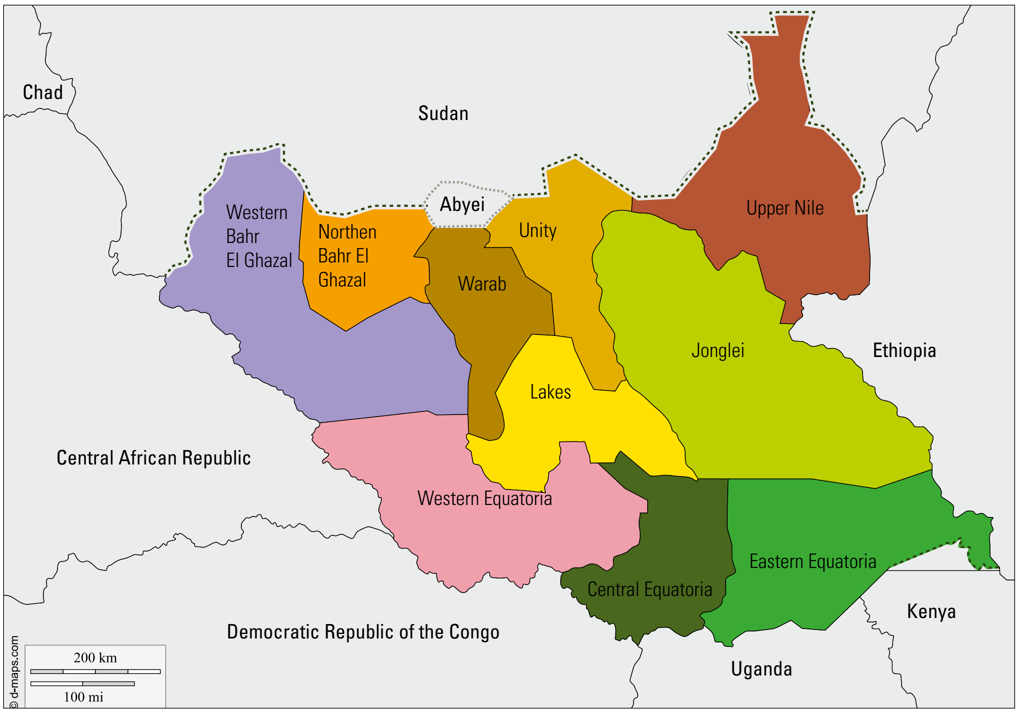


FIG. 3
STATES IN FORMER SOUTHERN SUDAN (2005)

When describing events from 2005 onwards, this report uses the ten states that were adopted by South Sudan

Source: Unicef Operation Lifeline Sudan, modified to comply with United Nations, 2020.

Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined



health lay with the humanitarian wing of the Sudan People's Liberation Movement (SPLM), the Sudan Relief and Rehabilitation Association (SRRA), while the government animal health system continued in the government-controlled areas but had limited access to rural areas (2). South Sudan became independent from the Republic of Sudan in 2011, after rinderpest was eliminated. In this article we therefore use the term southern Sudan.

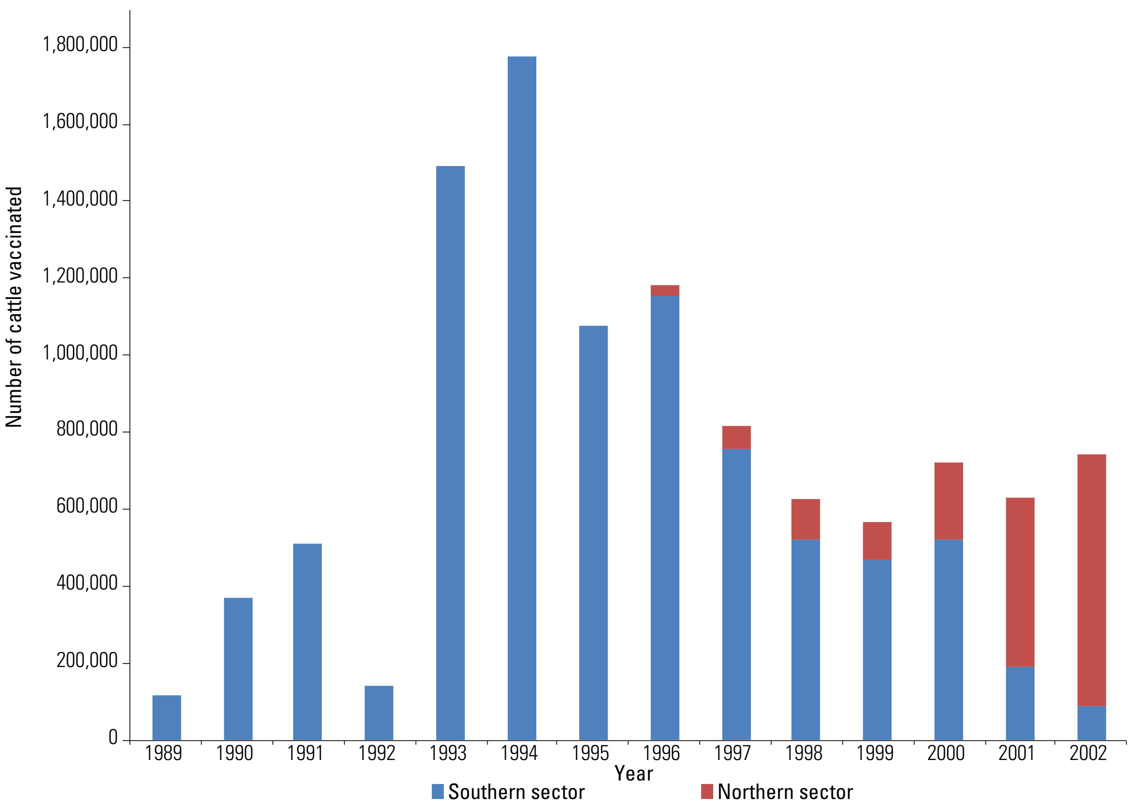
OPERATION LIFELINE SUDAN LIVESTOCK PROGRAMME: COMMUNITY-BASED ANIMAL HEALTH AND RINDERPEST CONTROL

In 1989, Operation Lifeline Sudan (OLS), a consortium of United Nations agencies and non-governmental organisations (NGOs) operating under a tripartite agreement between the Government of Sudan, the SPLM and the United Nations, started to provide humanitarian assistance to the war-affected communities of southern Sudan, including food relief, water, health, education and support for household food security. The OLS southern sector primarily operated in areas of southern Sudan under rebel control and accessed these areas by road and air from Kenya and Uganda. The OLS northern sector was based in Khartoum and worked in areas of southern Sudan under government control. The United Nations Children's Fund (UNICEF) coordinated OLS activities. UNICEF's core activities included health, education and water and sanitation, but it began to get involved in the vaccination of cattle against rinderpest after communities refused to have their children vaccinated until their cattle had been vaccinated, arguing that there was no point in the international community vaccinating children if those children were starving to death. Rinderpest outbreaks were widespread at the time and were having a significant impact on food security and child nutrition through the reduced availability of milk. UNICEF rinderpest vaccine was provided free of charge by 140 vaccinators who were trained, equipped and monitored by a UNICEF veterinarian (3). Between 1989 and 1992, an average of 280,750 cattle were vaccinated annually (Fig. 4).

FIG. 4
ANNUAL RINDERPEST VACCINATION FIGURES, 1989–2002

Some rinderpest vaccination was conducted by the Government of Sudan and ACCOMPLISH in the northern sector areas of Juba and Malakal prior to 1996 but these figures have not been obtained

Courtesy of the authors, based on data from Jones, 2001 (4) & Republic of Sudan, 2004 (5)



In 1993 the OLS community-based animal health programme was started by UNICEF with technical support from Tim Leyland (6). The goal of the OLS Livestock Programme was to improve household food security by strengthening livestock production. Consultation with livestock keepers revealed that the main constraint to livestock production was disease, and that, of the many diseases present, rinderpest was the most devastating (7). The OLS Livestock Programme objective became the control of rinderpest through the establishment of community-based animal health services. Livestock keepers were selected by their communities to be trained as community-based animal health workers (CAHWs). The two-week course covered disease diagnosis, vaccination and treatment of priority diseases using a training manual for community animal health workers in southern Sudan (UNICEF OLS, 1997, unpublished).

The OLS rinderpest control strategy was to provide three annual vaccinations to all cattle free of charge, and vaccinated animals were to be identified with a clover-leaf-shaped ear notch. The programme initially utilised a full cold chain and a heat-labile vaccine but switched to thermostable rinderpest vaccine as soon as it became available (8). The heat stability of the vaccine allowed it to be stored and transported without a cold chain for up to 30 days. Teams of CAHWs could travel for several days on foot to the grazing areas carrying vaccine and vaccination equipment in their backpacks, rather than having to rely on scarce vehicles that had difficulty moving in the wet season, or having to return daily to collect vaccines from the field fridges. This allowed much wider vaccination coverage (see Chapter 4.6).

The OLS northern sector livestock programme was based in Khartoum and led by UNICEF working together with the Pan-African Rinderpest Campaign (PARC; Chapter 4.2) Sudan and several local and international NGOs – ACCOMPLISH, Oxfam Great Britain (GB), Nile Milk Producers Cooperative Society and El Bir – to support community-based animal health services in government-controlled areas of southern Sudan. The southern sector livestock programme was led by UNICEF and involved up to 15 NGOs at different times, each covering different areas of the south: Agency for Co-operation and Research in Development (ACORD), Association of Christian Resource Organisations Serving Sudan (ACROSS), Adventist Development and Relief Association (ADRA), Diocese of Torit (DOT), German Agro-Action (GAA), Norwegian People's Aid (NPA), Oxfam GB, Oxfam Quebec, Save the Children United Kingdom of Great Britain and Northern Ireland, Vetaid, Vétérinaires Sans Frontières (VSF) Belgium, VSF Suisse, VSF Germany, Vetwork Services Trust and World Relief. Some were specialist livestock NGOs, others implemented livestock projects as part of multi-sectoral programmes, and some were southern Sudanese NGOs. UNICEF and the NGOs employed field veterinarians to provide training and technical support to the CAHWs, purchased and transported equipment and supplies, and provided incentives to the CAHWs. They worked closely with the humanitarian wings of the rebel groups and their chief veterinary coordinators (SRRA, Relief Association for South Sudan [RASS], Fashoda Relief and Rehabilitation Association [FRRA] and others), and the county or district veterinary coordinators. Many of the veterinary coordinators had been trained as veterinary assistants and had valuable field experience. They played an important role as leaders of the CAHWs, but as the numbers of CAHWs and the areas covered increased, the need for greater local supervision emerged. As a result, VSF Belgium was mandated by the livestock programme to set up the Southern Sudan Animal Health Auxiliary Training Institute to train animal health auxiliaries (AHAs; requiring four months' training) and stockpersons (requiring an additional five months' training) to fill the gaps.

The OLS Livestock Programme held regular livestock coordination meetings that were attended by the participating agencies and the veterinary coordinators, as well as visitors from PARC and other specialists. These meetings provided a forum to review achievements and constraints, share information and discuss future plans. Representatives from the northern sector livestock programme also attended the meetings, and southern sector representatives attended northern sector meetings in Khartoum. UNICEF handed over the livestock programme to FAO (Food and Agriculture Organization of the United Nations) when it joined the OLS southern sector in 2000. By 2001 there were approximately 1,400 active CAHWs, supervised by 180 AHAs, stockpersons and veterinary assistants, and supported by 35 veterinarians and livestock officers working for 12 NGOs and FAO.

As rinderpest vaccination coverage increased, there was demand from the communities for the control of other cattle, sheep, goat and poultry diseases, so vaccinations and treatments for a range of high priority diseases were provided by the CAHWs on a cost recovery basis (7). The annual rinderpest vaccination figures are shown in Figure 2. The highest coverage was in 1993–1994, when there were widespread rinderpest outbreaks and a high demand from livestock keepers for vaccination, but as the number of rinderpest outbreaks dropped, vaccination figures also dropped because of the reduced demand for vaccination, in spite of an increasing number of animal health workers and a wider geographical coverage. In 1996, in line with the programme policy of sustainability and cost recovery for services, a charge was introduced for rinderpest vaccination. In hindsight, because the vaccination strategy aimed to achieve high coverage, introducing a charge at this stage was counterproductive, as it further reduced demand from livestock keepers. It would have been better to provide the vaccine free of charge throughout the vaccination programme, especially in the later stages when the disease was reducing and livestock keepers were seeing less private benefit. Ear-notching was also not very popular with the livestock keepers because it interfered with their traditional identification system using ear cutting.

Blood samples were collected in a few areas to assess the efficacy of vaccination. Out of 1,126 sera from vaccinated cattle 79% were antibody positive, and the within-herd prevalence ranged from 56% to 91% (4). The samples were not randomly selected and the sample size was small, but these results give some indication that the rinderpest vaccination conducted by CAHWs was achieving adequate levels of immunity in the herds vaccinated.

In 1998, PARC provided funds for an additional UNICEF veterinarian to be the focal point for outbreak reporting and investigation, to stimulate reporting, improve investigation, especially sample collection for laboratory confirmation, and to ensure that all rumours of rinderpest and rinderpest-like disease were reported and followed up. Disease outbreak reporting and investigation guidelines were developed and disseminated to all field veterinarians and veterinary coordinators (9). Training was provided during the AHA and stockperson training courses, and sampling kits were distributed to all field bases. Suspected rinderpest outbreaks were reported by local veterinary personnel by high-frequency (HF) radio, by letter or face to face during coordination meetings, and were investigated by field veterinarians (HF radios were the main method of communication because there was no telephone network). Samples for laboratory diagnosis were submitted to the basic laboratory in Lokichokio, which forwarded samples for rinderpest antibody and antigen testing to the National Veterinary Research Centre at the Kenya Agricultural Research Institute, Muguga, Kenya, and to the World Rinderpest Reference Laboratory at Pirbright, United Kingdom.

After the widespread outbreaks of 1993 to 1995, there were fewer rinderpest reports and most of these were localised and unconfirmed. In early 1998, the Torit County Veterinary Coordinator, Quinto Asaye, reported an outbreak of rinderpest-like disease affecting young cattle in the Lopit hills of Eastern Equatoria (Fig. 2). Investigations by UNICEF, GAA and PARC found classic clinical signs of rinderpest in calves aged 6–12 months and a high case fatality. Samples submitted to Pirbright confirmed the cause to be rinderpest lineage 1 virus. A vaccination campaign to prevent spread was rapidly mounted to cover Lopit and neighbouring areas in Torit county, as well as Budi county to the east and Labone to the west, where suspected clinical cases were seen. PARC visited neighbouring areas of northern Uganda but found no evidence of clinical disease. The source of the Lopit outbreak was suspected to be some Toposa bulls from Riwoto, Kapoeta, that had been bartered for heifers. Rumours of disease in Toposa and Murle cattle were received, but investigations found no clinical disease, although the lack of security in the area prevented a full investigation. This outbreak would prove to be the last laboratory-confirmed rinderpest outbreak in southern Sudan, and the last confirmed lineage 1 rinderpest outbreak globally.

MOVING FROM RINDERPEST CONTROL TO ERADICATION

By late 2000 there had been no more confirmed rinderpest outbreaks, so experts in the Global Rinderpest Eradication Programme (GREP; Chapter 6.1) and the Pan-African Programme for the Control of Epizootics (PACE; Chapter 4.3) advised Sudan to end vaccination and introduce active surveillance. When this plan was presented to the southern sector livestock coordination meeting in November 2000, many field veterinarians and animal health workers felt that the plan was being imposed too quickly. They feared the resurgence of rinderpest outbreaks and wanted time to carry out final vaccination campaigns and conduct community dialogue to explain the change in strategy. Some areas such as the Sobat basin (Upper Nile), the Murle area (Jonglei) and parts of Eastern Equatoria had never been fully vaccinated because of poor security and access or lack of funds, and it was feared that these areas might be harbouring rinderpest virus. These fears were justified when in late 2000 and early 2001 rumours of rinderpest-like disease in white-eared kob and Jie cattle around Pibor in Jonglei region were received from several sources, followed in April 2001 by high mortality in Murle cattle around Gumuruk near to Pibor (Fig. 2). This area was allied to the government, so the outbreak was investigated by the OLS northern sector and the Federal Ministry of Animal Resources and Fisheries (FMARF). The clinical signs were indicative of rinderpest, but there was no laboratory confirmation. In spite of this lack of laboratory confirmation, a major rinderpest vaccination campaign was launched by northern sector, led by Jacob Korok, Pibor County Veterinary Officer, and the majority of the estimated 680,000 Murle cattle were vaccinated during 2001 and 2002.

In order to understand better the rinderpest situation in the poorly covered areas to the east of the Nile, the Community-based Animal Health and

Participatory Epidemiology (CAPE) Unit of PACE contracted Jeff Mariner to use participatory disease surveillance (PDS) methods in Murle, Jie, Toposa, Dinka, Anuak and Nuer areas in Jonglei and Upper Nile regions (10). The data collected were used to estimate the basic reproductive number (R0) for rinderpest in southern Sudan and to parameterise a mathematical model of rinderpest. While no evidence was found of current rinderpest disease, there was strong evidence of rinderpest-like disease events in the preceding two years. The most likely value of R0 was estimated to be 4.4, giving a herd immunity threshold of 77% (the proportion of immune animals in a herd that must be exceeded to stop virus transmission). As vaccine efficacy under field conditions was around 80%, 100% vaccination coverage was required to stop virus transmission. The model showed that lower levels of vaccination coverage could allow the virus to become endemic in a population. It was therefore recommended that targeted time-bound vaccination campaigns should be conducted only in high-risk areas where full coverage was feasible but that surveillance should be strengthened in all areas.

The strategy for the eradication of rinderpest from Sudan was discussed in various fora and was eventually finalised during a northern sector livestock coordination meeting in Khartoum in May 2001. With effect from January 2002, Sudan was divided into the following three zones based on the history of rinderpest outbreaks and perceived risk of rinderpest: the provisionally free zone (north Sudan and part of Bahr el Ghazal and Upper Nile), the surveillance zone (Equatoria west of the Nile, Lakes region and part of Bahr el Ghazal) and the infected zone (bounded by the Nile to the west and the Sobat river to the north) (Fig. 5). It was planned that all rinderpest vaccination would stop in December 2001 except in the infected zone, where it would stop by June 2002. A five-year period of surveillance would follow, with three years of reporting and investigation of suspected rinderpest outbreaks and active clinical surveillance, and with two serological surveys in the final two years (11).

As southern Sudan was probably the last focus of lineage 1 rinderpest, its progress towards rinderpest eradication was a high priority for PACE and GREP. Through cross-border movement of cattle for pasture and trade, it was a potential source of re-infection for neighbouring countries and could delay the progress of the region. The only other possible foci at this time were in southern Somalia (lineage 2) and Pakistan (lineage 3). The PACE programme contracted VSF Belgium to implement the 'Fight against lineage one virus' project in southern Sudan, which started in November 2001 for two years, but was later extended to April 2005. A two-year follow-on project, the Rinderpest Eradication Project for Southern Sudan, which aimed to complete the final eradication phase, started in June 2005, funded by the European Community Humanitarian Plus Programme II. VSF Belgium used some of its own funds to keep the project going in the six-week gap between the two projects. In order to complete all the final surveillance activities, appeals for additional funds had to be made and, thankfully, several agencies and projects were able to contribute funds to meet the shortfall.

PARTICIPATION IN RINDERPEST ERADICATION

The main reason for the successful control of rinderpest up to 2001 was the application of the community-based approach, involving livestock keepers and community leaders in the identification of priorities, planning and decision-making, and in training community members as CAHWs and veterinary coordinators. The OLS Livestock Programme had successfully coordinated the activities of the NGOs and southern Sudan authorities around common objectives, and it had standardised core elements while encouraging innovation and adaptation to local needs. For the success of the final stage of rinderpest eradication it was very important for all these southern Sudan stakeholders to continue to participate.

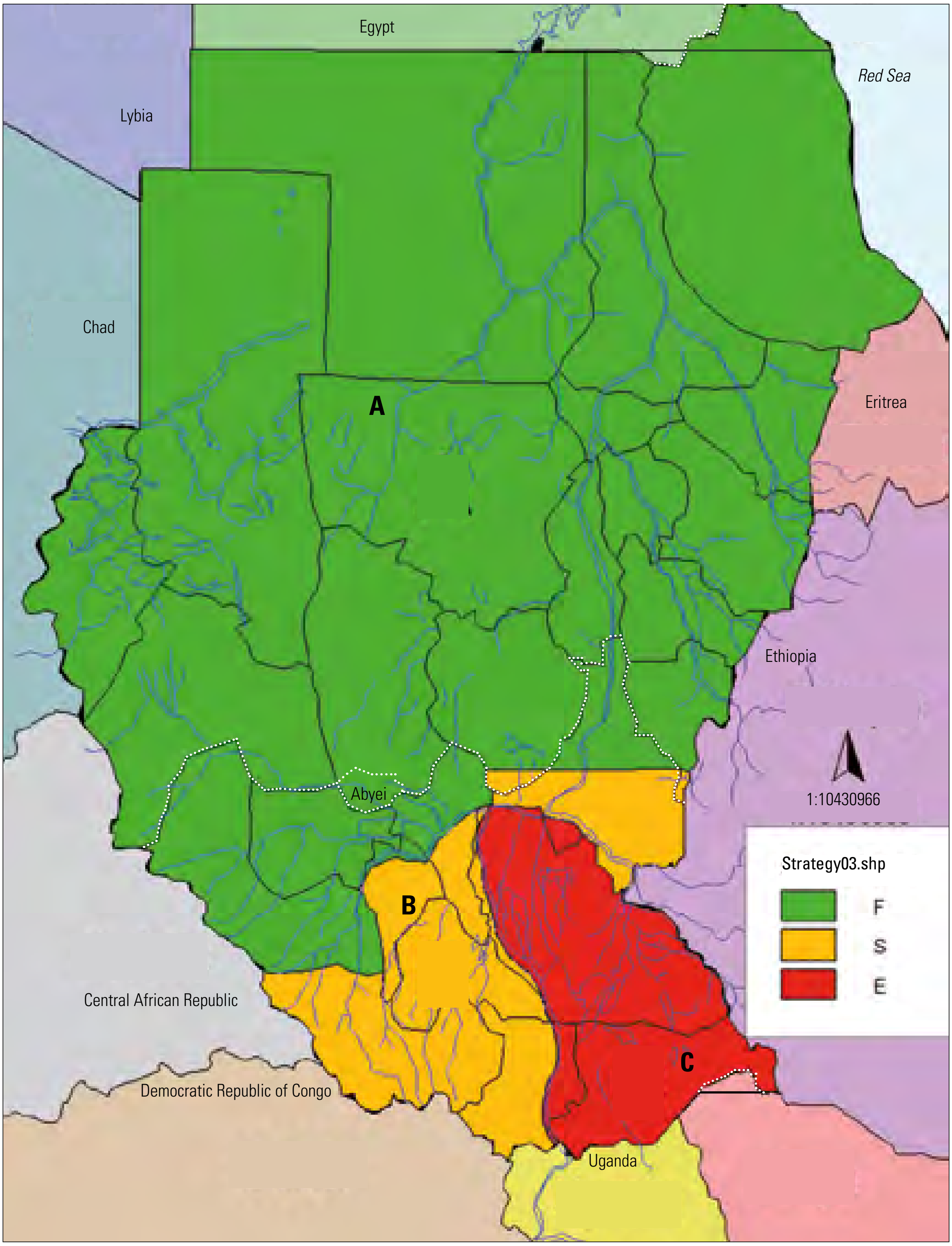
Once the Sudan rinderpest eradication strategy had been finalised, it became urgent for the strategy to be introduced to all stakeholders, to allow NGOs and veterinary coordinators time to spread information about the new plans and to carry out final vaccination campaigns where needed. However, the PACE southern Sudan project had not yet started, so the CAPE Unit stepped in to fund a six-month project (July–December 2001) for the development of training courses and communication materials that became the foundation for the final phase of eradication.

Rinderpest eradication strategy workshops were held in Nairobi and Lokichokio to explain the strategy and make detailed plans for field implementation. An important session focused on ending vaccination, because it was important for people to understand that this was necessary in order to progress to eradication. Participants expressed their concerns, the most important being the fear of resurgence of rinderpest outbreaks. The livestock programme was taking a huge risk on behalf of a very vulnerable community. An outbreak would have a serious impact on food security and livelihoods, as well as causing a loss of trust between the communities and the livestock programme. The impact of an outbreak, if it occurred, could be minimised by promoting community awareness of the importance of early reporting of suspected cases

FIG. 5
ZONATION OF SUDAN FOR THE RINDERPEST ERADICATION PROGRAMME, 2002

Zone A – provisionally free; zone B – surveillance; zone C – infected

Source: Republic of Sudan, 2004 (5), modified to comply with United Nations, 2020. Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined



and of timely investigation and confirmation, which would lead to rapid disease control. This meant that animal health workers at all levels needed to know what action to take and to have the necessary resources to respond, and a practical contingency plan and easily-mobilised contingency stocks and funds were essential.

A lot of effort was put into developing ways to explain to livestock keepers why rinderpest vaccination was being stopped. Since the beginning of the OLS Livestock Programme it had promoted regular rinderpest vaccination and, in general, livestock keepers were happy to have their cattle vaccinated because the vaccine had been effective. While demand for vaccination had reduced in the absence of outbreaks, livestock keepers wanted the vaccine to be easily available in case there was rinderpest in the future. They were used to experiencing outbreaks every five to ten years so they were expecting an outbreak at any time. It was anticipated that the livestock keepers would not be happy with the sudden change in strategy, and this might affect their participation in rinderpest surveillance. In order to pass the information to all communities, all the animal health workers and field veterinarians needed to be involved, and the challenge was to develop ways for them to be confident in explaining the new strategy to communities, addressing their fears and concerns, and getting their commitment to report any possible cases of rinderpest (12). In March 2001, a workshop was organised in Tonj county, a Dinka area, to develop locally appropriate community awareness-raising methods for the rinderpest eradication strategy. Veterinarians and animal health workers were brought together with community members to develop ways to pass the information to the local community. Previous work on rinderpest communications had been carried out by PARC (13, 14), and elements of this were incorporated into the workshop programme: developing the messages to be communicated, defining the target audience, identifying the best methods of communication, designing communication materials (pictures, songs, poems, stories and plays), and field-testing and revising materials. Performances of songs, poems and plays were filmed, and video and audio cassettes of these were distributed to animal health workers. The Dinka songs stimulated animal health workers and community members in other areas to record their own songs in their own language, and these were later compiled on a second audio cassette for distribution. The pictures were developed into posters, and PARC cloth flip charts depicting a story of a rinderpest outbreak were adapted to be suitable for the southern Sudanese audience. There was a huge demand from animal health workers for rinderpest t-shirts so they were invited to submit designs and two were chosen: a picture of a young cow with clinical signs of rinderpest and the slogan 'eradicate rinderpest – report sick cattle'; and a picture of a healthy cow being milked and a healthy baby drinking milk with the slogan 'no rinderpest, more milk!'.

All the materials were disseminated to all animal health workers and veterinarians. They were used extensively in community dialogue meetings and CAHW and AHA training courses. Guidelines for conducting community dialogue about rinderpest eradication were developed for NGOs and veterinary coordinators to use during community meetings to explain the goal of eradicating rinderpest from Sudan and the important role of the community in monitoring its cattle for signs of rinderpest and ensuring that any suspected rinderpest was reported quickly. The use of pictures and songs made community meetings less formal and more interesting, attracting all members of the community, including women and children, so that the information reached a wider audience.

A CAHW training module was developed to be incorporated into CAHW training courses and refresher courses. The CAHWs lived and worked within the community and were the frontline of the animal health services, providing basic treatments and vaccinations, and they were the first to receive outbreak reports. They were trained to conduct a basic investigation and pass the information to their veterinary supervisor. They were also key members of active surveillance teams who were liaisons between the livestock keepers and the veterinarians, providing local knowledge on cattle movements, as well as assisting with the surveillance.

A rinderpest eradication training course for veterinarians and animal health workers was developed and conducted in all areas, starting in the higher risk infected zone and eastern surveillance zone to strengthen outbreak reporting and investigation and surveillance. The ten-day training course covered the principles of rinderpest eradication, ending rinderpest vaccination, outbreak investigation, outbreak control, surveillance and contingency planning, as well as raising awareness of CAHWs and livestock keepers (15). To strengthen the surveillance system, training was also provided to specific personnel in PDS, clinical and laboratory diagnosis of rinderpest, disease reporting, laboratory skills and serosurveillance.

A major challenge was ensuring the complete coverage of southern Sudan for disease surveillance and emergency response. Owing to limited funds, difficult access or poor security, there were significant gaps in community-based animal health service coverage, some of them in areas that were considered to be at higher risk of rinderpest. The Rinderpest Eradication Project provided strategic support to the most important gap areas, including field visits for outbreak investigations and active surveillance, advice and support to veterinary coordinators, conducting community dialogue and CAHW training, provision of equipment, and sponsoring candidates for AHA training. For insecure areas, opportunistic visits were made whenever possible to assess the situation and conduct surveillance.

DEVELOPING A RINDERPEST SURVEILLANCE SYSTEM

The aims of the rinderpest surveillance system were to be able to detect any remaining foci of rinderpest, to provide evidence of freedom from disease and infection if rinderpest was no longer present and to meet the requirements of the OIE for recognition of freedom from rinderpest disease and infection. In the absence of a conventional veterinary service structure, VSF Belgium's approach was to take the surveillance methods recommended by the OIE, GREP and PACE and adapt them for use in pastoralist communities by using the existing network of CAHWs and AHAs with intermittent support from veterinarians. Rinderpest surveillance activities were integrated into the community-based animal health system by collaborating with and encouraging the participation of the other NGOs, strengthening the network of animal health workers, and providing the training required for all levels of stakeholders to be able to fulfil their roles. A variety of surveillance methods were used that, when combined together, would meet the objectives of the system by ensuring the detection of a high proportion of stomatitis–enteritis events and the early detection of rinderpest if it were still present and that would cover the whole of the southern sector, including the more remote and inaccessible areas. The surveillance methods used were: outbreak reporting and investigation, clinical surveillance in cattle camps and markets, monthly disease reporting, PDS, wildlife surveillance and randomised serosurveillance (11).

Disease outbreak reporting

All stakeholders were encouraged to report disease outbreaks, especially rinderpest-like disease outbreaks, and CAHWs, AHAs and veterinarians were trained to carry out investigations and sample collection. In 2002 and 2003 there were approximately 100 reports of disease outbreaks per year out of which approximately 20 were reports of rinderpest-like disease. The number of reports of rinderpest-like disease decreased from ten in 2004 to only two in 2006 and there were none in 2007. On investigation, none of the rinderpest-like disease reports indicated an outbreak of rinderpest; some were confirmed clinically or by laboratory diagnosis as outbreaks of other diseases, and some reports were found to be individual cases of rinderpest-like disease that were rinderpest negative in the laboratory and did not spread to other cattle. To encourage rinderpest outbreak reporting, the project offered a US$500 reward (later increased to US$1,000) to be shared among the key people involved in the reporting and investigation of the first confirmed case in a rinderpest outbreak. Although there was no confirmed case of rinderpest during the project, to maintain interest and encourage reporting the reward was paid retrospectively in 2003 to the personnel involved in the reporting and investigation of the 1998 rinderpest outbreak in Torit, and in 2004 a reward was paid to the personnel involved in the reporting and investigation of a rinderpest report in Unity State that was confirmed in the laboratory as malignant catarrhal fever.

Clinical surveillance

Randomised clinical surveillance was recommended by GREP, but prior to the 2005 peace agreement randomised surveys were too difficult and costly to carry out because of incomplete access and limited capacity. Therefore, a method was developed for regular surveillance visits to cattle camps and livestock markets by AHAs. Between May 2002 and June 2004, 3,756 cattle camps were visited and 2.7 million cattle out of an estimated population of 7.5 million were observed for clinical signs. From May 2002 to December 2006, 1,603 market surveillance visits were conducted in most of the approximately 100 livestock markets in southern Sudan. During both cattle camp and market surveillance visits rinderpest was rarely mentioned as a current problem and reports of rinderpest in the previous two to three years could usually be correlated with known outbreak reports of rinderpest-like disease or other diseases. No clinical cases of rinderpest were found, although a range of other common diseases were observed.

Participatory disease surveillance

Starting in 2003, PDS was used for purposive rinderpest clinical surveillance. Areas that were perceived to be high-risk areas for rinderpest were targeted with the objectives of determining whether rinderpest was circulating in the area and when the last rinderpest case was seen. A variety of participatory appraisal methods were used, including semi-structured group interviews and participatory mapping and timelines, together with observation of herds for clinical signs of rinderpest and investigation of any suspected rinderpest cases using pen-side tests (16) and by collecting samples for laboratory diagnosis. Between 2003 and 2007, PDS was carried out in 35 high-risk areas across all ten states, and no evidence of current rinderpest circulation was detected (see also Chapter 4.5.19).

Wildlife surveillance

Wildlife surveillance was carried out in February and March 2004 in Boma National Park, Jonglei region, by the SPLM Directorates of Livestock and Fisheries, and Wildlife, VSF Belgium, VSF Germany, PACE Epidemiology Unit and New Sudan Wildlife Conservation Organisation, assisted by the park warden, park rangers and animal health workers. This area was targeted because it was one of the few wildlife high-density areas in the country and was one of the places from which several rumours of rinderpest in cattle and wildlife had been received in the past few years, in particular the suspected rinderpest outbreak in the Pibor area in 2000 and 2001. A large population of approximately 200,000 white-eared kob, which are susceptible to rinderpest, have an annual migration in this area, and several other rinderpest-susceptible wildlife species were known to be present. For security reasons, it was not possible to use aircraft to locate and drive the animals, so capture nets were set up and vehicles were used to locate and drive herds of kob into the nets. Forty-three blood samples were collected from white-eared kob at three locations. One buffalo and one roan antelope were darted and sampled, and samples were collected opportunistically from two buffaloes and an eland that had been hunted and killed by the local Murlei livestock keepers. All samples were negative for rinderpest antibody.

Serological surveys

As required by the OIE Rinderpest Pathway, two serological surveys one year apart were carried out to verify the absence of rinderpest virus circulation. In 2003, Sudan was re-zoned into zone A (provisionally free) and zone B (surveillance) (Fig. 6), so these zones were defined as two strata for sero-surveillance and two annual surveys were planned for each zone: zone A, January to June 2005 and January to June 2006, and zone B, September 2005 to June 2006 and September 2006 to June 2007. Zone A included parts of southern Sudan: northern areas of Western and Northern Bahr el Ghazal, Warrap, Unity and Upper Nile states, while the rest of the south made up zone B. Blood samples were collected from cattle aged two to three years (based on their dentition) to ensure that they had been born after the end of the vaccination programme but were old enough for any maternally derived immunity to have waned. In each survey in each zone it was planned that 314 herds would be sampled based on the probability of detecting at least one positive herd with a confidence of 95% if the expected herd prevalence was 1%. Based on the estimated cattle population in each state, the 314 herds per zone were divided proportionally by state. It was planned that in each randomly selected herd, 20 cattle aged two to three years would be randomly selected and sampled in order to detect at least one antibody-positive animal with a confidence of 95% based on an expected antibody prevalence of at least 20% in an infected herd and a test sensitivity of at least 70%, and five additional samples would be collected per herd to allow for any post-sampling problems. The primary sampling unit for northern Sudan was the village, while for southern Sudan it was the cattle camp in the pastoralist areas and the village in sedentary mixed farming areas. A list of primary sampling units in each state was drawn up to make the sampling frame from which the required number of primary sampling units was randomly selected.

Out of the 314 herds to be sampled in zone A, 40 herds were sampled from southern Sudan. During the first survey, 528 samples were collected and tested from the southern sector and all were rinderpest antibody negative, but out of 420 samples collected from the northern sector, five from Western Bahr el Ghazal were positive. Follow-up investigations indicated that the age determination had been done incorrectly and four of these animals might have been vaccinated in 2001: 22 blood samples collected from two- to three-year old animals from the same villages were all rinderpest antibody negative. The second survey included 44 herds in southern Sudan: 1,104 serum samples were collected of which 1,090 (98.7%) were suitable for testing and all were rinderpest antibody negative.

During the first survey in zone B, 8,040 serum samples were collected from 324 herds of which 7,894 (98.2%) were suitable for testing. Four sera were positive, one each from Eastern Equatoria, Unity, Warrap and Jonglei states. Follow-up investigations were conducted for three of the positive animals, and there was no clinical or serological suspicion of rinderpest infection in any of the herds. In the second survey, 7,943 samples were collected from 324 herds of which 7,782 were suitable for testing (98.0%). There were four rinderpest antibody-positive animals, one each from Warrap, Lakes, Jonglei and Unity states. No clinical or serological evidence of current or recent rinderpest infection was found during follow-up investigations.

FREEDOM FROM RINDERPEST

In October 2004, Sudan submitted an application to the OIE for recognition of freedom from rinderpest disease on a zonal basis (zone A), which was accepted in May 2005 by the OIE. In August 2005 an application was made for recognition of freedom from rinderpest disease countrywide, which was accepted in May 2006. Finally, in August 2007 Sudan submitted an application to the OIE for recognition of freedom from rinderpest infection, which was accepted in May 2008. Surveillance data generated from southern Sudan

FIG. 6
ZONATION OF SUDAN FOR THE RINDERPEST ERADICATION PROGRAMME, 2003

Zone A – provisionally free; zone B – surveillance

Source: Republic of Sudan, 2007 (17), modified to comply with United Nations, 2020. Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined

were an important component of these applications (see Chapter 4.5.19).

REFLECTIONS

Although the aim of the vaccination programme up to 2001 was to achieve full vaccination coverage, even in the best year the proportion of cattle vaccinated reached only 31% and this proportion had reduced to 10% by 2000. However high local coverage was achieved in areas where the virus was currently or recently present. Southern Sudan is composed of many cattle subpopulations with varying contact rates between them. It is likely that rinderpest was maintained by epidemics circulating between the subpopulations; hence, by achieving high levels of immunity through vaccination in key subpopulations, transmission was interrupted. By the late 1990s the virus was apparently restricted to the subpopulations in Eastern Equatoria and Jonglei regions, as indicated by the outbreak in 1998 and the suspected outbreak in 2000 and 2001. The major vaccination campaign in the large pastoralist Murle population, conducted by FMARF and the OLS northern sector in 2001, together with vaccination in neighbouring areas by the OLS southern sector probably resulted in the end of virus circulation in this area and the final eradication of rinderpest from southern Sudan. In retrospect it can be seen that rinderpest was eradicated from southern Sudan by targeted vaccination in key subpopulations rather than through the mass vaccination of the whole population.

The network of CAHWs and veterinary coordinators played very important roles in rinderpest control and surveillance. Through their regular contact with the livestock keepers they were key to the identification of any last foci of rinderpest and the detection of rinderpest-like disease events. Surveillance teams were accepted more readily by the livestock keepers when they recognised their own animal health workers in the team. Rinderpest was only one of many important diseases that affected southern Sudanese livestock, and its importance to the livestock keepers reduced year by year because there were no longer any outbreaks, while other diseases were still causing major mortality and morbidity. It was very important that the basic animal health services were maintained in order to provide vaccinations and treatments for the diseases that were of highest priority for the livestock keepers, otherwise they could not be expected to participate fully in rinderpest surveillance. As much as possible the rinderpest field work was carried out through the community-based animal health projects, either by the CAHWs and veterinary coordinators themselves or in collaboration with them and their supporting NGOs, rather than by setting up a vertical disease-specific system. However, the VSF Belgium Rinderpest Eradication Project provided dedicated personnel with earmarked resources whose responsibility was the eradication of rinderpest so that, even when wider priorities changed or emergencies occurred, the essential activities of the eradication programme were not interrupted.

The combination of locally appropriate surveillance methods, implemented by CAHWs, AHAs and field veterinarians and coordinated by the Rinderpest Eradication Project veterinarians, was an effective surveillance system for pastoralist production systems within a difficult environment, and it was sufficiently sensitive and specific to detect rinderpest-like disease events and demonstrate the absence of rinderpest infection.

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CHAPTER 3.10

RINDERPEST SERO-MONITORING FOLLOWING VACCINATION

K. TOUNKARA [(1)*], F. NJEUMI [(2)], D. SYLLA [(3)] & M. LELENTA [(4)]

(1) OIE Regional Representation for Africa, Parc de Sotuba, Boîte postale 2954, Bamako, Mali
(2) Food and Agriculture Organization of the United Nations (FAO), Viale delle terme di Caracalla, 00153 Rome, Italy
(3) C/O Central Veterinary Laboratory, P.O. Box 2295, Bamako, Mali
(4) International Atomic Energy Agency Laboratories A-2444 Seibersdorf, Austria

*Corresponding author: k.tounkara@oie.int

SUMMARY **The antibody response of cattle to rinderpest vaccination was used to monitor the progress of the rinderpest eradication campaign in Africa, the Middle East and South Asia. It was used extensively and effectively to direct policy under the Pan-African Rinderpest Campaign (PARC), but less so in other regions.**

Twenty-one countries in Africa participated under PARC within the framework of a programme entitled 'Seromonitoring of Rinderpest throughout Africa'. This was coordinated by the Joint Food and Agriculture Organization of the United Nations (FAO)/International Atomic Energy Agency (IAEA) Division of the Nuclear Techniques in Food and Agriculture, Vienna, Austria. The epidemiology section within the PARC coordination unit was charged with developing an initial strategy for combating the virus. The strategy was to achieve a high level of herd immunity. This was assumed to be 80% by the Veterinary Services in Africa. The results of seromonitoring at the national level showed that the targeted seroconversion rate (at least 80%) for herd protection from rinderpest was not achieved in African countries. The lowest overall seroconversion obtained between 1989 and 1993 was 40.8% and the highest rate was 79.7%. The seroconversion rate within the analysed four age groups (less than one year, one to two years, two to three years and older than three years) varied significantly between countries. The highest rate was obtained within the age group of older than three years, with 88.1% being the highest recorded seroconversion rate. But when the immunity rate was assessed at the herd level, it was close to the target 80%.

The overall conclusion was that, while early modelling work had assumed that an 80% immunity rate was required in the national herd to eradicate rinderpest, the reality was that rinderpest was eradicated in many countries with significantly lower immunity rates. It was noticed that, in dense cattle populations (e.g. Egypt, Iraq and Turkey), high vaccination rates leading to high immunity rates were often achieved, but at the country-wide level, it was low. In these dense populations, eradication of rinderpest was attributed to vaccination. The immunity rate also varies according to the rinderpest lineage in the specific area.

KEYWORDS **Eradication – Rinderpest – Seroconversion – Seromonitoring vaccination.**

INTRODUCTION

The global eradication of rinderpest was achieved following the implementation of regional eradication programmes, as described in several chapters: 4.1–4.4, 4.5.1–4.5.22, 4.7–4.10, 4.11.1–4.11.12.

This chapter, using data generated through these regional programmes or individual countries, analyses the contribution of seromonitoring to the eradication of rinderpest.

Whereas earlier seromonitoring in the countries of the Middle East had been undertaken on an *ad hoc* basis, which was also the case in India, in Africa it was undertaken in a highly organised manner in conjunction with the implementation of PARC and the Pan-African Programme for the Control of Epizootics (PACE).

The monitoring of vaccination was undertaken by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture within the framework of a programme entitled 'Seromonitoring of Rinderpest throughout Africa', as part of their involvement in PARC. Its overall objective was to provide national and international eradication programme coordinators with information on the progress of the mass vaccination campaign. Specifically, it aimed to demonstrate that populations and subpopulations of cattle were protected from rinderpest and were incapable of maintaining the virus.

The seromonitoring coordinated research programme in Africa was implemented in two phases: phase I (1989–1990) and phase II (1991–1993).

THE SEROMONITORING PROGRAMME IN AFRICA

Twenty-one national laboratories in Africa participated in the seromonitoring programme, as part of their involvement in PARC. The countries involved were the following: Burkina Faso, Cameroon, Central African Republic, Chad, Côte d'Ivoire, Egypt, Ethiopia, Gambia, Ghana, Kenya, Mali, Mauritania, the Niger, Nigeria, Senegal, Sudan, United Republic of Tanzania and Uganda. The sampling protocol for each of the countries involved in the programme was designed using the manual *Guidelines for sero-monitoring of cattle conducted by PARC*, produced by the Joint FAO/IAEA Division and Organization of African Unity (OAU) Interafrican Bureau for Animal Resources (IBAR)/PARC (1). Samples of serum were recommended to be collected no earlier than three weeks after vaccination. The sampling unit was the herd. At each site, it was recommended to collect randomly 40 serum samples from four age groups: under one year, between one and two years, between two and three years, and over three years.

Epidemiological support was provided by the PARC Coordination Unit within OAU-IBAR to the PARC seromonitoring network and individual countries outside Africa, ensuring that acceptable sampling protocols were undertaken in participating countries (2). On average, countries tested around 5,000 samples in each seromonitoring study. Two serological tests were used in the programme, the indirect enzyme-linked immunosorbent assay (ELISA) (i-ELISA; see Chapter 6.3) during phase I of the PARC programme and the competitive ELISA (c-ELISA; see Chapters 3.3 and 6.3) during phase II. The c-ELISA had better sensitivity and specificity and was particularly valuable as PARC transitioned towards the phase of cessation of vaccination, with individual countries seeking declaration of freedom from the virus. The i-ELISA and c-ELISA kits were supplied to all participating countries by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, ensuring a uniformity of approach throughout PARC countries (see Chapter 6.3). In addition, a proficiency test programme within a quality assurance programme was implemented to provide both the testing laboratories and outside interested bodies with firm evidence that the results being produced were reliable.

The prevalence of antibody to rinderpest virus was estimated for each age group in the herd by dividing the number of sera that tested positive by the total number of sera tested in the herd (guidelines, 4, 5 and 6).

To assist with interpretation, it was decided to indicate in broad terms:

a) the level at which the prevalence of antibody in the herd was considered to be protective for the herd;
b) the proportion of protected herds considered necessary to confer protection on the cattle population of the country.

The actual value of the contact rate and basic reproductive rate (R0) (which is in part dependent on contact rate) was unknown. The 80% threshold was just the conventional veterinary wisdom available in textbooks at that time, which was taken over by the rinderpest programme. This was used to investigate the progress of an epidemic within herds of different sizes, immunity ages, sex structures and reproductive rates, and it was concluded that the prevalence of antibody in the herd needed to be at least 80% to break the transmission cycle (3). It is important to note that, at the commencement of the seromonitoring programme, the eradication of rinderpest through PARC was believed to be contingent upon achieving this degree of vaccine coverage.

Technical support was provided to the seromonitoring programme by Dr J. Anderson of the Pirbright Laboratories, Institute of Animal Health, United Kingdom of Great Britain and Northern Ireland, and Dr G. Libeau of the Institut d'Élevage et de Médicine Vétérinaire des Pays Tropicaux, Maisons Alfort, France.

SEROCONVERSION RATES IN PARTICIPATING AFRICAN COUNTRIES

The serological test used during phase I (1989, 1990) of the seromonitoring programme was the rinderpest i-ELISA test. The results obtained in participating countries (Table I) were presented at the annual research coordination meetings in Nairobi (Kenya) for seromonitoring activities carried out in 1989 and in Bingerville (Côte d'Ivoire) for activities carried out in 1990 (4).

The table indicates that the overall country seroconversion rate varied from 40.8% in Nigeria to 79.7% in Côte d'Ivoire.

The seroconversion rate according to the four age categories (less than one year, one to two years, two to three years and older than three years) showed large variation from one country to another. In general, the highest rate was obtained within the age category of older than three years, with the highest seroconversion rate of 88.1% being obtained in Côte d'Ivoire.

The serological test used during phase II (1991–1993) of the seromonitoring programme was the monoclonal based c-ELISA (5, 6). The results obtained in participating countries (Table II and Table III) were presented respectively at the annual research coordination meetings in Entebbe (Uganda) for seromonitoring activities carried out in 1991 and 1992 and in Cairo (Egypt) for activities carried out in 1993 (6).

Unlike the i-ELISA and the virus neutralisation test (VNT), the c-ELISA detects only antibodies to rinderpest virus and gives no cross-reactivity with antibodies to peste des petits ruminants (PPR) virus (4).

RECOMMENDATIONS MADE BY THE COORDINATION COMMITTEE DURING PARC

It was noted, at the coordination meeting held in Bingerville (Côte d'Ivoire) to discuss the results of the phase I seromonitoring (1989–1990), that several countries had reached acceptable levels of immunity in their national herds, but others had far lower than expected levels of immunity. In the prevailing situation in Africa, with the considerable east to west movement of cattle by owners seeking higher prices, it was crucially important that animals in the central block of countries (Cameroon, Central African Republic, Chad, Niger and Nigeria) had adequate levels of immunity to prevent the movement of the virus. It was also noted that the Central African Republic had not established a seromonitoring system. The main recommendation indicated that immediate steps should be taken

TABLE I
SEROCONVERSION RATES FOR THE PERIOD 1989–1990

Country	Seroconversion rate (%)				
	0–1 year	1–2 years	2–3 years	> 3 years	Overall
Cameroon	41.2	67.1	74	70.2	61
Chad	24.4	44.5	50.9	60.2	55
Côte d'Ivoire	57.5	80.5	92.9	88.1	79.7
Egypt	44.9–78.4				62.5
Ethiopia	Not provided	Not provided	Not provided	Not provided	76
Ghana	45	66	51	54	53
Kenya	32.8–79.3				Not provided
Mali 1989	45	59	58	54	Not provided
Mali 1990	53	68	83	86	Not provided
Niger	35	53	Not provided	66	58
Nigeria	34	39	42	Not provided	40.8
Senegal	52–91				Not provided
Sudan	56–90				Not provided
Uganda	20–63				55

TABLE II
SEROCONVERSION RATES FOR THE PERIOD 1991–1992

Country	Seroconversion rates (%)				
	0–1 year	1–2 years	2–3 years	> 3 years	Overall
Burkina Faso	68.9	75.6	80.6	84.9	77.4
Chad	18	39.4	52.6	58.4	45.3
Cameroon	45	61	69	76	63
Central African Republic	52	58	59	58	57
Ghana	62	59	77	81	71
Kenya	85	88	91	88	Not provided
Mali	47.3	70.5	78.2		Not provided
Mauritania	39	27	60	69	Not provided
Niger	47	46	54	64	55
Nigeria	38	44	57	63	52
Senegal	38.6	51	76.6	85.5	Not provided
Sudan	37.6–78.3	46.3–77.8	53.8–82.6	60.2–80	Not provided
Tanzania (United Republic of)	67	71.9	81.9	81.4	75.7
Uganda	55	62	63	64	Not provided

TABLE III
SEROCONVERSION RATES FOR 1993

Country	Seroconversion rates (%)				
	0–1 year	1–2 years	2–3 years	> 3 years	Overall
Burkina Faso	54.4	62.8	72.4	81.1	67.7
Cameroon	39	53	69	Not provided	Not provided
Central African Republic	65	60	62	52	60
Chad	36.3	51.5	66.5	74.3	57.5
Ethiopia	30	38	49	63	46
Ghana	63	72	80	85	76
Mali	44.3	68.3	73.5		62.2
Mauritania	23	33	52	69	45.7
Niger	44	42	45	49	46
Nigeria	38–60.4	38–54.5	41–54.7	42–63.4	41–60
Senegal	17.4–60	18.7–66	55–87.5	63–92	68
Sudan	30–60	50–59	63–73	Not provided	Not provided
Tanzania (United Republic of)	68.4	74.6	79.6	83.2	77.1

to improve the level of immunity of cattle in the central block of countries in the region to establish an immune barrier in Chad and the Central African Republic through improved vaccination and to establish serological monitoring in the Central African Republic.

The overall conclusion made at the end of the next coordination meeting in Entebbe (Uganda), held to discuss the results of phase II seromonitoring (1991–1992), was that immunity levels in countries in central Africa remained far too low, and the immune barrier in Chad and the Central African Republic was not realised. Immunity levels in cattle in Nigeria were considered ideal for endemic rinderpest, and there was a real possibility of rinderpest moving west from its endemic focus in Ethiopia to West Africa (mainly to Nigeria). Immunity levels in other West African countries were good, and in most countries in this region routine seromonitoring was well established.

The main recommendations from the Entebbe meeting indicated that every effort should be made to establish, and verify, an immune barrier in Chad and the Central African Republic. In Nigeria, revaccination was to be urgently undertaken and its success verified by seromonitoring.

The seromonitoring results obtained for 1993 were presented during the annual research coordination meeting in Cairo (Egypt). The seromonitoring results, combined with the absence of information from the field on rinderpest outbreaks, suggested that the disease had been eradicated from West Africa (see also Chapter 4.6). Routine seromonitoring results indicated that, in most countries, good systems for monitoring were now in operation. Although some countries had reached 85% or greater immunity, others had plateaued and were unlikely to improve in the near future.

It was concluded at the Cairo meeting that Mali, Senegal, Ghana, Burkina Faso, Côte d'Ivoire, Mauritania, Egypt and Nigeria should consider making a World Organisation for Animal Health (OIE) provisional declaration of freedom from disease in 1994. A prerequisite to this was a cessation of vaccination and the establishment of adequate surveillance, both of the disease and of the presence of rinderpest antibodies in non-vaccinated animals.

Accordingly, the meeting recommended that all PARC countries should proceed rapidly towards establishing a rinderpest surveillance capability based on the FAO/IAEA/Global Rinderpest Eradication Programme (GREP) guidelines.

In support of the transition from vaccination to rinderpest surveillance, a proposal was prepared by FAO/PARC and submitted in 1992 to the European Union. It had two components: the establishment of a central epidemiology unit at PARC headquarters in Nairobi; and continued support for national diagnostic laboratories to conduct seromonitoring and disease surveillance. Funding did not materialise, and the only support for the continuation of the seromonitoring activities was the support available under the IAEA's programme of technical cooperation (7). Nevertheless, the PARC seromonitoring network conducted annual serological surveillance in support of the country dossiers for rinderpest declarations of freedom from the disease and infection.

SEROCONVERSION RATES IN PARTICIPATING COUNTRIES IN THE MIDDLE EAST AND SOUTH ASIA

As previously mentioned, seromonitoring in other regions was less structured. In the Syrian Arab Republic, where vaccination occurred between 1990 and 1994, seromonitoring showed 69.8% seroconversion in 1991 and 76.7% in 1992.

During the Cairo meeting (6), data suggesting that small ruminants infected with peste des petits ruminants (PPR) virus could pose a problem for the vaccination of cattle against rinderpest were presented. Studies were recommended in a number of countries to ascertain the effect on cattle of PPR infection in small ruminants and determine whether cattle become infected with PPR and are subsequently refractory to rinderpest vaccination or the disease itself.
The results of these studies on the effect on cattle of PPR infection in small ruminants were also presented. It was found that PPR may be transmitted from sheep and goats to cattle under field conditions (6). Moreover, it was concluded that cattle with antibodies against PPR may not produce a humoral antibody response following rinderpest vaccination (6). While an analysis of field sera by Anderson and Mckay (8) found limited evidence to support the above conclusion, Couacy Hymann *et al.* (9) demonstrated its reality using experimental cattle. Anderson and Mckay's study found areas of West Africa with high PPR antibody levels in cattle, but the authors of a subsequent study (10) that looked at 2,696 sera from 75 herds with low levels of rinderpest antibodies after a PARC vaccination campaign and found an overall PPR antibody level of 4.6% remarked that this was not significantly different from that observed during a previous campaign (4.5%) and concluded that PPR only occasionally infected cattle and that this would have a negligible effect on a rinderpest vaccination programme.

In Turkey, between 1992 and 1997 rinderpest vaccination occurred in 72 provinces. The results of the seromonitoring are presented in Table IV. Although none of the yearly campaigns achieved 80% immunity at the country level, further analysis at the herd level indicated that the rates in several herds were above 80%.

After a series of training courses on antibody monitoring techniques, serum samples were collected in Egypt, Iraq, Jordan, the Syrian Arab Republic and Yemen to assess the antibody response of vaccinated cattle and buffaloes. In Egypt, between 1982 and 1996 the campaign intensity reached a level of around 77% of the population on an annual basis. The results of the seromonitoring are shown in Table V.

The percentage of animals showing a positive response was found to vary from 46.1% to 91.6%. Wherever the immunity was less than 60%, the vaccination was repeated. Although the vaccination coverage of each year varied widely, significant herd immunity had been built up by the end of 1993.

The survey in Yemen in 1992/93 was supported by the Overseas Development Administration (ODA).

TABLE IV
SEROMONITORING RESULTS AFTER RINDERPEST VACCINATION IN TURKEY

Year	No. samples collected	Prevalence of immunity (%)
1992	16,384	71.0
1993	17,004	74.0
1994	13,384	70.0
1995	13,117	73.7
1996	12,959	72.2
1997	13,363	69.6

There were two subsequent surveys in 1997 and 1998, conducted with assistance from the IAEA. The overall prevalence of rinderpest antibody in these two surveys was 38% and 25%, respectively.

Iran initiated vaccination as early as 1931, using a killed vaccine made in the Razi Institute. From 1965 to 1994, vaccination was restricted to young animals, but from 1994 to 2001 mass vaccination was undertaken in animals of all ages plus revaccination of calves under one year old in a drive towards eradication. In 2002, vaccination ceased in all but the eastern provinces, ending completely in 2003. Seromonitoring between 1994 and 2001 revealed an average immunity level of 67%.

In India, seromonitoring was carried out annually between 1994 and 1998 in 13 states, including union territories. Sera were examined from 5,490 cattle and 1,644 buffaloes for the presence of rinderpest antibodies in previously vaccinated animals. This confirmed the presence of antibody in 35% and 31% of cattle and buffaloes, respectively (Table VI).

CONCLUSION

During the decades of effort to control and ultimately eradicate rinderpest, seromonitoring was used as a tool to monitor vaccination efforts. With the development of a standardised ELISA in the late 1980s, countries could more reliably compare serological results across time and place. In Asia, a few countries had consistent, yearly reporting of seromonitoring results, while for others only sporadic values were reported. The majority of the data came from seromonitoring under PARC, as reported by the IAEA and FAO between 1989 and 1998.

The evaluation through seromonitoring of the vaccination programme guided the GREP in the long process towards rinderpest eradication. At the beginning of the campaign, it was thought that an 80% immunity rate was necessary if rinderpest were to be eradicated. The seromonitoring studies indicated that immunity levels of 50–60% were sufficient for eradication. Although immunity levels were targeted at 80–85%, only rarely were these achieved across an entire country and relatively infrequently, even within individual herds of cattle. During the latter stage of eradication, R0 was estimated (11). Older animals (over two years of age) generally had higher levels of seropositivity than the sampled herd average. Immunity to rinderpest declined over time and as the cessation of vaccination neared. This finding probably relates to the decline in immunity from natural infection as well as the use of targeted, rather than blanket, vaccination in the latter stages of some national eradication programmes. Longer intervals between the last rinderpest outbreak and the last use of vaccination in a country resulted in overall immunity levels that were somewhat lower than those for countries where the interval between last outbreak and last vaccination was shorter.

TABLE V
SEROMONITORING RESULTS FOLLOWING RINDERPEST VACCINATION IN EGYPT, IRAQ, JORDAN, THE SYRIAN ARAB REPUBLIC AND YEMEN BETWEEN 1991 AND 1993

Country	Year	No. sera tested (percentage of samples not tested due to poor quality)	Positive for antibody to rinderpest virus	Percentage positive
Egypt	1991	1,102 (0.02)	856	78.5
	1992	1,683 (0.03)	1,251	74.3
	1993	4,026 (0.08)	2,647	65.7
Iraq	1991–1992	6,744	5,724	84.8
	1992–1993	4,821 (0.28)	4,416	91.6
Jordan	1991–1992	403 (1.15)	284	46.1
Syrian Arab Republic	1991–1992	NA	NA	NA
Yemen [(a)]	1992–1993	10,572 (0.91)	4,984	47.0 [(a)]

[(a)] Sera harvested without assessing vaccination status

TABLE VI
SEROMONITORING RESULTS AFTER RINDERPEST VACCINATION IN INDIA

Year	Cattle			Buffaloes		
	Number tested	Number positive	Percentage positive	Number tested	Number positive	Percentage positive
1994–1995	68	37	54	56	16	29
1995–1996	1,400	598	43	801	301	38
1996–1997	2,300	841	36	396	67	17
1997–1998	1,682	440	26	391	123	32
Total	5,5	1,916	35	1,644	507	31

So, was it an error to suggest the target of 80%? This figure was selected by the FAO/IAEA/Swedish International Development Cooperation Agency (SIDA)/OAU/IBAR/PARC Coordinated Research Programme because

> 'it would be helpful to indicate in broad terms what prevalence of herd antibody is considered protective and what proportion of protected herds are considered necessary to confer protection on the population.'

Further reading of the document reveals that several caveats were applied to this opinion, most notably that

> 'the epidemiology of the disease is such that there is no simple rule for determining these levels and average figures are of rather limited epidemiological significance.'

In summary, while the decision to seek an 80% immunity among the cattle population was, in retrospect, not epidemiologically necessary, it was indeed the correct approach for GREP, as it provided the target that motivated the eradication campaign and led to its success. Several authors assumed contact rates that led to model outputs and herd immunity thresholds would be a function of assumptions not a result. Other models estimated R0 and the eradication threshold from serological data and found that herd immunity threshold for lineage 1 was less than 80% and lower than 50% for lineage 2.

This experience of using seromonitoring as a tool to support eradication policy has relevance for the eradication of other diseases by vaccination. As a general approach, first, developing a good epidemiological understanding and delineation of the disease should be emphasised. Today, fairly precise methods for the estimation of herd immunity thresholds based on the estimation of R0 are available and should be applied to set vaccination targets (3, 11). Second, the vaccination should be targeted at delineated areas of dense population of the targeted species, to achieve a high immunity rate. Third, in areas with a lower density of the targeted species, surveillance without vaccination may be sufficient for successful eradication if a rapid response to any outbreak of disease is enforced.

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PART 4
REGIONAL CONTROL AND ERADICATION PROGRAMMES

CHAPTERS

CHAPTER 4.1

JOINT PROGRAMME 15 (JP15) FOR RINDERPEST CONTROL IN AFRICA

P. ATANG [1], F. NJEUMI [2]* & H. WAMWAYI [3]

(1) École vétérinaire d'Alfort, 94704 Maisons-Alfort, France
(2) 42 rue de l'Est, 92100 Boulogne-Billancourt, France
(3) École vétérinaire d'Alfort, EpiMAI, USC Anses, 94704 Maisons-Alfort, France

*Corresponding author: felix.njeumi@fao.org

SUMMARY **In the early 1960s, several donors supported the implementation of a regional rinderpest vaccination programme in Africa. In each country, the national coordinator was responsible for obtaining the administrative, financial and political support of their respective government to ensure the smooth implementation of the campaign within national boundaries. Between 1962 and 1976, six phases of the Joint Programme 15 (JP15) were implemented in inter-tropical African countries. These phases considerably reduced the incidence of the disease – close to the point of eradication, but pockets of infection were left, despite the belief that the disease had been eradicated. At the end of JP15, no specific measures were defined and put in place to sustain the achievement made in reducing the incidence of the disease to zero. Unfortunately, these remaining foci in a few countries led to a resurgence of epidemic disease in West Africa in the early and mid-1980s.**

KEYWORDS **Joint Programme 15 – JP15 – Rinderpest – Vaccination.**

INTRODUCTION

At the conference of Governors of British East Africa Territories held in Nairobi on 7–8 February 1939 (some 30 years before the advent of the Scientific Technical and Research Committee (STRC) of the Organisation of African Unity (OAU)/STRC's Joint Campaign against rinderpest in eastern Africa), it was recommended that there be 'a formulation of plans aimed at the eventual eradication of rinderpest from eastern Africa' (1).

In the period following the end of the Second World War, rinderpest continued to affect livestock in Central, West and East Africa. Its presence there is outlined in Chapters 2.1 and 2.2 and in a book by the Interafrican Bureau for Animal Resources (IBAR) (2).

The control of rinderpest demanded huge investments in human and financial resources, which the African governments in the 1960s could not afford. In West Africa, while some countries made great efforts to annually vaccinate the majority of their cattle and tried to create buffer zones, other countries did not and experienced regular outbreaks of rinderpest, with disease often spreading to neighbouring countries. It was recognised that an internationally coordinated programme was needed if rinderpest were to be controlled and possibly eradicated.

According to Kesteven (3), in 1948 an African conference on rinderpest was held in Nairobi, Kenya, which recommended the creation of an African Rinderpest Bureau. Its creation had to await the establishment in 1950 of both a Commission for Technical Cooperation in Africa, South of the Sahara (CCTA) and a Foundation for Mutual Assistance in Africa, South of the Sahara (FAMA). A working party drawn from both organisations was instructed to study proposals for the creation of this bureau and, in so doing, widen its limits to encompass all epidemic diseases of livestock in Africa. In 1951, this bureau was established in Kenya as the Inter-African Bureau of Epizootic Diseases (IBED). When endemic diseases also came under the purview of the bureau, it became the Inter-African Bureau for Animal Health (IBAH), and later, in 1970 (4), when its responsibility was broadened to include animal production, it was renamed the IBAR, becoming one of the specialised units of the STRC of the OAU (2).

As the 1960s began, there was a growing recognition among Directors of Veterinary Services for concerted action against rinderpest. The CCTA/FAMA, succeeded by the OAU/STRC and the IBAH, initiated a joint campaign against rinderpest, supported by African member states and international aid.

FIG. 1
INAUGURATION OF A JP15 VACCINATION CAMP AT BOKKOS IN THE PRESENCE OF THE GOVERNOR, PLATEAU STATE, NIGERIA, 1962
Source: L.W. Rowe

FIG. 2
JP15 VACCINATOR AT WORK, NIGERIA, 1962
Source: L.W. Rowe

IMPLEMENTATION OF JP15

The heads of African Veterinary Services met in Kano, Nigeria, in May 1961 and welcomed proposals to launch a multinational joint project called JP15 under the aegis of the OAU. The first proposal was the control of rinderpest. The aim was to delineate a series of phased mass vaccination programmes across the sub-Saharan region of the continent and vaccinate all cattle of all ages in each phase every year for three successive years. Thereafter, each country undertook to vaccinate all calves and weaned animals annually. Twenty-two countries were involved in the JP15 project, at the beginning of which 17 had rinderpest. JP15 of the OAU/STRC, implemented from 1962 to 1976, was the first pan-African control/eradication programme. The JP15 was to embody both regional cooperation and coordination in an attempt to eradicate the disease (2). Vaccination, targeting all at-risk animals, was undertaken in the dry season between September and April/May (Figs 1 and 2) in an attempt to drive the immunity level of the national herds to a point at which the virus would not survive – a process later termed immunosterilisation (5). Vaccinated animals were marked with a characteristic ear punch – a cloverleaf symbol that was also used in the subsequent Pan-African Rinderpest Campaign (PARC).

JP15 was implemented in six phases. The first phase proposed creating a rinderpest-free zone across the Lake Chad Basin, involving the vaccination of cattle from Cameroon, Chad, the Niger and Nigeria. In sequence, phases II and III covered the remaining part of West Africa while phases IV, V and VI covered East Africa, as described in Table I.

The eastern extension of JP15 (phase IV) began in late 1968, some 30 years after the conference of Governors of the British East Africa Territories, but on a much larger geographical scale than that envisaged in 1938 and 1939 (1).

The inaugural technical meeting for phase IV was held in Kabete, Nairobi, Kenya – from 14 to 15 November 1968 – where the headquarters were initially established. The plan was to vaccinate all cattle at risk in Sudan, selected parts of Uganda, the United Republic of Tanzania, Kenya and throughout Somalia each year for three years beginning in late 1968 (1). Compared with previous Central–West Africa phases, for the first time a new element of disease control began with the introduction of a pilot project for the control of contagious bovine pleuropneumonia (CBPP) in the Masailands of Kenya and the United Republic of Tanzania.

TABLE I
PHASES AND COUNTRIES COVERED BY JP15

Phases	Period	Countries
Phase I	1962–1965	Cameroon, Chad, Niger and Nigeria
Phase II	1964–mid-1967	Benin, Burkina Faso (Haute Volta at that time), Ghana, the Lobi region of Côte d'Ivoire, central and eastern Mali, Togo and those parts of the Niger and Nigeria not included in phase I.
Phase III	1966–1969	Côte d'Ivoire, Gambia, Guinea, Liberia, western Mali, Mauritania, Sierra Leone, Senegal and the part of Chad not included in phase I.
Phase IV	1968–1971	Kenya, southern Somalia, Sudan, United Republic of Tanzania, and Uganda
Phase V	1970–1973	Ethiopia and the rest of Somalia
Phase VI	1973–1976	Repeated Ethiopia and Sudan

COORDINATION

International coordination was assisted by the appointment in 1961 of an international coordinator (Dr H.E. Lepissier, 1961–1969) and by two deputy international coordinators (Dr I.M. Macfarlane 1964–1968 and Dr S.J. Henstra 1968–1969). In 1968, Macfarlane assumed the role of international coordinator in East Africa (Fig. 3).

Coordination at the national level was undertaken by national coordinators appointed by the participating African governments (Fig. 4). These individuals were responsible for coordinating and organising vaccinations in their respective countries. Most importantly, the national coordinators were responsible for obtaining the administrative, financial and political support of their respective governments to ensure the smooth implementation of the campaign within national boundaries.

These international coordinators soon understood the necessity of extending activities to cover all cattle in the inter-tropical zone of West Africa, risking reproach for developing a programme that was over budget. The geographical limits of the activities were consequently set at 8° S and 19° N. Encouraged by the success achieved in the phase I area, phase II of the programme was quickly organised. This included the sparsely populated (as regards cattle) tropical coastal belts and the cattle rearing areas of Benin, Burkina Faso (formerly Haute Volta), Ghana, the Lomé region of Côte d'Ivoire, central and eastern Mali, those parts of the Niger and Nigeria not included in phase I, and Togo. Phase II ran from the start of the 1964 dry season and ended in mid-1967. West Africa then completed its participation in JP15 by moving into phase III, which consisted of a western extension taking in the remainder of Côte d'Ivoire, Gambia, Guinea, Liberia, western Mali, Mauritania, Sierra Leone and Senegal. There was an eastern extension covering the part of Chad that was not included in the phase I area. This phase of JP15 ran from 1966 to 1969 (2, 4).

The extension of JP15 to eastern Africa was operated in precisely the same manner as in earlier phases. Thus, it was under the aegis of the OAU/STRC, with Dr I.M. Macfarlane as the regional coordinator (1, 6). He was charged with the full responsibility of the operation in respect of time, place and method. As with West Africa, the

FIG. 4
DIRECTORS OF VETERINARY SERVICES OF THE JP15 CAMPAIGN'S AFRICAN MEMBER COUNTRIES IN 1964 (VOM, NIGERIA)
Source: AU-IBAR

FIG. 3
DR IAIN M. MACFARLANE, OAU/STRC-JP15 INTERNATIONAL COORDINATOR, KABETE, 1968
Source: AU-IBAR

operation was based on vaccinating all bovines at risk in the working area each year for three years in a coordinated manner, with close attention being given to coordinating operations in frontier areas (1).

Phase I ran under the aegis of the CCTA, whereas phases II, III, IV and V ran under the aegis of the OAU/STRC. In essence, the OAU took over the last five years of this seven-year long programme in West and Central Africa as the donors' sole reference point in the implementation of the campaign. The OAU/STRC was seen as essential for the smooth running of the campaign, acting on the one hand as a permanent intermediary between the Coordinators Office and the states and with the United States Agency for International Development (USAID) on the other (the European Development Fund [EDF] arrangements appear to have been bilateral and not to have involved the OAU/STRC). The OAU/STRC was instrumental in maintaining open transfer of information to the World Organisation for Animal Health (OIE) and ensuring that the Coordinators Office kept the Food and Agriculture Organization of the United Nations (FAO) abreast of progress. The role of the IBAH was to transfer information to the OIE and FAO.

FINANCING OF JP15

The programme was supported by international donors, but the implementation was undertaken by the respective national Veterinary Services.

For the most part, donor assistance (Table II) came from the EDF (see also Chapter 5.8), the United Nations Development Programme (UNDP) (see also Chapter 5.12) and USAID (see also Chapter 5.9). Other inputs came from the British government (see also Chapter 5.11), the federal German government and the Canadian government. Financing agreements were discussed and signed in May 1961 by the Executive Secretary of the OAU/STRC. African governments also made their own national contributions to the project budget (Tables III and IV). The EDF financed the campaign in the francophone Sahelian-type states, and USAID did so in the anglophone and francophone coastal states and in northern Nigeria. Requests for financing were presented individually by each state, but they were prepared in advance with the CCTA/FAMA (which later became the OAU/STRC) and the coordinator. It is estimated that the national governments contributed around US$ 6.5 million, while external donors contributed a further US$ 8.3 million. Table II shows the total financing agreement (US$ 9,141,956) adapted from Macfarlane (1) and Lepissier (4).

TABLE II
TOTAL FINANCING AGREEMENT OF JP15

Donors	Currency (US dollars)
EDF	6,615,962
USAID	2,291,403
British aid (estimate)	67,448
Aid from Federal Germany (estimate)	107,143
Canadian aid (estimate)	60,000
Total	**9,141,956**

Adapted from Macfarlane (1) and Lepissier (4)

VACCINE AND IMMUNITY

At the onset of the campaign, the attenuated rinderpest vaccine was grown in goats; at the end, it was grown in tissue culture (Fig. 5). Small quantities of lapinised rinderpest vaccine were produced and used (Fig. 6).

The vaccine was supplied by laboratories at the National Veterinary Research Institute (NVRI), Vom, Nigeria, and the Institut national de recherche vétérinaire (INRV) de Farcha, Ndjamena, Chad, for Central and West Africa. For East Africa, vaccines were produced in Asmara (Eritrea), Kabete in Kenya, Khartoum in Sudan and later Mogadishu in Somalia. In phases I to III, a total of 81,483,126 animals were vaccinated (Table V). During phase IV and part of phase V, 61,489,993 animals were vaccinated (Table VI). From October 1962 to 30 June 1973 during the field operations of the campaign against rinderpest in Africa from the Atlantic Coast to the Red Sea, a total of 142,973,119 vaccinations were administered.

All these vaccines were expected to produce durable levels of immunity. The vaccination coverage (vaccinations administered/livestock population) in the first three phases of the campaign was above 75.4% (Table VII). Seromonitoring to assess the vaccination efficiency was carried out at the NVRI, Vom, Nigeria (4, 7). Sera collected from Nigerian cattle across the three years of phase I showed that levels of population immunity peaked at over 90% after two rounds of vaccination. In East Africa (phases IV to VI), the East African Veterinary Research Organisation (EAVRO), Muguga, Kenya, carried out seromonitoring using the virus neutralisation test, and more than 50,000 serum samples were analysed. It was clearly shown that over 70% immunity was attained (2).

TABLE III
COSTS OF JP15 (US DOLLARS) IN WEST AFRICA

Country	National contributions	External aid contributions	Totals
Cameroon	285,714	216,612	502,326
Côte d'Ivoire	125,161	287,003	412,164
Benin	61,500	167,749	229,249
Gambia [a]	18,074	71,635	89,709
Ghana [b]	195,000	157,005	352,005
Guinea	240,734	68,611	309,345
Upper Volta	469,387	753,976	1,223,363
Liberia	800	8,699	9,499
Mali	637,708	1,048,825	1,686,533
Mauritania	428,571	514,446	943,017
Niger	1,020,408	1,623,652	2,644,060
Nigeria	907,000	743,556	1,650,556
Sierra Leone [a]	90,653	234,509	325,162
Senegal	734,693	72,808	807,501
Chad	1,224,489	1,275,074	2,499,563
Togo	32,653	67,400	100,053
Total	**6,472,545**	**7,311,560**	**13,784,105**
Coordination			792,598
Vom, Nigeria (diagnostic and vaccine services)			59,786
Miscellaneous			19,276
German aid			107,143
Grand total EDF/USAID			**14,762,908**

[a] Includes contribution from British aid

[b] Includes contribution from Canadian aid

TABLE IV
COST OF JP15 (US DOLLARS) IN EAST AFRICA

Country/organisation	National contribution	External contributions	Donors
Ethiopia	2,089,932	920,000	France [a]
		500,000	United Kingdom (ODA)
		1,096,400	UNDP
		1,102,000	USAID [b]
Kenya	800,000	700,000	France, Germany [a]
Somalia	500,000	100,000	USAID
		142,000	UNDP
		250,000	United Kingdom (ODA) [a]
Sudan	1,384,400	924,000	United Kingdom (ODA) [a]
Tanzania (United Republic of)	300,000	464,000	United Kingdom (ODA)
Uganda	560,000	232,000	United Kingdom (ODA)
East African Veterinary Research Organization (EAVRO)	EA Community	660,000	USAID
Coordinating unit (IBAR)		234,512	USAID
		112,500	United Kingdom (ODA)
Total	**5,633,932**	**6,823,412**	

[a] Continuing as follow-up measures and CBPP control

[b] Including phases IV and V and pre JP15 only

ODA, Overseas Development Administration

FIG. 5
LYOPHILISED TISSUE CULTURE VACCINE PRODUCED IN ETHIOPIA UNDER JP15
Source: Debre Zeit Laboratory, Ethiopia

FIG. 6
THE FIRST STEP TOWARDS PRODUCING RABBIT-ADAPTED LAPINISED VACCINE FOR EXOTIC BREEDS AND GRADE ANIMALS AT ASMARA VETERINARY LABORATORY DURING JP15
Source: Debre Zeit Laboratory, Ethiopia

TABLE V
NUMBER OF RINDERPEST VACCINATIONS ACHIEVED IN PHASES I TO III OF JP15 – WEST AFRICA

Phase	Period	Number of vaccinations
Phase I	1962–1965	36,401,931
Phase II	1964–1967	24,452,612
Phase III	1966–1969	20,628,583
Total	**1962–1969**	**81,483,126**

TABLE VI
NUMBER OF RINDERPEST VACCINATIONS ACHIEVED IN PHASES IV AND V OF JP15 – EAST AFRICAN COUNTRIES

Country	Number of vaccinations
Ethiopia	24,779,631
Kenya	7,494,191
Somalia	4,976,101
Sudan	9,560,430
Tanzania (United Republic of)	5,025,447
Uganda	9,627,193
Total	**61,489,993**

TABLE VII
RINDERPEST VACCINATIONS ADMINISTERED AND PROPORTION OF CATTLE POPULATION VACCINATED DURING PHASES I, II AND III OF JP15

Country	Total vaccination	Estimated coverage of cattle population (%)
Benin	951,623	81.4
Burkina Faso	6,629,537	88.5
Cameroon	2,076,241	89.2
Chad	10,366,107	80.4
Gambia	678,871	94.1
Ghana	1,052,627	83.4
Guinea	1,712,035	38.1
Côte d'Ivoire	792,761	85.1
Liberia	4,100	27.5
Mali	10,932,324	78.1
Mauritania	5,993,284	79.7
Niger	12,200,944	88.4
Nigeria	21,099,147	91.9
Senegal	6,412,816	85.4
Sierra Leone	475,460	79.0
Togo	106,248	33.3

TRAINING

Across all phases of the JP15 campaign to control and eradicate rinderpest, many meetings, seminars, workshops and other forms of training courses were held. A special logo (Fig. 7) was used during such events and on all JP15 equipment. At the national level, the focus was on field-related problems, such as shortages of vaccines, storage of vaccines and a vaccination timetable. Similar meetings were also held between neighbouring states to synchronise vaccination along their common borders and to ensure that all the cattle were vaccinated, including those belonging to herders who were attempting to avoid the vaccination teams. Training workshops, seminars and discussion groups were convened to constantly update the national workers and review the process.

FIG. 7
LOGO OF THE JP15 CAMPAIGN IN THE EARLY 1970S
Source: OAU STRC

Annually, the OAU/STRC organised international conferences attended by the coordinators of the countries involved in each phase of the campaign. International and other common regional problems were discussed. These annual conferences were also attended by donors and representatives of vaccine producing laboratories.

RINDERPEST OUTBREAKS DURING AND AFTER JP15

The results from JP15 phases I to III

The reduction in the number of rinderpest outbreaks in West Africa during the different phases of JP15 are shown in Table VIII. With the probable exception of Côte d'Ivoire, in the countries endemically infected at the start of JP15, the incidence of infection was greatly reduced but not eliminated. In fact, shortly after the relevant phases ended, incidents of rinderpest began to be reported. This was particularly apparent in the countries involved with phase I, for example Cameroon, Chad, the Niger and Nigeria. These would probably have represented remnants of the earlier endemic situation.

At the end of phase III, the OAU/STRC/IBAR continued to monitor the rinderpest status in the countries that had been involved. This revealed that, across the region, a fresh epidemic began to emerge as early as 1971, with a wave of outbreaks moving eastwards from Mali and Mauritania (Table IX). By 1977, rinderpest was considered endemic in the whole of southern Mauritania, south of latitude 17, and in Mali between latitudes 12 and 17 (4, 8). Its possible spread to Senegal was aborted by the government, which took firm and effective measures to prevent the spread of the disease in the country. This was done by applying a slaughter policy and undertaking good vaccination coverage. Despite these actions, rinderpest was reported on the south bank of the Senegal river in 1978, in transhumant Mauritanian cattle, and again in 1979 in the Thies region, having been introduced by Mauritanian trade cattle.

In West Africa, the high cattle density in certain areas and the movement of livestock for climatic reasons and trade were important in determining the spread of the disease. Transhumance movements indicated that all of the hinterland of

TABLE VIII
OUTBREAK NUMBERS IN WEST AFRICA BEFORE, DURING AND AFTER VACCINATION UNDER JP15 PHASES I TO III

Country	Prior rinderpest status	Phases I – 1962 to 1965 / Phase II – 1964 to 1967 / Phase III – 1966 to 1969								Post-JP15
		1962	1963	1964	1965	1966	1967	1968	1969	1970
Cameroon	Endemic	**25**[(a)]	0	**12**	**3**	1	34	5	14	4
Chad	Endemic	**163**	**33**	**9**	**7**	**46**	**39**	**25**	**26**	19
Niger	Endemic	**133**	**60**	**60**	**1**	**3**	**4**	9	23	9
Nigeria	Endemic	**104**	**7**	**2**	**1**	**2**	**17**	15	45	34
Benin	Endemic	5	0	**0**	**0**	**1**	**0**	0	0	0
Burkina Faso	Endemic	109	21	**32**	**26**	**1**	**0**	1	0	74
Ghana	Endemic	34	14	**1**	**0**	**0**	**0**	0	0	0
Côte d'Ivoire	Endemic	14	16	**22**	**6**	**0**	**1**	**0**	**0**	8
Gambia	Non-endemic	6	1	1	0	**0**	**0**	**0**	**0**	0
Guinea	Non-endemic	0	1	1	0	1	3	0	0	0
Mali	Endemic	308	149	**159**	**71**	**82**	**0**	**3**	**8**	11
Mauritania	Endemic	52	102	108	54	**48**	**41**	**2**	**3**	1
Sierra Leone	Non-endemic	0	0	0	0	**0**	**0**	**0**	**0**	1
Senegal	Endemic	38	71	110	13	**33**	**76**	**9**	**0**	0
Togo	Endemic	1	0	**0**	**0**	**0**	**0**	0	0	0

[(a)] Numbers in bold signify rinderpest outbreaks occurring in a particular country during a particular phase

TABLE IX
RINDERPEST OUTBREAKS IN WEST AFRICA POST-JP15, 1971–1981

Country	Number of declared outbreaks of rinderpest										
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Benin	2	44	0	5	0	0	0	0	0	2	4
Burkina Faso	44	26	31	2	0	0	0	0	0	9	8
Côte d'Ivoire	0	12	6	0	0	0	0	0	0	0	0
Ghana	0	0	6	2	0	0	0	0	0	0	0
Mali	33	47	53	23	0	4	11	9	29	11	7
Mauritania	1	1	8	26	1	2	47	13	18	0	0
Niger	0	12	6	0	0	0	0	0	0	0	0
Nigeria	49	19	1	0	0	0	0	0	0	20	11
Senegal	0	0	0	0	0	0	0	8	1	0	0
Togo	0	4	0	0	0	0	0	0	0	0	0

Upper Volta (now Burkina Faso), and the northern borders of Côte d'Ivoire, Ghana, Benin and Nigeria were threatened by contamination. The identification of the major trade routes and watering/grazing areas may have assisted targeting intervention. As a result of trade cattle movements, Senegal had been threatened with infection from Mauritania and Mali. Côte d'Ivoire faced threats from Mali and Upper Volta, and the north of Ghana was also threatened through the movement of trade animals. The west of the Niger was threatened with infection from Mali. Togo, Benin and Nigeria were threatened because of trade cattle from Mali and Upper Volta (3).

Having maintained itself in Mali and spread along the course of the river Niger, in 1980, rinderpest entered Nigeria from the Niger, as described in Chapter 2.4. By 1981, the situation in West Africa had deteriorated to an extent that an emergency vaccination campaign was launched (see below).

The results from JP15 phases IV to VI in eastern Africa

Prior to JP15, substantial levels of control had been achieved in Kenya, Uganda and the United Republic of Tanzania, but in Sudan rinderpest was causing large numbers of outbreaks. It was also endemic in Ethiopia (Table X)

The situation during and after JP15 in eastern Africa is shown in Table XI.

In Sudan, the greatest number of outbreaks occurred around northern and southern Kordofan, northern Darfur, Northern province, Khartoum province, and Upper Nile and Blue Nile provinces, the last two having a common border with Ethiopia (6).

Phase IV obviously made a big impact on the level of endemicity in Sudan but failed to eradicate the disease, and on the basis of reported incidence levels, this would appear to have also been the case in Ethiopia, where difficult and mountainous terrain made mass vaccination difficult. Moreover, in some districts, cattle owners did not trust the vaccination team and even proved hostile towards them.

Elsewhere, there was greater success; JP15 brought endemicity to a close in the United Republic of Tanzania and Uganda, but in Kenya a rinderpest outbreak was signalled in March 1972, almost as soon as the JP15 campaigns ended, possibly having had an origin in common with the 1972 Ethiopian outbreak mentioned below. Within Kenya, it spread west towards Marsabit and then south towards Mombasa, as a result of the rapid illicit movement of sick and infected cattle. Thereafter the outbreak was controlled.

In 1977, the security situation in Ethiopia became untenable, and the last phase of JP15 ended. Between 1973 and 1978, while poorly represented in the historical record, a massive epidemic gripped the whole of southern Ethiopia and also raged across the centre of the country.

TABLE X
OUTBREAKS OF RINDERPEST BEFORE JP15 IN EASTERN AFRICA [(a)]

Year	Kenya	United Republic of Tanzania	Uganda	Sudan	Ethiopia
1960	44	4	29	213	+
1961	13	4	2	151	+
1962	7	0	5	108	18
1963	12	0	12	196	75
1964	8	0	8	192	4
1965	2	1	1	536	61
1966	0	1	2	416	55
1967	2	0	0	422	36
Totals	**87**	**10**	**59**	**2,234**	**249**

[(a)] Figures are based on Atang and Plowright (6) and Chapter 4.5
+, no information available but unlikely to be free from the virus

Discussing the period after the end of JP15 in 1975, Roeder *et al.* (9) stated that:

> 'As JP15 phased out, and at a time that Ethiopia was generally considered to have been cleared of rinderpest, reports of giraffe (Giraffa camelepardalis) and lesser kudu (Tragelaphus imberbis) mortality in southern Ethiopia presaged the later emergence of typical rinderpest in the cattle populations of the Rift Valley and neighbouring Arssi southern highlands of Ethiopia. Initiating control of the developing epidemic was hampered for some months by misdiagnosis as 'pasteurellosis'. Subsequently, despite concerted efforts to control the disease it spread slowly but progressively northwards along the Rift Valley and around the central massif of the Ethiopian Highlands. It entered the Afar rangelands in 1976 and spread westwards to cross into Sudan in about 1978.'

The political atmosphere in the region at the time was not conducive to effective disease control. With rinderpest endemic in Ethiopia, the disease had, on several occasions, been transmitted into Sudan, quite often by military movements. For example, in July and September 1977, the disease was reported in Gederef and around Kassala, and in March 1978 outbreaks were reported in El-Kama on the Blue Nile near Khartoum within the 'disease-free zone'. In southern Sudan, the rinderpest situation was very confused, but a major epidemic occurred, lasting from 1973 to 1978. In 1982, the OIE reproduced information provided by the Sudanese authorities demonstrating that the situation in Sudan had become dangerous (see Box 1, Table XII, Fig. 8) as the virus threatened to spread westwards, which it subsequently did, transiting Chad and entering Nigeria in 1983 (see Chapter 2.4).

TABLE XI
RINDERPEST OUTBREAK NUMBERS IN EASTERN AFRICA BEFORE, DURING AND AFTER VACCINATION UNDER JP15 PHASES IV TO VI

Country	Prior rinderpest status	Phase IV 1968–1971 / Phase V 1970–1973 / Phase VI 1973–1976								
		1968	1969	1970	1971	1972	1973	1974	1975	1976
Kenya	Endemic	+	+	+	+	5	0	1	0	0
Somalia	Endemic	+	**25**[(a)]	+	+	**4**	+	6	0	0
Sudan	Endemic	**234**	**178**	**216**	**6**	+	+	+	**3**	10
United Republic of Tanzania	Endemic	**0**	**0**	**0**	**0**	0	0	0	0	0
Uganda	Endemic	**36**	**0**	**0**	+	0	0	0	0	0
Ethiopia	Endemic	35	53	**13**	+	+	+	+	+	+

[(a)] Numbers in bold signify outbreaks occurring in a particular country during the appropriate phase

+, no information available but unlikely to be free from the virus

CONTROL AFTER JP15 ENDED

Thus, within a few years of the end of JP15, there was a resurgence of rinderpest from two locations: the first from an area on the Mali–Mauritania border and the second from southern Sudan and Ethiopia. The eastward-moving virus appeared to be a mild strain causing little clinical disease, whereas the westward-moving virus was highly virulent and caused a disastrous epidemic with heavy loss of livestock (11).

In general, the rinderpest situation in Africa had significantly deteriorated by the end of 1980, necessitating the launch of an emergency campaign against rinderpest in 1981 (12). This emergency vaccination programme was supported by European Economic Community (EEC) funds of one million ECUs (the nominal unit of currency used in the EEC before the euro) granted in November 1980 (13) and through the Technical Cooperation Programme (TCP) of FAO (Box 2).

All animals were vaccinated, and 6-to 18-month-old calves were given a second vaccination. Table XIII below summarises the number of animals vaccinated in selected countries in 1981 (12, 14).

This emergency vaccination campaign brought rinderpest under control, and outbreaks were halted in several countries. FAO staff and consultants, in cooperation with the EEC, not only provided emergency assistance but also helped establish plans for national rinderpest control projects for 28 African countries,

BOX 1
THE RINDERPEST SITUATION IN SUDAN
According to an announcement received on 25 November 1982 from the Embassy of Sudan, Paris
Source: World Organisation for Animal Health, 1982 (10)

During the last three years the incidence of rinderpest has increased due to the following factors:
1. The increased number of refugees crossing the Eastern, Western and Southern borders of the Sudan accompanied by their sick cattle.
2. The complete breakdown and deterioration of works facilities: vehicles, cold chain, vaccination and camping equipments.
3. Lack of foreign currency for renewal and replacement of work facilities.
4. Reluctancy of cattle owners to vaccinate their calves; a situation which is encouraged by the low incidence of rinderpest.

The disastrous outbreak of rinderpest reported from the Northern Kordofan province was a predictable event because of the decreased annual vaccination coverage and build-up of the susceptible cattle population coupled with a lack of facilities and uncontrolled nomadic movements. This outbreak was the first reported in Northern Kordofan since 1971 and resulted in:
a) serious losses amounting to more than 30,000 head of cattle;
b) transmission of the disease to neighbouring provinces through nomadic herds and trade movements of cattle.

TABLE XII
REPORTED OUTBREAKS OF RINDERPEST IN THE SUDAN IN 1981 AND 1982

Months	Provinces				
	Northern Kordofan	Southern Kordofan	Northern Darfur	Northern province	Khartoum province
September 1981	3	2	-	-	-
October 1981	1	-	-	-	-
November 1981	3	-	-	-	-
December 1981	1	5	-	-	-
January 1982	2	1	-	-	-
February 1982	19	2	-	-	-
March 1982	1	-	-	-	-
April 1982	3	2	-	4	-
May 1982	6	-	-	-	-
June 1982	1	-	-	-	-
July 1982	+	-	-	-	-
August 1982	+	-	10 [(a)]	15 [(b)]	-
September 1982	+	-	5	-	-
October 1982	+	-	-	-	1 [(c)]

Source of infection from northern Kordofan:
[(a)] Through nomadic movement
[(b)] Through cattle transport in trucks for trade purposes
[(c)] Through cattle on hoof for trade purposes

which, together, were to form PARC (13). During the course of reviewing the result of the JP15 eradication campaign in West Africa and East Africa, it was proposed that a simultaneous eradication campaign be undertaken not only to address the two 'infectious centres' in West Africa and East Africa but in buffer zones established around these centres and the intermediate zones.

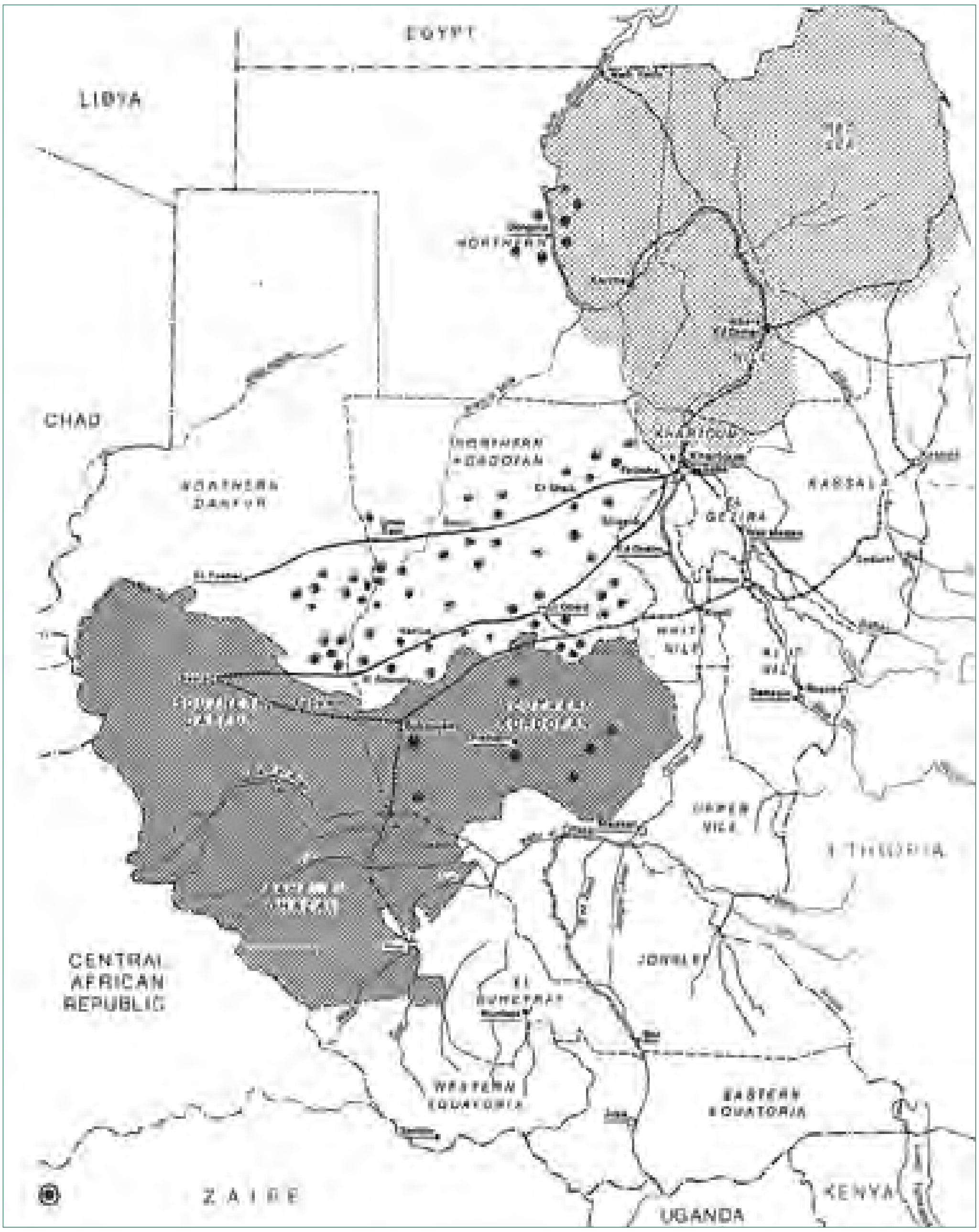
ANALYSIS

It is now well accepted that eliminating rinderpest from a population can only be achieved if the principle of immunosterilisation is applied, to arrive at a herd immunity level sufficient to eliminate infection from the population and exclude its introduction. This procedure was not properly implemented throughout the period of JP15.

BOX 1 (CONT.)

FIG. 8
RINDERPEST IN SUDAN, 1981-1982

Source: OIE, 1982 (10). The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of FAO or the OIE concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement



Mass vaccination was carried out on the assumption that a high immunity rate would be achieved to eradicate the disease. But this implied a false understanding of herd immunity and the sero-monitoring. In reality, vaccination coverage rarely generates such high levels of immunity in animals, because it takes no account of the dynamics of herd turnover and assumes that cattle populations are homogeneous, which they are not.

The JP15 was implemented in phases with long gaps, even years, between different regions. Had the vaccination campaign been conducted concurrently across the entire infected area, this might have produced a reduction in disease incidence such that a follow-up period of epidemiologically targeted interventions - that identified those last foci and specifically targeted them for elimination through vaccination - could have achieved eradication.

BOX 2
FAO'S TCP IN THE LATE 1970S TO SUPPORT RINDERPEST CONTROL

In the late 1970s, FAO established the TCP, providing funds of up to US$500,000 to assist countries in cases of emergency and to support the emergency vaccination programme against rinderpest. In 1980, 1981 and the first half of 1982, TCP funds were directed to Egypt, Uganda and nine West African countries (Mauritania, Senegal, Mali, Gambia, Upper Volta, Niger, Ghana, Togo and Benin) at a total cost of about US$1.1 million, including a regional project to support IBAR (12). In the second half of 1982, FAO staff and consultants visited 22 countries (Mauritania, Senegal, Mali, Niger, Upper Volta, Guinea, Côte d'Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Chad, Central African Republic, Zaire, Sudan, Egypt, Ethiopia, Somalia, Kenya, Uganda and the United Republic of Tanzania) to plan emergency action and assist in the implementation of a vaccination campaign. The major rinderpest vaccine production laboratories in Egypt, Sudan, Ethiopia, Somalia, Kenya, Nigeria, the Niger, Mali, Senegal and Guinea were also visited to determine requirements for essential equipment and supplies, as well as the technical assistance required to increase vaccine production. Thus, FAO technical assistance through these TCPs supported the improvement of vaccine production and quality control, training and communication, promotion of research specifically on the role of wildlife in the epidemiology of rinderpest (13), and a review of diagnostic methods (which subsequently led to the establishment of the IAEA laboratory network in Africa (see Chapter 5.4). Further details of the TCP can be found in Chapter 5.3.

But even within a region, there were failures in vaccination. For instance, the vaccination phases in the Niger were completed two years apart. Even the one-year discontinuity between different regions of Chad presented problems, as a number of Nigerian outbreaks came from this source (11).

In addition, while the JP15 campaign recommended annual calf crop vaccination by national authorities for several years to sustain the achievements made in reducing the incidence of rinderpest, (see Chapter 4.5), such measures were possibly under implemented in many African countries at the end of the JP15 phase in their respective region. It was assumed that the individual countries would automatically stamp out any outbreaks that occurred, but this did not happen. Comfort was taken from the notion that the campaign, having a target of 80% vaccination coverage, would have automatically eliminated the virus. (For further discussion of this topic, see Chapter 3.10.)

The campaign in East Africa was carried out without taking into account an epidemiological study previously conducted by Atang and Plowright (6). This study had defined two endemic areas, namely the Masailand ecosystem and a vast stretch of territory encompassing northern Uganda, northern Kenya and southern parts of Ethiopia and Sudan. Atang and Plowright (6) had recognised that rinderpest was still endemic in the Somali ecosystem, a region that was later shown to be endemic for the lineage 2 rinderpest virus (8). In retrospect, had the planners of the JP15 campaign recognised the epidemiological findings of Atang and Plowright (6), rinderpest would have probably been eradicated in phase V of the campaign by using a more targeted approach to achieve immunosterilisation.

TABLE XIII
NUMBER OF ANIMALS VACCINATED IN 1981 UNDER THE FAO PROJECTS

Country	Estimated number of cattle	Number of vaccinations	Percentage coverage
Benin	524,883	453,763	86.5
Ghana	823,661	128,654	15.6
Côte d'Ivoire	612,000	380,150	62.1
Mali	5,054,000	2,427,058	48.0
Mauritania	1,900,000	542,311	28.5
Niger	3,354,710	2,738,208	81.62
Senegal	2,565,100	1,290,695	50.3
Togo	205,369	156,706	76.3
Upper Volta	2,708,000	2,623,934	87.87

It is arguable that the JP15 campaign failed to eradicate rinderpest because no clear benchmark for success had been defined, and no point of cessation of vaccination had been identified. With the benefit of hindsight, a concept such as that developed by the OIE in 1989, which became known as the OIE Pathway, was badly needed at this time. As the OAU subsequently understood and persuaded its benefactors of this need, eradicating the virus, which was effected through PARC and subsequently PACE, was fairly straightforward (see Chapters 4.2 and 4.3).

CONCLUSION

Generally, JP15 did a good job by demonstrating the value of mass vaccination in reducing the number of outbreaks of rinderpest to the point of extinction in most areas. No doubt, it had its shortcomings, resulting in pockets of infection occurring during and after the programme. It was therefore necessary, based on the lessons learnt through JP15, to launch another more comprehensive campaign aimed at eradicating the disease.

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CHAPTER 4.1.1

JP15 SUPPLEMENT

The Joint Programme 15 (JP15) represented a pivotal point in the history of rinderpest in Africa and the start of a new level of intensified rinderpest control through repetitive mass vaccination across West, Central and East Africa, internationally coordinated but not simultaneously implemented. JP15 was a bold experiment that undoubtedly had the potential but not the necessary administrative experience to achieve continental eradication. It probably did so in several countries but alas only on a temporary basis. However, lessons were learnt, Veterinary Services strengthened, trust and friendships forged and when, 20 years later, the opportunity arose to have a second crack at eradication (PARC), the result was never in doubt.
The foregoing analysis of JP15 has provided facts and figures from across the continent, but to provide some flavour of the actual implementation of the scheme the editors have asked Dr Tony Wilsmore to provide a personal account of what it was like for a young internationally recruited veterinarian to lead teams of vaccinators in Ethiopia in the 1970s.

JOINT PROGRAMME 15 – LIFE AS A TEAM LEADER

T. WILSMORE

Veterinary Epidemiology & Economics Research Unit, University of Reading, School of Agriculture, Policy and Development, Earley Gate, P.O. Box 237, Reading RG6 6AR, United Kingdom

Correspondence: tony.wilsmore@panveeru.netar

SUMMARY **The JP15 rinderpest eradication campaign, which started in Ethiopia in 1972, is described by the team leader of the British Veterinary Team. The campaign got off to a slow start as donors and supplies trickled in, but, ultimately, all provinces were covered by vaccination campaigns for three successive years, apart from Eritrea where civil war curtailed activities.**

KEYWORDS **Ethiopia – Joint Programme 15 – JP15 – Rinderpest – Vaccination.**

I started working on the JP15 rinderpest eradication campaign in 1972 in Ethiopia, having never seen the disease. This was despite having been a veterinary field officer in Kenya for five years and routinely vaccinating cattle against the disease and hot branding them with a 'Z' mark to signify that they had been vaccinated. In fact, during the five years I spent on JP15 in Ethiopia, I saw clinical rinderpest only once. That was at a bridge across the Gibi (Omo) river between Shoa and Kaffa provinces. It was later, when I had moved to the Yemen Arab Republic (formerly North Yemen), that I saw the full impact of the disease after it had spread across the Red Sea from Africa into a naive cattle population. Here, although cattle mortality was very high, the situation for farmers who did not lose their cattle seemed worse as they tried to nurse 'recovered' animals that had had their gut mucosa destroyed and were immunological cripples subject to starvation and secondary infections.

I arrived in Addis Ababa to commence rinderpest work in the middle of 1971, eager to start in the field on JP15 rinderpest vaccination. The Kabete 'O' strain rinderpest vaccine, developed by Plowright, was being grown and lyophilised by a French team working at a laboratory they had developed at Debre Zeit (now known as Bishoftu), 50 km to the south of Addis Ababa. The problem was, however, that the international donors, including the UK Overseas Development Administration, which had recruited me, had not yet provided the finance and equipment to start JP15 campaign field work.

Life could have been very frustrating, but, fortunately, there was a team of veterinary students from the Royal Veterinary College, London, undertaking an animal disease investigation in Ethiopia. They were well equipped, and I was able to tag along with them, hopefully making myself useful, and, when they left, I inherited all their remaining sampling materials, with which I could do more work while waiting for JP15 to start.

I put their materials to use in southern Ethiopia at Wollamo Soddu where a World Bank project had been set up to increase agricultural production. I was asked by the project manager, Victor Burke, to investigate disease constraints to cattle production.

I produced a monograph on diseases of cattle in Wollamo that was well received by the Chief Veterinary Officer who wanted to print it for distribution until he read the results of the serology: some cattle were seropositive for one of the strains of foot-and-mouth disease, which was supposed not to occur in Ethiopia. He asked me to remove the result from the text, which I refused to do, so the monograph did not get any further. Perhaps today I would be more pragmatic.

In 1972, when I had completed this piece of work and funds and equipment to start the JP15 rinderpest control campaign had still not arrived, but, having tired of waiting, I got hold of an old Land Rover station wagon and an ex-army Bedford 4-ton truck through the British Embassy. With these, and a loan from a hotelier at Lake Awassa, I put together four vaccination teams and headed south, picking up vaccine, diluent and ice at Debre Zeit on the way to the southern border of Shoa province, where I had been initially assigned. I cannot remember where I got other equipment (syringes, needles, ear notchers, ice boxes, refrigerator, beds and tents), but I managed somehow. There was no shortage of vaccinators and animal health assistants to work with, who were eager to start and get their daily allowances, which substantially boosted their incomes.

The JP15 plan was to carry out blanket vaccination of the cattle population for three consecutive years. With Ethiopia's cattle population of 30 million and rugged terrain, this was no small task.

My first small effort was hampered by a cholera epidemic in the area where we were vaccinating, and we returned to Addis Ababa ignominiously after we had run out of money.

Towards the end of 1972, however, United States Agency for International Development (USAID) and British funds arrived, as did our fleet of Land Rovers, and we started our full operations.

To reach the villages with cattle in the mountainous areas, we had to leave our Land Rovers and hire donkeys and mules. They were usually available, but there were welfare considerations. Most of our equipment was not animal transport friendly, being refrigerators designed to be installed in caravans, large butane gas bottles, tents and camp beds. These items got strapped on somehow, much to the discomfort of the donkeys and mules. For me, there was also discomfort as the mules' wooden saddles were hard and unyielding, and for much of the time it was more comfortable to walk alongside them.

A campaign started by making a plan with administrators in an *awraja* (administrative region) to cover all of its *woredas* (administrative districts). To execute the programme in an *awraja* would take at least one month, and, often, teams would seamlessly continue to the next *awraja* without returning to base. An expatriate field officer, recruited by the donors, would usually manage five teams. He (only men were involved) would go into the field for two weeks, returning to Addis Ababa for two to three days to pick up vaccine, diluent, ice and groceries (bread, rice, pasta) that they could not get in the field.

After meeting government officials at *woreda* (district) level and *balabats* (chiefs) at village level, all of whom were always cooperative, public meetings were held, usually under a tree, to publicise the vaccination campaign and set up a programme to cover each *woreda*. At the meetings, messages were put across in at least three languages. I would speak in English, and it was interpreted into Amharic and Oromigna, and also possibly into Kembattigna and Gudeligna. As this was a common procedure, there was an interpreter for each language, and they were good showmen, adding exclamations and gesticulations and probably embroidering the content with comments of their own. It would have been an interesting exercise, but one I never carried out, to have the final oration translated back into English to see if it had any relation to what I had said at the start.

A vaccination team consisted of three government veterinary staff, comprising an animal health assistant, trained at the school in Debre Zeit, which is now the Faculty of Veterinary Medicine, and two vaccinators. Each team also hired a cook from the area where they were working.

Camps were set up at each vaccination site, and cattle keepers were usually given about five days to bring their cattle. An open space was all that was required. Putting cattle into crushes slowed the work down. The herdsmen would catch their cattle individually and pull them head first into a circle surrounding the vaccinators. Usually two, one with the vaccination syringe and a bottle of reconstituted vaccine, and the other with the pliers to simultaneously clip each vaccinated animal's ear in a distinctive clover leaf pattern, which identified a vaccinated animal, would work their way around the circle.

The syringes were metal with glass barrels and held ten 2 ml doses. The 16 gauge needles were not disposable and were sterilised by boiling before reuse. We had small field sterilisers that were put on the gas rings we used for cooking (we took bottled gas with us). Our routine was to take a needle from the boiling (or recently boiled) steriliser when we returned to the tent to reconstitute a 200 ml bottle of freeze-dried vaccine with diluent and recommence vaccinating. So the needle was replaced after every 100 vaccinations. The syringes were disassembled, cleaned and sterilised after a day's use. We carried many spare parts for them. At busy vaccination sites these chunky syringes soon caused blisters and lost skin on the fingers of the vaccinators, and an essential was the first aid kit with a large supply of sticking plasters. It could get very busy: at one site in the Great Rift Valley, where there were many pastoralists with cattle, we vaccinated more than 50,000 head, after which the site looked as if a battle had been fought there.

A major concern was maintaining the cold chain for the attenuated vaccine: we could successfully get it to remote vaccination sites on ice and keep it there in our portable refrigerators, but I was especially concerned when the vaccine was in its diluent in the field and the rate of cattle coming for vaccination was slow. We covered the 200 ml bottles with wet cloths to protect the vaccine from sunlight and keep it cool through evaporation from the cloths.

Not all vaccination sites were busy: in some areas cattle keepers did not regard rinderpest vaccination as a priority and stayed away, despite having been encouraged by those implementing the programme and being cajoled, even threatened, by officers of the local administration and the *balabats* – and here was the problem with JP15.

In the field we soon became aware that a blanket vaccination campaign for the whole cattle population was, first, not achievable and, second, not needed. A large number of the livestock owners lived with their sedentary cattle in remote mountainous areas, cut off from the large pastoral, sometimes nomadic herds where rinderpest could be maintained and from where it could spread. We should have concentrated on the large pastoral/nomadic herds in the lowlands and not wasted our resources on reaching sedentary cattle in the mountainous areas, as cattle in the mountains generally only mixed with other cattle from their village and outbreaks of rinderpest would come to a 'dead end' because of the limited numbers available to be infected and the mountainous natural barriers between villages. An extreme example of efforts to vaccinate sedentary cattle in remote mountainous areas was provided by a Canadian JP15 team deployed to the *ambas* (flat mountain tops) in the Simien mountains that went to the extreme lengths of using helicopters to deploy vaccinators to its most inaccessible sites.

We, or I anyway, were consequently challenging our chiefs and policy-makers, proposing that we concentrated our campaigns in the pastoral populations and along the cattle trade routes and livestock markets emanating from them, undertaking rinderpest surveillance at the same time.

For me, the JP15 campaign was a flawed programme, not only for the above reasons but also because it concentrated all resources on one disease, neglecting the control of the other, mainly endemic, diseases of livestock in Ethiopia.

The major lesson I learnt in Ethiopia during the JP15 campaign was that three annual blanket vaccination campaigns could not successfully cover the large and diverse cattle population, as, despite the use of vigorous publicity campaigns, livestock keepers made use of their own veterinary knowledge to assess the risk from rinderpest and then made decisions based on prioritisation of their activities. If they perceived the risk of rinderpest to be low, taking cattle to a vaccination site could be seen as less important than planting/harvesting activities or moving to better grazing. In addition, in some circumstances, movement to a vaccination site could mean walking through the territory of clans with which they had bad relations or into areas where tick-borne diseases were more prevalent. The lesson for me was that vaccination campaigns could have been more successful if accompanied by active surveillance for rinderpest and the use of risk analysis to plan targeted campaigns.

Nevertheless, despite the above and the civil war taking place at the same time, the opportunity I was given to live and work for five years with the rural populations of Ethiopia and benefit from their enormous friendliness and hospitality – and to visit remote and staggeringly beautiful parts of the country – has left me with memories I treasure.

CHAPTER 4.2

PAN-AFRICAN RINDERPEST CAMPAIGN (PARC)

W.N. MASIGA [1], S.H. MARIAM [2], J. MULDER [3] & S.W. WAKHUSAMA [4]*

(1) P.O. Box 47926-00100, Nairobi, Kenya
(2) P.O. Box 7417, Addis Ababa, Ethiopia
(3) Brink 11, 7981BZ Diever, Netherlands
(4) P.O. Box 19687-00202, Nairobi, Kenya

*Corresponding author: s.wakhusama@oie.int

SUMMARY

A programme entitled the Pan-African Rinderpest Campaign (PARC) was developed by the Organization of African Unity Interafrican Bureau for Animal Resources (OAU-IBAR), now known as AU-IBAR, financed by the European Commission and implemented from 1986 to 1998. The objective of the programme was to eradicate rinderpest from the African continent. The main components of the programme included technical assistance; intensive vaccination across sub-Saharan Africa; establishment of vaccine banks; research, with a focus on epidemiology and diagnostics; establishment of a cordon sanitaire (quarantine zone) to limit the spread of the disease; provision of emergency funds for interventions in newly infected areas; and quality control of vaccines used in the campaign. OAU-IBAR's role in the programme was to promote political support; implement national coordination and monitoring activities; establish and manage vaccines banks; and harmonise donors and technical participation in the campaign. The Pan-African Veterinary Vaccines Centre (PANVAC) was charged with the responsibility for quality control of the vaccines used in the campaign, while individual Member States of the then OAU, now the African Union (AU), implemented the programme at their national levels. At the conclusion of the programme in 1998, rinderpest had been eradicated in western and central African states, and the disease had not been reported from the majority of eastern African countries. Sixteen countries had joined the World Organisation for Animal Health (OIE) Pathway for rinderpest by declaring provisional/zonal freedom from the disease. The cattle population on the continent significantly increased as a result of reduced mortality attributable to rinderpest, with, for example, Ethiopia and Sudan recording a 2015 population increase of 136% and 190%, respectively, above the 1985 census levels. Apart from the programme showing that the disease was self-limiting in African buffalo (*Syncerus caffer*), it also therefore excluded wildlife as a reservoir for the disease. The area of pastureland was increased, and trees were planted to prevent soil erosion and to cater for the expected increase in the cattle population following the eradication of rinderpest in Djibouti and Ethiopia. The programme also strengthened Veterinary Services through the privatisation of some services and cost sharing between government and private veterinary services.

A cost–benefit ratio estimated across ten countries participating in PARC was 1.83:1. The internal rates of return (IRR) varied from 11% for Côte d'Ivoire to 11.8% for Burkina Faso. All of these were well above the opportunity cost of the capital. The total welfare gains from PARC were established at ECU 57.5 million (European currency units,

the unit of account for the European Community that preceded the euro), which could be translated into ECU 10.7 million (or US$11.68 million) to consumers.

KEYWORDS **Cost–benefit – Pan-African campaign – Rinderpest eradication – Vaccine banks – Vaccination.**

INTRODUCTION

Period in the aftermath of Joint Programme 15 and lessons drawn

The Joint Programme 15 (JP15) programme, its outcome, its successes and eventual undoing are discussed in Chapter 4.1 of this book; rinderpest had not been eradicated and was regaining lost ground.

It is now well accepted that rinderpest elimination from a population can be achieved only if the principle of immunosterilisation is applied to arrive at a level of herd immunity sufficient to eliminate infection from the population and exclude its reintroduction (1, 2). It goes without saying that for this dictum to be effective the immune coverage has to encompass the whole of the target population at the same time, which is no easy matter when the population is a national one. Thus, a major difficulty in relation to eradicating rinderpest following the JP15 phasing formula related to the long gap between actions; for instance, the vaccination phases in the Niger were completed two years apart. Even the one-year discontinuity between different regions of Chad presented problems, as a few residual Nigerian outbreaks came from this source. This procedure was not properly implemented throughout the period of the JP15 project or afterwards.

It was assumed that the affected countries would automatically stamp out any outbreaks that occurred, but this did not happen. Comfort had been taken in the notion that ongoing campaigns with a targeted 80% vaccination coverage would automatically eliminate the virus. However, in reality, the targeted vaccination coverage percentage rarely generates a similar percentage of immune animals across the target population, as this will depend on several factors involved in vaccine handling and application in the field. In addition, this understanding takes no account of the dynamics of herd turnover and assumes that cattle populations are homogeneous, which they are not. The recommended solution was for states to continue vaccinating their yearling populations for several further years and to take appropriate sanitary measures should an outbreak occur (3); such measures were possibly under implemented in many African countries when the campaign concluded in 1973. In Nigeria, for a time at least, an attempt was made to continue to try to maintain high immunity levels by implementing a mass vaccination policy using national resources. In addition, the OAU Scientific Technical Research Commission (STRC) and the OAU-IBAR had to continue to monitor the rinderpest status in the event of an outbreak of the disease occurring in any OAU Member State.

The experiences and challenges encountered during the JP15 campaign informed subsequent programmes for the eradication of rinderpest in Africa. A concept developed by the OIE in 1989, which became known as the OIE Pathway, was instrumental in this endeavour, and the OAU-IBAR along with other stakeholders promoted the PARC and Pan-African Control of Epizootics (PACE) programmes in order to eradicate the virus using a straightforward approach and secure the outcome by having a series of national surveillance audits to ensure continental safety.

In summary, although the JP15 campaign did not eradicate rinderpest from Africa, it substantially reduced the prevalence of disease and provided good lessons for subsequent campaigns.

Outbreaks of rinderpest after JP15 and the development of the Pan-African Rinderpest Campaign

Post-JP15 epidemiological intelligence indicated that rinderpest virus was present within two endemic areas along the Mauritania–Mali and Ethiopia–Sudan borders (4) although in the absence of a comprehensive assessment, further hidden foci may have remained, as for instance in the Somali ecosystem.

Although figures on vaccinations showed coverages of 78% and 79% in Mali and Mauritania, respectively, rinderpest remained in some defined foci in these countries and in many other Central and West African countries. Given the dynamics of the nomadic pastoral production systems in these countries, the herd immunity profiles are likely to have declined precipitously within a short time after the JP15 programme. This, coupled with residual foci of undetected rinderpest, was instrumental in the resurgence of rinderpest epidemics in West Africa in the early and mid-1980s, during which more than half of the countries in West Africa reported an increased number of outbreaks (see Chapters 4.1 and 4.5). In 1981, a joint OAU-IBAR/Food and Agriculture Organization of the United Nations (FAO)/OIE meeting proposed a continental campaign for rinderpest, as well as for contagious bovine pleuropneumonia (CBPP). In this proposal, one of the lessons learnt from the failure of JP15 was incorporated, namely the need to concentrate resources in the areas where the resurgence of rinderpest was having the maximum impact. The plan that was developed called for intensive vaccination of all cattle for five consecutive years with a combined rinderpest and CBPP bivalent vaccine. Under the guidance of an international coordinator, this programme was undertaken in West Africa: Benin, Burkina Faso, Côte d'Ivoire, Mali, Mauritania, Senegal, Togo and part of the Niger. These countries were subjected to vaccination ringed with a buffer zone consisting of cattle vaccinated for three consecutive years. In point of fact, this emergency programme ran for only two years and was complemented with vaccination already being provided by FAO through their technical cooperation programme (TCP) (see Chapter 5.3). Despite this programme, by 1985, rinderpest outbreaks were being reported in Benin, Burkina Faso, Ethiopia, Ghana, Côte d'Ivoire, Kenya, Mauritania, the Niger, Nigeria, Sudan, the United Republic of Tanzania and Togo, the virus having continued to spread eastwards within West Africa between 1980 and 1982 and from East to West Africa between 1982 and 1983 (see Chapter 2.4). This resurgence in rinderpest necessitated the development of a more comprehensive programme: the Pan-African Rinderpest Campaign, to build on the achievements of JP15 and ensure rinderpest eradication.

Learning from the shortcomings of JP15, and building on its achievements, PARC was launched by the OAU-IBAR in consultation with those African states experiencing rinderpest outbreaks, FAO, the OIE and donor agencies. The approach was a two-pronged effort combining the regional activities of a coordination unit and national projects in 35 participating countries (Fig. 1). The hallmark of PARC was to carry out a comprehensive regional undertaking aimed at the complete eradication of the disease across the continent.

THE SIGNING OF A JOINT AGREEMENT BETWEEN THE ORGANIZATION OF AFRICAN UNITY AND THE EUROPEAN COMMISSION

The financial agreement for the implementation of PARC between the European Commission and the OAU was signed by His Excellency the late Ide Oumaru, the then Secretary General of the OAU, at the first conference of African Ministers of livestock affairs in Addis Ababa, Ethiopia, on 3 July 1986. Additional funding for PARC was also committed by donors, including the Governments of Belgium, Italy and Nigeria.

THE MAIN COMPONENTS OF PARC

The main PARC programme was defined in 1986 and consisted of six principal components, all essentially focused on the control and eradication of rinderpest.

The components were:

- technical assistance to the OAU-IBAR;
- immediate action in areas where rinderpest was endemic;
- direct action against rinderpest in participating countries not covered by emergency actions;
- research programmes;
- establishment of vaccine banks;
- a reserve fund for possible emergencies;

Technical assistance to the OAU-IBAR

Before the PARC project was initiated, the OAU-IBAR had received technical and financial assistance to coordinate the project to eradicate rinderpest. Planned initially for two years, the technical assistance element of the coordination unit was maintained throughout the programme. The number of coordination unit personnel, however, remained relatively low, with one coordinator for West and Central Africa and another for East Africa. There were also three technical assistants, one in Bamako and two in Nairobi supported by the European Commission funds, and a technical adviser supported by the UK Department for International Development (DfID). In addition, there was an epidemiology unit supported by FAO, initially with Japanese trust funds and later with EU funds, in part channelled through FAO. Important contributions from USAID were sustained from 1990 to about 1998 that resulted in tools such as thermostable vaccine, community-based vaccination and participatory disease surveillance. They were implemented under the PARC umbrella.

Although different donors financed different units, the staff generally worked harmoniously under the direction of the OAU-IBAR. It is regrettable, however, that with the exception of the posts financed by the European Union, the other units

FIG. 1
COUNTRIES PARTICIPATING IN PARC

Final boundary between the Sudan and South Sudan has not yet been determined

Source: Andreas 06 (2006). – Political map of Africa. Available at: https://en.wikipedia.org/wiki/File:Blank_Map-Africa.svg (accessed on 9 June 2021), modified to indicate country participation

were discontinued because of a lack of continued funding by other donors. Nevertheless, this did not adversely affect the operations and objectives of the programme.

In summary, it can be concluded that during the PARC project's implementation, OAU-IBAR coordination played a key role in the reform and harmonisation of livestock policies at country level (see section 4.3 below) and in both the design and setting up of the strategy against rinderpest (see section 4.5 below). In general, this coordination made it possible to guarantee continuous implementation of the programme as soon as local conditions permitted. The work relied on a series of visits to the countries in order to establish a policy dialogue and to assist in the preparation and follow-up of national components. This process made it possible to ensure a coordinated approach to the fight against rinderpest.

Immediate action in the areas where rinderpest was endemic

The PARC technical plan called for immediate action to cope with the emergency situation created by the rinderpest resurgence post-JP15 in both West Africa and East Africa. Intensive vaccination in Ethiopia, Somalia, Djibouti and Sudan, similar to that practised earlier along the Mauritania–Mali border, failed, however, to take into account the fact that by 1984, before the start of PARC implementation, the virus was already west of the Nile and was possibly also present elsewhere, such as in the Somali ecosystem. Although the outbreaks had been robustly met with emergency vaccination, implemented through FAO TCPs, it was realised that the initial concept of the two intensive action zones described above had been overtaken by epidemiological events.

Direct action against rinderpest in participating countries not covered by emergency action

A revised proposal under PARC called for a zone of intensive action to stretch across the entire Sahelian region and down the east coast of Africa to include the whole of Kenya and the United Republic of Tanzania (5). Within this zone there would be simultaneous and protracted vaccination in those countries harbouring the virus until a zero incidence level was achieved. A buffer zone was also to be limited to the stretch along the West African coast extending to Central Africa.

When PARC was launched in 1986, the virus was still present in East, Central and West Africa. Reports received at the OAU-IBAR and the OIE showed that the disease was more active in some countries than others. A series of FAO emergency TCPs had provided vaccine and vaccination support and had reduced the incidence to zero in many countries in West Africa in the lead up to PARC. It was therefore decided to establish priority actions against the disease in accordance with its prevailing level of activity. Accordingly, the initial strategy was a fire-fighting approach in which PARC decided to take immediate action in Nigeria, Burkina Faso and Mali in West Africa and in Ethiopia and Sudan in East Africa. The campaign then targeted more systematic intensive action in the following countries: Benin, Burkina Faso, Burundi, Cameroon, the Central African Republic, the Congo, the Democratic Republic of the Congo, Djibouti, Egypt, Ethiopia, Equatorial Guinea, Gambia, Gabon, Chad, Ghana, Guinea-Bissau, Côte d'Ivoire, Kenya, Mali, Mauritania, the Niger, Nigeria, Rwanda, Senegal, Somalia, Sudan, United Republic of Tanzania, Togo and Uganda (see Chapter 4.5). It must be emphasised that, although some of these countries had not reported rinderpest, they were expected to provide a buffer zone to prevent the spread of the disease from the infected countries.

Implementing this strategy secured a remarkable victory over rinderpest in Central Africa, from where it was eliminated as early as in 1988.

THE ORGANISATION OF PARC

Appropriation of PARC funds

When the OAU approached the European Commission for assistance to combat rinderpest outbreaks, there was initial apprehension in the services of the European Commission (Directorate-General 8, now the Directorate-General for International Cooperation and Development). After all, the European Development Fund (EDF) had not too long before financed the major part of JP15, an earlier effort to eradicate rinderpest. Opinions in the Commission were therefore divided on how to approach the crisis this time.

The original proposal forwarded by the OAU-IBAR, which did not differ very much from the JP15 approach, was mainly of a technical nature. It was later modified to answer the question – how was it then possible that in Africa, with many more veterinarians than in the previous decade, rinderpest could spread so rapidly? At that time, African government budgets for the maintenance of Veterinary Services had declined. The major part of the budget went to the payment of salaries and very little was left for the veterinary personnel to use to implement activities. This budget allocation meant that only limited field activities could be implemented, thus adversely affecting rinderpest vaccination. Nonetheless, this was the prevailing situation in all African countries, and the OAU had little impact on changing the situation, even though it did not agree with it. The opinion in the European Commission at the time had been that, if a campaign along the lines of JP15 were undertaken again, this would produce similar results, as long as the fundamental problem was not addressed. Moreover, the Commission felt that more attention was needed to address research into the role of wildlife in the epidemiology of the disease. It was also important to improve vaccine quality and delivery. In this regard, the development of a thermostable vaccine that could withstand the poor infrastructure, overcome the cold chain shortcomings and allow the vaccine to reach the remote and difficult areas of Africa while remaining viable was desirable (6). There was also the need for improvement of diagnostic methods in order to generate accurate data on the epidemiology of the disease and for the establishment of vaccine banks.

On the basis of the above, the PARC funds from the European Commission were destined for use in three main ways. They were to be used, first, to suppress the virus circulation, with blanket vaccination designed to boost the level of immunity of the cattle population of an entire country; second, to create buffer zones to block virus movement in a particular direction; and, third, to target vaccination when the incidence of infection was reduced. By 1987, the need to include CBPP within a mass vaccination programme had been realised. Other uses of the funds included strengthening the capacity of national Veterinary Services to undertake vaccination campaigns. The Veterinary Services would then implement their own campaigns under the coordination of the OAU-IBAR, in accordance with the financing agreement signed between the OAU and the European Commission. PARC funds were also to be used to support livestock policy reforms in participating countries, in order to ensure a better financial foundation and the sustainability of Veterinary Services. Consequently, the appropriation of funding became dependent on the articulation of policy reforms and on strengthening the delivery of the national Veterinary Services.

Organisation of the PARC programme in OAU Member States

A central coordination unit was established at the OAU-IBAR in Nairobi and there were two sub-regional coordination offices, for East Africa in Nairobi, Kenya, and for West and Central Africa in Bamako, Mali. Having agreed on the components of national projects with the OAU-IBAR and the European Commission, participating countries appointed PARC national coordinators. These coordinators became responsible for supervising the implementation of PARC activities at national level in accordance with the continental strategy and technical guidance on future actions. High-level annual ministerial meetings consisting of all OAU Member States were organised to oversee the progress of PARC and to provide guidance on policy matters. A technical committee was established, comprising donors, technical partners, OAU Member States, and the OAU-IBAR. The technical committee met twice a year to review the progress of the PARC project's implementation.

The OAU, the EDF and national government support

From the outset, the Director of the OAU-IBAR was appointed as the authorising officer for the EDF funds directly earmarked for PARC activities. The OAU-IBAR's role was to enhance political support, to coordinate and monitor the implementation of national-level activities, to establish and manage vaccines banks, and to harmonise donor and technical participation in the campaign.

Funds allocated to countries were made available as and when implementing protocols were signed between each country and the local EU delegation. The first financing agreement paved the way for an input of ECU 50 million, of this ECU 25 million was allocated to immediate 'fire-fighting' action and the creation of vaccine banks to insure against supply failures and to specified research programmes. The remaining ECU 25 million was allocated to regular programmes designed to strengthen Veterinary Services for the control of rinderpest and to improve livestock productivity. In 1990, a further ECU 7.5 million was made available for allocation to country programmes, and, by 1995, ECU 35.5 million had been added. In 1995 a further ECU 5 million was invested in controlling the outbreak of rinderpest in wildlife in Kenya, bringing the external financial inputs to PARC from the European Union alone to ECU 97.9 million for the period from 1986 to 1995.

PARC finances, unlike JP15, were focused on strengthening Veterinary Services and implementing mass vaccination, together with a parallel programme aimed at improving the efficiency of Veterinary Services through the creation of revolving funds that promoted the privatisation of Veterinary Services and the formation of herders' associations. These latter components were regarded as part of a broader structural adjustment programme. In addition to vaccination against rinderpest, there were costs related to communication campaigns, monitoring and technical assistance. Thus, it can be seen that PARC was about much more than rinderpest eradication, even if this was its prime focus. The underlying concept relied on an understanding that Veterinary Services had become very weak and that only by strengthening vertical and other livestock services would it be possible to eradicate rinderpest. However, this principle was not universally accepted by many OAU Member States who viewed this as a political intrusion into their day-to-day decision-making and governance.

Studies on inputs to the PARC programme in ten countries estimated the contributions of the national governments at around 45% of that of the EDF contributions (7). By the end of the programme, the equivalent of approximately €106 million (or US$115.76 million) had been spent on rinderpest eradication, without taking into account the considerable inputs made by international organisations, such as FAO and the International Atomic Energy Agency (IAEA), the OIE, and other donors, such as France, Japan, Nigeria, Sweden, the United Kingdom of Great Britain and Northern Ireland, and the United States of America (USA).

The PARC policy reforms initiatives

Policy reforms were undertaken over a period of two years, resulting in the following actions:

- support for revitalisation or restructuring of livestock services;
- support for the implementation of pricing policies and livestock trade and marketing policies;
- the implementation of anti-desertification measures, e.g. destocking, forage and pasture development and afforestation.
- support for livestock production in areas of intensive crop farming, and improved control of water resources in grazing areas.
- the privatisation of Veterinary Services.

Although the implementation of most of these policies slowed down the pace of the control and eradication of rinderpest, they nevertheless ensured that Veterinary Services were prepared for any possible reintroduction of the disease.

The PARC coordination, organisation, management and follow-up

During the PARC project's implementation, the OAU-IBAR played a key role in both the design and setting up of the strategy. The overall campaign was coordinated by the OAU-IBAR, while the Ministries of Livestock Affairs of OAU Member States were in charge of the overall implementation of the PARC programme. Cross-border meetings were organised frequently to make sure that countries were collaborating on the implementation of PARC activities between two or three neighbouring countries. The OAU-IBAR PARC coordination office provided continuous support, including frequent visits to the countries in order to establish policy dialogue and to assist in the preparation and follow-up of national components. This process made it possible in the later years to ensure a coordinated approach by the AU-IBAR (formerly the OAU-IBAR) to the fight against rinderpest in such areas as the ecosystems of the Maasailand in Kenya and the United Republic of Tanzania, the Somali ecosystem in Somalia, Kenya and Ethiopia and the Afar region found in Djibouti and Ethiopia (8). Generally, countries were brought together and their campaigns were synchronised.

The rinderpest eradication strategy

The epidemiology section within the PARC coordination unit was charged with developing an initial strategy for combating the virus. The strategy was to achieve a high level of herd immunity. This was assumed to be 80% by the Veterinary Services in Africa. In order to stop the spread of the disease from Sudan to West Africa and from East Africa to Southern Africa, the first technical committee meeting in Nairobi in 1986 recommended the creation of cordons sanitaires in Central, West and East Africa because it was believed that the disease in West Africa had originated from Sudan. Within these buffer zones, mass vaccination was to be carried out to create an immunity level of at least 80%. Indeed, epidemiological modelling carried out later confirmed that an 80% immunity level was more than sufficient to limit virus circulation and eliminate the disease (9), thus reinforcing the view that a greater than 80% herd immunity level should be sought.

The PARC coordination unit also decided to use serology as a management tool, by employing the seromonitoring of vaccinated animals to determine the levels of herd immunity achieved by the vaccination campaign, and serosurveillance to follow up and trace virus circulation. A network of competent laboratories was established and used the competitive enzyme-linked immunosorbent assay (c-ELISA) technology for determining the level of herd immunity to rinderpest (see Chapter 3.3). A massive programme to transfer the technology to national and regional laboratories was carried out by the PARC coordination unit and the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria. The European Commission provided funding for this activity.

Emergency preparedness plans

Early in the PARC programme, the issue of sudden and unexpected outbreaks of rinderpest was addressed. All countries participating in PARC were encouraged to develop emergency preparedness plans, which included availing themselves of finance, equipment, materials and personnel for immediate intervention in the event of rinderpest recurrence. Emergency preparedness planning was aided by FAO's Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES), which developed guidelines and regional workshops on the subject, in support of PARC. Emergency vaccine banks, emergency funds and rinderpest contingency plans were all made available in the middle stage of PARC. This approach prompted all countries participating in PARC to be well prepared and alert to deal with any possible rinderpest outbreaks. Fortunately, outbreaks of the disease did not occur in cattle in participating countries except Kenya and Ethiopia, where the last cases were recorded in 1989 and 1995 (5). It should, however, be noted that outbreaks of the disease also occurred in buffaloes in Tsavo West National Park from 1994 to 1999, in Nairobi National Park in 1996 and in Meru National Park in 2001, all in Kenya (9). To contain the disease, the OAU-IBAR negotiated the provision of emergency funds from the European Union to support the vaccination and acquisition of vaccine. Rinderpest vaccine produced at the Kenya Veterinary Vaccines Production Institute (KEVEVAPI) was used in the campaign, following its quality assurance by PANVAC. Cattle populations in areas adjoining the parks were vaccinated and the disease was controlled.

Revision of vaccination strategy and the broader long-term continent-wide vaccination campaigns

In the course of implementing PARC, strategies for vaccination and seromonitoring were improved. A new vaccination strategy involved targeted vaccination as opposed to the blanket mass vaccination previously used in immediate action countries at the start of the campaign. An ELISA technique given technical support by the joint division of FAO and IAEA was introduced and transferred to a number of national laboratories in countries affected by rinderpest. This greatly facilitated serological testing to support epidemiological surveillance activities and seromonitoring following vaccination. Lessons learnt from the initial operations of PARC in 1987 identified the need to proactively involve all stakeholders, ranging from cattle owners to government decision-makers, in rinderpest eradication initiatives. Without this approach, the control of rinderpest had become challenging. Cross-border meetings were frequently organised by the PARC coordination unit, involving those responsible for the livestock of neighbouring countries, directors of Veterinary Services and PARC coordinators, to facilitate harmonious implementation of vaccination campaigns and disease surveillance activities. Their cooperation was vital to achieve eradication of the disease and the delivery of livestock services to the grassroots level. In addition, it was envisaged by some that the progressive control and eradication of rinderpest would result in increasing cattle and wildlife populations, with potential negative impacts on the environment. Thus, the stakeholders were deemed to be pivotal in safeguarding the environment against desertification. There was also an urgent need to strengthen the public relations image of the campaign in order for it to achieve sufficient momentum and priority at national, regional and international levels.

Cordon sanitaire

Within the wider campaign, PARC developed the concept of interterritorial vaccine belts, with the intention of dividing the endemic regions in sub-Saharan Africa in a way that defined epidemiologically relevant 'cells' that were separated from one another with populations of well-vaccinated cattle. The establishment of 'cordons sanitaires' under this strategy helped each country to progress independently of the others towards eradication.

In 1988, with estimates showing that more countries in eastern Africa were infected than in western Africa, PARC and FAO proposed the establishment of the 'Central Africa block (CAB)', made up of highly immunised cattle in Chad and the Central African Republic, in order to prevent reinfection of animals in West Africa from eastern Africa. The 'West Africa block (WAB)', running through Nigeria, the Niger, Burkina Faso, Mali and Senegal, and adjoining the eastern end of the CAB was also conceptualised. However, the improving situation in West Africa rendered the WAB redundant, but the CAB was implemented in the eastern areas of the Central African Republic and Chad.

Seromonitoring results obtained from Chad, however, illustrated that the cordon sanitaire was not a success, as seropositivity fell far short of the 80% mark intended for the immunosterilisation of the corridor. These seromonitoring results were the outcome of the 1989–1996 vaccination campaigns. It is possible that there had been entry of naive animals from outside the cordon, but more likely the remoteness of the cordon area precluded effective implementation. The situation was no different for the other participating country, the Central African Republic. However, the cordon sanitaire strategy enabled the fast tracking of the West Africa rinderpest freedom accreditation process, which started in 1999, by providing a framework for countries to cease vaccination, a prerequisite for embarking on the OIE Pathway for the final eradication of rinderpest.

In the meantime, to rid the Sudan of the remaining foci of rinderpest, an intensive vaccination programme of the Murle and associated Jie herds was conducted, with the resultant elimination of the disease as confirmed by subsequent epidemiological investigations. The last rinderpest vaccination was in 2002, and subsequent investigations provided no basis for the belief that rinderpest was still present in southern Sudan. The final stage of rinderpest eradication in southern Sudan was coordinated by two units of the United Nations (UN) Operation Lifeline Sudan (OLS).

Lokichoggio town, based in northern Kenya, was the site for the southern Sudan UN base. This centre brought together 13 non-governmental organisations (NGOs) that were collaborating with the United Nations Children's Fund (UNICEF), and later FAO humanitarian assistance operations. At this stage, the most important element of the NGO interventions supported by the PARC/PACE programmes was the fight against Africa lineage 1 rinderpest virus, which was executed by Vétérinaires Sans Frontières (VSF) Belgium. The other unit, the northern coordination unit that again came under FAO's OLS humanitarian assistance programme, collaborated closely with the government of Sudan. Alongside PARC and its successor programme, PACE (see Chapter 4.3), the Community Animal Health (CAH) and Participatory Epidemiology (PE) Project supported the rinderpest eradication programme by training community animal health workers (CAHWs) in Lokichoggio and by commissioning epidemiological studies (10).

In conclusion, the creation of cordon sanitaires is an innovative approach to compartmentalisation, in theory at least, restricting disease spread and thereby preventing the contamination of disease-free areas. As actually practised, given operational constraints, its most important benefit was to provide a framework for countries in West Africa to abandon mass vaccination and proceed with accreditation of rinderpest freedom.

Establishment of vaccine banks

It was envisaged that later in the programme, and with the progressive cessation of rinderpest vaccination on a 'mission-accomplished basis', cattle populations would become increasingly susceptible to infection. It was therefore necessary to establish rinderpest vaccine banks as a precaution against a re-emergence of the disease. PARC established and maintained a stock of approximately 11 million doses of the vaccine at the Botswana Vaccine Institute (BVI), Gaborone, Botswana; the Laboratoire National d'Élevage et de Recherches Vétérinaires (LNERV), Dakar, Senegal; the National Veterinary Institute (NVI), Debre Zeit, Ethiopia; the National Veterinary Research Centre (NVRC), Muguga, Kenya; and the Facha Veterinary Research Laboratory, N'Djamena, Chad. In addition, the project funded a rinderpest vaccine bank in Lokichoggio in north-western Kenya and in Khartoum, Sudan, during the final stages of the rinderpest campaign in southern Sudan. PARC paid manufacturers retention fees for maintaining the vaccine banks. The manufacturers were allowed to replace the stocks to maintain good-quality vaccines for the bank and not exceed vaccine batch shelf lives. When batches were sold, they were immediately replaced by fresh, potent vaccine. One million doses were utilised for emergency in Kenya and the United Republic of Tanzania, between 1995 and 1996. After 1991, only the vaccine bank at the BVI was retained.

RESEARCH FOCUSING ON RINDERPEST, ESPECIALLY ON EPIDEMIOLOGY AND DIAGNOSTICS

It was envisaged that, for the successful control and eradication of rinderpest, PARC had to take cognisance of the relevant research findings in the areas of immunology, epidemiology and diagnostics.

Immunosuppression

A research programme involving the Institute for Animal Health (IAH) Pirbright, United Kingdom, investigated the possible immunosuppressive effects of vaccination against rinderpest. The conclusion was that vaccination with the attenuated strains did not compromise the bovine immune system (11).

Vaccine thermostability

In 1989, a group from Tufts University working in the USA and the Niger showed that, by adapting virus production to Vero cells and improving the lyophilisation cycle, it was possible to develop a thermostable rinderpest vaccine that was still potent 30 days after leaving the cold chain (12). This product became known as Thermovax. With a view to making this vaccine available within PARC, a technology transfer project was initiated with the NVI, Ethiopia; the Laboratoire National Vétérinaire (LANAVET), Cameroon; and the Central Veterinary Laboratory (LCV) in Mali. The technology was successfully transferred and when Thermovax became commercially available in 1993, the Botswana Vaccine Institute initiated large scale production to remain competitive. The availability of Thermovax was useful because CAHWs in this region were able to utilise the technology to vaccinate pastoral herds in some remote areas that would have been otherwise impossible to access using the conventional Veterinary Services (13). Rinderpest had already been eliminated from Central and West Africa and the thermostable product was mainly used in Somalia, south Sudan, Ethiopia and Uganda by the International Red Cross, VSF, UNICEF, and national governments as part of PARC. The application of the product and its use by CAHWs aided the timely eradication of rinderpest from the most challenging locations, including the Karamoja region of Uganda, the Afar region of Ethiopia, then southern Sudan (now South Sudan) and Somalia.

Rinderpest in wildlife

The PARC programme had to deal with the possible persistence of rinderpest in wildlife in northern United Republic of Tanzania, where an outbreak in cattle in 1982 had spread to buffaloes (14). With the vaccination of the affected cattle populations, the disease eventually died out in wildlife. Following this, it was believed that rinderpest was close to being eradicated from the continent, but in 1994 an outbreak of the disease caused by lineage 2 virus occurred in Tsavo West National Park, Kenya (15, 16). The disease spread in slow and fast waves between 1994 and 1997, involving many species but mostly affecting buffaloes (*Syncerus caffer*), lesser kudus (*Tragelaphus imberbis*) and eland (*Taurotragus oryx*) (17) (see also Chapter 2.5). As a result of this outbreak, there was increased coordination and integration of disease surveillance in susceptible wild species during the last phase of the PARC programme, and its successor, PACE.

Investigations in livestock in the Somali ecosystem using participatory disease surveillance found a long history of undetected rinderpest circulating in the region. This was often as mild disease, but well known to Somali herders. These investigations ultimately led to the confirmation of active disease in Fino, Kenya and are highly suggestive that cattle were the ultimate reservoir of rinderpest in the region and the wildlife outbreak was an extended spill-over event (18).

Following the outbreak of rinderpest in wildlife, an African wildlife project was established, with the aim of carrying out disease investigation and retrospective surveillance (19). PARC funded investigations to ascertain the infection status of certain wildlife species. Fortunately, the results demonstrated that the virus had died out and that buffalo populations across the United Republic of Tanzania had not retained the virus. Similar research was undertaken in Cameroon, and the results were the same as those observed in wildlife in the United Republic of Tanzania. The project was concluded in 2000. The results of the project showed that most of the East African wildlife, including those species in the Serengeti ecosystem, were free from rinderpest. The project also showed that the disease was self-limiting in buffaloes, and therefore wildlife was not a reservoir of infection. The project generated data verifying the absence of circulating rinderpest virus in high-risk areas of Chad, the Central African Republic, Sudan (including the area that is now South Sudan), Ethiopia, Kenya, Uganda and the United Republic of Tanzania. It also enabled the collection of samples for the confirmation of rinderpest in buffaloes in Tsavo West National Park in 1994–1999, the Nairobi National Park in 1996 and the Meru National Park in 2001, all in Kenya. The project enhanced the capacity to perform wildlife surveillance techniques in the participating countries, through the training of veterinarians and technicians in immobilisation, clinical examination and sampling of different wildlife species.

PROVISION OF A RESERVE FUND OF ECU 3 MILLION FOR POSSIBLE EMERGENCY INTERVENTIONS

The EU delegation in Kenya held a reserve fund of ECU 3 million for emergency interventions. The funds were available to countries with approved contingency plans on assurance of subsequent reimbursement. This fund was eventually discontinued and ECU 0.5 million were transferred to the OIE, Paris, as a reserve with the same understanding. Accordingly, all countries developed contingency plans in readiness for any outbreaks. The creation of a reserve fund, as described above, greatly contributed to the eradication of rinderpest, as this was an incentive to countries as a fall-back in times of emergency. This fund could only be accessed by countries with approved contingency plans. Rinderpest was eradicated before any country accessed the funds.

THE OIE PATHWAY FOR ACCREDITATION OF RINDERPEST FREEDOM

As no rinderpest outbreak had been reported in West and Central Africa since 1988, the joint OAU-IBAR/FAO-EMPRES workshop held in Bamako in 1995 prevailed on West Africa PARC-participating countries to end mass vaccination and declare provisional freedom from the disease. The fifth PARC technical committee meeting, held in 1997, further urged countries in West and Central Africa to join the OIE Pathway immediately. A similar recommendation was made at the sixth PARC technical committee meeting, held in 1998. For the rest of the countries, the OAU-IBAR recommended a focused vaccination strategy, with rinderpest vaccination being restricted to infected and surrounding areas. Elsewhere, the countries were advised to strengthen emergency preparedness, cease vaccination and declare provisional freedom from rinderpest to the OIE, either as a country or as a zone within a country.

THE PAN-AFRICAN VETERINARY VACCINE CENTRE

Following a preparatory phase study, which had shown that some rinderpest vaccine manufacturing laboratories were experiencing problems meeting international potency standards, the OAU-IBAR and FAO decided to establish regional vaccine quality control and training centres in Dakar, Senegal, and in Debre Zeit, Ethiopia. These centres, together known as PANVAC, were established to carry out quality assurance testing of rinderpest vaccines for use throughout the campaign and to transfer the technology to the African vaccine production laboratories. Funding to sustain the laboratories, however, proved difficult to obtain. The function of ensuring the quality of rinderpest vaccine used in PARC was maintained continuously with a combination of funding from the United Nations Development Programme (UNDP), FAO technical cooperation programmes and FAO trust funds, provided by Japan and the European Union. However, financial constraints forced the closure of the Dakar facility in 1993, and all subsequent activities were centred in Debre Zeit, Ethiopia, with continuing support from the Ethiopian government. Later in 1998, this laboratory was established as PANVAC, an OAU institution with the mandate to serve as an independent vaccine quality assurance laboratory. The funding provided by the OAU to PANVAC reversed an earlier trend that saw manufacturers releasing sub-standard vaccines. In 1994, 78% of vaccine samples reached the international potency standard of $10^{2.5}$ $TCID_{50}$ per dose, while in 1996, 1997 and 1998 the figures were 82%, 95% and 89%, respectively. The use of quality-assured vaccine throughout the campaign was pivotal in the eradication of rinderpest, and thus PANVAC was integral to the success of PARC. The implementation of PANVAC is more fully described in Chapter 5.6.

COMMUNICATIONS

To give the campaign momentum and priority at the national and international levels, it was important to increase the awareness of various organisations and the public regarding PARC. Accordingly, communication units and media reference centres were established in the Nairobi and Bamako PARC coordination units. The aim of these units was to assist in national capacity-building and for the formulation and implementation of communication components aimed at improving the linkages with rural communities. The objective then was to gain the cooperation of government and livestock owners in the implementation of PARC strategies for policy reforms, environmental safeguards and rinderpest eradication through vaccination (see also Chapter 6.2).

Key communication issues were identified through participatory rural communications appraisal research in 14 countries. This led to the formulation of national PARC communication strategies. The central communication units provided guidance in the development of television news items, radio programmes, press releases, newsletters, annual reports, transparencies, sensitisation booklets, posters and the OAU-IBAR website.

ECONOMIC ANALYSIS

In 1995, an economic support unit was set up in collaboration with the International Livestock Research Institute (ILRI), with the specific objective of estimating the economic impact of rinderpest control on livestock productivity and on the well-being of society and producers. It also examined the cost-effectiveness of alternative implementation methods and evaluated policy reforms instituted under PARC. Results obtained from the analysis showed that the average cost of vaccinating a cow was ECU 0.42 and provided convincing evidence of the cost-effectiveness of rinderpest eradication (20).

An analysis of funding for the national campaigns, taking cognisance of policy reforms, showed almost an equal commitment to the programme by national governments and the principal donor, the European Union. Examination of the implementation costs in the countries indicated generally that PARC was implemented in a cost-effective manner, with average costs appearing within a relatively narrow range.

By examining economic losses that would have accrued without PARC and measuring these against the losses that occurred with PARC, it appeared that 88% of the projected loss could have been realised as a benefit from PARC. This suggested that PARC had saved Africa ECU 99 million by the end of the project in 1998. A cost–benefit ratio estimated across ten countries participating in PARC was 1.83:1. The IRR varied from 11% for Côte d'Ivoire to 11.8% for Burkina Faso. All were well above the opportunity cost of the capital. The total welfare gains from PARC were established at ECU 57.5 million, of which ECU 10.7 million were for the consumers. Table I shows the cost of rinderpest eradication under PARC.

IMPACT OF PARC ON RINDERPEST

The interplay between vaccination and rinderpest is discussed in Chapter 4.5. Essentially, at the start of PARC rinderpest had already been eliminated from West Africa, and the massive input of vaccine over the next decade ensured that it did not return. In East Africa, PARC faced a situation in which the virus was endemically entrenched across the region, but, at its conclusion, the incidence of rinderpest had been reduced dramatically (5). The rinderpest histories of specific PARC member countries subsequently required to submit dossiers to the OIE are narrated in Chapters 4.6.1 to 4.6.22. Largely, the continent was safer at the end of the programme than at its beginning. It was decided to move to a process of determining the security of and confidence in this achievement. This would require that countries with no apparent rinderpest stop vaccinating and only monitor the situation. Most countries participating in PARC countries in Central and West Africa had been in positions to do this for several years but did not take the necessary measures, despite the PARC technical committee repeatedly urging them to do so. Eventually, PARC was able to bring a number of these countries to the starting point

TABLE I
COST OF RINDERPEST ERADICATION UNDER PARC (ECU)

Country	National contributions	Contributions by European Development Fund	Total cost (ECU)
Benin	193,500	430,000	**623,500**
Burkina Faso	1,390,050	3,090,000	**4,480,050**
Cameroon	184,500	410,000	**594,500**
Central African Republic	720,000	1,600,000	**2,320,000**
Democratic Republic of the Congo	593,100	1,318,000	**1,911,100**
Djibouti	146,700	326,000	**472,700**
Ethiopia	6,317,550	14,039,000	**20,356,550**
Gabon	292,500	650,000	**942,500**
Gambia	202,500	450,000	**652,500**
Ghana	450,000	1,000,000	**1,450,000**
Guinea-Bissau	202,500	450,000	**652,500**
Guinea	1,464,750	3,255,000	**4,719,750**
Côte d'Ivoire	1,818,945	4,042,000	**5,861,045**
Kenya	958,275	2,129,500	**3,087,775**
Mali	823,113	4,307,000	**6,245,295**
Mauritania	1471500	1,829,140	**2,652,253**
Niger	2,257,650	3,270,000	**4,741,500**
Nigeria	234,000	5,017,000	**7,274,650**
Rwanda	1,190,250	520,000	**754,000**
Senegal	2,323,355	2,645,000	**3,835,250**
Somalia	1,608,750	5,160,700	**7,484,145**
Sudan	756,900	3,575,000	**5,183,750**
United Republic of Tanzania	574,650	2,550,000	**3,697,500**
Chad	No data available	1,682,000	**2,438,900**
Togo	No data available	1,277,000	**1,851,650**
Uganda	No data available	1,799,000	**2,608,550**
Research	–	1,606,400	**1,606,400**
Emergency logistics	–	3,000,000	**3,000,000**
Technical assistance to the OAU-IBAR	–	1,200,000	**1,200,000**
Vaccine banks	–	1,012,000	**1,012,000**
Vaccine quality control	–	800,000	**800,000**
Epidemiology project	–	1,410,000	**1,410,000**
Economic analysis	–	345,000	**345,000**
Total contribution	**26,175,038**	**76,195,030**	**106,265,313**

of the OIE Pathway by terminating vaccination campaigns and making a declaration of provisional freedom from rinderpest.

Table II shows the rinderpest situation at the close of PARC in 1998, at which time no outbreak had occurred for over ten years in West and Central Africa and in most East African countries. Many of the countries had joined the OIE Pathway by declaring provisional/zonal freedom from the disease, and rinderpest was on the verge of being eradicated. There was a significant increase in the cattle population on the continent, which was due to reduced mortality ascribed to rinderpest (based on recent cattle census results in different countries). For example, in 1985, the cattle populations in Sudan and Ethiopia, the largest cattle herds on the continent, were 22 million and 38 million, respectively. In 2015, the populations stood at 42 million and 51.8 million, respectively. At the conclusion of the programme, there were increased relations between the OAU-IBAR, FAO, the OIE, the International Cooperation Centre for Agronomic Research and Development (CIRAD), the European Union, the DfID, the United States Agency for International Development (USAID), the IAEA, and national, regional and international laboratories. The Veterinary Services were strengthened through the privatisation of service delivery systems and

TABLE II
THE POSITION OF PARC COUNTRIES ON THE OIE PATHWAY AT THE END OF 1998

Country	Last recorded rinderpest outbreak	Year vaccination stopped	Declared provisional freedom from rinderpest under PARC
Benin	1987	1999	No
Burkina Faso	1987	1988	Yes, 1989
Cameroon	1983	1999	No
Central African Republic	1975	1997	Yes, 1999 (zonal)
Djibouti	1986	NA	No
Eritrea	1995	1996	Yes, 1996
Ethiopia	1995	1997	Yes, 1999
Gabon	1995	1997 (partial)	Yes, 1999 (zonal)
Gambia	1965	1990	Yes, 1990
Ghana	1988	1996	Yes, 1997
Guinea-Bissau	1986	Never vaccinated	No
Guinea	1968	1996	1996
Kenya	1996-later 2001	1998 (partial)	Yes, 1999 (zonal)
Mali	1988	1997	Yes 1997
Mauritania	1988	1998	No
Niger	1986	1997	Yes, 1997
Nigeria	1987	1996	No
Rwanda	1933	1997	No
Senegal	1968	1996	Yes, 1997
Sierra Leone		1989	No
Somalia	1999	1998	No
Sudan	1999	1997 (zonal)	Yes, 1997 (zonal)
United Republic of Tanzania	1997	1997	Yes, 1998 (zonal)
Chad	1983	1999 but vaccinating in cordon sanitaire	Yes, 1989 (zonal)
Togo	1986	1998	Yes, 1996
Uganda	1994	1999 but vaccinating in cordon sanitaire	No

cost sharing. There was an increase in pastureland, planting of trees and the prevention of soil erosion to cater for the expected increase in cattle population following the eradication of rinderpest in Djibouti and Ethiopia.

In order to consolidate the success of PARC, and to avoid the mistakes made in JP15, it was important to vigorously sustain efforts to eliminate any remaining foci of rinderpest. Continued serosurveillance and immunosterilisation of the affected cattle population were of the essence. For this reason, PACE was conceived to continue the rinderpest eradication process and also to establish and strengthen epidemio-surveillance networks for rinderpest and other transboundary animal diseases throughout the continent.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support and contribution provided by the Veterinary Services staff of the OAU Member States that participated in PARC towards the eradication of rinderpest from the African continent. The financial support provided notably by the European Commission, DfID, USAID, Japanese trust fund and the Governments of Belgium, Italy and Nigeria during the implementation of the programme is well appreciated. The technical support of CIRAD, FAO, the IAEA, the OIE and Tufts University is acknowledged. Lastly, we wish to acknowledge the support received from the OAU-IBAR staff, in particular the PARC technical staff.

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CHAPTER 4.3

PAN-AFRICAN PROGRAMME FOR THE CONTROL OF EPIZOOTICS (PACE) IN RINDERPEST CONTROL

R. BESSIN [(1, 2)*], A. ELSAWALHY [(2)], B. DIOP [(1, 2)], K. TOUNKARA [(2, 3)], D. BOURZAT [(2, 3)†], F. NJEUMI [(1, 2)], B. BERHANU [(1, 2)], B. KEBKIBA [(2, 4)], H. WAMWAYI [(2)], J. MUSIIME [(2)†] & B. VALLAT [(3)]

(1) Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy
(2) African Union Interafrican Bureau for Animal Resources (AU-IBAR), Kenindia Business Park, Museum Hill, Westlands Road, P.O. Box 30786-00100, Nairobi, Kenya
(3) World Organisation for Animal Health (OIE), 12 rue de Prony, 75017 Paris, France
(4) Institut de Recherche en Elevage pour le Développement (IRED), BP 433, N'Djamena, Chad
† Post mortem as key players and contributors to the draft of this chapter

*Corresponding author

SUMMARY

At the completion of the Pan-African Rinderpest Campaign (PARC) the priority interventions for the forthcoming Pan-African Programme for the Control of Epizootics (PACE) were to include targeted vaccination based on a clear strategy, the establishment of epidemiological surveillance and the strengthening of laboratory and communication networks. Multiplier effects were obtained through the efficient use of regional and subregional coordination. The African Union Interafrican Bureau for Animal Resources endorsed this approach, consistent with the Food and Agriculture Organization of the United Nations Global Rinderpest Eradication Programme (FAO-GREP) strategy and the World Organisation for Animal Health (OIE) Terrestrial Animal Health Code guidelines. The approach ensured successful coordinated efforts towards rinderpest eradication in Africa. As part of the sustained multi-donor support, the financial aid from the European Development Fund, and other donors contributed to building the structural, institutional and human resource capacities required for rinderpest eradication efforts at national, regional and continental levels. PACE endeavoured to both consolidate the achievements of rinderpest eradication and take further steps in the control of major epidemic diseases, e.g. contagious bovine pleuropneumonia, prevailing in the region.

The sustained political support from the ministers, heads of state and governments of the African Union countries, as well as the financial, technical and human resource commitments from the participating African governments ensured the successful outcome of PACE. This would not have been possible without the support and participation of the livestock producers and other key stakeholders within the target countries.

KEYWORDS **Epidemiological surveillance – Eradication – Laboratory networks – OIE Pathway – Performance indicators – Rinderpest — World Organisation for Animal Health.**

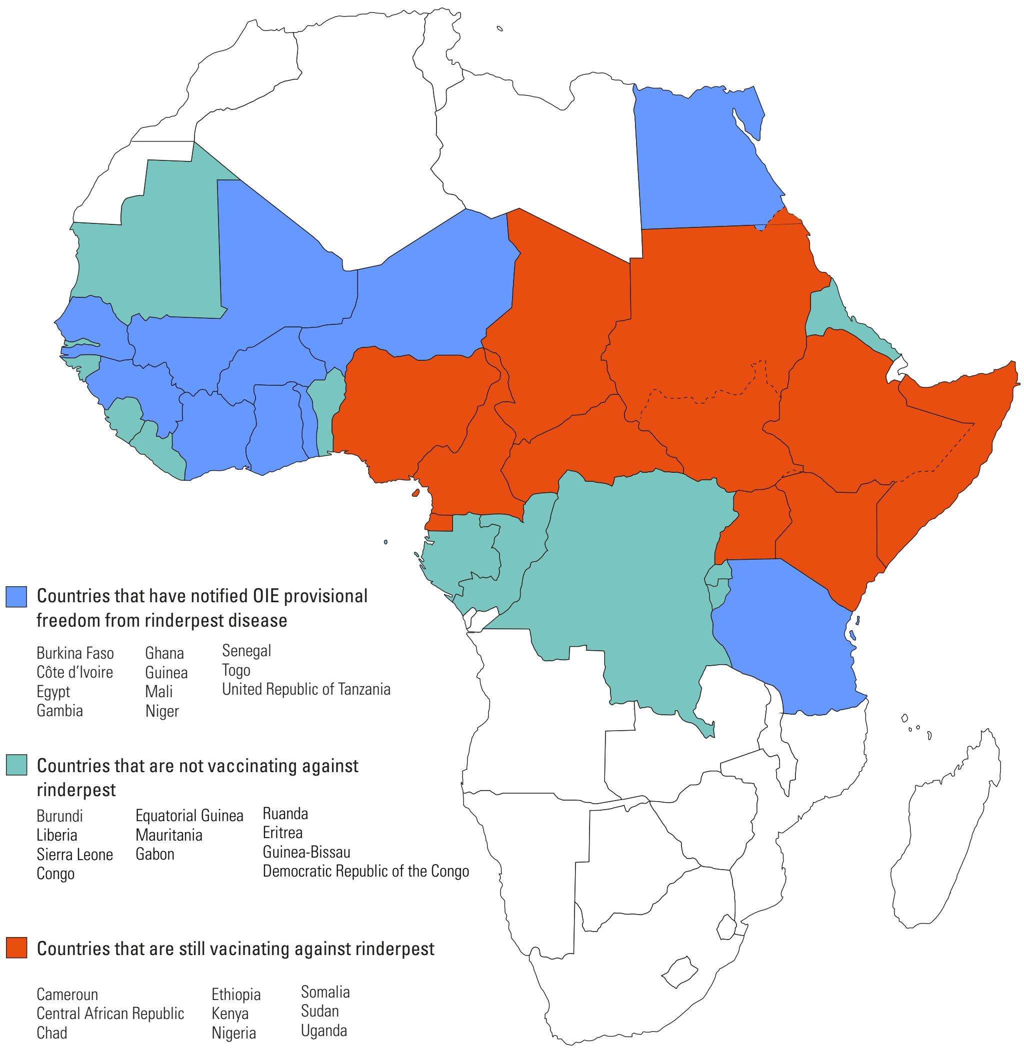
INTRODUCTION

Concerted actions to eradicate rinderpest from Africa began with the 'Joint Programme 15' (JP15; Chapter 4.1) which was implemented from 1962 to 1976, followed by the Pan-African Rinderpest Campaign (PARC; Chapter 4.2) from 1986 to 1998. Thereafter, the Pan-African Programme for the Control of Epizootics (PACE) was implemented from 1999 to 2007. To all intents and purposes, the mass vaccination strategy followed during the PARC project eliminated rinderpest everywhere in Africa, except in the Somali ecosystem, an area comprising south-eastern Ethiopia, north-eastern Kenya and southern Somalia and corresponding to a zone occupied by the Somali ethnic community and the contiguous areas into which their livestock moved for pasture or trade purposes as discussed in Chapter 4.4. During the implementation of PACE, the improved understanding of rinderpest transmission required that national authorities should end vaccination and fulfil the conditions laid out in the World Organisation for Animal Health (OIE) Pathway leading to rinderpest eradication as, in fact, had already been done by some authorities. A 1999 review of the situation in countries moving from the PARC to the PACE programmes is shown in Figure 1. Those countries that had not moved to the PACE programme were encouraged to make a declaration of provisional freedom from the disease

FIG. 1

MAP OF RINDERPEST ZONES PRIOR TO THE START OF PACE (1999)

Source: Andreas 06, 2006 (4), modified to indicate zones prior to PACE by data provided by OIE, April 2006. Final boundary between the Sudan and South Sudan has not yet been determined



if, after two years, they had not diagnosed rinderpest. All participating countries then were required to undertake several years of clinical and serological surveillance and to submit their surveillance data for scrutiny by the OIE to gain the official status of freedom from rinderpest infection. Throughout a decade-long process, PACE enhanced the skills and abilities of the directorates of national Veterinary Services to fulfil these requirements. During this period, PACE played a vital role in the strengthening of national Veterinary Services (NVS)

It is important to note that, although the concept and approach of PACE was multifaceted, the present description is restricted to the contribution of PACE in safeguarding the gains of PARC and providing evidence that the rinderpest virus was no longer circulating in Africa (1).

THE MANDATE OF PACE

PACE aimed to eradicate rinderpest and other epidemic diseases, to improve animal productivity, trade and food security, and to reduce poverty through disease control in Africa. The programme focused on strengthening animal disease surveillance. The goal was to generate appropriate disease control programmes and to protect African Union (AU) member states against major epidemics as defined in the old classification of diseases notifiable to the OIE List A (the former OIE List A diseases) (2).

At the national level, PACE endeavoured to consolidate the achievements of rinderpest eradication and take further steps in the control of major epidemic diseases, e.g. contagious bovine pleuropneumonia. The PACE programme contributed to:

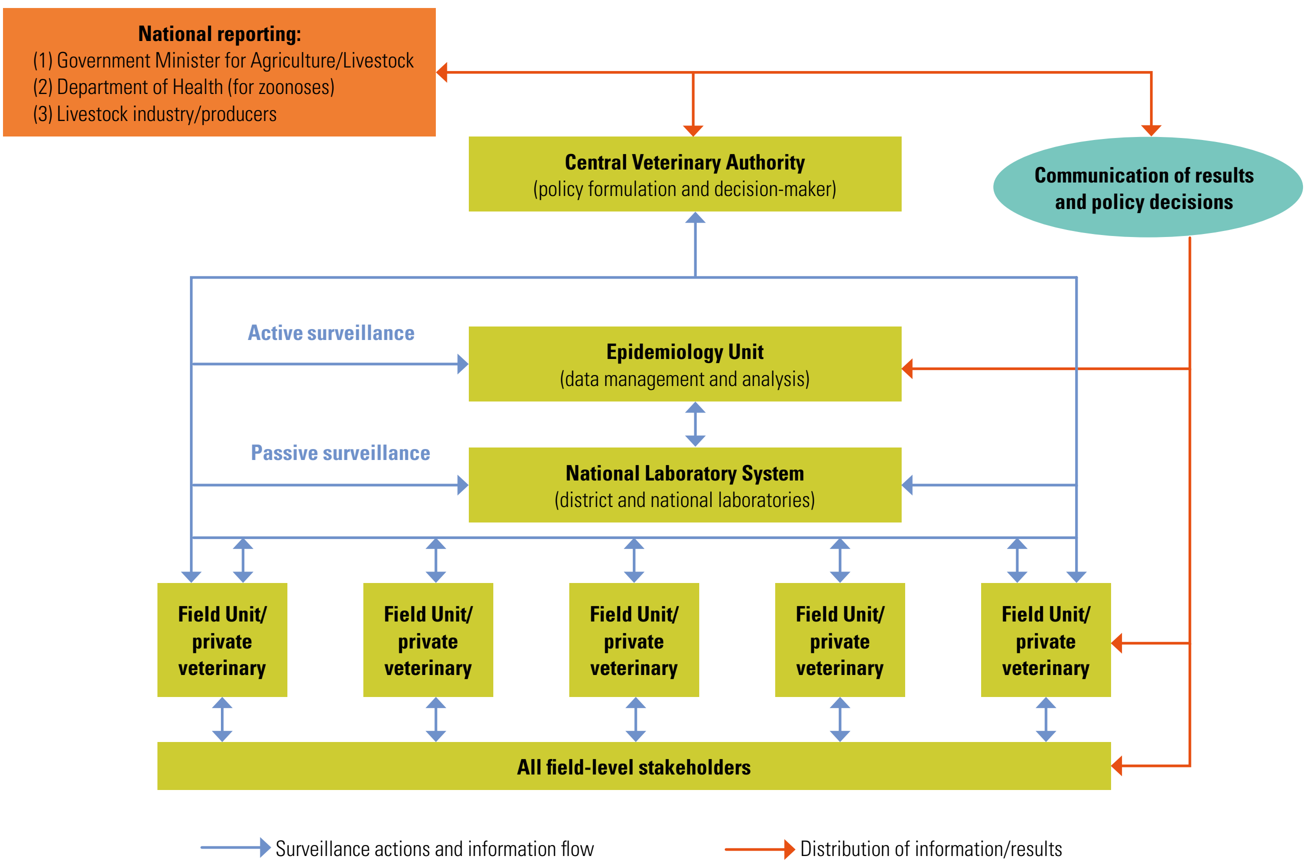
- the reinforcement of animal epidemiology services within the directorates of Veterinary Services for better disease control (Fig. 2);
- the promotion of the privatisation of NVS;
- the organisation of private actors, livestock associations and farmers.

The support for the privatisation scheme was to establish sanitary mandates for private veterinarians and to ensure the continued existence of extended animal health services in remote areas.

FIG. 2

SIMPLIFIED ELEMENTS OF EPIDEMIO-SURVEILLANCE INTEGRATED INTO AN EFFECTIVE VETERINARY SERVICE

Courtesy of the authors



PACE ORGANISATION AND MANAGEMENT

The management and operations of PACE were organised at continental, regional and national levels. The continental management as well as the regional coordination for eastern Africa was based at the African Union Interafrican Bureau for Animal Resources (AU-IBAR; see Chapter 5.5) in Nairobi, Kenya, and the regional coordination unit for West and Central Africa was located in Bamako, Mali. Initially, 32 sub-Saharan African countries were identified to take part in the PACE programme. However, because of political unrest at the time, Liberia and Sierra Leone did not participate and finally 30 countries took part. The national PACE programmes were funded through annual work plans based on indicative budget allocations. The continental and regional PACE coordination units were assisted by the programme's common services including:

- **an epidemiology unit:** this comprised three subunits – one in Nairobi, Kenya, for rinderpest endemic areas, one in Bamako, Mali, for countries where rinderpest vaccinations had ceased and OIE procedures had started, and a third in N'Djamena, Chad, where a western cordon sanitaire was established to protect West Africa against reinfection from East Africa; the cordon aimed to vaccinate cattle in this region with the high immunity rate and follow it with surveillance to be able to detect any incursion or resurgence of rinderpest;
- **a communications unit:** in Nairobi, with a subregional office in Bamako, to support technical units, produce advisory backup materials, promote control strategies and help veterinary schools to introduce epidemio-surveillance and wildlife disease surveillance into future curricula;
- **a socio-economics unit:** to develop appropriate socio-economic disease evaluation tools;
- **a privatisation unit:** to support the privatisation of NVS, the use of veterinary auxiliaries, para-veterinarians, community-based animal health workers and related legal aspects;
- **a financial unit:** hosted by the AU-IBAR and assisted by an international expert supported by the EU delegation, to establish real-time analytical accounts and control via regular internal audits of PACE finances;
- **a data management unit;**
- **a monitoring and evaluation unit;**
- **the Pan-African Veterinary Vaccine Centre (PANVAC):** located in Debre Zeit, Ethiopia, to provide vaccine quality control.

The staff of these units were full-time PACE employees.

The PACE management had various structures in place to provide an interface with the national authorities and to ensure adherence to administrative regulations and international financial standards and regulations.

In addition, two important bodies were established: an advisory committee and a policy committee. The advisory committee met regularly every six months for five years, alternating between Bamako in West Africa and Nairobi in East Africa. The advisory committee was presided over by the Director-General of the OIE. Membership of the advisory committee included representatives from FAO, the International Atomic Energy Agency (IAEA), two rinderpest world reference laboratories (the French Agricultural Research Centre for International Development [CIRAD] Department of Livestock and Veterinary Medicine [EMVT] and the Pirbright Institute), the European Union and the AU-IBAR. The advisory committee was instrumental in providing sound, timely and robust technical guidance. Under the PACE programme, the AU-IBAR organised a meeting of government ministers responsible for livestock in AU member states every two years. This meeting promoted and recommended major policies and strategies for the sustainable development of the livestock industry and alleviating poverty in Africa.

PACE FINANCING PARTNERS

The financing partners were the European Union, the United Kingdom's Department for International Development (DfID) and the Governments of Switzerland, France, Italy, Netherlands and Germany. The PACE financing agreement was signed on 5 July 1999 by the European Commission and on 30 August 1999 by the AU-IBAR to the tune of €72 million for the period from November 1999 to October 2004 and €5 million for the PACE extension for the period from November 2004 to February 2007. From these funds, €51.7 million was allocated to the 30 countries for national interventions and €25.3 million was allocated for programme coordination, audits, consultancies and research.

From October 2000 to September 2004, the DfID funded the Community-based Animal Health and Participatory Epidemiology (CAPE) Unit, a complementary component, that later evolved into a project. It promoted sustainable animal health services in remote pastoral areas, particularly those in the Greater Horn of Africa.

The French Government provided assistance to the AU-IBAR by providing both strong and robust technical assistance and substantial financial resources throughout the implementation of the programme.

Individual consultants to PACE were supported by several international agencies and groups: the German Technical Cooperation Agency (GTZ); the consultancy group, Société d'assistance technique et de conseil (SATEC); CIRAD (Centre de coopération internationale en recherche agronomique pour le développement); the consultancy firm, Études et Conseils (AGRER); FAO and the IAEA. The Italian and Swiss Governments funded part of the activities in Somalia.

The governments of member countries within PACE contributed financially and technically to the implementation of the PACE programme.

Terra Nuova, an Italian non-governmental organisation (NGO) working in Kenya in partnership with the AU-IBAR and supported by both Italy and the EU Delegation in Kenya, implemented field activities with a strong focus on surveillance. The United Nations Children's Fund (UNICEF) also contributed to PACE through Operation Lifeline Sudan (OLS). These activities were only possible through the strong commitment, involvement and contributions of livestock owners at the country level.

For rinderpest laboratory diagnosis, the AU-IBAR and the IAEA signed a collaborative agreement in 1999, with an overall objective of addressing national and regional animal disease diagnostic and surveillance needs (see also Chapter 5.4). Specific objectives were to:

- support the AU-IBAR/PACE coordination unit to improve national capabilities for detecting and controlling economically devastating livestock diseases and to verify the eradication of rinderpest from Africa;
- assist the AU-IBAR in establishing a sustainable regional supply of critical diagnostic reagents and kits.

The IAEA seconded a regional expert to the AU-IBAR from June 2001 to March 2005 to support the work in the diagnostic laboratories.

PACE IMPLEMENTATION WITH REFERENCE TO RINDERPEST

PACE facilitated the establishment or improvement of animal disease surveillance systems and diagnostics to ensure reliable disease detection and reporting in the 30 target countries. The strategy covered passive and active disease surveillance. For rinderpest, the OIE Pathway was the tool that guided surveillance activities under the PACE programme.

Through the implementation of the PACE programme, the AU-IBAR developed performance indicators to measure and monitor the performance of countries towards rinderpest eradication and to demonstrate that they had effective NVS. With the support of FAO-GREP, the AU-IBAR spearheaded the eradication of rinderpest from Africa through PACE and the Somali Ecosystem Rinderpest Eradication Coordination Unit (SERECU; see Chapter 4.4). Under the PACE programme, epidemio-surveillance systems were established within each NVS, including a central unit and field units and involving livestock keepers and private veterinarians (Fig. 2), for systematic, continuous data collection and analysis and evaluating disease control measures. The epidemiology units worked closely with the veterinary laboratories to ensure the timely testing of samples collected from the field. The passive surveillance systems focused on monthly disease reports from the field, data from laboratories and abattoirs, and information from community animal health workers and traders. Active surveillance involved searching for the presence of disease or infection (see Fig. 1 in Chapter 3.7). Serosurveillance for rinderpest focused on detecting specific antibodies to rinderpest virus. The challenge, when using serosurveillance to confirm the absence of rinderpest virus in the population, was to distinguish between naturally occurring virus and virus from the vaccine.

In support of the above strategy, the PACE programme strengthened disease diagnosis by establishing a network of laboratories for rinderpest diagnosis and surveillance, using techniques such as the enzyme-linked immunosorbent assay (ELISA) and the polymerase chain reaction (PCR) (see Chapter 6.3). This was facilitated by IAEA fellowships, workshops and training of national veterinary laboratory personnel and scientists in laboratory diagnostic techniques, the use of relevant software, quality assurance and the interpretation of surveillance data. Technology transfer was achieved by establishing a regional capability to supply reagents for diagnosis via the International Laboratory of Molecular Biology at the University of California, Davis, for rinderpest and peste des petits ruminants (PPR) indirect ELISA tests in Mali, Senegal, Nigeria and Côte d'Ivoire. An evaluation tool for the assessment of national epidemiological surveillance systems was developed in August 2004.

FREEDOM FROM RINDERPEST

The PACE programme, as described above, enabled member countries to comply with the OIE Pathway and thus to be recognised as free from rinderpest disease and infection. PACE assisted countries to prepare a science-based national dossier, supported by surveillance and laboratory performance indicators, not only to confirm the absence of the disease but also to report on the result of active surveillance programmes established in member countries, including serological studies designed to detect any rinderpest virus circulation or activity. The following countries were recognised as free from rinderpest disease by May 2006: Benin, Burkina Faso, Chad, Côte d'Ivoire, Ghana, Guinea, Mali, Mauritania, the Niger, Nigeria, Senegal, Togo, Ethiopia (zonal basis), Eritrea, Kenya (zonal basis), United Republic of Tanzania, Sudan and Uganda. In May 2006, the following countries were recognised as free from rinderpest infection: Benin, Burkina Faso, Congo (historical basis), Democratic Republic of the Congo (historical basis), Guinea, Guinea-Bissau (historical basis), Mali, Senegal, Togo, Burundi (historical basis), Eritrea and Rwanda. An indication of national progress between 1999 and 2006 is provided in Table I. These countries achieved accreditation of rinderpest freedom from the OIE prior to completing the global accreditation task. National progress can also be gauged by comparing Figures 1 and 3 (3).

TABLE I
RINDERPEST STATUS WITH REGARD TO THE OIE PATHWAY IN PACE COUNTRIES BY MAY 2006

Country	Provisionally free	Freedom from disease	Freedom from infection
Benin	1999	2003	2005
Burkina Faso	1998	2003	2006
Cameroon	1999		
Central African Republic	2004		
Congo			2006 (historical)
Chad	2002	2006	
Democratic Republic of the Congo	2003 (ZB)		2006 (historical)
Côte d'Ivoire	1997	2004	
Gambia	1990		
Gabon	2005		
Ghana	1997	2003	
Guinea	1996	2003	2006
Guinea-Bissau	2003		2006 (historical)
Mali	1997	2003	2006
Mauritania	1999	2003	
Niger	1999	2003	
Nigeria	1998	2004	
Senegal	1997	2003	2005
Togo	1996	2003	2005
Burundi	2003		2006 (historical)
Ethiopia	1999, 2004 (ZB)	2005 (ZB)	
Eritrea	1999	2004	2005
Djibouti	2003		
Kenya	2004 (ZB)	2006 (ZB)	
Rwanda	2003		2006 (historical)
United Republic of Tanzania	1998	2005	
Sudan	2004	2006	
Uganda	2002	2006	

ZB, zonal basis

PACE AND RINDERPEST VACCINES

In 1986, FAO established two regional vaccine quality control and training centres. These were located in Debre Zeit (Ethiopia) and Dakar (Senegal) and aimed to improve the quality of the rinderpest vaccine produced and used in Africa. Collectively the two centres represented the Pan-African Veterinary Vaccine Centre (PANVAC). In 1993, the two units were merged at one site in Debre Zeit, which was subsequently established as an Organisation of African Unity (OAU) institution in 1998 (Chapter 5.6). In July 2000, during the PACE implementation, FAO funding to support PANVAC came to an end. In order to ensure vaccine quality control, PACE provided complementary financial support to PANVAC from 2000 until January 2004. During this period technical assistance was provided by CIRAD-EMVT.

As a result of ceasing rinderpest vaccination throughout Africa and as a precaution against the possible re-emergence of the disease, a vaccine emergency bank and emergency fund were established by PACE. The vaccine banks were housed in three different places: at the Botswana Vaccine Institute (a stock of 500,000 doses of quality-controlled vaccines); at UNICEF-OLS in Lokichokio, north-west Kenya (approximately 100,000 doses, discussed in Chapter 3.9); and under the custody of Veterinary Services in Khartoum, Sudan (about 80,000 doses). An emergency fund for the management of rinderpest vaccine was entrusted in 2003 to the OIE via a convention signed in July 2001 between the AU-IBAR and the OIE. Initially €2 million was provided and this was later reduced to €500,000 to facilitate funding of the PACE extension phase. Access to the emergency fund was subject to the development of rinderpest contingency plans (Fig. 4).

THE MAIN CHALLENGES FOR PACE

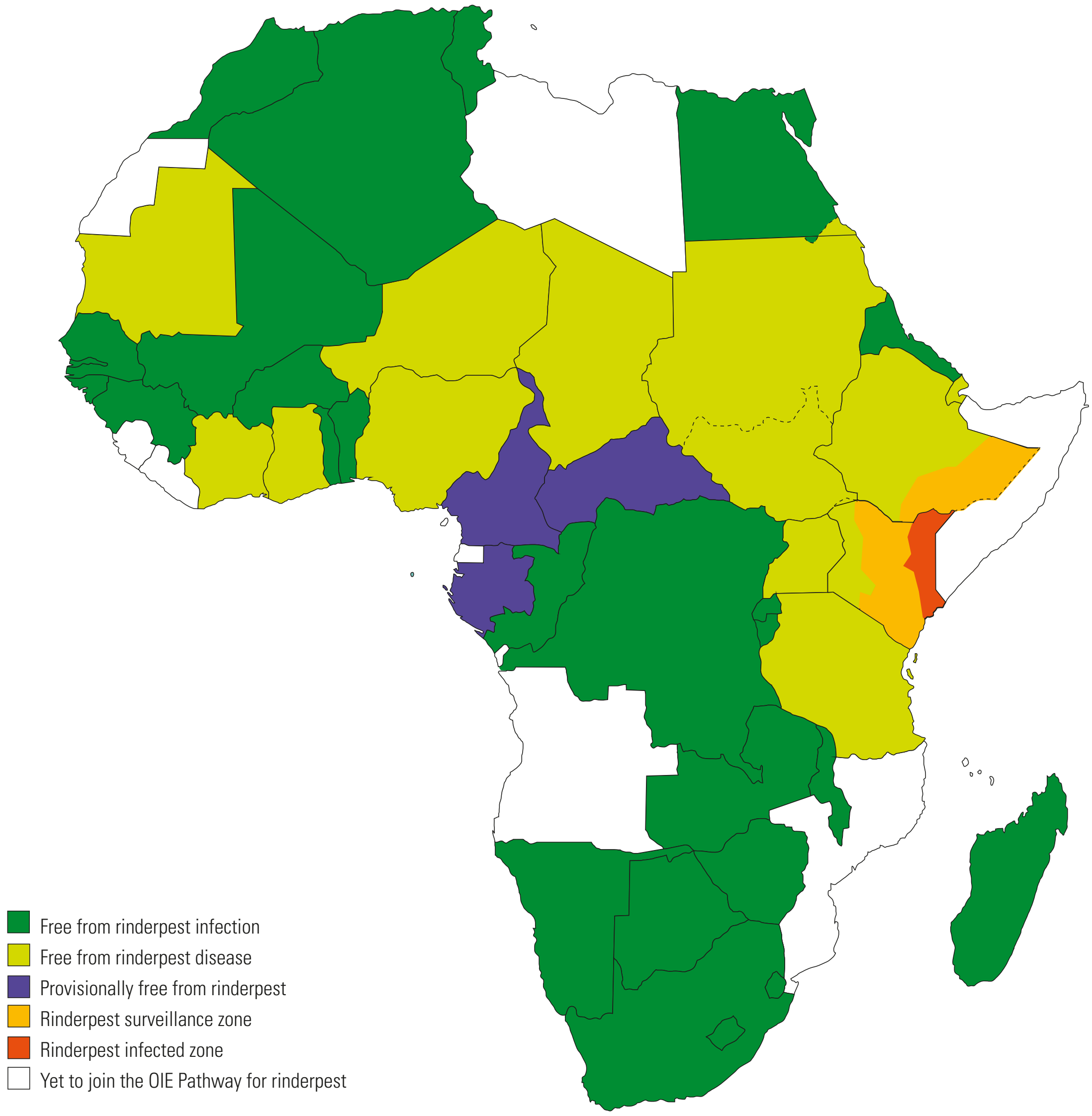
Strengthening and widening the laboratory diagnostic services for rinderpest surveillance and

FIG. 3

RINDERPEST STATUS AS PER THE OIE PATHWAY – MAY 2006

Final boundary between the Sudan and South Sudan has not yet been determined

Source: Andreas 06, 2006 (4), modified to indicate status as per OIE Pathway

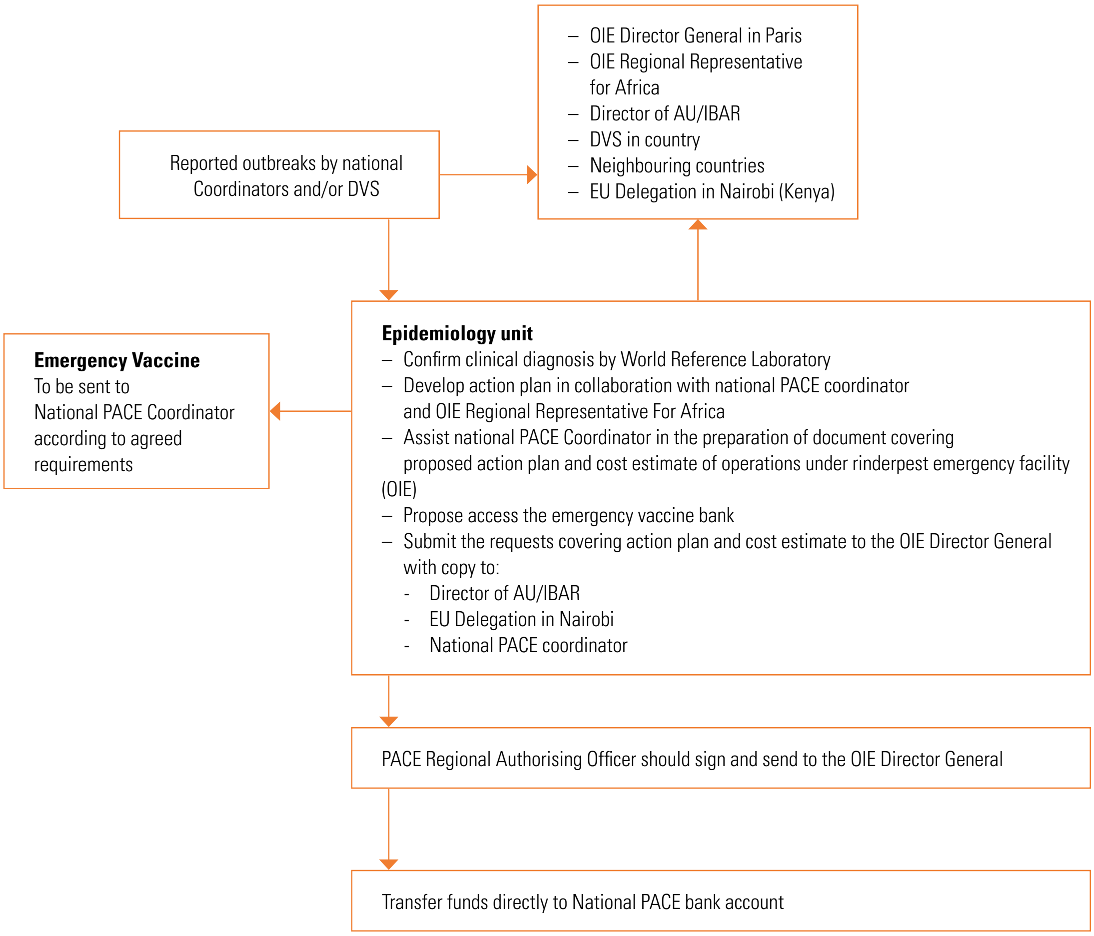


diagnosis was a challenge throughout the PACE programme. The collaboration between the AU-IBAR and the IAEA improved this situation through the appointment of a laboratory expert in June 2001. This strengthened laboratory diagnostic capacity in countries through training and provision of equipment and reagents to ensure timely diagnosis and support for the serological surveillance that was required to obtain the certification of freedom from rinderpest infection. A rinderpest-testing laboratory network was also established and sustained. The national veterinary laboratories' capacity for diagnostic testing was assessed. The regional laboratories at the Kenya Agriculture Research Institute (KARI), Muguga, Kenya, the Institut Sénégalais de Recherche Agricole (ISRA), Dakar, Senegal, and the Laboratoire National d'Appui au Développement Agricole (LANADA), Bingerville, Côte d'Ivoire, were major assets in rinderpest diagnosis, using serology, virus isolation and PCR. The molecular characterisation of African rinderpest virus strains was carried out at the world reference laboratories through collaborative arrangements with the regional laboratories and facilitated by the PACE programme.

Despite funding problems for PANVAC operations, the PACE programme ensured that PANVAC operated with an adequate budget. PACE contributed significantly to the revitalisation of PANVAC and its eventual adoption as a specialised technical office of the AU alongside the AU-IBAR.

The implementation of the PACE programme in conflict areas (e.g. South Sudan and Somalia) was a challenge. This was mitigated by using alternative veterinary delivery systems including

FIG. 4
RINDERPEST EMERGENCY RESPONSE
Courtesy of the authors



community-based animal health workers (CAHWs). This was implemented by CAPE and Vétérinaires Sans Frontières. The preparation and validation of the annual work plans was a challenging exercise with a few countries requiring regular supporting missions from the regional coordination units and consultations with the respective national EU delegations. The major challenge remaining was the sustainability of the epidemio-surveillance networks, which required national governments to support them financially at the end of PACE. Many countries managed to keep their epidemio-surveillance networks, although their performance was not optimal. The regional epidemiology and laboratory networks established during PACE were not properly supported until FAO provided technical and financial support to revitalise them during the highly pathogenic avian influenza crisis. Owing to budgetary constraints, the PACE programme was not able to validate or document all the training materials, success stories and best practices for all the beneficiaries, including CAHWs and para-professionals. The initial approach within PACE was to establish one central communication unit in Nairobi to cover all the 30 member states. Given the growing importance of communication during the final eradication phase, a second PACE communication unit was established in Bamako to cover West and Central African countries. It was further decided to have national communication units operational, but there was no budget to cover this new structure. The budgets of the PACE communication units were consequently too low and this affected the implementation of activities to increase awareness among the various stakeholders, particularly the livestock producers. Wildlife surveillance had both scientific and practical benefits and facilitated the preparation of national OIE Pathway dossiers for applications for recognition of freedom from disease or infection. However, the sustainability of wildlife surveillance activities remained a concern at the country level for a number of reasons, including the challenge of pooling resources and sharing data of a transboundary nature.

THE LEGACY OF PACE

The AU-IBAR, as the pan-African technical office responsible for animal resources continent-wide and for the implementation of PACE, played an

FIG. 5
PRESENTATION IN RECOGNITION OF PACE ACHIEVEMENTS BY THE PACE PROGRAMME COORDINATOR AT A BILATERAL AU-IBAR/EU MEETING, NAIROBI, SEPTEMBER 2007
Right to left: Otto Moller, EU Rural Development Adviser; René Bessin, PACE Coordinator; and Martin van der Linde, EU Head of Delegation in Kenya
Courtesy of the authors

important role in coordinating the eradication of rinderpest from Africa. The AU-IBAR endorsed a regional concept approach to control transboundary animal diseases and epidemiological surveillance in Africa, in line with the FAO-GREP strategy. This proved to be a successful strategy and model for other epidemic diseases such as contagious bovine pleuropneumonia and highly pathogenic avian influenza.

The establishment and strengthening of disease surveillance systems, according to the OIE Terrestrial Animal Health Code guidelines, represented a priority intervention area for PACE. Information flow from field levels to the central Veterinary Services and laboratories improved through the use of new information system software and traditional data transmission channels. PACE communication activities provided visibility and these activities were transferred to individual PACE countries to support active communication, data management and the introduction of business training modules into veterinary school curricula. PACE promoted the privatisation of veterinary services to achieve better control of other epidemic diseases, such as contagious bovine pleuropneumonia and PPR (Fig. 5).

ACKNOWLEDGEMENTS

The authors wish to thank the PACE member countries and all those who contributed to the successful eradication of rinderpest. They also wish to thank the peer reviewers and editors. They are also indebted to donor communities for their financial support, in particular to the European Union. We are most grateful to Otto Moller, Alain Vandersmissen, Philippe Vialatte, Bernard Rey, Walter Masiga, Amadou Samba Sidibé, Fatah Bendali, Paul Rossiter, Richard Kock, Baba Soumaré, Dickens Chibeu, Cecile Squarzoni, Gavin Thomson, Solomon Haile Mariam, Adama Sow, the PACE national coordinators and the directors of Veterinary Services for their support to the PACE programme.

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CHAPTER 4.4

SOMALI ECOSYSTEM RINDERPEST ERADICATION COORDINATION UNIT (SERECU)

F. NJEUMI [(1)*], A. ELSAWALHY [(2)], D. CHIBEU [(2)], S. GUTA DEBELA [(3)], E. COUACY-HYMANN [(4)] & HENRY WAMWAYI [(2)]

(1) Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, Rome, Italy
(2) African Union Interafrican Bureau for Animal Resources (AU-IBAR), P.O. Box 30786-00100, Nairobi, Kenya
(3) Veterinary Epidemiology Unit; Ministry of Livestock and Fisheries, National Animal Health Diagnostic and Investigation Center (NAHDIC), P.O. Box 04 Sebeta, Ethiopia
(4) Laboratoire National d'Appui au Développement Agricole (LANADA)/Central Laboratory for Animal Diseases, B.P. 206 Bingerville, Côte d'Ivoire

*Corresponding author: felix.njeumi@fao.org

SUMMARY **The last outbreak of rinderpest was reported in 2001 in the Somali ecosystem (SES). At the experts' consultative meeting of the Global Rinderpest Eradication Programme (GREP) in 2002, the SES was thought to contain the last possible focus of rinderpest in the world. Shortly before the end of the Pan-African Programme for the Control of Epizootics (PACE) in 2007, the need to dedicate special attention to any suspicion of mild rinderpest in the SES led to the unanimous decision of the tenth PACE Advisory Committee to develop a strategic plan for the verification of absence of rinderpest from the SES, in line with the global Food and Agriculture Organization of the United Nations (FAO)-GREP strategy and the World Organisation for Animal Health (OIE) Pathway for rinderpest eradication. The Somali Ecosystem Rinderpest Eradication Coordination Unit (SERECU) was established as a specialised component of PACE in 2006. All components of the surveillance system implemented in the area led to the confirmation that rinderpest virus was not circulating in the zone.**

KEYWORDS **Global Rinderpest Eradication Programme – GREP – Rinderpest – SERECU – Somali ecosystem – Somali Ecosystem Rinderpest Eradication Coordination Unit.**

INTRODUCTION

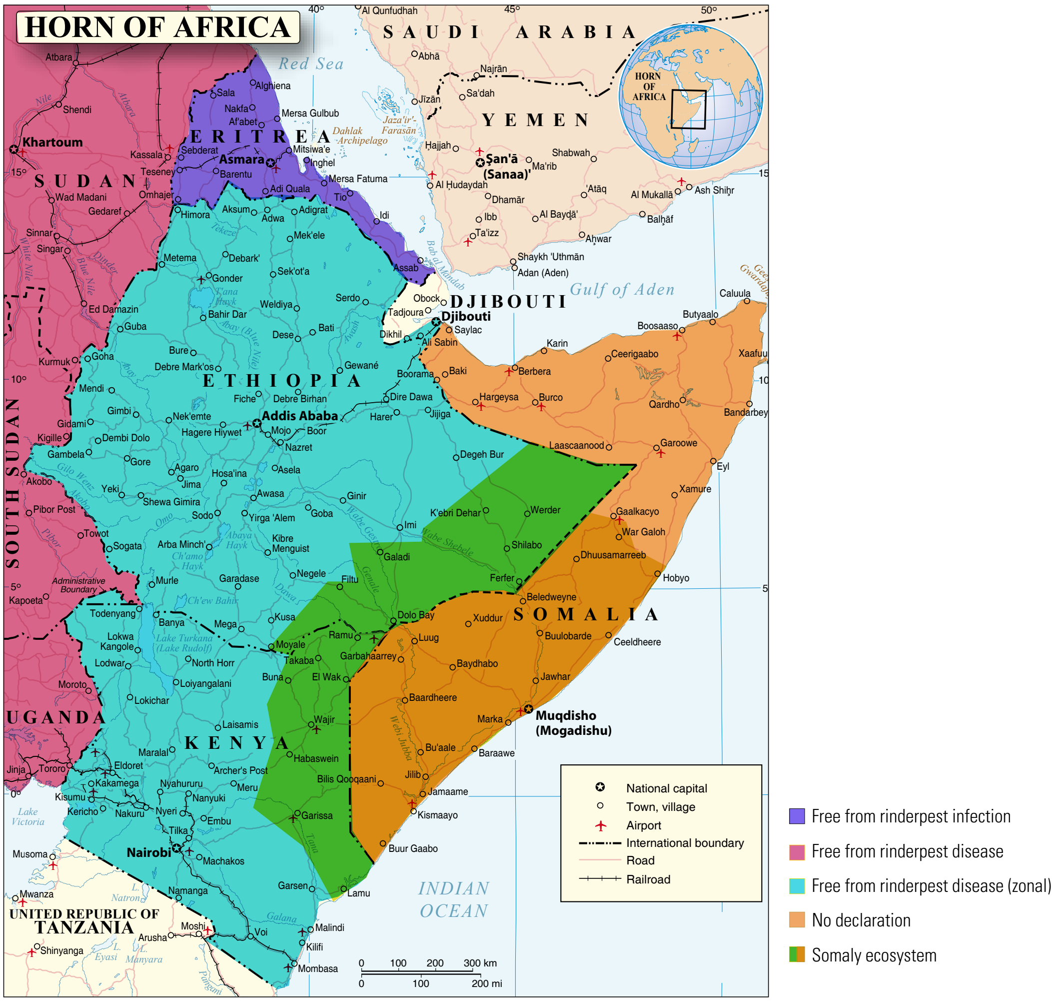
The Pan-African Programme for the Control of Epizootics (PACE) (see Chapter 4.3) completed the eradication of rinderpest from most of Africa, with the exception of the Somali ecosystem (SES). The SES is an area extending across Ethiopia, Kenya and Somalia that corresponds to a zone occupied by the Somali ethnic community and contiguous areas into which they and their livestock move for pasture or trade purposes. In 2006, the SES covered central and southern Somalia, 27 *woredas* (districts) of south-eastern Ethiopia, and the then North-eastern province of Kenya (Fig. 1). The SES had an estimated cattle population exceeding seven million (Ethiopia ~36%, Kenya ~26% and Somalia ~38%) (2).

FIG. 1

THE SOMALI ECOSYSTEM IN 2006, WITH THE OIE RINDERPEST ACCREDITATION STATUS OF COUNTRIES IN THE EASTERN AFRICAN REGION BEFORE THE START OF SERECU

Source: United Nations, 2012 (1), modified to indicate the OIE accreditation status prior to SERECU

Final boundary between the Sudan and South Sudan has not yet been determined



Despite the successes of PACE (1999–2007), there were concerns that a residual focus of rinderpest might have remained in the SES. The area was the last place where rinderpest had been confirmed in 2001, and the zone was thought to contain the last possible focus of rinderpest in the world. The suspicion was based on evidence of a disease syndrome in cattle consistent with mild rinderpest, and successive serological surveys in Somalia that had detected seropositive unvaccinated cattle. It thus became apparent that rinderpest would not be eradicated from Africa during the lifespan of PACE, which ended in 2007. Just before the end of PACE, the need to dedicate special attention to suspicions of mild rinderpest harboured in the SES led to the unanimous decision of the tenth PACE Advisory Committee to develop a strategic plan for the verification of the absence of rinderpest in the SES, in line with the global FAO-GREP strategy and the OIE Pathway for rinderpest eradication. For this reason, the Somali Ecosystem Rinderpest Eradication Coordination Unit (SERECU) was established as a specialised component of PACE in 2006. The SERECU project was designed to ensure that the three SES countries would attain international recognition of rinderpest freedom through an epidemiologically driven strategy. Their status at the commencement of SERECU is shown in Fig 1. The project adopted an ecosystem approach, with enhanced coordination and harmonisation between the Veterinary Services of the three SES countries. The first phase of SERECU was funded within PACE from January 2006 to February 2007, with a total investment of €1,818,928. FAO-GREP and the African Union Interafrican Bureau for Animal Resources (AU-IBAR) supported a bridging phase between March 2007 and April 2008 while the second phase was funded by the European Union (€4 million) and was implemented from May 2008 to December 2010 (1).

The first phase of SERECU aimed to delineate endemic areas of rinderpest in the SES, followed by focused vaccination to achieve immunosterilisation of the targeted cattle populations. In the absence of rinderpest endemicity, countries were to pursue accreditation following the OIE Pathway. In 2006, the results of a regionally coordinated survey ruled out rinderpest endemicity in Ethiopia and Kenya but were inconclusive in the case of Somalia. During the bridging phase, follow-up investigations conducted at seropositive sites (combining a random map coordinate survey with participatory epidemiology) in Somalia ruled out recent virus circulation and concluded that the previously observed seropositivity could have been due to sampling of ineligible cattle (below one year and above three years) (3, 4).

The second phase of SERECU was therefore prepared with the key mandate of verifying eradication and ensuring that each of the three SES countries was accredited as free from rinderpest by the OIE, in line with the GREP deadline of 2010. The overall objective of SERECU was to contribute to the reduction of poverty of those involved in the livestock farming sector and of the wider populations in the three countries by enhancing livestock development and trade opportunities resulting from the progress made in the OIE's accreditation of rinderpest freedom for the SES countries (2).

COORDINATION

The SERECU staff comprised a project coordinator, an epidemiologist seconded by FAO, a finance manager, three national liaison officers (one for each country), a wildlife expert, an expert familiar with the deployment of community animal health workers, and support staff (accountant, administrative secretaries, drivers/messengers and a data entry clerk), all based in AU-IBAR in Nairobi, Kenya.

SERECU was managed by a steering committee mandated to provide appropriate scientific, technical and management guidance as well as to oversee and validate the overall direction and policy of the project. It was composed of the Director of AU-IBAR as the regional authorising officer, the Chief Animal Health Officer of IBAR, the GREP secretary, a representative of the EU-funded Somali Animal Health Services Project (SAHSP) and the directors of the Veterinary Services of Kenya, Ethiopia and Somalia. The steering committee meetings were convened twice per year (2).

WHY FOCUS ON THE SOMALI ECOSYSTEM?

At the GREP experts' consultative meeting in 2002, SES was recognised as one of the last possible focuses of rinderpest around the world. Emphasis was given to the approach of 'search–confirm–eradicate' for cases of stomatitis–enteritis in the SES countries. In September 2003, applying the principles of participatory epidemiology (4, 5, 6), disease searches in north-eastern Kenya detected clinical signs suggestive of mild rinderpest in Garissa district of north-east Kenya. Samples collected from affected cattle tested positive in the polymerase chain reaction (PCR) test at the Kenya Agricultural Research Institute, Veterinary Research Centre (KARI-VRC), Muguga, but sequence analysis of the samples from Kenya at the World Reference Laboratory at the Pirbright Institute indicated a relationship with the RBOK (rinderpest bovine old Kabete, usually referred to as Kabete 'O') vaccine rather than with the lineage-2 rinderpest virus strain, the expected cause (3, 4, 5, 6, 7). However, as no actual virus was isolated, and as the Plowright vaccine has no history of reverting to virulence, the prevailing interpretation was that this represented the last evidence of rinderpest circulating in the area. The Kenyan authorities carried out ring vaccination (150,000 doses), and the Somali PACE project vaccinated the contiguous part of the Lower Juba region in southern Somalia using a further 150,000 doses of rinderpest vaccine (2).

It is possible that the 2003 vaccinations in north-eastern Kenya and in the neighbouring part of southern Somalia, i.e. Lower Juba, actually eliminated the primary endemic focus from the SES, which would explain the declining seroprevalence and the absence of seropositive results in Kenya in a subsequent survey in 2006. As rinderpest transmission depends on close contact, and mild rinderpest virus strains spread slowly (i.e. they have a low basic reproduction number), the expectation was that the infection would die out as a result of the increase in the numbers of immunised cattle following the vaccinations. In addition, the movement of Somali cattle herds was based on the movement of the clans who own the livestock. Because the clans moved in a segregated manner, herds from different clans did not mix easily. Moreover, the eradication of the disease in contiguous parts of neighbouring Kenya and Ethiopia meant that there was no incursion of the disease from outside. These factors may have given any low-level persistent focus of rinderpest virus infection in Somalia time to burn out. By 2004, and based mainly on the results of surveys in Somalia, the SES remained the last unresolved focus of serological evidence of infection. This made the SES the subject of considerable attention in achieving the final global eradication of rinderpest (3, 4, 8). The first phase of SERECU was designed to facilitate surveys that would verify the absence of rinderpest, both in cattle and wildlife, in the three SES countries, leading to the preparation of rinderpest dossiers for submission to the OIE during the second phase of the project.

SEROSURVEILLANCE

Backtracing of positive serological results

During the GREP consultation meeting held in Rome in September 2007, concerns were raised on the persistence of antibodies to rinderpest virus in southern Somalia. Further field serosurveillance carried out in December 2007 in previously seropositive sites did not confirm the presence of antibodies in targeted cattle herds, thus raising the possibility that the previously observed seropositivity might have been due to sampling of ineligible cattle (aged below one year or above three years). In this case, residual maternal antibodies or antibodies from previous vaccinations were most probably the factors contributing to the seropositivity previously detected.

As a further follow-up of the GREP consultative meeting, approximately 20,000 sera from Kenya, Somalia and Ethiopia were sent to the OIE World Reference Laboratory for rinderpest at the Pirbright Institute for parallel testing. Overall, there was a greater than 99.9% agreement between the results from the Kenya and Ethiopia laboratories and Pirbright. The results were quite clear, with only one result from the 20,000 sera tested giving a discrepant value (unpublished GREP report submitted to the OIE *Ad hoc* Group on rinderpest).

Wildlife serology results

A survey conducted on wildlife in the Kulbiow area of Badhade district and in Afmadow district of the Lower Juba region of Somalia in August and September 2006 revealed no clinical suspicions of rinderpest in the abundant warthog populations in the areas. Serum samples collected from 33 warthogs captured in the survey were all negative for rinderpest antibodies. Serological surveys targeting warthog populations in Lower Juba, Middle Juba and Gedo regions were carried out in March and April 2009, and a total of 58 sera were collected from captured warthogs (Fig. 2). The samples tested negative for rinderpest antibodies, and no clinical signs of rinderpest were observed in any of the captured warthogs.

Serological surveys carried out in susceptible wildlife, particularly buffaloes, warthog, giraffe, waterbuck and lesser kudu, in north-eastern Kenya, south-eastern Ethiopia and southern Somalia in 2006 (SERECU phase I) and between 2008 and 2010 (SERECU phase II) demonstrated that rinderpest virus was not circulating within the wildlife populations in the region. This implied that, despite previous infections in wildlife, the virus did not persist and never became endemic in wildlife in the SES (2, 5, 6).

FIG. 2
KENYA WILDLIFE SERVICE GAME RANGER RESTRAINING WARTHOG FOR SAMPLING
Courtesy of the authors

In Ethiopia, 481 sera were collected, and all of them were negative for rinderpest antibodies using the competitive enzyme-linked immunosorbent assay (c-ELISA) test conducted at the National Animal Health and Disease Investigation Center (NAHDIC) laboratory, Sebeta. In Kenya, all 280 cattle and 30 warthog sera tested gave negative results in the c-ELISA tests conducted at the Central Veterinary Laboratory (CVL), Kabete, Kenya. These results consolidated the findings of previous studies that dispelled the possibility of wildlife serving as a reservoir for rinderpest in this ecosystem. Thus it was unequivocally shown that the remaining rinderpest focus in the SES and indeed in Africa had been eliminated. AU-IBAR and GREP concluded that the results negated the theory of endemic status for Ethiopia, Kenya and the three regions of southern Somalia (Gedo, Middle and Lower Juba) and that the previous (2002–2006 samples) seropositivity was likely due to sampling of the wrong age groups of cattle or animals vaccinated in 2003 (2, 3, 6, 8).

CAPACITY-BUILDING

Through EU financial support for SERECU phases I and II and FAO financial support for the bridging period, AU-IBAR, through SERECU, sustained regional coordination activities in the SES. This was achieved through workshops, personnel training activities and support for field investigations, thereby enhancing and ensuring the coherence and complementarities between the activities of FAO-GREP and AU-IBAR in the verification of rinderpest freedom for the SES countries. Sometimes capacity-building was followed by cross-border harmonisation meetings that aimed to harmonise activities in the SES.

REVISIONS TO THE 'OIE PATHWAY'

Based on activities carried out in the SES and elsewhere around the world, GREP and AU-IBAR developed guidelines and requested the OIE to re-evaluate the OIE Pathway. The request was based on the epidemiological situation of the disease in the SES (mild rinderpest) and the cessation of vaccination in many countries in Africa. This request resulted in the adoption of a new *Terrestrial Animal Health Code* chapter on rinderpest and its annex by the 75th OIE General Session in May 2007, marking the start of the final thrust to achieve global rinderpest freedom accreditation by 2010. Thereafter, countries were able to apply for freedom from rinderpest either on a historical basis or through a dossier including serosurveillance data and information on a disease-free, unvaccinated population (9).

THE CONTRIBUTION OF PARTICIPATORY EPIDEMIOLOGY TO RINDERPEST SURVEILLANCE

The accreditation process for a previously rinderpest-infected country required the inclusion of the results of a systematic active disease search programme; in a number of countries this was of a participatory nature. Participatory epidemiology and community-based service delivery systems developed considerably and made a major contribution to rinderpest eradication and animal health delivery systems in the SES (2, 3). Simple, but effective, participatory tools were used to map rinderpest in the lead-up to the final eradication. The mapping exercises were conducted by field veterinarians trained in the socioanthropological approaches that underline participatory techniques in animal health. Hard and 'soft' data on rinderpest occurrence were plotted on two occasions, three years apart, indicating clearly that progress in disease control had been made and identifying areas of concern (4, 5, 8, 9, 11, 12). In southern Somalia, participatory disease searches (PDS) detected a clinical syndrome consistent with mild rinderpest (known locally as *elser* or *shifow*) in several locations, but on collection of samples from affected animals, laboratory testing found them to be negative (8, 12). Cross-border harmonisation workshops (Fig. 3) were the forums used to plan regional activities and sharing of experiences and information.

FIG. 3
NINTH CROSS-BORDER MEETING OF THE SOMALI ECOSYSTEM RINDERPEST ERADICATION COORDINATION UNIT (SERECU), 29–30 MARCH 2010, ADDIS-ABABA, ETHIOPIA
Seated: Walter Masiga and Evans Kariuki, part of the SERECU core team responsible for stakeholders working in the field

Courtesy of the authors

A STUDY OF RISK-BASED SURVEILLANCE

The GREP commissioned a study conducted by Angus Cameron at Ausvet, with the objective of enabling the quantification of the sensitivity of complex surveillance systems, taking into account biases or targeting. It also enabled the integration of multiple components of a surveillance system and the incorporation of historical SES surveillance data into estimates of the current probability of area freedom. The method involved identification of all factors that influence the probability of infection (at the herd or animal level) or the detection of infection. For each factor, the proportion of the population in each level of the factor and the proportion of herds or animals in the surveillance system are determined or estimated (2, 12). For factors influencing the risk of infection, the relative risk is also estimated as shown in Table I. Tables II and III present the number of animals sampled in livestock serosurveys as well as the number of villages visited for participatory disease searches. In all cases, the laboratory did not confirm any virus circulation.

This study used stochastic scenario-tree modelling to quantitatively estimate the sensitivity of seven different components of the rinderpest surveillance system in Kenya, Somalia and Ethiopia, from 2004 to 2008. These included passive disease reporting and serosurveys for both livestock and wildlife, livestock market surveillance, participatory disease searching and zero reporting systems. All components, except the wildlife serosurvey, were able to meet or greatly exceed recommended standards for rinderpest surveillance sensitivity (95% with a herd-level design prevalence of 1% and an animal-level design prevalence of 5%). Despite a variety of

TABLE I
FACTORS INFLUENCING THE PROBABILITY OF DETECTION OF DISEASE IN DIFFERENT SURVEILLANCE SYSTEM COMPONENTS

Component	Factor
Passive livestock disease reporting	Animal shows clinical signs
Passive wildlife disease reporting	Reporter notices signs
	Reporter contacts Veterinary Services
	Veterinarian takes sample
	Sample tested for rinderpest
	Initial test positive
	Follow-up investigation positive
Livestock serosurvey	Initial test positive
Wildlife serosurvey	Follow-up investigation positive
Participatory disease surveillance	Animal shows clinical signs
Zero reporting	Reporter notices signs
	Initial test positive
	Follow-up investigation positive
Market surveillance	Animal shows clinical signs
	Initial test positive
	Follow-up investigation positive

able to detect a herd-level prevalence of 0.001%. The combination of the sensitivity of the different components further increased the capacity of the system to detect extremely low levels of disease. The study found that, by combining evidence over multiple time periods, the surveillance system generated a probability of greater than 99% that the three countries did not have a single infected herd. Uneven coverage of the population suggests that caution was warranted, but even in those parts of the population with the lowest confidence (wildlife in Somalia), the normally rapid spread of rinderpest in naive populations meant that, after five years, its chance of remaining hidden was very low (unpublished GREP report submitted to the OIE *Ad hoc* Group meeting).

The study suggested that, for diseases that reliably show clear clinical signs, the passive disease reporting systems are normally the most sensitive (because of the large number of animals under observation) and the least expensive (as they form part of the normal veterinary structure). However, weaknesses due to gaps in the reporting pathway, the passive livestock disease reporting system had the greatest ability to detect disease outbreaks at a low level, because of the high coverage of the population. In a single time period, it was

TABLE II
NUMBER OF ANIMALS SAMPLED IN LIVESTOCK SEROSURVEYS

Country	Region	Species	2008	2007	2006	2005	2004	2003	2002	2001	2000
Kenya	High risk	Cattle	2,453	280	3,406	368	495	1,778	879	9,465	0
		Sheep	0	0	0	0	138	0	120	336	0
		Goat	0	0	0	0	377	0	150	116	0
	Low risk	Cattle	6,923	0	11,484	96	9,581	928	2,464	0	0
		Sheep	0	0	0	0	0	0	4	0	0
		Goat	0	0	0	0	0	0	6	0	0
Somalia	High risk	Cattle	5,319	2,160	3,599	3,599	1,440	2,879	3,599	720	720
	Low risk	Cattle	2,070	840	1,401	1,401	560	1,121	1,401	280	280
Ethiopia	High risk	Cattle	0	0	6,000	2,543	1,114	0	200	0	0
	Low risk	Cattle	0	1,219	8,435	8,800	10,424	2,280	11,680	12,260	6,834
Total			**16,765**	**4,499**	**34,325**	**16,807**	**24,129**	**8,986**	**20,503**	**23,177**	**7,834**

TABLE III
NUMBER OF VILLAGES VISITED FOR PARTICIPATORY DISEASE SEARCHES

Country	Region	2007	2006	2005	2004	2003
Kenya	High risk	0	69	20	47	42
	Low risk	0	23	66	297	108
Somalia	High risk	20	210	420	420	210
Total		**20**	**302**	**506**	**764**	**360**

zero reporting and livestock market surveillance also provide very high sensitivity at very low cost. The study also highlighted the challenges of wildlife surveillance. The surveillance data that they provided, and which were analysed, clearly exceeded the OIE standards that underpinned the successful eradication of the disease in the rest of the world. As occurred with smallpox, confidence in the successful completion of the eradication of rinderpest would continue to grow with time. However, the analysis presented in the study demonstrated that the level of confidence already achieved was extremely high. The findings of the study were used to support Somalia's application for OIE accreditation of freedom from rinderpest (unpublished GREP report submitted to the OIE *Ad hoc* Group meeting).

LESSONS LEARNT IN IMPLEMENTING SERECU

1. The regionally coordinated ecosystem approach with regular cross-border meetings to exchange information on transboundary disease interventions and to harmonise and plan activities was a key factor in the eradication of rinderpest from the SES and could be applied in the future control and eradication of other transboundary animal diseases (TADs).
2. The centralised way of administering some activities such as procurement and training proved to be less cumbersome and saved time.
3. The adaptability of the project allowed countries to collect baseline data for other TADs, thereby optimising the use of project resources.
4. Simulation exercises for any recurrence of rinderpest were crucial in identifying the gaps in the contingency plans. For example, it was quite evident that countries had not internalised and owned the contingency plans and that the matter of compensation and stamping out remained theoretical/academic to the countries concerned; thus, more needed to be done.
5. In spite of undertakings by various national governments to sustainably fund epidemio-surveillance activities after PACE, this did not fully materialise in some countries in the SES.
6. Oversight support given by the steering committee played an important role in the implementation process (Fig. 4).

CONCLUSIONS

SERECU developed capacities and experience to integrate national-level actions with regional and global actions, including setting the pace for timely and simultaneous implementation of the surveys in the three SES countries and ensuring their adherences to regionally agreed operating procedures. Concurrently, the unit encouraged and brought in coordinated regional and international approaches (e.g. involving AU-IBAR, FAO-GREP, OIE and IAEA – the International Atomic Energy Agency) to agree on standards and interpretation of data. Furthermore, the unit facilitated the routing, registering and dispatch of samples to regional and international reference laboratories (Muguga, CIRAD – the French international research centre for agricultural development – and the Pirbright Institute). The regional experience also included the use of the Kenya Wildlife Service for training of personnel and supporting wildlife surveys in Ethiopia and Somalia.

Significant lessons drawn from SERECU included the building of consensus among stakeholders that facilitated coordinated and harmonised surveillance activities and emergency interventions, such as the follow-up of cross-border events, in addition to integrated epidemiological data analysis for disease mapping and risk analysis.

At the beginning of SERECU, Ethiopia and Kenya were rinderpest disease-free on a zonal basis, with the SES considered infected. Components of

FIG. 4
FINAL STEERING COMMITTEE MEETING, MOMBASA (JUNE 2010)

Standing (left to right): Rhona Walusimbi, Amsalu Demissie, Gerald Nyamatcherenga, Joseph Mosabi, Felix Njeumi, Ahmed Elsawalhy, Peter Sturesson, Luciano Mosele, Hans Jurgen Scholl, Peter Ithondeka, and Paul Rambo. Kneeling/squatting: Dickens Chibeu, Mesfin Sahle, Habiba Sheikh Hassan Hamud, Mohamed Farah Dirie and Eric Kimani

Courtesy of the authors

serosurveillance in both domestic and wildlife populations were carried out. Testing and retesting of 20,000 sera at the World Reference Laboratory, coupled with the commissioned risk-based surveillance study did not detect any seropositivity. This led to the accreditation of the three countries as rinderpest-free.

ACKNOWLEDGEMENTS

We acknowledge the following:

- the Ministry of Livestock, Forestry and Range of the Federal Republic of Somalia for the use of the information in the Somalia rinderpest dossier to the OIE for rinderpest-free status recognition;
- the Somali Veterinary Authorities for the use of data and information from rinderpest surveillance activities in central and south Somalia, Puntland and Somaliland;
- Terra Nuova and implementing partners for use of data and information from disease surveillance activities under the Somali PACE and SAHSP I and II projects;
- the Governments of Ethiopia and Kenya for use of data and information from disease surveillance activities.

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CHAPTER 4.5

INTRODUCTION TO THE RECENT HISTORY OF AND EVIDENCE FOR THE ERADICATION OF RINDERPEST FROM AFRICA

Between 1960 and 1999 a number of African countries participated in two mass vaccination programmes designed to either control or eliminate infection with rinderpest virus. These were the Joint Programme 15 (JP15 – Chapter 4.1) and the Pan-African Rinderpest Campaign (PARC – Chapter 4.2). Although linked to international support and guidance, the actual implementation of these campaigns lay in the hands of the national Veterinary Services of the participating countries. Equally, the basis for evaluating the success of these campaigns lay in the obligation of the Veterinary Services to report the number of vaccinations administered and the number of outbreaks of rinderpest experienced. Whereas JP15 did not succeed in bringing outbreak numbers to zero, PARC certainly did. An understanding of the point at which the rinderpest outbreak level reached zero became critical to subsequent events, involving, firstly, the end of vaccination to generate a rinderpest-susceptible bovine population and, secondly, the scrutiny of this population, both clinically and serologically, for evidence of the presence or absence of the virus. For 22 countries of sub-Saharan Africa, and as a reflection of the massive efforts of the Veterinary Services, the interplay between vaccination and the incidence of rinderpest outbreaks has been charted from 1950 to the point at which rinderpest disappeared (see Chapter 4.6). The transition from vaccinating to surveillance turned on an international declaration of provisional freedom from rinderpest based on this evidence.

The countries discussed in this section had probably remained rinderpest infected since the Great African Pandemic of the late 19th century (Chapter 2.2), and the individual chapters outline their rinderpest history to the point at which surveillance subsequently provided evidence – developed in fulfilment of internationally agreed criteria (the World Organisation for Animal Health [OIE] Pathway – mentioned briefly in Chapter 4.1 and more fully discussed in Chapter 5.2) – that the country could claim to be rinderpest-free. This claim, backed by a dossier of evidence, had to be made to the OIE Scientific Commission, the body responsible for evaluating the claim; the evidence contained in the country dossiers is presented in the individual chapters.

In 2011, in compiling a comprehensive list of rinderpest-free Members, the Scientific Commission was also prepared to accept, without evidence from surveillance, countries where rinderpest vaccine had not been used during the past 10–25 years and rinderpest had not been recorded. These Members, specifically Gambia, Guinea-Bissau, Liberia, Sierra Leone, Burundi and Rwanda, are not considered in this section.

CHAPTER 4.5.1

BENIN

L.K. GNAHO

Former Director of Livestock, Ministry of Agriculture, Livestock and Fisheries, Benin

SUMMARY **The last case of rinderpest was in 1987. Vaccination was carried out in the 1980s and 1990s under the Joint Programme 15 (JP15) and the Pan-African Rinderpest Campaign (PARC). Vaccination was halted in 1999. Benin declared itself provisionally free from rinderpest on 1 June 1999 and began clinical surveillance of the national herd. Serological surveillance from 2003 to 2004 confirmed the absence of rinderpest. Benin was officially recognised as a country free from rinderpest in May 2005.**

KEYWORDS **Benin – Rinderpest – Surveillance – Vaccination.**

HISTORY OF RINDERPEST AND RINDERPEST VACCINATIONS

Up until the early 1960s, rinderpest was endemic in Benin, but this was brought to a halt by participation in phase II of JP15, which ran from 1964 to 1967 (Chapter 4.1). Intermittent introductions occurred during the 1970s, followed by a more sustained period of endemicity in the 1980s, dealt with first by an emergency vaccination campaign of the Food and Agriculture Organization of the United Nations (FAO) in 1980 and 1981 followed by participation in PARC (Chapters 4.2 and 4.6).

Table I summarises the vaccinations carried out under PARC.

TABLE I
SUMMARY OF VACCINATIONS OVER FIVE YEARS

Year	Cattle population	Rinderpest vaccinations	Vaccination coverage rate
1994	1,286,850	545,937	42.4%
1995	1,087,290	507,373	46.7%
1996	1,300,000	457,716	35.2%
1997	1,345,000	508,398	37.8%
1998	1,293,400	292,888	20.3%

The last recorded case occurred in Néganzi in the north-east of the country in 1987. It transpired that some of the commercial animals implicated in Néganzi ended up in the slaughterhouses of Cotonou-Porto Novo in the municipality of Sèmè-Podji, where 75 deaths were also reported.

Seromonitoring activities were conducted from 1993 to 1997. After more than a decade of annual vaccination campaigns, vaccination was halted in January 1999, and Benin declared itself provisionally free from rinderpest on 1 June 1999 (Fig. 1 [1]).

CLINICAL AND SEROLOGICAL CLINICAL SURVEILLANCE

Following a buffalo mortality episode in Pendjari National Park in 1998, Benin began epidemiological surveillance for rinderpest in 1999. It was assisted in this endeavour by the Regional Epidemiology Unit of PARC, based in Bamako, with the same unit subsequently working for the Pan-African Programme for the Control of Epizootics (PACE) (see Chapter 4.3). In 1999, a total of 2,817 cattle were clinically examined and 39 of them were sampled for serum, among which nine were positive for rinderpest antibodies. This positivity was ascribed to vaccination, which stopped in 1999. Since 2000, no suspected cases of rinderpest have been detected.

FIG. 1
ADMINISTRATIVE MAP OF BENIN
Source: United Nations, 2020 (1)

A total of 299 herds were kept under surveillance for instances of stomatitis–enteritis until 2002. In the course of 10,445 clinical examinations, no animal was suspected of having rinderpest.

During the course of these examinations, based on clinical suspicion, a number of sera were collected and tested. Results are shown in Table II.

From 2003 onwards, clinical surveillance was coupled with serological surveillance, and the sampling size was increased to 314 herds.

Serological surveillance was conducted on a random sample of eligible cattle, namely cattle born after the cessation of vaccination and lacking maternal antibodies, as well as on other eligible animal species, in particular small ruminants and wildlife. Samples were examined using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; Chapters 3.3 and 6.3). In 2003, of the 2,611 sera tested, 20 (0.76%) were found to be positive. The distribution of these positives among sampling units led to the identification of just two villages (Ouenra and Gbene) with a relatively high

TABLE II
RESULTS OF CLINICAL AND SEROLOGICAL SURVEILLANCE BETWEEN 1999 AND 2003

Year	Cattle	
	Clinical examinations	Sera collected
1999	2,817	339 (9 positives)
2000	2,343	350
2001	2,097	373 (0 positives)
2002/2003	3,188	1,172 (0 positives)

seropositivity rate. Following investigations and the monitoring of animals in the villages concerned, it was not possible to link these cases of positivity to the circulation of the virus in cattle herds.

In 2004, of the 2,035 sera analysed, three (0.155%) were positive. As a result of the investigations and the specificity of the test used, these cases were judged to be false positives.

Investigations into wildlife also confirmed that the rinderpest virus was not circulating. In the risk areas (namely wildlife reserves), purposive sampling was carried out by the Parakou Serosurveillance Laboratory on an annual basis.

In 2003, of the 43 wildlife sera collected, only one was found to be positive; however, it had come from an eight-year-old buffalo and was therefore ineligible. In 2004, none of the 21 sera collected was found to be positive.

DOSSIER

The results of clinical surveillance and serological surveys of both cattle and wildlife in Benin in 2003 and 2004 provide clear proof that the rinderpest virus is no longer circulating among Benin's rinderpest-susceptible animal population. In May 2003, Benin was found to be a country free from rinderpest disease, following evaluation of the dossier by the World Organisation for Animal Health (OIE) (2).

In November 2004, the Delegate of Benin submitted a dossier to secure the status of country freedom from rinderpest. The dossier was examined by the relevant OIE Commissions (3), and country freedom from rinderpest was accorded to Benin by the World Assembly of OIE Delegates at its 73rd General Session in May 2005.

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CHAPTER 4.5.2

BURKINA FASO

Z. COMPAORE

Former Director of Veterinary Services, Ministry of Animal Resources, Burkina Faso

SUMMARY **Following Joint Programme 15 (JP15), rinderpest re-emerged in Burkina Faso on several occasions between 1980 and 1988. Mass vaccination of all livestock was carried out from 1987 to 1996. Following the cessation of vaccinations, an epidemiological surveillance network was established, and serological surveillance was conducted in 2003 and 2004. Burkina Faso was declared free from rinderpest in May 2006.**

KEYWORDS **Burkina Faso – Epidemiological surveillance – Rinderpest – Vaccination.**

INTRODUCTION

Burkina Faso is a mainland country in central West Africa that shares a border with six countries: Mali to the west and north, the Niger to the east, and Togo, Benin, Ghana and Côte d'Ivoire to the south. Administratively, the country is divided into 13 regions (Fig. 1). It has a surface area of 274,000 km^2 and a human population of over 15,000,000. It is a Sahelian country in which livestock farming plays a prominent role. In 2010, the national herd was estimated to include 8,400,000 head of cattle.

Animal health activities are managed at national level by the General Directorate of Veterinary Services and at regional, provincial and local levels by 13 regional animal resource directorates, 45 provincial animal resource directorates and 100 veterinary posts.

HISTORY OF RINDERPEST IN BURKINA FASO

Control of rinderpest was one of the major concerns of the Veterinary Services in the African countries that took part in the first continental programme for the control of rinderpest – JP15 (see Chapter 4.1). At the end of the programme, no outbreak was reported, and the vaccination coverage rate was over 80%. This positive situation led to the assumption that rinderpest had been eradicated or at the very least that any new or remaining outbreaks would be stamped out quickly. However, for various reasons, the resources made available to the Veterinary Services for the application of precautionary vaccination proved insufficient to prevent a series of outbreaks in the period up to 1974, eventually eliminated with the assistance of the Food and Agriculture Organization of the United Nations (FAO).

However, JP15 did not succeed in eradicating the disease from the region, and, after an absence of five years, in August 1980 rinderpest returned to the northern part of the country (nine outbreaks), having spread there from neighbouring countries.

This led to the implementation of an emergency vaccination campaign in 1980 and 1981, during which 2,624,534 animals were vaccinated out of a total of 2,986,000 head (a vaccination coverage rate of 87.9%). Lower coverage levels over the next few years could not eliminate the disease but, after the launch of the Pan-African Rinderpest Campaign (PARC) in 1986 (see Chapter 4.2), Burkina Faso organised an annual mass vaccination of the country's entire cattle population. The disease disappeared from the country in 1988.

Outbreak and vaccination levels are given in Chapter 4.6.

FIG. 1

MAP SHOWING INTERNATIONAL BORDERS AND NEIGHBOURING COUNTRIES AND MAJOR ADMINISTRATIVE DIVISIONS OF BURKINA FASO

Source: United Nations, 2016 (1)

RESULTS OF CLINICAL AND SEROLOGICAL SURVEILLANCE

Starting in 1990, the vaccination campaigns were evaluated. At the end of the campaigns, sera were collected from animals in each randomly selected village, according to age group (Table I).

Table I shows that the immunisation coverage rate of animals over three years of age was more than 80% in all the seromonitoring campaigns conducted.

TABLE I

RESULTS BY AGE GROUP OF SEROCONVERSION FROM 1990/1991 TO 1995/1996 FOLLOWING RINDERPEST VACCINATION

Campaign	Seroconversion to rinderpest virus by age group			
	0–1 year	1–2 years	2–3 years	> 3 years
1990/1991	65%	73%	82%	89%
1991/1992	50%	55%	70%	81%
1993/1994	62%	65%	78%	82%
1995/1996	60%	65%	79%	86%

Epidemiological surveillance

Burkina Faso stopped vaccinating against rinderpest on 1 January 1997, and an Epidemiological Surveillance Network for Animal Diseases (RESUREP) was established.

The country declared itself provisionally free from rinderpest in 1998 and ceased vaccination. The country then embarked on the World Organisation for Animal Health (OIE) procedure for declaring country freedom from rinderpest by setting up active surveillance and then serological surveillance.

Active clinical surveillance

The stratified survey method was used for sampling. Burkina Faso's cattle population was considered a single stratum.

To ensure a 95% probability of detecting the disease if clinical signs were present in 1% of herds, 300 villages were randomly selected from a total of

8,000 villages. Border areas subject to significant livestock movements because of transhumance and large livestock markets, such as Pouytenga, Kaya, Youba, Djibo, Markoye, Nadiabonli, Fada and Béna, were also identified as risk areas.

Staff of the 45 surveillance posts visited the 300 villages or herds at least once a year and the aforementioned risk areas at least twice, searching for signs of rinderpest.

The only serious suspicion, which occurred in 2002 at the border with Benin and the Niger, proved to be an outbreak of malignant catarrhal fever, confirmed by the Bingerville animal disease laboratory (Côte d'Ivoire).

Apart from active surveillance, the passive surveillance posts provided no information on any disease that might be rinderpest.

Serological surveillance

The standard applied in serological surveillance was the same as that for clinical surveillance. The sampling method used has to detect infection with a 95% probability if antibodies are present at a prevalence of 1% in farms in any selected stratum of the susceptible population. To comply with this standard, the random sample of selected villages was 314 villages. Serological surveillance was carried out for a total period of two years. Serological surveillance began in 2003 and continued in 2004. Samples were evaluated using the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3 and 6.3). In 2003, the sera collected were from cattle, small ruminants and wildlife.

To facilitate field operations in cattle, samples were taken from all unvaccinated animals born after 1997 (the year when vaccination ceased) and aged between two and four years. The analysis of 7,156 cattle sera revealed no presence of infection-induced antibodies to the rinderpest virus.

A total of 1,140 small ruminant sera were tested. Of these 1,140 sera, 6 tested positive but, after verification, all proved to be animals that had been vaccinated against peste des petits ruminants using the rinderpest vaccine.

A total of 69 wildlife sera were collected and 60 sera were tested. There were no positive sera. As the analysis of all the sera collected from cattle, small ruminants and wildlife had failed to reveal the presence of infection-induced antibodies to the rinderpest virus, it was concluded that the rinderpest virus was no longer circulating in the national territory.

In 2004, a further serosurveillance campaign was conducted.

In cattle, samples were taken from 10,622 unvaccinated animals born after 1997 (the year when vaccination ceased) and aged between two and five years. The analysis of 9,261 cattle sera failed to reveal the presence of infection-induced antibodies to the rinderpest virus.

A total of 1,501 sera were collected from small ruminants, 1,361 of which were submitted for testing.

A total of 38 wildlife sera were analysed. There were no positive sera. These results were confirmed by the Bingerville animal disease laboratory.

There was therefore no circulation of the rinderpest virus in the national territory. This confirmed and reinforced the results of the first rinderpest serology campaign.

CONCLUSION AND DOSSIERS

Based on the active clinical surveillance reports from veterinary posts, an initial dossier including a report on epidemiological surveillance and a rinderpest emergency response plan was submitted to the OIE in December 2002. A review of this dossier by the OIE (2) enabled the OIE International Committee to declare Burkina Faso free from rinderpest disease on 21 May 2003.

Based on the results of serological surveillance and the existence of an effective disease reporting system, including the establishment of an epidemiological surveillance network, the country submitted an application dossier to the OIE in 2005. A review of this dossier by the OIE (3) enabled the World Assembly of OIE Delegates to declare the country free from rinderpest infection on 25 May 2006.

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CHAPTER 4.5.3

CAMEROON

H. SAÏDOU

Former Director of Veterinary Services, Ministry of Livestock, Fisheries and Animal Industries, Yaoundé, Cameroon

SUMMARY Cameroon's first cases of rinderpest occurred during the First World War in 1918. Cameroon experienced an extremely deadly epidemic between 1926 and 1927. Outbreaks were recorded up until 1971. Vaccination campaigns began in 1962 and continued until 1998. The last case of rinderpest was detected in 1986, and vaccination was halted in 1998. In 2004, Cameroon established an epidemiological surveillance network. Serological surveys were conducted between 2005 and 2009. Cameroon was declared free from rinderpest in May 2010.

KEYWORDS Cameroon – Rinderpest – Surveillance – Vaccination.

INTRODUCTION

The Republic of Cameroon is situated at the north-eastern end of the Gulf of Guinea. It is bordered to the north by Lake Chad, to the south by Equatorial Guinea, Gabon and Congo, to the east by the Central African Republic and Chad, and to the west by Nigeria. Cameroon opens onto the Atlantic Ocean along almost 300 km of coastline (Fig. 1).

Agriculture is the country's main economic activity. The livestock sector provides an income for nearly 30% of the rural population and accounts for 5–8% of Cameroon's total gross domestic product. Cattle farming in Cameroon predominantly consists of the traditional extensive system based on range-land grazing. Pure pastoralism is practised by nomadic transhumant pastoralists, involving 30% of cattle and 18% of small ruminants. This system is characterised by constant movements in search of pasture and water, a practice conducive to the spread of diseases.

Government interest in the livestock sector led to the establishment of the Ministry of Livestock, Fisheries and Animal Industries. Animal disease control is a priority for this ministry, which has a Veterinary Services Directorate that deals with animal health matters. Rinderpest is one of the diseases on which the Veterinary Services have focused for many years.

HISTORY OF RINDERPEST ERADICATION

In Cameroon, the first cases of rinderpest were recorded and diagnosed by colonial veterinarians during the First World War in 1918 in the areas surrounding Lake Chad. The disease had probably been introduced into Cameroon by transhumant animals during the Great African Rinderpest Pandemic of 1887–1900 (see Chapter 2.2). The southern part of the country was spared for many years by its geographical location, being separated from northern Cameroon (before the 1980s, 'northern' referred to the three regions Far North, North and Adamaoua) by an extensive tsetse-infested area not conducive to farming and by the Ngaoundéré cliff, which forms a natural barrier that is difficult for herds in northern regions to cross. However, the region immediately adjacent to the Adamaoua plateau (currently the Adamaoua region) – Cameroon's foremost cattle farming region – experienced an extremely deadly epidemic between 1926 and 1927. Colonial veterinarians introduced measures to isolate sick animals, incinerate carcasses and

FIG. 1

ADMINISTRATIVE MAP OF CAMEROON SHOWING THE TEN REGIONS AND NEIGHBOURING COUNTRIES

Source: United Nations, 2020 (1)

vaccinate susceptible animals, limiting the scale of the epidemic waves that occurred. Following this episode, the Adamaoua plateau remained free until the period 1960-1961, when there was a serious but rapidly contained outbreak.

In the north of the country, rinderpest was endemic throughout the 1950s and 1960s. Lepissier's (2) Joint Programme 15 (JP15) report tabulates outbreaks between 1952 and 1961 as follows: 1952 (181), 1953 (92), 1954 (43), 1955 (275), 1956 (108), 1957 (114), 1958 (95), 1959 (181), 1960 (207), 1961 (90), 1962 (25); see also Chapter 4.6.

Livestock vaccination campaigns organised as part of the Pan-African control programme, JP15 phase I, from 1962 to 1965, significantly reduced the incidence of rinderpest in Cameroon but failed to eliminate the infection (see Chapter 4.1). Although no further occurrence of the disease was recorded in the Adamaoua plateau after 1964, outbreaks continued to be recorded from northern Cameroon up until 1975. Then, after an absence of seven years, outbreaks were again reported during the period 1983–1986, as part of the second African pandemic. The last outbreak was in 1986.

Vaccines and vaccinations

Rinderpest was brought under control in Cameroon through routine vaccinations of livestock, coupled with the rapid application of animal health measures during epidemics, namely isolation of outbreaks, stamping-out measures and the control of animal movements. Immunisation of livestock against rinderpest was carried out on a national basis.

Rinderpest vaccination trials in Cameroon began in 1929 with the use of the formalin vaccine. These were imported mainly from Chad until 1984, when Cameroon built a laboratory for rinderpest diagnosis and vaccine production – the National Veterinary Laboratory (LANAVET). From then on, all the vaccines used were produced locally. LANAVET produced two types of vaccine: 'Bovipestovax', a monovalent vaccine targeted solely at rinderpest; and 'Bivax', a bivalent vaccine targeted at both rinderpest and contagious bovine pleuropneumonia.

In response to the rinderpest recurrence in 1983, the Food and Agriculture Organization of the United Nations (FAO) provided assistance in procuring and using the vaccine. Further intensive vaccinations came during PARC (Chapter 4.2) between 1986 and 1998. Estimates put the average uptake level at 60% of the national herd. Vaccination was halted in 1998. Table I shows vaccinations from 1969 to 1998 (see also Chapter 4.6).

TABLE I
RINDERPEST VACCINATION OF CATTLE IN CAMEROON, 1969–1998

Year	Number of districts (provinces) vaccinated	Estimated population	Number of vaccinations	Prevalence of vaccination (%)
1969	04	2,742,945	1,594,546	58
1970	04	2,865,871	1,888,098	70
1971	04	2,865,871	1,886,123	66
1972	04	3,045,987	1,863,987	61
1973	04	3,045,987	1,876,098	62
1973	04	3,412,736	1,975,009	58
1974	04	3,402,654	1,835,007	54
1975	04	3,402,654	2,000,355	59
1976	04	3,743,398	2,453,452	66
1977	04	3,883,098	2,907,076	75
1978	04	3,876,056	2,918,581	75
1979	04	3,876,056	2,345,654	60
1980	04	3,876,056	1,076,876	28
1981	04	3,867,987	1,056,654	27
1982	04	3,876,456	1,987,643	52
1983	06	3,834,786	1,006,098	26
1984	06	3,856,786	1,006,001	26
1985	06	3,856,900	1,006,001	26
1986	06	4,175,000	2,241,083	54
1987	06	4,710,000	2.733,635	58
1988	06	4,710,000	2,772,815	59
1989	06	4,710,000	3,124,455	66
1990	06	4,710,000	3,017,569	64
1991	06	4,710,000	2,984,714	63
1992	06	4,710,000	2,720,420	58
1993	06	4,710,000	3,035,993	64
1994	06	5,100,000	3,207,991	63
1995	06	5,100,000	3,908,397	76
1996	06	5,100,000	3,892,401	76
1997	06	5,120,000	3,984,503	78
1998	06	5,122,000	3,396,543	66

RINDERPEST CLINICAL AND SEROLOGICAL SURVEILLANCE

Clinical surveillance

At the outset, rinderpest surveillance was an exclusively passive routine activity of the Veterinary Services. In 2004, Cameroon established an epidemiological surveillance network to boost the Veterinary Services in their surveillance of rinderpest and other major epidemic diseases, in order to couple continuous surveillance of livestock with active clinical and serological surveillance based on representative samples of the susceptible animal population. The objectives of rinderpest surveillance were to:

- detect any hidden outbreaks;
- rapidly detect any resurgence and/or reintroduction of the disease;
- confirm the absence of the disease and the absence of virus circulation among susceptible animal populations (livestock and wildlife);
- retain country freedom from rinderpest after completion of the entire eradication procedure.

Cameroon's epidemiological surveillance network for animal diseases was built around a central unit, which coordinated activities countrywide and decentralised structures grouped into two components: the livestock component, which dealt with farm animals; and the wildlife component.

Clinical surveillance remains a priority for Cameroon's Veterinary Services. Passive surveillance did not detect suspicion of rinderpest after the last confirmed case in 1986. Table II below summarises the number of suspect samples collected from animals showing stomatitis–enteritis in the main livestock farming regions from 2007 to 2009 and tested in the laboratory.

Continuous wildlife surveillance was provided by officers working from observation posts in parks. Wildlife surveillance was based on searching for signs of suspected rinderpest in susceptible species (buffaloes, antelopes, etc.) and on collecting samples from the carcasses of fallen animals or animals killed during the 2008-2009 hunting season. The types of sample collected and tested were whole blood (20), sera (18) and intestine, liver and kidney (26). None of these tested positive for rinderpest.

TABLE II
NUMBER OF SAMPLES COLLECTED DURING CLINICAL SURVEILLANCE FOR RINDERPEST, 2007–2008

Region	Nasal swabs	Eye swabs	Oral swabs	Sera
Adamaoua	14	13		75
East	22	4		23
Far North	10		2	60
North		4		37
North-west	131	13	60	59
West	3			
Total	**180**	**39**	**62**	**295**

Note: All the samples tested negative. Blank cells indicate samples not collected

Serological surveillance

The epidemiological unit selected for sampling was the village herd, as these were easier to list than actual herds. The sampling frame consisted of 8,275 village herds identified in the six regions covered by Veterinary Service staff. Livestock markets and transhumance areas serving as animal assembly points were included in this list and were considered as village herds. The sample size was determined on the basis of 95% probability of virus detection if the infection prevalence was 1%. Using statistical software, a total of 314 village herds were drawn at random, that is, 299 village herds statistically valid for an infinite number of villages, plus a margin of 15 additional village herds to offset any villages found during the surveys to have no animals. In 2007, serum samples were collected from eligible animals in each of the 314 randomly selected village herds. Any animals showing a sign of legitimate suspicion of rinderpest were also clinically examined, and samples were taken to search for the virus. Results are given in Table III.

The sera were tested by LANAVET using the competitive enzyme-linked immunosorbent assay (c-ELISA; Chapters 3.3 and 6.3) adapted to rinderpest. Of the 5,393 sera analysed, 11 tested positive, giving a seroprevalence rate of 0.20%.

In the second year of surveillance in 2008, 982 sera were collected from eligible animals on randomly selected farms, with no suspect clinical signs of

TABLE III
NUMBER OF SERA COLLECTED BY REGION AND BY SPECIES AND EXAMINED FOR ANTIBODIES TO RINDERPEST VIRUS IN 2007

Region	Cattle	Sheep	Goats	Wildlife	Total	Seroprevalence rate (%)
Adamaoua	823	13	15		**851**	0.35
Centre	32		11		**43**	0
East	254	7	12		**273**	0
Far North	1,018	21	36		**1,075**	0
Littoral	14				**14**	0
North	1,739	34	68	43	**1,884**	0.26
North-west	1,005	45			**1,050**	0.28
West	114		17		**131**	0
South	266				**26**	0
South-west	46				**46**	0
Total	**5,071**	**120**	**159**	**43**	**5,393**	**0.20**

rinderpest being found. An analysis of these sera revealed no circulation of the rinderpest virus.

With respect to wildlife, 43 useable sera were collected in 2007 from susceptible species killed during the hunting season. The sera were tested by LANAVET and all were negative for rinderpest.

DOSSIER

Vaccinations were halted in 1998, and Cameroon declared itself provisionally free to concentrate its efforts on epidemiological surveillance of rinderpest. After successfully completing the clinical surveillance phase in accordance with the World Organisation for Animal Health (OIE) procedure, Cameroon was recognised as a country free from rinderpest (disease) in May 2007.

Serological surveillance, to prove that the virus had disappeared from the country, was conducted between 2007 and 2009, both on a random basis among the randomly selected farms and on a purposive basis among the animals most at risk of infection.

In May 2010, the above results were included in a dossier evaluated by the OIE and accepted as being representative of country freedom from rinderpest infection (3).

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CHAPTER 4.5.4

CENTRAL AFRICAN REPUBLIC

E. NAMKOISSE

Former Director-General of the National Livestock Development Agency (ANDE), Former Director of Veterinary Services, Bangui, Central African Republic

SUMMARY **The last outbreak of rinderpest in the Central African Republic occurred in 1984. As soon as the disease emerged, vaccination was started throughout the country and continued until December 2000, when it was suspended in the western region and part of the central region. Vaccination was definitively halted in December 2003. An epidemiological surveillance network was set up in 1999. In May 2007, the Central African Republic was declared free from rinderpest disease, and in May 2010 it was declared free from rinderpest.**

KEYWORDS **Central African Republic – Rinderpest – Surveillance – Vaccination.**

INTRODUCTION

The Central African Republic is a vast landlocked country in the heart of Africa, spanning an area of 623,000 km². It is a country with a tradition of agropastoralism and, in common with most countries in the subregion, its economy is based mainly on agriculture and livestock.

The Central African Republic is subdivided into 16 prefectures and 57 subprefectures. In terms of livestock organisation in the country, there are three regional directorates of the National Livestock Development Agency (eastern, central and western regions) and an oversight body for the northern region, which covers the prefectures of Bamingui-Bangoran and Vakaga.

The Central African Republic is bordered by Cameroon to the west, Sudan to the east, Chad to the north and Congo and the Democratic Republic of the Congo to the south (Fig. 1).

Livestock accounts for 29% of the country's agricultural gross domestic product (GDP) and 14% of national GDP. In 2003, it was estimated that there were 3,120,000 cattle in the Central African Republic.

RINDERPEST ERADICATION

The exceptional appearance of rinderpest in the north-west of the country in 1983 did not lead to an in-depth investigation of the outbreak, although there was every reason to believe that the disease entered the country through transhumant herds from Chad. Cattle movements between Chad and the Central African Republic and between Sudan and the Central African Republic may explain this infection. No cases of rinderpest have been recorded anywhere in the national territory since the last cases occurred in 1984 – as a continuation of the 1983 incident. In the eastern Central African Republic, rinderpest has been unknown since 1930. The country did not participate in Joint Programme 15 (JP15).

RESULTS OF CLINICAL AND SEROLOGICAL SURVEILLANCE

Strategy

The strategy adopted was mass vaccination (1983–2003), followed by the systematic marking of animals. In part, this assisted in the creation of the so-called Central African Block – a zone (*zone*

FIG. 1
ADMINISTRATIVE MAP OF THE CENTRAL AFRICAN REPUBLIC
Source: United Nations, 2020 (1)

tampon or vaccine belt) of highly immunised cattle proposed during the Pan-African Rinderpest Campaign (PARC) (Chapter 4.2). Other measures, including the control of livestock movements within the country and the regulation of transhumance, were adopted to complement vaccination.

In 2000, the Central African Republic's veterinary authorities decided to confine the vaccination requirement to a zone in the east of the country bordering with three countries considered to be at risk of rinderpest (Sudan, Chad and the Democratic Republic of the Congo). The aim of this protection zone (or 'cordon sanitaire') was to protect the Central African Republic's cattle population by providing herds in this zone with good immune protection through mass vaccination. This would stop the virus moving from East Africa to West Africa by contact transmission through the national herd. The cordon sanitaire was formalised by ministerial decree 054/MPR/CAB of 6 December 2000. The cordon sanitaire was dismantled following a tripartite meeting of the Central African Republic, Chad and Sudan in Khartoum (Sudan) in November 2001, because it had become pointless. A buffer zone had been established between the cordon sanitaire zone and the non-cordon zone. Heightened surveillance of livestock movements was introduced in the buffer zone. Teams travelled back and forth throughout the zone.

Vaccines and vaccination (organisation and implementation)

The national campaign mobilised all livestock managers. The Directorate-General of the National Livestock Development Agency (ANDE) ordered vaccines from Debre Zeit (Ethiopia), then from Cameroon's National Veterinary Laboratory (LANAVET), and finally from Botswana to be made available to the regions. Vaccination teams were set up by livestock area managers.

The vaccines used successively during campaigns were Bivax, Bovipestovax Neobisec, Pestobov and Tissupest. From 1983 to 2000, a national vaccination campaign was organised every year against rinderpest and contagious bovine pleuropneumonia, after which vaccination was confined to the northern region and part of the eastern region, bordering Chad and Sudan, until 2003 (Table I).

The number of cattle vaccinated every year (see Chapter 4.6) was not even half of the total estimated population of just over 3 million head because farmers having their animals vaccinated never brought their entire herd for vaccination.

Laboratory analysis (Laboratoire Central Vétérinaire – LACEVET) of the 5,131 samples taken throughout the country in 1999 (the year of the last national vaccination campaign) shows that 2,334 cattle had antibodies against the rinderpest virus, i.e. 45.48% of vaccinated animals. The coverage rate is therefore below the threshold generally accepted for animals to be considered able to prevent the spread of infection.

Clinical surveillance

Passive surveillance

The epidemiological surveillance network was up and running in 1999. It provided significant results thanks to the Central African Republic animal health information system (SISAC). Surveillance of these diseases is continuous. At the slightest suspicion of rinderpest, the herds concerned were immobilised, and officers took samples and sent them quickly to the central laboratory. Depending on the case, one of the two mobile teams based at Bangui were dispatched to check the facts to either reinforce the measures taken by the network officer or discontinue the measures if the suspicion did not prove to be rinderpest.

Active surveillance (purposive sampling)

As part of active surveillance, SISAC mobilised 42 officers distributed throughout the country. These trained officers provided continuous surveillance throughout the year. Each officer held two outreach meetings per month with farmers and other stakeholders in the meat and livestock sector and visited at least four different herder camps, two livestock markets, and two slaughterhouses or two killing floors. High-risk areas, such as borders (gateways for foreign livestock from Chad or Sudan), transhumance routes, livestock markets, herder camps or other livestock assembly points were targeted to increase the likelihood of detecting the disease.

When there was a suspicion of rinderpest, samples were submitted for laboratory testing at the national laboratory in Bangui, where competitive enzyme-linked immunosorbent assays (c-ELISA; see Chapters 3.3 and 6.3) and virus neutralisation tests were carried out. In 2005, there were 28 cases suspected, none of which were confirmed. In 2006, 2007 and 2008, no rinderpest suspicions arose.

Serological surveillance

The first serological surveillance campaign on the national herd was conducted in 2006/2007. Prior to that, 638 sera that had been collected in a preliminary serological survey lasting 21 days in October and November 2004 in the western region (where vaccination ceased in December 2000) were sent for analysis to the Animal Production and Tropical Veterinary Medicine Department of the French Agricultural Research Centre for International Development (CIRAD/EMVT), and all were negative.

Given the extensive nature of cattle farming as a whole, the sampling unit consisted of an entire village. For clinical surveillance, 300 villages were drawn randomly from a sampling frame of all 8,539 villages in the country.

At the end of the Pan-African Programme for Control of Epizootics (PACE; Chapter 4.3), the Food and Agriculture Organization of the United Nations (FAO) assisted a few countries to complete the accreditation process. In the Central Africa Republic, 4,500 samples were collected in 2007/2008 and tested at the LACEVET.

All the samples collected and analysed were negative. Special emphasis was placed on controlling cattle movements both at the borders and in the country's interior, as well as on controlling animal

TABLE I
NUMBER OF VACCINATIONS FROM 1991 TO 2000

Region	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Western region	333,923	374,266	390,000	376,000	320,000	279,000	203,000	192,962	190,877	186,651
Eastern region	78,580	62,964	58,000	125,000	117,000	72,000	66,000	54,885	42,972	36,976
Central region	102,221	109,875	118,000	158,000	130,000	117,000	124,000	10,993	142,254	140,024
Northern region	28,524	20,957	61,000	31,000	40,000	14,000	55,000	55,010	66,000	39,565
Total	**543,248**	**568,062**	**627,000**	**690,000**	**607,000**	**482,000**	**448,000**	**411,850**	**502,103**	**403,916**

TABLE II
THE LOG OF SERA COLLECTED FROM WILDLIFE KILLED BY HUNTERS AND FROM ANAESTHETISED CAPTURED ANIMALS FROM 1999 TO 2004

Species	Year					
	1999	2000	2001	2002	2003	2004
Buffalo	34	33	8	7	–	6
Giant eland	–	–	–	1	–	2
Blue duiker	–	–	–	1	–	3
Kudu	–	–	–	–	–	1
Topi	–	–	–	–	–	1
Oribi	–	–	–	–	–	1
Bongo	–	–	–	–	–	1
Bush pig	–	–	–	1	–	2
Baboon	–	–	–	–	–	1
Warthog	–	–	–	2	–	–
Hartebeest	–	–	–	1	–	–
Susceptible species combined	89	114	41	–	–	–
Total	**123**	**147**	**49**	**13**	**–**	**18**

products. This fully functioning system continued to work as it should to avoid the catastrophic consequences of rinderpest being reintroduced into the Central African Republic.

Wildlife surveillance

Wildlife surveillance relied on the wardens of the four national parks in the northern Central African Republic (Sangba, Saint-Floris, Manovo and Bamingui) completing the survey forms for hunting guides. These wardens collected information on wildlife health and passed it to the PACE coordination unit, in addition to serum samples (Table II).

The results proved to be negative for rinderpest. There were no clinical suspicions of rinderpest in wildlife.

DOSSIER

As the spectre of the disease gradually receded, vaccination was definitively halted and banned throughout the national territory in December 2003. The country then declared itself provisionally free from rinderpest in February 2004. The epidemiological surveillance network, established in 1999 under PARC, was strengthened, equipped and deemed operational following evaluation by the PACE epidemiology unit. Taking into account all the above-mentioned points, in May 2007 the Central African Republic was found to be free from rinderpest disease following evaluation by the World Organisation for Animal Health (OIE) of the first application dossier submitted in 2006 (2) and, in May 2010, it was accorded country freedom from rinderpest following evaluation by the OIE of the dossier submitted in 2009 (3).

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CHAPTER 4.5.5

CHAD

A. HASSAN YACOUB

Former Director of Veterinary Services, Ministry of Livestock, Chad

SUMMARY **With a tradition of pastoralism, Chad currently has more than 10 million cattle, 12 million small ruminants, 3 million camels and 47 million poultry. Livestock production represents 53% of agricultural gross domestic product and employs more than 40% of the rural population. For more than seven decades, rinderpest took a heavy toll on Chad's cattle farming, with the last outbreak dating back to 1983. With the help of the international community, Chad was recognised as a country free from rinderpest disease in May 2006 and obtained the status of country freedom from rinderpest in May 2010.**

KEYWORDS **Active surveillance – Chad – Outbreak – Passive surveillance – Rinderpest – Vaccination.**

INTRODUCTION

Situated in the heart of Africa, the Republic of Chad is a vast landlocked country with an area of 1,284,000 km². It has a human population of 10 million. The rural population amounts to 70% of the total population and is employed chiefly in agriculture and livestock production.

Administratively, Chad is divided into 22 regions (Fig. 1), 54 departments and 200 subprefectures.

Chad includes three ecological zones: the Sahara or desert zone in the north, the Sahel zone in the centre and the Sudanian zone in the south.

With a tradition of pastoralism, Chad currently has more than 10 million cattle, 12 million small ruminants, 3 million camels and 47 million poultry. Livestock production represents 53% of agricultural gross domestic product and employs more than 40% of the rural population.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN CHAD

Rinderpest was officially identified in Chad in 1913 by Dr Pecaud, a French colonial veterinarian, during a field mission in the Ouaddai region of eastern Chad. The epidemic raged between 1913 and 1914 and was believed to have arrived from Darfur in Sudan. It led to the loss of 30% of the national herd.

Four years later, in 1918, Dr Pecaud reported the resurgence of rinderpest in eastern Chad (Adré), originating from Sudan. This second epidemic resulted in the loss of 200,000 cattle, mostly young, because the older animals had apparently been largely immunised during the previous epidemic.

From 1919 onwards, rinderpest was endemic in Chad. These early rinderpest epidemics proved to be particularly deadly, because no vaccine existed at the time and animal health policies were difficult to apply. Despite this, various measures were taken in 1919 to limit the spread of the disease, such as the creation of a cordon sanitaire between Melfi and Bokoro (east central Chad) and the injection of glycerinated bile to effect a sort of primitive immunisation in inoculated animals.

In 1933, two centres were established for the production of formalin vaccine (inactivated vaccine): one at Fort Lamy (now N'Djamena) and the other at Abéché in eastern Chad. In 1953, the Farcha laboratory opened its doors and began manufacturing freeze-dried caprinised rinderpest virus vaccine

FIG. 1
ADMINISTRATIVE MAP OF CHAD

Source: United Nations, 2014 (1)

and in 1965 it introduced the tissue culture rinderpest vaccine (TCRV).

Joint Programme 15 (JP15) began in Chad in September 1962, prior to which Chad was endemically infected with rinderpest in spite of annual vaccinations. Participation in phase I ran from 1962 to 1965, and participation in phase III ran from 1966 to 1969. Table I contains the epidemiological data observed during JP15. Endemic rinderpest was not eliminated during JP15 (see Chapter 4.1).

At the end of JP15, the Chadian government opted to continue with mass vaccination. Until Chad's civil war in February 1979, no rinderpest outbreaks were detected on Chad's territory.

TABLE I
EPIDEMIOLOGICAL DATA OBSERVED DURING JOINT PROGRAMME 15 (JP15)

Year	Number of outbreaks	Number of sick animals	Number of deaths
1963	33	980	716
1964	9	1,892	1,802
1965	7	658	257
1966	46	2,152	756
1967	39	967	660
1968	25	446	267
1969	26	927	516
1970	19	408	228

Source: Activity reports of the Livestock Directorate

Rinderpest broke out in December 1982, after entering the country from Sudan. Within a few weeks, it had spread across the country, from east to west, by commercial animals following the track of the 13th parallel. Many breeders fleeing rinderpest also contributed to the spread of this scourge over a great distance. A vaccination campaign was initiated under very difficult conditions because of a lack of logistical and human resources, but it was very quickly supported by public and private bodies. Mortality rates in the various regions were as follows: centre-west (70%), east (10%), north-west (2%), south-east (10%), centre (8%) and south-west (10%).

In 1983, more than 218 outbreaks were recorded with a mortality rate between 8% and 10%. With the help of its development partners, including the European Union, the Food and Agriculture Organization of the United Nations (FAO) and the French Fund for Aid and Cooperation (FAC), Chad vaccinated 6,152,346 head of cattle. As a result of this robust response, rinderpest disappeared from Chadian territory. No outbreaks of rinderpest have been reported in Chad since 1983. However, Chad's veterinary authorities maintained mass vaccination as a precautionary measure and also adhered to the vaccination policy of the Pan-African Rinderpest Campaign (PARC; Chapter 4.2) between 1989 and 2000. Reported outbreak numbers and vaccination returns from 1950 onwards are given in Chapter 4.6.

Seromonitoring to assess the quality of annual vaccination campaigns was not performed routinely. However, according to a serological study conducted with a view to setting up PARC, the level of rinderpest immunity of Chad's herd was between 65% and 70%. This level was established on a nationwide basis. Table II shows the results of annual seromonitoring during PARC-Chad.

TABLE II
RESULTS OF SEROMONITORING UNDER THE PAN-AFRICAN RINDERPEST CAMPAIGN (PARC) IN CHAD

Year	Number of sera analysed	Number of positive sera	Prevalence rate (%)
1990	3,504	1,685	48.08
1991	4,475	2,027	45.29
1992	2,147	936	43.59
1993	5,701	3,271	57.37
1994	5,505	2,667	48.44
1995	6,155	4,183	67.96
1996	7,004	3,981	56.83
1997	7,066	2,659	37.63
1998	5,338	1,407	26.35

Source: Seromonitoring reports

No rinderpest outbreaks were reported during the term of PARC-Chad. On this basis, Chad ceased vaccination in western Chad in June 1998 and declared itself provisionally free from rinderpest disease on a zonal basis (western Chad).

Vaccination continued elsewhere in Chad under the Pan-African Programme for the Control of Epizootics (PACE; Chapter 3.3), which called for the creation of a cordon sanitaire consisting of the immunised bovine population of the six *departements* bordering Sudan and the Central African Republic. A summary of the vaccine returns is given in Table III

On 24 July 2002, the Minister for Livestock issued order no 273/ME307/DG/DSV/2002 prohibiting rinderpest vaccination throughout Chadian territory.

RESULTS OF CLINICAL AND SEROLOGICAL SURVEILLANCE

Passive and active surveillance

As part of their routine activities, livestock officers, in collaboration with livestock producers, collect epidemiological data on priority diseases, especially rinderpest. Between 2000 and 2004, only one suspicion of rinderpest was reported.

Serosurveillance

During the 2004 serological survey, a total of 197 herds were inspected, and 3,322 serum samples were collected. These samples were analysed, and 55 sera were found to be positive (1.65%) and 19 of the 197 herds were also positive. During the 2009 serological survey, a total of 2,129 serum samples were collected and analysed, all analyses being made with the competitive enzyme-linked immunororbent assay (c-ELISA; Chapter 3.3). No sera were found to be positive.

Serosurveillance in wildlife

In 1999, three missions were carried out to collect serum samples from rinderpest-susceptible wild animals (including buffaloes, antelope and warthogs). The mission team collected a total of 113 sera, all of which tested negative.

Investigations were also carried out from 2000 to 2004. None of the 171 samples collected was

TABLE III
RESULTS OF VACCINATIONS PERFORMED DURING THE PAN-AFRICAN PROGRAMME FOR THE CONTROL OF EPIZOOTICS (PACE) IN CHAD

Year	Number of livestock districts concerned	Estimated cattle population in the cordon sanitaire	Number of animals vaccinated	Percentage of animals vaccinated
1999	4	3,000,000	1,462,276	48.74
2000	4	3,200,000	642,377	20.07
2001	4	3,250,000	405,866	12.48
2002	4	3,500,000	74,493	2.12

Source: Activity reports of the Veterinary Services Directorate

positive. In 2003, no sample collection was conducted because of a lack of vehicles.

CONCLUSION

No cases of rinderpest were reported further to the 1982–1983 rinderpest episode. As many livestock producers, especially the older ones, are very familiar with the disease, if it had been present anywhere in the country, they would have reported it. A suspicion of rinderpest that was reported in Abéché in April 2002 was diagnosed as pasteurellosis by the Farcha laboratory. Wildlife investigations carried out from 1999 to 2004 showed no indication of rinderpest virus circulation. Finally, the 2009 serological survey carried out among animals that had not been vaccinated and no longer had maternal antibodies proved that these animals had not been in contact with the rinderpest virus.

On the basis of these encouraging results and given that no legitimate suspicion of rinderpest had been reported for 27 years, Chad prepared a dossier to request the status of country freedom from rinderpest infection.

DOSSIER

After the relevant commission (2) had reviewed the dossier sent by the Delegate of Chad to the World Organisation for Animal Health (OIE) in December 2003, the World Assembly of OIE Delegates, at its 72nd General Session in May 2004, recognised western Chad as free from rinderpest disease. Two years later, in August 2005, the national veterinary authorities submitted a dossier to the OIE to obtain the status of freedom from rinderpest disease for the entire country. After the dossier had been reviewed by the relevant commission (3), the World Assembly of OIE Delegates, at its 74th General Session in May 2006, recognised Chad as free from rinderpest disease throughout the national territory.

In September 2009, the Delegate of Chad submitted a dossier to secure the status of country freedom from rinderpest. The dossier was examined by the relevant OIE commission (4), and country freedom from rinderpest was accorded to Chad by the World Assembly of OIE Delegates at its 78th General Session in May 2010.

References

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4. World Organisation for Animal Health (OIE) (2010). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 2–5 March 2010. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_march2010_public.pdf (accessed on 25 May 2019).

CHAPTER 4.5.6

CÔTE D'IVOIRE

C. KANGA KOUAME

Former Director of Veterinary Services, Ministry of Animal Production and Fish Resources, Côte d'Ivoire

SUMMARY **The participation of Côte d'Ivoire in Joint Programme 15 (JP15; Chapter 4.1) and the Pan-African Rinderpest Campaign (PARC; Chapter 4.2) helped to consolidate the action of the Veterinary Services in controlling an epidemic of rinderpest that was reintroduced by commercial or transhumant livestock in 1970 and 1983. The last outbreak of rinderpest was reported in 1986. Rinderpest vaccination was halted in 1996, and the country declared itself provisionally free from the disease on 7 January 1997, in accordance with the World Organisation for Animal Health (OIE) procedure. Subsequent controls and surveillance revealed no presence of infection or virus circulation. In 2006, Côte d'Ivoire submitted a dossier to the OIE to secure the status of country freedom from rinderpest infection. Following its examination by the relevant OIE Commission, Côte d'Ivoire was officially recognised as free from rinderpest in May 2007.**

KEYWORDS **Côte d'Ivoire – Rinderpest – Surveillance – Vaccination.**

INTRODUCTION

The Republic of Côte d'Ivoire is situated in West Africa and shares a border with five countries: Burkina Faso, Ghana, Guinea, Liberia and Mali (see Fig. 1). Trade in animals and animal products takes place across these borders. In 2017, Côte d'Ivoire's cattle herd numbered 1,667,000.

The Ministry of Animal Resources and Fishery (MIRAH) has a central Veterinary Services Directorate and devolved services represented by regional and departmental directorates and livestock posts. This is the level at which field officers responsible for animal health and veterinary public health actions work.

RINDERPEST IN CÔTE D'IVOIRE

Before participating in phases II and III of JP15 between 1964 and 1968, Côte d'Ivoire was endemically infected with rinderpest. Although it appeared that JP15 had successfully overturned this status, in spite of vaccination, rinderpest was reintroduced by commercial or transhumant livestock in 1970 (eight outbreaks), 1972 (12 outbreaks) and 1973 (six outbreaks). The country remained rinderpest-free between 1973 and 1983. The Ivorian cattle herd was again infected (Fig. 2) during the resurgence of the virus across West Africa (Chapters 4.2 and 4.6).

VACCINATION

Further to the vaccination conducted during JP15, the Food and Agriculture Organization (FAO) organised an emergency campaign in 1980 and 1981. Rinderpest vaccination, coupled with identification of vaccinated animals, was conducted under PARC from 1986 to 1995. Table I shows the results of the PARC campaign, which succeeded in eliminating rinderpest from Côte d'Ivoire.

FIG. 1

MAP OF CÔTE D'IVOIRE

Source: United Nations, 2020 (1)

TABLE I

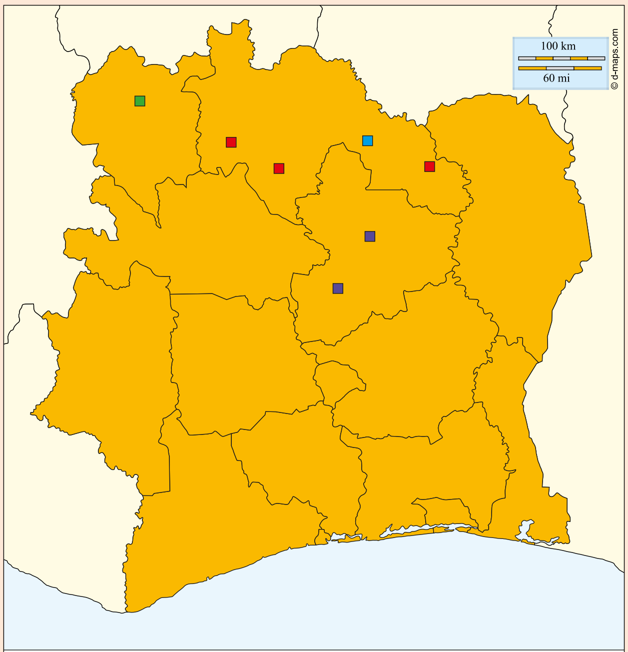
VACCINATIONS FROM 1988 TO 1995 [(a)]

	1988	1989	1990	1991	1992	1993	1994	1995
Total population	968,818	1,027,508	1,087,781	1,093,037	1,143,031	1,195,495		832,146
Number vaccinated	846,635	882,995	983,327	630,170	353,828	287,665		550,811
Percentage of animals vaccinated	87	86	90	58	31	24		66
Conversion rate	79	82	88	76		64		37

[(a)] No vaccination undertaken in 1994 because of a lack of funding

FIG. 2
RINDERPEST OUTBREAKS IN CÔTE D'IVOIRE DURING THE FINAL EPIDEMIC

Source: d-maps.com (2020). - Map of the Cote d'Ivoire. Available at: https://www.d-maps.com (accessed on 9 June 2021), modified to show rinderpest outbreaks



- 1983: three outbreaks, including one in Ferkessédougou and two in the central region
- 1984: one outbreak (Odienné)
- 1985: four outbreaks, including one in the central west region and a further three in Korhogo, Boundiali and Ferkessédougou
- 1986: one outbreak (Bouaké-Katiola)

CLINICAL AND SEROLOGICAL SURVEILLANCE

Clinical surveillance

No outbreaks of rinderpest were recorded in Côte d'Ivoire after 1986.

Serological surveillance

The Bingerville Laboratory developed a sampling plan with the support of PARC. It took into account geographical location, age groups and farming systems.

TABLE II
RESULTS OF SAMPLING (NUMBERS) OBTAINED USING THE C-ELISA TEST

Year	Cattle	Small ruminants	Total	Seropositive (%)
2004	1,691	442	**2,133**	0.66
2005	2,334	712	**3,046**	0.10

All samples were examined using the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3 and 6.3). Table II shows the results.

In 2004, the animals ranged in age from six to nine years. Field investigations to retrace positive animals showed that seven of the eight positives were more than ten years old – judging by tooth wear – and had been vaccinated. The same applied to the eight positives in 2005, which were around nine years old.

Wildlife surveillance

All 39 sera collected from wild ungulates in the wildlife ecosystem shared by Côte d'Ivoire and Burkina Faso tested negative.

DOSSIER

Following examination by the relevant OIE Commission of the dossier submitted by the Delegate of Côte d'Ivoire (2), Côte d'Ivoire was declared free from rinderpest disease at the 72nd OIE General Session in Paris in May 2004. The country retained this status in 2005 and 2006.

In September 2006, the Delegate of Côte d'Ivoire submitted a dossier to secure the status of country freedom from rinderpest. The dossier was examined by the relevant OIE Commission (3), and country freedom was accorded to Côte d'Ivoire by the World Assembly of OIE Delegates at its 75th General Session in May 2007.

References

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2. World Organisation for Animal Health (OIE) (2004). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 10–11 March 2004. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_2004.pdf (accessed on 5 June 2019).
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CHAPTER 4.5.7

DJIBOUTI

M. IBRAHIM CHEICK

Director of Agriculture, Livestock and Veterinary Services, Ministry of Agriculture, Livestock and the Sea, Djibouti

SUMMARY **The last outbreak of rinderpest reported in the territory dates back to 1985, during the last African rinderpest pandemic. Vaccination was carried out until 1995. Surveillance measures were put in place after vaccination ceased. Clinical surveillance, supplemented by serological surveillance in 2004, failed to detect any cases of rinderpest. Djibouti was officially recognised by the World Organisation for Animal Health (OIE) as free from rinderpest in May 2010.**

KEYWORDS **Djibouti – Outbreak – Rinderpest – Surveillance – Vaccination.**

INTRODUCTION

The Republic of Djibouti is situated in the Horn of Africa – bordered by Eritrea, Ethiopia and Somalia – and has a surface area of 23,200 km^2, with 370 km of coastline. Administratively, the country is divided into five districts: Obock and Tadjourah in the north and Dikhil, Ali Sabieh and Arta in the south. The capital, Djibouti, has a special status (city) (Fig. 1).

Livestock farming remains the predominant activity in rural areas. In the absence of a recent census, the national herd is estimated at 550,000 goats, 450,000 sheep, 50,000 cattle, 60,000 camels and 6,500 donkeys (1978 census, re-estimated in 1982). These figures are thought to be an underestimate, especially for goats and camels, and an overestimate for sheep.

In the context of livestock development, the Livestock Directorate, under the authority of the Ministry of Agriculture, Livestock and the Sea, manages, organises, structures and controls all the country's livestock posts. It is supported by regional rural development subdirectorates within the districts.

RINDERPEST ERADICATION

The last outbreak of rinderpest reported in the territory dates back to 1985, during the last African rinderpest pandemic. This outbreak occurred in the north-west of the country at the Ethiopian border. It involved a transhumant herd.

Djibouti was a beneficiary of the Pan-African Rinderpest Campaign (PARC, Chapter 4.2), and the last vaccination campaign was conducted in 1995. This campaign was carried out on a total population of roughly 3,000 young cattle, mainly around the capital and in the Ali Sabieh district.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Clinical surveillance

After 2003, a number of clinical surveillance campaigns were conducted countrywide. No evidence of rinderpest was detected in the animals inspected.

Serological surveillance

The launch of an animal disease diagnostic laboratory in April 2004 allowed a batch of sera to be tested. Adhering to the OIE guide (which calls for 300–400 villages to be sampled) would have resulted in nearly all the villages in Djibouti being sampled. Given the country's livestock

FIG. 1
ADMINISTRATIVE DISTRICTS OF DJIBOUTI
Source: United Nations, 2011 (1)

distribution and number of villages, sampling was conducted in high-density livestock areas. Risk-based surveillance (finding cattle in a village) was conducted in 23 villages. In each village, 15–17 animals were sampled. A total of 363 sera were collected and tested with the c-ELISA (see Chapters 3.3 and 6.3), only one of which proved positive.

DOSSIER

In January 2008, the Delegate of Djibouti submitted a dossier to secure the status of country freedom from rinderpest. The dossier was examined by the relevant OIE Commissions (2), and country freedom from rinderpest was accorded to Djibouti by the World Assembly of OIE Delegates at its 78th General Session in May 2010.

Reference

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2. World Organisation for Animal Health (OIE) (2010). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 2–5 March 2010. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_march2010_public.pdf (accessed on 27 May 2019).

CHAPTER 4.5.8

ERITREA

G.T. MAHRU

Former Director, Agricultural Promotion and Development Department, Ministry of Agriculture, Asmara, Eritrea

SUMMARY **Eritrea experienced rinderpest outbreaks in 1992 and 1994, the disease coming from Ethiopia. Annual vaccination campaigns succeeded in preventing the virus from becoming endemic. Vaccination ended in 1997. Serosurveillance between 2002 and 2004 demonstrated declining levels of rinderpest-positive animals.**

KEYWORDS **Eritrea – Outbreaks – Passive surveillance – Rinderpest – Vaccination.**

INTRODUCTION

Eritrea lies between latitude 12' 21'' and 17' 59'' N and between longitude 36' 26'' and 43' 08'' E, bordering Ethiopia to the south, Sudan to the west and north-west, Djibouti to the south-east and the Red Sea to the east. The regions of Eritrea are Gash Barka, Maekel, Anseba, Debub, South Red Sea and North Red Sea. In 1997 it was estimated that there were 2.15 million cattle in the country and that 60% of these occurred in the two western regions – Gash Barka and Anseba. Livestock rearing is carried out from sedentary compounds rather than by nomadic herding.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN ERITREA

Rinderpest was introduced into Eritrea at the end of the 19th century with the Italian colonisers and it spread to the rest of the Horn of Africa. The Veterinary Institute at Asmara was established in 1903 by the Italians to combat the ravages of rinderpest. During the early and mid-20th century, rinderpest was very active in the region, including Eritrea. The disease was especially persistent in the pastoral and agro-pastoral south-western parts of the country. The situation was further complicated by the war of independence in the early 1970s. When finally the war came to an end in 1991, meaningful control of rinderpest began to take place.

Outbreaks were reported to the World Organisation for Animal Health (OIE) in 1962. Eritrea was considered free of rinderpest from 1967 until 1992, although there were rumours that, during the war of independence, outbreaks of rinderpest occurred in some parts of the country; however, these were difficult to confirm. The last major outbreak of the disease was reported in January 1992 in the south-east of the country (Danakil area). The source of the outbreak was suspected to be animals migrating from deep inside Ethiopia and about 15,000–20,000 head of cattle were involved over an area of about 5,000 km^2. Morbidity and mortality rates were high.

A minor outbreak was reported in December 1994/January 1995 in Zalambessa, a town in the southern–central part of the country on the border with Ethiopia. Only a few animals were detected with clinical signs of rinderpest – which was laboratory confirmed. According to the owners, the animals had been purchased from markets inside Ethiopia. Vaccination was quickly carried out and the disease was once more under control. Epidemiological surveillance in the subsequent phase of the EU-assisted Pan-African Programme for the control of Epizootics (PACE) (see Chapter 4.3) provided evidence that the virus was no longer present in Eritrea.

The Eritrean People's Liberation Front (EPLF) and the Eritrean Government supported rinderpest vaccination from 1977 to 1992. Table I shows the vaccination coverage during this period as well as during the Pan-African Rinderpest Campaign (PARC) period of mass vaccination between 1992 and 1997 (see Chapter 4.6), during which time the vaccination coverage improved and reached 76% in 1996. Vaccination was with tissue culture rinderpest vaccine (TCRV) of Ethiopian manufacture.

TABLE I
RINDERPEST VACCINATION FIGURES FOR 1977 TO 1997

Year	No. cattle vaccinated	National herd total	Coverage (%)
1977	234,561	765,423	31
1978	165,230	756,340	22
1979	154,670	745,236	22
1980	172,345	730,450	24
1981	163,435	727,650	22
1982	NA	NA	NA
1983	73,245	768,432	9.5
1984	653,267	860,457	75
1985	567,240	873,245	65
1986	465,436	873,245	53
1987	432,125	865,342	50
1988	NA	NA	NA
1989	413,675	832,467	49.6
1990	432,678	879,540	49
1991	206,900	1,945,231	20
1992	362,119	1,258,000	20
1993	477,140	1,300,000	37
1994	601,813	1,300,000	46
1995	668,288	1,300,000	53
1996	987,000	1,300,000	76
1997	510,000	1,300,000	39

NA, not available

The last vaccination was carried out between August and December 1997, during which cattle populations along the international border with Ethiopia and Sudan were immunosterilised while the rest of the country ceased vaccination.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Passive clinical surveillance

From 1999 onwards, livestock were constantly monitored for signs of rinderpest including oral lesions, ocular discharges, nasal discharges, salivation, diarrhoea and corneal opacity. None of these were found.

During the course of this exercise, 85 tissues sample were tested from suspected outbreaks of peste des petits ruminants (PPR) in sheep and goats. Thirty-nine samples (45.9%) were positive for PPR and negative for rinderpest while 46 samples (53.1%) were negative for both diseases. All the of tested samples were negative for rinderpest virus.

TABLE II
RINDERPEST C-ELISA RESULTS FOR SAMPLES COLLECTED IN 2002, 2003 AND 2004

Year	Sampling units	No. samples	No. rinderpest-positive samples	Rinderpest-positive samples (%)
2002	268	4,020	253	6.29
2003	297	4,425	140	3.16
2003 resampling	78	1,170	4	0.34
2004	313	4,650	44	0.94

Serosurveillance

In each of 2002, 2003 and 2004 an attempt was made to visit 300 randomly selected sampling units, and collect and test 15 samples from each using the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3 and 6.3). The results obtained are shown in Table II.

Most of the positive animals, when studied retrospectively, were found to be at the upper age limit of the eligible group. Thus, these animals could very easily have been much older than they were depicted and therefore possibly vaccinated. With improved sampling experience, the percentage of positive samples fell year on year and by 2004 the national herd could be considered rinderpest-free.

DOSSIER

The result of the serological surveillance from 2002 to 2004 supported by the clinical surveillance indicated that rinderpest virus was not circulating in the national herd of Eritrea. Accordingly, Eritrea applied to the OIE in November 2004 to be recognised as a rinderpest-free country. The application was upheld by the OIE (1) and Eritrea was declared free from rinderpest on 24 May 2005 by the World Assembly of the Delegates of the OIE.

Reference

1. World Organisation for Animal Health (OIE) (2005) – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 14–19 January 2005. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_Jan05.pdf (accessed on 20 February 2020).

CHAPTER 4.5.9

ETHIOPIA

B.G. TEKOLA

Animal & Plant Health Regulatory Department, Ministry of Agriculture and Rural Development, Ethiopia

SUMMARY **Rinderpest was introduced into Ethiopia for the first time in 1887 through the importation of infected zebu cattle from India. It was controlled through several African programmes. The last outbreak of rinderpest in Ethiopia was in November 1995. Vaccination was withdrawn from 80% of the country in 1997 and then from 92% in 1999 when Ethiopia declared provisional freedom from rinderpest. Country freedom from rinderpest was accorded to Ethiopia in May 2008.**

KEYWORDS **Ethiopia – Rinderpest – Surveillance – Vaccination.**

INTRODUCTION

The Federal Democratic Republic of Ethiopia is located in north-eastern Africa lying between latitude 3.5 and 15 °N and longitude 33 and 48 °E (Fig. 1). The country shares international borders of 5,328 km length with the following countries: Somalia 1,600 km in the east and south-east, Kenya 861 km in the south, Sudan 1,606 km in the west and north-west, Eritrea 912 km in the north and Djibouti 349 km in the east. For administrative purposes the country is divided into regional states, zones and waredas.

The agricultural sector, which employs 80–85% of the population, is the mainstay of the economy of the country; cattle in particular play an important role in the farming economy and the lives of the people. Livestock farming occurs in the highlands and lowlands. The highland crop–livestock farming system is integrated and people are mainly sedentary. These areas encompass about 30% of land and more than 65–70% of the human population. Livestock in the highlands play a vital role in the household economy directly through milk and meat production, sale of animals, providing manure (for fertiliser and fuel) and transport, and indirectly by contributing 85–95% of draught power for crop production. In the vast lowland areas mainly occupied by pastoralists, livestock is the only means of earning a livelihood and has remained so for centuries.

HISTORY OF RINDERPEST IN ETHIOPIA

Rinderpest was introduced into Ethiopia for the first time in 1887 through the importation of infected zebu cattle from India to feed Italian soldiers engaged in a military campaign in Ethiopia ([2], see also Chapter 2.2). The cattle were imported through the port of Massawa, which at that time was part of Ethiopia.

That part of the country falling within what is now referred to as the Somali ecosystem (see Fig. 1 in Chapter 4.4) suffered particularly badly with losses of up to 90% of the indigenous cattle and wildlife populations.

Thereafter the disease remained endemic. It was controlled but not eliminated during phases V and VI of Joint Programme 15 (JP15) between 1970 and 1976 (see Chapter 4.1) (3) and its three-year follow-up programme from 1977 to 1979. Chapter 4.1 states that 'between 1973 and 1978, while poorly represented in the historical record, a massive epidemic gripped the whole of southern Ethiopia and also raged across the centre of the country. In 1977, the security situation in Ethiopia became untenable and the last phase of JP15 ended'. Between 1979 and 1985, vaccination was carried out using national resources and FAO assistance. In 1983, FAO assistance was US$245,000 (4).

FIG. 1

OUTLINE OF TERRAIN SPANNING ETHIOPIA, KENYA AND SOMALIA THAT CORRESPONDS TO A ZONE OCCUPIED BY THE SOMALI ETHNIC COMMUNITY INTO WHICH THEIR LIVESTOCK MOVE FOR PASTURE OR TRADE PURPOSES

Source: United Nations, 2012 (1), modified to indicate the zone of the Somali Ethnic Community

Final boundary between the Sudan and South Sudan has not yet been determined

Subsequently, large areas of the country became inaccessible because of civil war, and vaccination coverage fell. The country remained infected until the resumption of mass vaccination programmes under the Pan-African Rinderpest Campaign (PARC). In 1989, PARC-Ethiopia (5) initiated a two-year emergency vaccination programme designed to reduce the prevalence of the disease.

As PARC progressed, it became evident that low vaccination coverage and inaccessibility were not the primary reasons for the continuing persistence of rinderpest in Ethiopia. Field investigations of disease outbreaks in the years 1991 to 1994 provided an insight into the factors responsible for this situation, which were related to the complex sociological, agricultural and trade interactions between the various ethnic groups in the country.

During these investigations, the intention was to confirm the presence of rinderpest, to determine the source of infection and its extent and to establish relationships between the disease incidents. This was effected by travelling to reported outbreak areas and tracking down active disease by interviewing livestock owners and animal health staff in the field. Wherever possible, samples from appropriate cases of disease were taken for laboratory testing by the agar gel immunodiffusion test (AGIDT) and later by the differential immunocapture enzyme-linked immunosorbent assay (ELISA) for the presence of rinderpest virus antigen as a confirmatory test (see Chapters 3.3 and 6.3).

A 'search, find and eliminate strategy' was pursued by focusing on the endemic foci. PARC also introduced alternative vaccination strategies to eradicate the last foci of rinderpest by using thermostable vaccine and animal health technicians to vaccinate young and unvaccinated stock in the most inaccessible areas of the country. Vaccination was targeted in areas where the disease was endemically maintained, i.e. the lowland pastoral areas of Afar, the lowlands to the west of Lake Tana and areas bordering southern Sudan.

The last two outbreaks of rinderpest observed in Ethiopia were in September 1995 in Temejayaze, Bench Zone of the SNNP (Southern Nations Nationalities and Peoples) Regional State (southernmost), and in November 1995 in Mehoni, Southern Zone of Tigray Regional State (northernmost) (Fig. 2).

In 1964 the National Veterinary Institute took on responsibility for the production and local distribution of rinderpest vaccine. In 1969, the NVI changed rinderpest vaccine production from goat-attenuated vaccine to tissue culture vaccine. During the JP15 and PARC programmes in Ethiopia, the National Veterinary Institute supplied all the rinderpest vaccines. Rinderpest vaccines and vaccination services were provided free of charge. During the later stages of PARC, the vaccines used against rinderpest were certified by the African Union Pan African Veterinary Vaccine Centre (PANVAC) and thermostable rinderpest vaccine was produced for use in the Afar endemic foci. Between 1989 and 2000, 57 million vaccinations brought the rinderpest incidence to zero (annual vaccine returns are shown in Chapter 4.6).

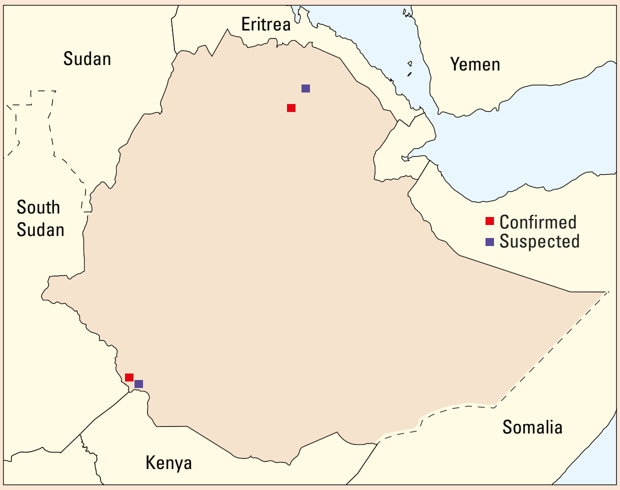
Vaccination was withdrawn from 80% of the country in 1997 and then from 92% in 1999 when Ethiopia declared provisional freedom from rinderpest. Vaccination continued until March 2000 within a surveillance zone on the border with South Sudan (where an outbreak was reported in 1998) (Fig. 3).

FIG. 2

LOCATION OF LAST RINDERPEST OUTBREAKS IN ETHIOPIA, LATE 1995

Final boundary between the Sudan and South Sudan has not yet been determined

Source: D-maps, 2020 (8), modified to indicate rinderpest outbreaks



When Ethiopia stopped vaccination in the six sanitary cordon districts it declared itself 'provisionally free from rinderpest on a countrywide basis'.

CLINICAL AND SEROLOGICAL SURVEILLANCE

In the period from 1995 to 2004 active disease searching and serosurveillance had detected no rinderpest. However, a perceived threat that mild rinderpest could enter Ethiopia from either Somalia or Kenya required the demarcation of a surveillance zone (Fig. 4). This was an area of low cattle density,

FIG. 3

RINDERPEST PROVISIONALLY FREE, SURVEILLANCE AND VACCINATION ZONES IN ETHIOPIA, MAY 1999

Final boundary between the Sudan and South Sudan has not yet been determined

Source: D-maps, 2020 (8), modified to indicate relevant zones

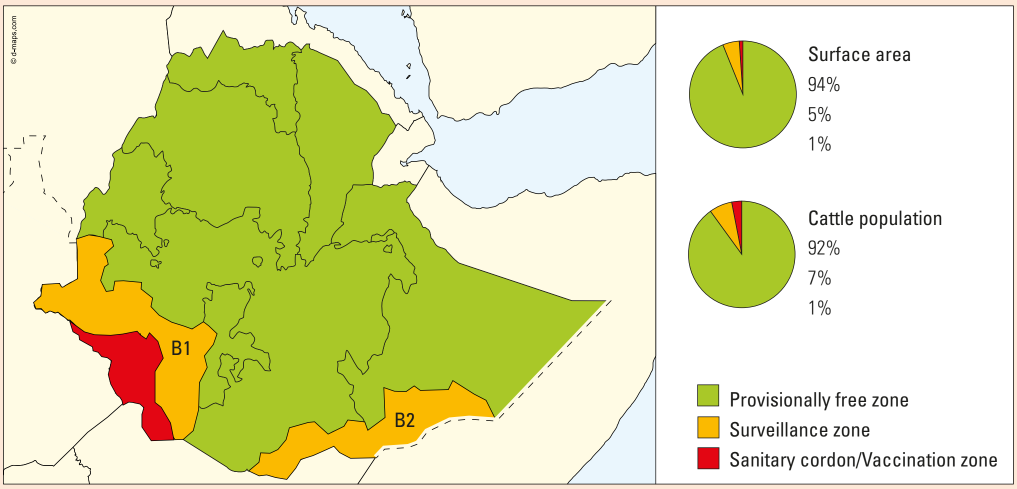


FIG. 4
RINDERPEST-FREE ZONE AND SURVEILLANCE ZONE IN ETHIOPIA SHOWING TRADITIONAL LIVESTOCK MOVEMENTS (ARROWS)

Final boundary between the Sudan and South Sudan has not yet been determined

Source: D-maps, 2020 (8), modified to indicate relevant zones

separated from the disease-free zone by the geographical barrier known as the lowland/highland interface.

Active clinical surveillance in the rinderpest-free zone was conducted on an annual basis on randomly selected herds aimed at detecting stomatitis–enteritis syndrome with laboratory testing in instances where stomatitis–enteritis was encountered. During the clinical investigations, interviews with the livestock keepers and rinderpest history surveys were undertaken. In addition, serosurveillance was implemented targeting animals between one and three years. The results clearly indicated that there had been no rinderpest circulating in this zone.

In the surveillance zone, monthly searches were performed in 173 randomly selected peasant/pastoral associations. Serious attention was given to large cattle aggregations such as common grazing lands or watering points as well as trade routes.

Following this intensive active surveillance as well as participatory disease surveillance activities carried out under the Pan African Control of Epizootics

TABLE I
RESULTS OF A SEROLOGICAL SURVEY FOR ANTIBODIES TO RINDERPEST VIRUS IN CATTLE IN REGIONS OF ETHIOPIA IN 2004

Region	No. zones	No. districts	No. sampling units	Total no. samples	No. positives
Afar	3	12	44	880	0
Amhara	7	45	100	2,800	0
Benshangul Gumz	3	12	24	480	0
Gambella	2	6	53	1,060	0
Oromia	9	46	69	1,380	0
SNNP	15	49	197	3,904	0
Somali	2	2	51	1,034	27
Tigray		41	49	980	0
Total	**41**	**213**	**587**	**12,518**	**27**

TABLE II
RESULTS OF A SEROLOGICAL SURVEY FOR ANTIBODIES TO RINDERPEST VIRUS IN CATTLE IN REGIONS OF ETHIOPIA IN 2005

Region	No. zones	No. districts	No. sampling units	Total no. samples	No. positives
Afar	2	7	22	440	0
Amhara	4	28	53	1,060	0
Oromia	15	126	372	7,440	0
SNNP	3	12	25	500	0
Somali	3	9	120	2,403	2
Total	**27**	**182**	**592**	**11,843**	**2**

TABLE III
SUMMARY OF SEROSURVEILLANCE FOR ANTIBODIES TO RINDERPEST VIRUS IN CATTLE CONDUCTED IN THE DISEASE-FREE ZONE IN 2006

Region	No. samples collected	No. positives
Afar	909	0
Amhara	2,800	0
Oromia	1,100	0
Tigray	700	0
SNNP	220	0
Benishangue Gumz	330	0
Total	**6,059**	0

TABLE IV
SUMMARY OF SEROSURVEILLANCE FOR ANTIBODIES TO RINDERPEST VIRUS IN CATTLE CONDUCTED IN THE SURVEILLANCE ZONE IN 2006

Region	Zone	No. samples collected	No. positives
Somali	Afder	2,160	1
	Fik	48	0
	Gode	1,340	0
	Warder	619	0
	Korahey	169	0
	Liben	1,700	3
Oromia	Bale	120	0
	Borema	20	0
Total		**6,176**	**4**

TABLE V
SUMMARY OF SEROSURVEILLANCE FOR ANTIBODIES TO RINDERPEST VIRUS IN CATTLE CONDUCTED FROM 1997 TO 2005

Year	No. districts surveyed	No. samples tested	Percentage positive
1997	47	11,150	2.8
1998	66	11,020	1.3
1999	104	17,560	1.1
2000	30	5,124	0.3
2001	60	12,030	1.48
2002	59	12,060	1.25
2003	10	2,280	2.4
2004	213	12,518	0.22
2005	182	11,843	0.02
2006	60	12,095	0.03

(PACE) programme, the country was certified by the World Organisation for Animal Health (OIE) as of 25 May 2005 as 'free from rinderpest disease' on a country basis (6). This included an awareness that no virus had circulated in the rinderpest-free zone but that there had been two positive tests in Mustahil and Ferfer districts in the surveillance zone (part of the Somali ecosystem surveillance zone). Going forward there would be further surveillance within the disease-free zone and also within the surveillance zone, consisting of 27 districts bordering Kenya and Somalia.

Serosurveillance with a view to demonstrating freedom from infection commenced in 2004. Samples were analysed using competitive ELISA (c-ELISA; see Chapters 3.3 and 6.3). Survey results for the whole country are shown in Table I. A similar survey was undertaken in 2005 (Table II).

In addition, a survey of the disease-free zone was undertaken in 2006 when a total of 6,059 samples was collected. The results (Table III) showed there was no rinderpest circulating in that part of the country.

In the surveillance zone, sampling in 2006 was coordinated with the African Union Interafrican Bureau for Animal Resources (AU-IBAR) by considering the Somali ecosystem as one epidemiological unit (see Chapter 4.4). The relevant serosurveillance results are shown in Table IV.

Incorporating earlier serosurveillance results, it can be seen that between 1999 and 2006, 92,243 serum samples were tested in the National Animal Health Research Centre laboratory in Sebata. When the later serosurveillance results were compared with earlier results, a declining rate of antibody prevalence could be seen (Table V) providing a clear demonstration of the absence of rinderpest in Ethiopia.

Taking into consideration that active surveillance had not identified rinderpest within the country since 1995, the relevant Commission (6), the World Assembly of OIE Delegates, at its 75th General Session in May 2007, recognised Ethiopia as free from rinderpest disease. In January 2008, the Delegate of Ethiopia submitted a dossier to secure the status of country freedom from rinderpest. The dossier was examined by the relevant OIE Commission (7) and country freedom from rinderpest was accorded to Ethiopia by the World Assembly of OIE Delegates at its 76th General Session in May 2008.

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CHAPTER 4.5.10

GHANA

M. AGYEN-FREMPONG

Former Director of Veterinary Services, Ministry of Food and Agriculture, Ghana

SUMMARY **Following its involvement in the resurgence of rinderpest across West Africa in the mid 1980s, Ghana's mass vaccination before and during the Pan-African Rinderpest Campaign (PARC) eradicated the virus in 1988. Surveillance over the next 15 years failed to detect the disease. Serosurveillance undertaken between 2002 and 2004 demonstrated that the national herd was not supporting the virus. The World Organisation for Animal Health (OIE) granted Ghana freedom from rinderpest in 2007.**

KEYWORDS **Clinical surveillance – Ghana – Rinderpest history – Serosurveillance – Vaccination.**

INTRODUCTION

The Republic of Ghana lies in the middle of West Africa, and extends between latitude 4°45' N and 11°11' N and longitudes 3° W and 1°14' E. It is bordered to the south by the Atlantic Ocean, to the west by Côte d'Ivoire, to the north by Burkina Faso and to the east by Togo (Fig. 1).

Ghana covers an area of 238,537 km^2 (92,100 square miles). It is a typical tropical country with thick rainforest in the south-west, changing gradually to the Sudanese climate near the extreme north. The other four agro-ecological zones in Ghana include deciduous forest, a transition zone, the Guinea Savannah and the Coastal Savannah. The average day temperature ranges between 25.5° C and 27° C. The rainy season encompasses April to October – interrupted in August by a brief dry season – and the long dry season runs from November to March.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION

Ghana recorded rinderpest for the first time in 1916 and lost over 50% of its cattle population. The first step towards controlling the disease was the release of funds in 1930 for the construction of a laboratory for the production of rinderpest immune serum at Pong Tamale. This, in turn, led to the launch of immunisation through the serum-simultaneous method. It was at this time that the hyper-susceptibility of the West African Shorthorn breed came to be known. As a result, an unusually large amount of immune serum was required so that the host might survive the reaction.

A good degree of control was achieved, but even in 1937 it was necessary to restock areas where the cattle population had been decimated by rinderpest. In 1948, the goat-adapted virus was used for the first time under field conditions but caused severe reactions in the Shorthorn breed, in which it was substituted by a lapinised vaccine.

During the period prior to Joint Programme 15 (JP15), Ghanaian cattle were constantly being infected with rinderpest introduced by trade cattle from Burkina Faso to the north. After mass vaccination in phase II of JP15 between 1964 and 1967 (see Chapter 4.1), the situation changed dramatically, and the country remained largely rinderpest-free for over a decade. However, isolated outbreaks were noted in 1973 and 1974. Between 1985 and

FIG. 1
OUTLINE MAP OF GHANA AND ITS NEIGHBOURS
Source: United Nations, 2005 (1)

1988, the disease resurged as part of its renewed spread across West Africa. In total, 65 outbreaks were reported with the loss of 2,953 head of cattle.

Ghana was assisted by the Food and Agriculture Organization of the United Nations (FAO) in an emergency vaccination campaign to combat the outbreak in 1972. In 1978, the Veterinary Services resumed annual vaccination, and this continued up until and throughout the PARC period (1988–1997); outbreak numbers and vaccination returns are included in Chapter 4.6. The last vaccination was in December 1996.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Passive surveillance

The Veterinary Services Department instituted disease monitoring as early as 1987, and a specific epidemiology unit was established in 1996. Epidemiological surveillance was enhanced through the establishment of permanent epidemiological clusters (groups of three or four villages) across the country. Passive epidemio-surveillance was enhanced between 2002 and 2004, during which time the districts collected information on rinderpest, contagious bovine pleuropneumonia, peste des petits ruminants, African swine fever and Newcastle disease, as these were listed as priority diseases by the Pan-African Programme for the Control of Epizootics (PACE; see Chapter 4.3). Clinical rinderpest was not detected in Ghana after 1998.

Active clinical surveillance

For the purpose of conducting active epidemio-surveillance, Ghana was classified as a single stratum, and a maximum sample of 300 village herds were randomly selected, allowing a 95% probability of detecting clinical rinderpest if 1% of the herds contained animals showing clinical signs of the disease. A visit was made to each of the 300 village herds chosen each year. The cattle in each selected village were visually examined for signs of bilateral lacrimation, nasal discharges, salivation, diarrhoea and corneal opacity. All cattle showing any of these clinical signs were restrained and examined for oral lesions and fever. Herds that showed discharges (ocular and nasal) and any two of the above-mentioned clinical signs were sampled for further examination in the laboratory. Meanwhile, surveillance was focused on the main cattle markets (Bawku, Bolgatanga, Salaga, Gushiegu, Techiman, Yeji, Kumasi Mayanka, TMA kraal, Juapong) and the border entry points.

In addition, the Veterinary Services established rumour registers in the veterinary districts. Farmers' rumours of livestock disease were treated as such by veterinary staff but also investigated. Although data for questionnaires and clinical surveillance were transferred on a monthly basis, any stomatitis–enteritis case detected in any herd was communicated to the Director of Veterinary Services by the fastest means of communication – telephone – following which a rinderpest expert team (RET) investigated the disease and collected samples, which were submitted for laboratory testing for rinderpest. Between 2002 and 2004, samples from 24 cases of stomatitis–enteritis were submitted to the Accra Veterinary Laboratory for diagnosis. Eight of these were confirmed as foot-and-mouth disease (FMD) and none as rinderpest.

Serological surveillance

Following the declaration of disease-free status in May 2003, Ghana embarked on two major serosurveys, one in 2002/2003 and the other in 2003/2004.

A sample size of 314 herds was chosen to give a 95% probability of detecting serological evidence of rinderpest infection if antibodies were present at a prevalence of 1% of herds within the livestock population of Ghana. The serological testing was restricted to eligible animals within a herd. The eligible animals were those that were either too old to have maternally derived antibodies or too young to have been vaccinated, i.e. animals between two and four years old. In the respective rounds of serosurveillance, a total of 5,200 samples and a total of 5,140 samples were collected and tested using the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3 and 6.3), but no antibodies were detected to rinderpest.

Wildlife surveillance

Wildlife epidemio-surveillance was undertaken in eight protected areas employing active clinical surveillance and serosurveillance.

Post-mortem examinations on animals during surveillance were negative for rinderpest. The serological results on four Kob samples in the Mole National Park were negative (Table I).

DOSSIER

After declaring provisional freedom from rinderpest in 1997, Ghana successfully eliminated rinderpest

TABLE I
RESULTS OF ANTIBODY DETECTION IN WILDLIFE SERA USING C-ELISA [a] IN THE NATIONAL LABORATORY, ACCRA

Code	Date of sampling	Species	NPPRV		NRPV		HRPV	
			PI	Status	PI	Status	PI	Status
Kob-01	16-07-05	Antelope	29	Neg.	27	Neg.	19	Neg.
Kob-02	18-07-05	Antelope	10	Neg.	14	Neg.	26	Neg.
Kob-03	18-07-05	Antelope	2	Neg.	18	Neg.	32	Neg.
Kob-04	18-07-05	Antelope	3	Neg.	11	Neg.	36	Neg.

[a] Both haemagglutinin (H) and nucleocapsid (N) protein-based monoclonal antibodies against rinderpest virus and peste des petits ruminant viruses
Neg., negative; PI, percentage inhibition; PPRV, peste des petits ruminants virus; RPV, rinderpest virus.

in 1988 and maintained this situation through mass vaccination until 1996. After an analysis of the country's dossier by the OIE's specialist Commission (2), Ghana was declared free from disease during the World Assembly of the OIE Delegates in May 2003. Based on the results of active clinical and serological surveillance undertaken between 2002 and 2004, Ghana requested recognition as a rinderpest infection-free country. This claim was upheld by the OIE (3), and Ghana was declared free from rinderpest infection during the World Assembly of the OIE Delegates in May 2007.

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CHAPTER 4.5.11

GUINEA

D. BANGOURA

Former Head of the Development Support Division, National Livestock Directorate, Ministry of Agriculture and Livestock, Conakry, Guinea

SUMMARY **The first ever outbreaks of rinderpest in Guinea were observed around 1940 in the major cattle farming region of Gaoual, north-west of Fouta-Djallon and close to the country's borders with Senegal and Guinea-Bissau. A combination of the slaughter of sick animals and vaccination was used to eradicate this scourge. The last outbreak was recorded in 1967. Following the cessation of vaccination in 1994, the country began annual serosurveillance for rinderpest in 1999, which lasted until January 2005. Guinea obtained the status of country freedom from rinderpest infection in May 2006.**

KEYWORDS **Country freedom – Guinea – Rinderpest – Surveillance – Vaccination.**

INTRODUCTION

The Republic of Guinea is situated in West Africa, bordered to the north by Senegal and part of Mali, to the north-west by Guinea-Bissau, to the west by the Atlantic Ocean, to the south by Sierra Leone and Liberia, and to the east by Côte d'Ivoire and part of Mali. The country is divided into four natural regions (Fig. 1). Guinea has a surface area of 246,000 km^2.

Cattle farming in Guinea is primarily extensive, using collective pastoral resources, and is extremely diverse, not only at the regional level but also at the local level. In 2000, the cattle population was as follows: Maritime Guinea (528,988), Middle Guinea (1,124,058), Upper Guinea (996,463) and Forested Guinea (226,552).

HISTORY OF RINDERPEST IN GUINEA

The first ever outbreaks of rinderpest were observed around 1940 in the major cattle farming region of Gaoual, north-west of Fouta-Djallon and close to the country's borders with Senegal and Guinea-Bissau. A combination of the slaughter of sick animals and vaccination was used to eradicate this scourge.

In March 1947, outbreaks were reported in herds in the Siguiri gold mining district of Upper Guinea. Sick and infected animals were slaughtered, and the carcasses handed over to gold miners. The disease then spread to neighbouring villages. Fear of the disease spreading further made it necessary to ask for additional staff from Kankan, after which the disease was brought under control.

In July 1948, there were several outbreaks in Kankan. Reinforcement staff from Mamou and Labé joined the Kanakan mobile team to stamp out the disease. During the same period, the disease occurred in Beyla, presumably originating from Côte d'Ivoire. To protect Beyla's large livestock population, the Kankan mobile team was called in urgently to stamp out the outbreaks.

In August 1949, the disease occurred in Gueckedou, where it affected several villages. Quick action by the Kankan team stopped the disease from spreading.

FIG. 1

ADMINISTRATIVE MAP OF GUINEA SHOWING THE FOUR NATURAL REGIONS

Source: United Nations, 2014 (1), modified to show the four natural regions of Guinea

In the same year, isolated cases re-emerged among the Kankan herds. A vaccine production centre to protect livestock in Upper Guinea and Forest Guinea was then built in Siguiri.

In 1950, the first deaths were recorded in the Mali subdivision (which shares a border with Senegal). Gradually, the disease spread to herds in Labé, Pita, Tongué, Dalaba, Dinguiraye, Faranah and Dabola. This epidemic, which caused so much disruption, came from Kédougou (Senegal). This was the most extensive spread of the disease since it first arrived in Guinea, which mobilised nearly all of Guinea's livestock officers and the reinforcement staff seconded from Bamako (Mali) to stamp out the outbreaks.

In 1951, sporadic deaths were reported, probably as a result of the animals that had escaped immunisation. Animal health measures were applied to all infected herds. After that, the Veterinary Services conducted regular vaccinations in the five years prior to the launch of Joint Programme 15 (JP15) to control rinderpest (see Chapter 4.1). Rinderpest was never endemic in Guinea, even before JP15. Instead, it made periodic incursions whenever border surveillance was lax. Outbreaks were reported to the World Organisation for Animal Health (OIE) in 1961 and the last one was in 1967 (see Chapter 4.6).

VACCINATION

The first vaccinations against rinderpest date back to 1949, with the establishment of a vaccine production unit in Siguiri. Prior to JP15, animals were immunised by inoculating an inactivated vaccine prepared from the lymph nodes of infected animals. In the five years preceding the launch of JP15, a total of 23,134 animals were vaccinated. During JP15 (1967–1969), around 1.8 million doses were used to immunise animals. In some cases, vaccination was coupled with the slaughter of diseased herds. JP15 started in May 1967, and the vaccination campaigns were gradually extended from north to south across the whole country (2). At the same time, Ivorian teams moved in parallel on the other side of the border, while Senegalese and Gambian teams advanced from east to west. Throughout the three-year term of JP15, regular technical and coordination meetings were held between officials from the countries involved in the programme. During the Pan-African Rinderpest Campaign (PARC; Chapter 4.2), vaccination continued as shown in Table I. From the end of JP15 to the start of PARC, the laboratory in Guinea, with assistance of the Food and Agriculture Organization of the United Nations (FAO), was able to produce 1 million doses of tissue culture vaccine (3).

TABLE I
SUMMARY OF RINDERPEST VACCINATIONS FROM 1987 TO 1994

Year	Number of animals vaccinated
1987	54,730
1988	351,909
1989	481,492
1990	377,572
1991	324,605
1992	246,690
1993	79,492
1994	40,492
Total	1,956,982

In 1994, Guinea ceased mass vaccination against rinderpest. On 2 July 1996, an order was issued to prohibit rinderpest vaccination.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Clinical surveillance is based on the legitimate suspicion of rinderpest, meaning the onset of clinical signs possibly related to the disease in one or more animals of susceptible species. This refers to stomatitis–enteritis syndrome. Surveillance showed that rinderpest disappeared clinically in 1967.

An epidemiological surveillance network for animal diseases was established in 1996, with 31 surveillance posts (at subprefecture or district level) for domestic animals and four posts for wildlife.

Continuous surveillance, which began in 2003, covered the entire livestock population and involved all field officers (public and private). Livestock producers and their associations also participated in continuous surveillance (passive and active).

A total of 314 herds were randomly selected for serosurveillance. From January 1999 to December 2002, a total of 3,790 sera were collected, of which 46 had doubtful results and none were positive. From 31 December 2002 to 31 December 2004, a total of 538 samples were collected, with four doubtful results and no positives. No antibodies were detected in 400 sera from small ruminants. All 40 sera collected from hunted wild animals were negative, as were the six sera collected from live wildlife.

Conclusion

The last outbreak was in 1967. Guinea, which was declared provisionally free from rinderpest, with the cessation of vaccination in 1994, recorded no further outbreaks. It established a functional epidemiological surveillance network at field level (continuous and active surveillance) during the period 1999–2004, which allowed it to apply for the status of country freedom from rinderpest disease.

An analysis of 5,508 cattle sera, 400 small-ruminant sera and 46 wildlife sera, as part of serological surveillance, demonstrated the absence of rinderpest virus circulation in the country. These results, in line with clinical surveys, showed the absence of rinderpest infection among Guinea's cattle population.

DOSSIER

Following an evaluation of the application dossier by the OIE (4), Guinea was declared a country free from rinderpest disease at the OIE General Session in May 2003.

Based on the results of serological surveillance, the country submitted a dossier to the OIE in 2005. The OIE's review of this dossier (5) enabled the World Assembly of OIE Delegates to declare the country free from rinderpest infection on 25 May 2006.

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CHAPTER 4.5.12

KENYA

P. MAINA ITHONDEKA

Former Director of Veterinary Services, Department of Veterinary Services, Kenya Ministry of Livestock Development, Kenya

SUMMARY **Rinderpest was first detected in Kenya during the first African pandemic in the late 1880s. The country participated in the control of rinderpest through Joint Programme 15 (JP15), the Pan-African Rinderpest Campaign (PARC) and the Pan-African Programme for the Control of Epizootics (PACE). The last use of vaccines was in 2003, and the last outbreak was in 2001 in Meru National Park. Kenya relied on both clinical surveillance and serosurveillance in both livestock and wildlife in its pursuit of freedom from infection. Testing undertaken between 2006 and 2008 demonstrated that rinderpest no longer circulated in Kenya, and in 2009 the World Organisation for Animal Health (OIE) recognised that Kenya was free of rinderpest.**

KEYWORDS **Clinical surveillance – Kenya – Last known outbreak – Rinderpest – Serosurveillance – Vaccination.**

INTRODUCTION

The Republic of Kenya lies along the equator on the eastern coast of Africa. The country covers an area of approximately 582,000 km^2 and has a human population of over 32 million. Administratively, the country is divided into eight provinces. Kenya shares common borders with the United Republic of Tanzania, Uganda, South Sudan, Ethiopia and Somalia. It also has a coastline on the Indian Ocean (Fig. 1).

The livestock subsector contributes about 12% of the country's total gross domestic product (GDP). About 80% of the country is arid and semi-arid land (ASAL), while a humid ecosystem occupies the remaining 20% of the country (Fig. 2). The main economic activity on the ASAL is livestock keeping.

North Rift, South Rift, north of the Eastern province (Marsabit, Moyale and Isiolo districts), the North Eastern province, and the Tana River and Lamu districts in the Coast province mainly practise pastoralism. The rest of the country comprising Central, Nyanza, Western, Eastern, Coast and Central Rift provinces mainly practise mixed farming in settled areas. Livestock reared in these areas are sedentary. In some parts of this region, extensive cattle keeping is practised on large ranches and dairy farms.

The Kenyan Department of Veterinary Services (DVS) was established in 1890 as a development service for settler livestock farmers. In 1954, the Swynerton Plan encouraged indigenous Kenyans to keep exotic livestock. The development of Kenya's dairy sector owes a lot to this plan. After independence in 1963, Veterinary Services were expanded to include the small-scale farmers and pastoralists. Laboratory services in Kenya were introduced at the Veterinary Research Laboratories, Kabete, in 1910. The National Veterinary Research Centre (NVRC) at Muguga had the capacity to produce the rinderpest vaccine. It also had the capacity to diagnose rinderpest. In 1990, the NVRC was merged with two other institutions producing vaccines in Kenya under the collective name of the Kenya Veterinary Vaccine Production Institute (KEVEVAPI).

FIG. 1
ADMINISTRATIVE MAP OF KENYA
Source: United Nations, 2011 (1)

HISTORY OF RINDERPEST IN KENYA

Following the introduction of rinderpest to Kenya around 1889, during the Great African Rinderpest Pandemic (Chapter 2.2), rinderpest remained endemic.

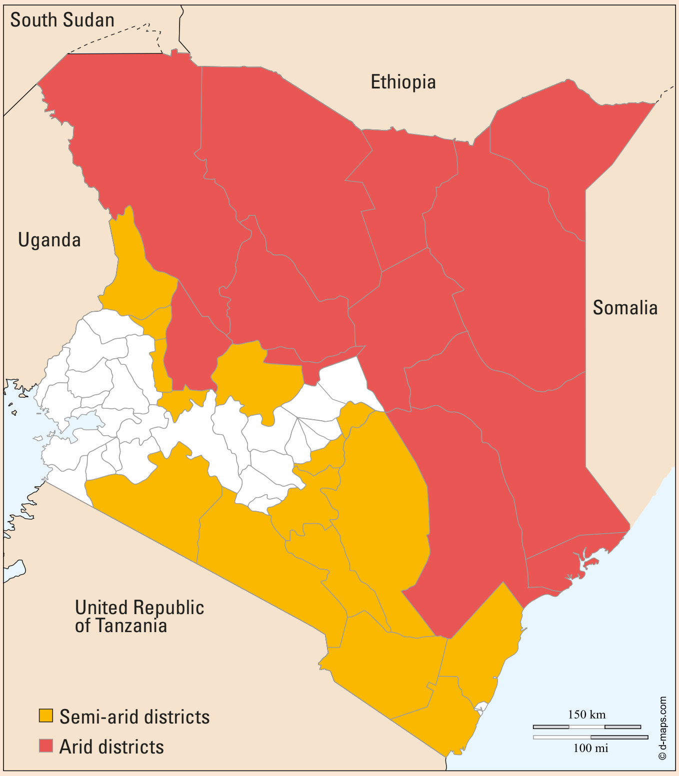
Kenya participated in the first major coordinated effort aimed at its control – JP15 – between 1968 and 1971 (see Chapter 4.1). The programme relied on mass vaccination and was able to confine the disease to the more remote areas of the country, but it was unable to eradicate it. Additionally, Kenya ended up bordering two areas known for being foci of endemic rinderpest virus: South Sudan in the north and the Somali ecosystem (SES) in the east. Once the pressure on vaccination was reduced, the disease briefly reappeared in the form of an epidemic spreading towards Marsabit and Mombasa. From 1970 to 1981, wildlife serology indicated the constant presence of rinderpest in Kenya (2), although outbreaks in cattle were not reported until the mid-1980s, when Wafula and Kariuki (3) confirmed the presence of the disease in unvaccinated calves in West Pokot district at the start of an epidemic that, between 1986 and 1989, brought lineage 1 rinderpest virus as far south as Nairobi (4). Those charged with eradicating rinderpest in Kenya were jolted by these outbreaks.

The participatory epidemiological studies of Mariner and Roeder (5) provided evidence of the persistence of (unreported) rinderpest within the Somali ethnic areas on the Kenya–Somalia border, dating back to 1981 and ascribed to lineage 2. Rinderpest on the Kenya–Somalia border probably served as the source of a severe rinderpest epidemic in buffaloes in Tsavo National Park (see Chapter 2.5) between 1994 and 1995; an associated spread of the virus occurred westward, as far as Nairobi National Park in 1996. Species affected during the outbreaks in the national parks were buffaloes, lesser kudu and eland. During the 1996 outbreak, 14/23 bovine eye swabs were positive on agar gel immuno-diffusion testing, and 3% of 3,423 bovine sera were positive for antibodies to the rinderpest virus. The virus also moved south into northern United Republic of Tanzania (see Chapter 4.5.20).

During the period after JP15, the government continued to fund rinderpest control efforts through compulsory vaccinations, particularly in the ASAL districts. After the re-emergence of rinderpest in Kenya in 1986, several emergency vaccination campaigns were undertaken, funded by the Government of Kenya and the European Union. However, the reappearance of rinderpest in 1994/1995 led to the launch of the Emergency Programme for the Eradication of Rinderpest in Kenya (EPERK) in 1996, which worked alongside the now activated Kenya component of PARC (see Chapter 4.2); both were sponsored by the European Union, but there was some financial input from FAO into EPERK. While EPERK ran for one year, PARC-Kenya ran between 1996 and 1999. The aim of EPERK was to control rinderpest in two rounds of vaccination in 1997/1998 in the rinderpest high-risk districts, which it did. Vaccination figures for this period are shown in Chapter 4.6. Seromonitoring was carried out in the vaccinated herds during the rounds of vaccination, in which average herd antibody prevalence was 58% and 62%, respectively.

As a result of the success of these measures, in December 1998 vaccination was stopped in the western half of the country, with the exception of two districts in the north-west (Turkana and West Pokot) that border South Sudan and Uganda, which continued to serve as a buffer zone to the ingress of the virus, as did a similar zone along the border with Somalia. In January 1999, the Kenyan DVS declared provisional freedom (excluding these zones) and notified the OIE, the African Union Interafrican Bureau for Animal Resources and all neighbouring countries.

FIG. 2
MAP OF KENYA SHOWING ARID AND SEMI-ARID LANDS
Source: d-maps.com, 2020 (8), modified to show relative aridness of lands



In December 2001, vaccinations ended in the Turkana and West Pokot districts, which joined the provisionally free zone in 2003.

A vaccine was briefly reintroduced to the Garissa and Ijara districts in 2003 (see below).

CLINICAL AND SEROLOGICAL SURVEILLANCE

Clinical surveillance

In November 2001, scheduled field surveillance activities identified rinderpest (lineage 2 virus) in buffalo herds in Meru National Park, within the provisionally free zone. This led to a loss of provisional freedom status. After intensive surveillance, the source of the infection was concluded to be pastoralists' cattle from the North Eastern province that had entered the park in search of pastures. Intensive surveillance in and around the park revealed that infection had in actual fact not spread beyond the two buffalo herds within the national park (Chapter 2.5). Retrospectively, it became apparent that this was the last record of a rinderpest infection worldwide (see Chapter 7.2).

In October 2003, through rinderpest participatory disease surveillance (PDS) in the Somali ecosystem

(SES; see Chapter 4.4), several foci of stomatitis–enteritis syndrome were identified. Subsequent investigations revealed rinderpest virus RNA in samples collected at Ruga (Garissa district) and Meri (Wajir district). The regional laboratory in Muguga, carried out the testing. Gene sequencing that followed at the World Reference Laboratory, Pirbright, United Kingdom of Great Britain and Northern Ireland, showed the virus to be related to the Kabete 'O' strain (which existed as a virulent laboratory strain and its attenuated vaccine derivative). From the sample provided, it was not possible to determine conclusively whether the virus was related more to the vaccine or to the wild strain. The contradictory explanations proposed were that this might have been the vaccine reverting to virulence or the last outbreak of rinderpest. This may have been the last outbreak considering that the vaccine used in the area had never reverted in virulence. Nevertheless, on the strength of these results, focused precautionary vaccination was undertaken in Garissa and Ijara districts in November and December 2003.

Clinical suspicion

Between 2006 and 2008, 348 samples from suspected stomatitis–enteritis cases in cattle were submitted as rinderpest-suspected incidents. The results in Table I below show that all were negative for rinderpest.

Serosurveillance

A regional approach to the final eradication of rinderpest was launched with the formation of the Somali Ecosystem Rinderpest Eradication Coordination Unit (SERECU) within PACE. Kenya signed the memorandum of understanding, alongside Ethiopia and Somalia. Joint surveillance activities were carried out and are described in Chapter 4.4. All samples were tested using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; Chapters 3.3 and 6.3).

In 2006, random surveys were carried out in the disease-free zone and in the Kenyan part of the SES. A total of 393 primary sampling units were visited, in which cattle were clinically examined and sampled. In the Kenyan part of the SES, a total of 263 locations were visited, and serum samples were collected from animals in Mandera and Wajir districts. In addition, one-to-two-year-old animals were sampled in the Garissa and Ijara districts, where the last vaccinations had been carried out in December 2003. These surveys were supplemented with a purposive survey, revisiting herds that had produced positive results. In 2006, 635 wildlife sera were collected from Garissa, Ijara, Meru National Park, Tsavo ecosystem, Amboseli National Park, Maasai Mara National Park, Ruma National Park, Nakuru National Park, and the Mandera, Wajir and Marsabit districts; one buffalo sample was positive in the c-ELISA test but negative in the neutralisation test.

Results for 2006 are shown in Table II. The rate of positivity was 0.24%.

In 2007, there was a limited epidemiological investigation to allay suspicion aroused by positive samples from adjacent Somalia and further sampling of wildlife when 179 serum samples were collected from the Laikipia and Naivasha districts. Results for 2007 are shown in Table III. No positive samples were found.

In 2008, serosurveillance was undertaken in the disease-free zone and the provisionally disease-free zone (see Table IV). The rate of positivity was 0.03%. In addition, 418 serum samples were collected from susceptible wildlife in the Ijara, Wajir, Mandera and Marsabit districts, Meru National Park and the Tsavo ecosystem. None of these yielded a positive result.

Results for 2008 are shown in Table IV. The results did not show evidence of rinderpest virus in the country. Two cattle were seropositive from the 4,421 animals tested in the provisionally disease-free zone. Similarly, for the disease-free zone,

TABLE I
RESOLUTION OF SUSPECTED STOMATITIS–ENTERITIS CASES IN CATTLE

Year	Number of samples	Species	Type of samples	Testing method	Differential diagnosis	Results negative for rinderpest
2006	60	Bovine	Serum, tissues, whole blood	c-ELISA, PCR	East Coast fever (ECF), babesiosis, anaplasmosis foot-and-mouth disease (FMD) serotypes A, O, SAT1 and SAT2	60
2007	165	Bovine	Serum, tissues, whole blood	c-ELISA, PCR	FMD serotypes O and SAT2	165
2008	123	Bovine	Serum, tissues, whole blood	c-ELISA, PCR, microscopy	FMD serotypes O, SAT1 and SAT2	123

c-ELISA, competitive enzyme-linked immunosorbent assay; PCR, polymerase chain reaction

TABLE II
RESULTS OF SEROLOGICAL TESTS FOR RINDERPEST ON SAMPLES COLLECTED IN 2006

Type of surveillance	Number of samples	Species	Results positive for rinderpest
Random serosurveillance in SES	3,927	Bovine	1
Purposive survey in SES	1,972	Bovine	0
Random survey in disease free zone	6,508	Bovine	29
Purposive surveillance (follow-up for random survey)	895	Bovine	2
Wildlife surveillance	635	Buffaloes, giraffes, warthog, waterbuck, lesser kudu, wildebeest, eland	One buffalo positive on c-ELISA but negative on virus neutralisation test

TABLE III
RESULTS OF SEROLOGICAL TESTS FOR RINDERPEST ON SAMPLES COLLECTED IN 2007

Type of surveillance	Number of samples	Species	Results positive for rinderpest
Follow-up epidemiological investigation	280	Bovine	0
Wildlife purposive surveillance	179	Buffalo, giraffe, warthog, waterbuck, lesser kudu, eland, impala	0

TABLE IV
RESULTS OF SEROLOGICAL TESTS FOR RINDERPEST ON SAMPLES COLLECTED IN 2008

Type of surveillance	Number of samples	Species	Number of samples positive
Random survey in provisionally disease-free zone	4,421	Bovine	2
Random survey in disease-free zone	4,955	Bovine	1
Wildlife purposive serosurveillance	418	Giraffe, warthog, gerenuk, buffalo, lesser kudu, eland, waterbuck	0

only one animal was seropositive for the rinderpest virus out of 4,955 cattle sampled. Seropositive results were probably due to false-positive reactions to the test.

Rinderpest was not clinically diagnosed during the wildlife surveys, and all the samples collected within the period were negative on laboratory tests.

Wildlife surveillance

Wildlife surveillance was used in support of the OIE Pathway to rinderpest freedom. Strong collaborative approaches were developed with the Kenya Wildlife Service, with at least 80% of districts searched for the presence of diseased animals in markets and along stock routes.

Rinderpest was not clinically diagnosed during the wildlife surveys. The serosurveillance results (see tables above) indicated the absence of circulating rinderpest virus in wildlife in different parts of Kenya and provided further assurance that rinderpest virus had not escaped beyond the infected herd of buffaloes in Meru National Park.

Sixty-two buffaloes from fifteen herds as well as one giraffe were sampled from different areas of Tsavo East National Park and Tsavo West National Park and the ranches. Emphasis was placed on areas where the Somali livestock and local community livestock frequently interact with wildlife. The buffaloes were aged between one year and three months and ten years (average three years). The giraffe was aged about three years.

DOSSIER: FREEDOM FROM INFECTION

In August 2005, the country was zoned (Fig. 3), and on that basis an application for freedom from rinderpest disease was made to the OIE.

FIG. 3
ZONATION OF KENYA FOR RINDERPEST DISEASE-FREE STATUS IN 2006

Source: d-maps.com, 2020 (8), modified to show rinderpest-free status

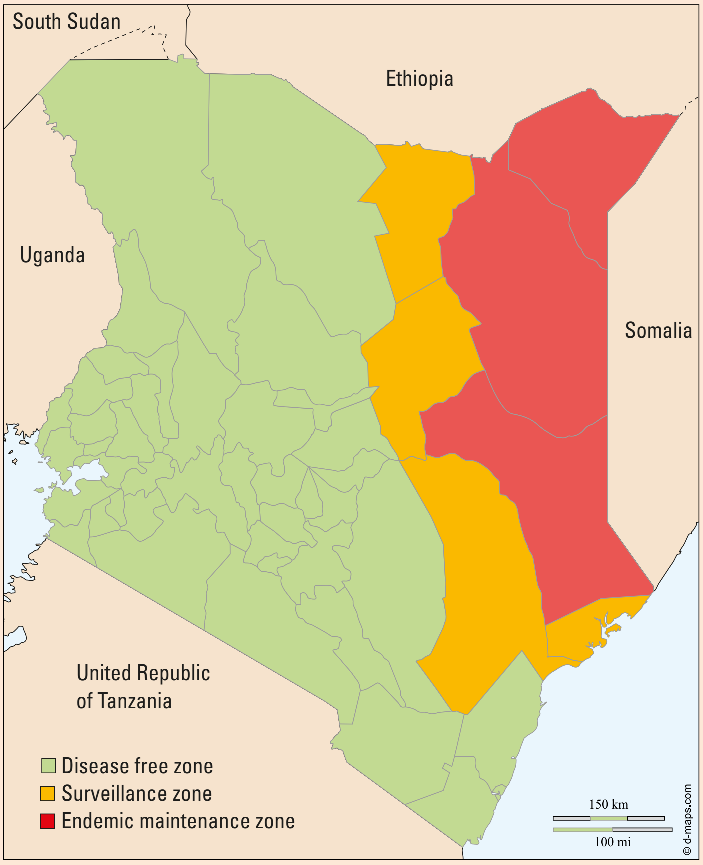


FIG. 4
MONUMENT IN KENYA'S MERU NATIONAL PARK

Right to left: His Excellency Mwai Kibaki (President of Kenya) celebrating the opening of a commemorative monument to mark the end of rinderpest in his country

Source: FAO/Tony Karumba

Kenya received an accreditation of freedom from rinderpest disease on a zonal basis in May 2006 (6).

Based on the results presented here, Kenya was declared free from rinderpest infection by the OIE in May 2009 (7). In 2010, celebrations of rinderpest eradication in Kenya and the final activities to rid the world forever of this pandemic were commemorated in the form of a monument in Meru National Park, Kenya (Fig. 4).

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CHAPTER 4.5.13

MALI

M. KANE

Former Director of Veterinary Services, Ministry of Livestock and Fisheries, Mali

SUMMARY **From the time of the first pandemic in 1890 to its eradication, rinderpest inflicted a heavy toll on the cattle population of Mali. Outbreaks persisted until 1986, finally eliminated as the result of several years of vaccination. No vaccination was carried out after 1997, and surveillance was implemented after vaccination ceased. Between 2003 and 2005, serological surveillance was carried out to supplement clinical surveillance. Mali was recognised as a rinderpest-free country by the World Assembly of the World Organisation for Animal Health (OIE) Delegates in May 2006.**

KEYWORDS **Mali – Outbreak – Rinderpest – Surveillance – Vaccination.**

INTRODUCTION

The Republic of Mali, a West African country whose capital is Bamako, lies between latitude 10° and 25° N and between longitudes 12° W and 5° E. It is landlocked and surrounded by seven other countries: Algeria to the north, Mauritania to the north-west, the Niger to the east, Burkina Faso to the south-east, Côte d'Ivoire and Guinea to the south and Senegal to the west (Fig. 1). Mali's most important cities are Kayes, Ségou, Sikasso, Mopti, Gao, Timbuktu and Kidal. Mali covers an area of 1,241,138 km^2.

HISTORY

Rinderpest was continuously recorded in Mali from 1954 to 1966. Between 1964 and 1969, Mali participated in Joint Programme 15 (JP15; see Chapter 4.1), and the reported number of outbreaks gradually decreased, reaching zero in 1967; they then reappeared in 1968, increasing in extent and proving remarkably persistent up until 1981 (Table I), despite the resources employed by the Government of Mali and its partners (especially the United States Agency for International Development, USAID).

The chosen vaccination strategy was to vaccinate all cattle in designated areas (targeting 105 million zebu cattle and 9 million taurine cattle). Assisted by the Food and Agriculture Organization of the United Nations (FAO) emergency inputs, the uptake of vaccines by 1989 equated to around 50% of this population, and by 1987 the incidence of rinderpest had been reduced to zero (see Chapter 4.6). Vaccinations continued under the Pan-African Rinderpest Campaign (PARC; Chapter 4.2) until 1997 (Table II), when the population immunity level was 74%. Rinderpest vaccination was terminated in 1997.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Continuous (passive) clinical surveillance

A total of 11,082 villages were visited from April 2002 to December 2004, as well as 79,153 herds of cattle and 22,205 herds of sheep/goats. During these visits, six samples collected because of suspected stomatitis–enteritis syndrome were sent to the Central Veterinary Laboratory in Bamako. The results were negative for rinderpest but revealed foot-and-mouth disease.

FIG. 1
ADMINISTRATIVE DIVISIONS OF MALI

Source: United Nations, 2020 (1)

TABLE I
EVOLUTION OF REPORTED RINDERPEST IN MALI FROM 1962 TO 1981

Year	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
No. outbreaks	308	149	159	71	82	0	3	8	11	33
Year	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**
No. outbreaks	47	53	23	0	4	11	9	29	11	7

Active clinical surveillance

In livestock

Active clinical surveillance lasted three years and involved randomly sampled cattle herds in 299 villages and purposively sampled small ruminant herds in at-risk areas until 2002. As of 2003, clinical surveillance was coupled with serological surveillance, and the sample size was increased to 314 villages/herds. The surveillance consisted of one annual visit to herds by heads of veterinary posts. During the visit, the animals were subjected to a systematic clinical examination to search for stomatitis–enteritis syndrome. The results are shown in Tables III, IV and V.

In summary, during the clinical and serological campaigns (2002–2004), six cases of stomatitis–enteritis were reported (in Ansongo, Yélimané, San, Koulikoro, Tominian and Ségou). Laboratory investigations confirmed foot-and-mouth disease, serotypes SAT2, A and O. Rinderpest was not encountered.

In wildlife

Surveillance involved buffaloes, warthogs, antelopes, bushbucks, common duikers and dorcas gazelles. It consisted of searching for signs of rinderpest and rinderpest-like diseases (African swine fever) and sampling blood and organs from

TABLE II
RINDERPEST VACCINATION BETWEEN 1988 AND 1997

Year	Number of cattle vaccinated against rinderpest
1988	1,636,043
1989	2,330,293
1990	2,116,944
1991	1,656,780
1992	1,691,458
1993	1,684,661
1994	1,230,353
1995	1,750,576
1996	1,482,815
1997	680,477

TABLE III
CLINICAL SURVEILLANCE, 2001–2002

Visits	Number of villages	Number of risk areas
Planned	300	101
Carried out	300	101
Fulfilment	100%	100%
Suspicion of stomatitis-enteritis	15	3
Confirmation	0	0

TABLE IV
CLINICAL SURVEILLANCE, 2002–2003

Visits	Number of villages	Number of risk areas
Planned	300	101
Carried out	300	101
Fulfilment	100%	100%
Suspicion of stomatitis–enteritis	3	1
Confirmation	0	0

TABLE V
CLINICAL SURVEILLANCE, 2003–2004

Visits	Number of villages	Number of risk areas
Planned	314	101
Carried out	303	101
Fulfilment	96%	100%
Suspicion of stomatitis-enteritis	3	0
Confirmation	0	0

carcasses. In total, 23 clinical examination forms were completed and sent to the network's central unit. Rinderpest was not detected.

Serosurveillance

Surveillance was implemented between 2003 and 2004 (Table VI) and between 2004 and 2005 (Table VII). Results for wildlife are shown in Table VIII. All samples were examined using the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3 and 6.3)

TABLE VI
SEROLOGICAL SURVEILLANCE IN LIVESTOCK, 2003–2004

Year	Sera collected	Sera tested	Positive sera	Percentage of positive sera
2003–2004	5,313	5,101	0	0

TABLE VII
RESULTS OF SEROSURVEILLANCE IN LIVESTOCK, 2004–2005

Region (district)	Sera tested	Positive sera	Percentage of positive sera
Kayes	1,091	0	0
Koulikoro	638	3	0.47
Sikasso	1,593	0	0
Ségou	1,800	0	0
Mopti	1,451	0	0
Timbuktu	403	0	0
Kidal	63	0	0
Bamako (district)	215	0	0
Total	**7,254**	**3**	**0.47**

TABLE VIII
WILDLIFE SPECIES SAMPLED IN THE PERIOD 2004–2005

Species	Samples collected
Warthog	28
Common duiker	3
Bushbuck	2
Dorcas gazelle	4
Total	**37**

Wildlife surveillance

In 2004, a total of 42 samples were collected in protected areas in Niénendougou (Bougouni) and Fina (Baoulé). During the period 2004–2005, a further 24 samples were tested (Table VIII). All samples were negative for rinderpest.

DOSSIER

On consideration of the relevant dossiers, in 2003 Mali was considered by the OIE to be a country free from clinical rinderpest (2), and in 2006 it was declared to be free from rinderpest (3).

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CHAPTER 4.5.14

MAURITANIA

M. FALL

Former Director of Livestock, Ministry of Rural Development and Environment, Mauritania

SUMMARY **The last case of rinderpest in Mauritania was reported in 1986. Mauritania conducted mass vaccination from 1965 up until the mid-1980s, after which vaccination was relaxed because of a lack of funding. Then, two vaccination campaigns were conducted between 1995 and 1997, which increased the herd immunity. A surveillance network was set up in 1998. Serological surveys were conducted in 2004 and 2005. Mauritania was declared by the World Organisation for Animal Health (OIE) to be free from rinderpest in May 2007.**

KEYWORDS **Epidemiological surveillance–Mauritania–Rinderpest–Vaccination.**

INTRODUCTION

The Islamic Republic of Mauritania covers an area of 1,030,000 km². It is situated entirely north of the Senegal river and bordered to the east and south-east by Mali. It has a 700-km-long coastline to the west and is bordered by Western Sahara to the north-west and by Algeria to the north-east.

Administratively, Mauritania is divided into 13 wilayas (regions) – including the capital district of Nouakchott (Fig. 1) – 53 moughataas (departments) and 208 communes.

HISTORY OF RINDERPEST IN MAURITANIA

For more than three decades, Mauritania carried out a rinderpest control strategy by organising an annual campaign of mandatory routine vaccinations for cattle and the application of animal health measures, including the restriction of animal movements and stamping out and compensation for animal owners to induce them to report any cases of rinderpest among their herds. A list of the outbreaks of rinderpest reported between 1956 and 1986 is given in Chapter 4.6.

Like other African countries concerned with the control of rinderpest, Mauritania conducted mass vaccinations between 1966 and 1969 under phase III of Joint Programme 15 (JP15) (Chapter 4.1); nevertheless, the virus persisted. Vaccination continued up until the mid-1980s with the aim of limiting the rinderpest outbreaks that the country was experiencing; this included emergency support from the Food and Agriculture Organization of the United Nations (FAO) in 1980 and 1981. The last case of rinderpest in Mauritania was reported in 1986.

From 1987 to 1990, full responsibility for funding the livestock prophylaxis campaign was transferred from JP15 to the African Development Bank, the World Bank and the Mauritanian government under phase II of the livestock development project 'Élevage II'.

The period 1990–1995 was marked by a relaxation of vaccination activities owing to a lack of external finance and farmers' lack of interest in vaccination, because, for them, rinderpest was just a distant memory.

Two vaccination campaigns were undertaken during the periods 1995–1996 and 1996–1997 (see Chapter 4.6 for the number of animals vaccinated,

FIG. 1
ADMINISTRATIVE MAP OF MAURITANIA
Source: Nations Online Project, 2021 (1)

with funds from the Pan-African Rinderpest Campaign (PARC; Chapter 4.2). This increased the herd's immunity from 36% in 1995 to 60% in 1997.

The cessation of rinderpest vaccination was notified to the regional services by circular letter no. 18 from the Minister for Rural Development and Environment, dated 18 September 1997, in which the minister instructed regional officials to cease vaccination as of 1998.

As a logical consequence of the above, in 1998 Mauritania set up a surveillance network for priority animal diseases, including rinderpest. In 1999, it declared itself to the OIE as provisionally free from rinderpest.

Clinical surveillance

Clinical surveillance involved the entire cattle population. It was implemented by the epidemio-surveillance network as a whole, including private veterinarians (REMEMA, or the Mauritanian epidemio-surveillance network for animal diseases).

A total of 1,421 clinical samples were collected to investigate suspicious disease, all of which tested negative.

In May 2003, Mauritania was declared to be a country free from rinderpest disease, following an evaluation of the application dossier carried out by the OIE (2). However, as discussed below, this status was suspended the same year, after the discovery of sera from two warthogs testing positive for rinderpest antibodies.

To address the suspension by the OIE, between July 2003 and January 2004, a total of 1,889 cattle sera were collected in the area where the two warthog sera had tested positive for rinderpest (Fig. 2).

After these cattle sera were tested by the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3. and 6.3) method, only two were found to be positive. Although the diagnosis could not be confirmed by a reference laboratory in one of the two cases (as there was insufficient serum), the age of the animals (two years and five years) nevertheless raised doubts about the origin of the rinderpest antibodies; in both cases, the antibodies could have been vaccine induced. This survey allowed Mauritania to regain its freedom from clinical rinderpest status in May 2004.

Serological surveillance results

Between 2004 and 2005, in accordance with the OIE Pathway, two surveys of cattle were conducted to detect antibodies against the rinderpest virus in all wilayas where cattle were farmed. In 2004, the survey teams inspected 306 herds and collected 4,816 sera. Upon laboratory examination, the seroprevalence rate was 0.30. In 2005, a total of 3,713 sera were analysed, and the seroprevalence rate was 0.48. The 18 seropositives were found in two wilayas (Hodh Ech Chargui and Hodh El Gharbi). Back-tracing led to the conclusion that the 18 positive animals had been eight years old or older and were therefore false positives.

Surveillance of wildlife

A total of 64 warthog sera were collected during the hunting season 2001–2005, of which 14 were unusable. Except for the two positive sera in 2003, all the others tested negative for rinderpest.

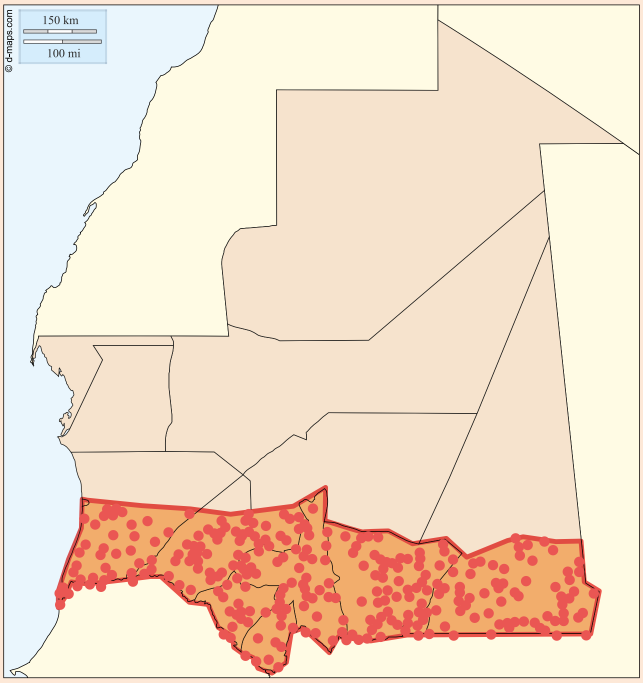
CONCLUSION

With regard to the steps in the OIE rinderpest pathway, Mauritania ceased vaccination in 1998 and declared itself to the OIE as provisionally free from rinderpest in 1999 – a status that was granted in 2003 but suspended following the discovery of two warthogs with positive serology.

In May 2004, Mauritania regained the status of country freedom from rinderpest following

FIG. 2
RINDERPEST SURVEY AREA IN MAURITANIA FOLLOWING THE DISCOVERY OF RINDERPEST ANTIBODIES IN WARTHOGS

Source: d-maps.com (2020). - Map of Mauritania. Available at: https://www.d-maps.com (accessed on 9 June 2021), modified to show rinderpest survey area



evaluation by the OIE of a detailed report (3) outlining the measures taken to clarify the epidemiological situation in the areas where the positive warthog sera had been discovered.

To continue the implementation of the OIE Pathway, two serological survey campaigns were conducted in 2004 and 2005, in addition to clinical surveillance, to obtain the final status of country freedom from rinderpest infection. This was obtained in May 2007 following evaluation by the OIE of a detailed report (4).

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CHAPTER 4.5.15

NIGER

M. SALEY

Former Director General of Veterinary Services, Ministry of Livestock and Animal Industries, Niger

SUMMARY **The Niger experienced its first epidemic of rinderpest in 1865, followed by the African pandemic between 1890 and 1895. Systematic mass vaccination campaigns were carried out annually from 1962 to 1996. The Niger did not record an outbreak of rinderpest after 1986. This allowed a number of measures to be taken, including the cessation of vaccination in 1998 and the establishment of an epidemiological surveillance network for rinderpest. The Niger was recognised as being free from rinderpest disease in May 2005 and was declared officially free from rinderpest in May 2010.**

KEYWORDS **Niger – Outbreaks – Rinderpest – Surveillance – Vaccination.**

INTRODUCTION

The Republic of the Niger is situated in West Africa and bordered by Algeria and Libya to the north, Chad to the east, Nigeria and Benin to the south, and Mali and Burkina Faso to the west (Fig. 1). The Niger's economy is based primarily on agriculture and livestock, which employ more than 82% of the population.

In 2004, the national herd was estimated at 3,686,828 cattle, 7,457,512 sheep, 9,448,013 goats, 1,177,173 camels, 650,745 horses and 354,886 donkeys.

The duties of the General Directorate of Veterinary Services (DGSV) and Central Livestock Laboratory (LABOCEL) include protecting livestock from animal diseases and epidemics. Animal disease control is underpinned by 8 regional directorates for livestock and animal industries and 36 departmental directorates.

HISTORY OF RINDERPEST

The Niger experienced its first rinderpest epidemic in 1865 and was again affected between 1890 and 1895 within the Great African Rinderpest Pandemic (see Chapter 2.2). After that, it was not until 1915 that the disease re-emerged in cattle in south-east of the Niger, the infection having entered from Chad via Nigeria.

Since the early years of independence, rinderpest control was one of the major concerns of the Niger's Veterinary Services.

The first continental programme for the eradication of rinderpest in Africa was launched with the participation of the Niger in phases I and II of the Joint Programme 15 (JP15) between 1962 and 1967 (see Chapter 4.1). The goal was to vaccinate the entire cattle herd. Vaccinations were free of charge and up to 80% of cattle were vaccinated. Between 1962 and 1967, a total of 12.2 million cattle were vaccinated. JP15 was followed by the Niger's participation in the Pan-African Rinderpest Campaign (PARC, 1986–1998) (see Chapter 4.2) and then the Pan-African Programme for the Control of Epizootics (PACE) (see Chapter 4.3). Between 1968 and 1985, vaccination was carried out using national resources, with the Food and Agriculture Organization of the United Nations (FAO) and other partners' assistance. During that period, vaccination was focused only in high-risk areas. The last diagnosed outbreak of rinderpest was in 1986. The effect of vaccination on the incidence of rinderpest is shown in Table I, which also includes the results of seromonitoring carried out between 1990 and 1997 under PARC.

FIG. 1
MAP OF THE NIGER WITH MAJOR ADMINISTRATIVE BOUNDARIES
Source: United Nations, 2018 (1)

RINDERPEST SURVEILLANCE

Rinderpest surveillance was introduced in the Niger by Decree No. 032/MRA/DSA of 18 June 2001 for the creation, organisation and operation of the epidemiological surveillance network for rinderpest and other major cattle diseases.

Clinical surveillance

Passive surveillance

Passive surveillance was a routine activity of the state and private Veterinary Services covering the general notification of animal diseases. This passive declaration system took the form of a monthly report on the animal health situation (reporting form) at all levels. For all officials of the Veterinary Services (public and private) this formed part of their ongoing daily animal disease control activities.

Suspicions in the field

Rumours or reports by farmers, or any other person with a legitimate suspicion of rinderpest, were recorded in a register and verified by the competent Veterinary Service at local and/or subregional and/or regional level.

Table II below shows the different suspicions identified in the field and that no suspected cases of rinderpest were reported between 2006 and 2008.

Wildlife surveillance

Wildlife surveillance came into effect in 2002. Reports from agents in the wildlife network covering the period from January to October can be summarised as follows:

– 26 reports were received from agents;
– 34 field inspections were carried out;
– 37 personal interviews (tourists, guides and inhabitants of outlying districts) were conducted;
– 1,330 susceptible wild animals were encountered, as follows:
  dorcas gazelle: 84
  red-fronted gazelle: 55
  defassa waterbuck: 22
  lechwe: 16

TABLE I
RINDERPEST OUTBREAKS AND VACCINATION IN THE NIGER FROM 1966 TO 1998
(SEE ALSO CHAPTER 4.6)

Year	No. outbreaks	No. reported deaths	Cattle population	Vaccinations	Vaccination coverage (%)	Immunisation coverage (%) [c]
1966	3	20	3,520,810	3,096,367	88	
1967	4	48	3,629,701	2,085,914	57	
1968	9	61	3,741,959	1,374,739	37	
1969	23	114	3,857,690	1,291,541	33	
1970	9	41	3,977,000	1,113,052	28	
1971	0	0	4,100,000	1,074,672	26	
1972	11	58	4,220,000	2,069,842	40	
1973	6	46	2,200,000	1,416,564	64	
1974	1	2	2,312,770	868,270	37	
1975	0	0	2,508,000	1,298,000	52	
1976	0	0	2,671,700	1,570,000	59	
1977	0	0	2,969,000	2,085,650	70	
1978	0	0	2,990,000	1,804,772	60	
1979	0	0	3,257,000	2,140,392	66	
1980	7	85	3,419,000	2,676,541	80	
1981	0	0	3,472,000	2,223,778	65	
1982	6	79	3,524,000	2,926,874	84	
1983	5	100	2,114,000	2,850,646	81	
1984	2	–	1,649,000	3,411,170	161 [a]	
1985	2	4	1,429,000	872,648	53	
1986	1	6	1,495,000	1,249,000	87	
1987	0	0	1,564,000	1,257,000	84	
1988	0	0	1,636,000	1,211,000	77	
1989	0	0	1,711,000	1,342,000	82	
1990	0	0	1,790,000	1,341,972	48	58
1991	0	0	1,872,000	930,734	33	
1992	0	0	1,909,000	616,514	21	55
1993	0	0	1,947,700	502,888	17	46
1994	0	0	1,986,600	634,659	21	55
1995	0	0	2,047,600	344,313	11	52
1996	0	0	2,088,500	626,456	20	53
1997	0	0	2,905,128	827,596	26	47
1998	0	0	3,368,299	56,073 [b]		

[a] Many transhumant animals from Nigeria and Chad were vaccinated
[b] Only the Diffa region carried out vaccination
[c] Data available only for years in which seromonitoring undertaken

kob: 90
hippotragus: 156
giraffe: 156
warthog: 56
oribi: 15
buffalo: 673
hartebeest: 13
duiker: 4;

- 7 sick wild animals were found: 5 giraffes and 2 defassa waterbuck;
- 4 dead bodies of wild animals were observed: 2 giraffes, 1 lechwe and 1 warthog.

The dead giraffes were:

- 1 female giraffe following diarrhoea with traces of blood;
- 1 other adult giraffe, probably killed by a snake bite.

The remarkable work carried out by network agents, especially in Kouré and Tapoa, gave an overview of the wildlife health situation in zones containing the species most susceptible to rinderpest (buffalo, giraffe). None of the suspected cases was confirmed in the laboratory.

TABLE II
SUSPECTED CASES OF VARIOUS DISEASES 2006–2008

Disease	Year		
	2006	2007	2008
Rinderpest	0	0	0
Contagious bovine pleuropneumonia	0	2	2
Foot-and-mouth disease	21	113	78
Peste des petits ruminants	2	2	15
Sheep pox	16	21	91
Highly pathogenic avian influenza	2	0	0
Dermatosis	9	0	1
Bovine pasteurellosis	130	221	22
Anthrax	9	21	3
Blackleg	26	29	32
Pasteurellosis in small ruminants	273	481	105
Anthrax in small ruminants	8	176	2

Serological surveillance

The dossier presented for disease freedom in 2005, included the following information on the seroprevalence of rinderpest in cattle: in 2003, a total of 4,769 samples were collected and 10 were positive. In 2004, 3,628 were analysed, revealing 26 positives. These 26 samples were scattered throughout Zinder (20), Maradi (4) and Tahoua (2), with major concern in Zinder because of the epidemiological situation of this region where animals gathered. Alternatively, the seropositivity rates of 0.2% and 0.71% for 2003 and 2004, respectively, could be false positives due to the specificity of the enzyme-linked immunosorbent assay (ELISA) kit used. In wildlife, 110 samples were collected and none were positive.

Owing to the inconclusive serological surveillance results for 2003 and 2004, a fresh campaign was undertaken in 2009. The samples were tested using competitive ELISA (c-ELISA; see Chapters 3.3 and 6.3), and the results are given in Table III.

The 2009 serological surveillance results provided proof of the absence of rinderpest infection in the Niger.

TABLE III
INCIDENCE OF RINDERPEST-POSITIVE BOVINE SERUM SAMPLES BY REGION

Region	No.	No. positive	Total	Apparent prevalence (%)
Diffa	340	0	**340**	0.00
Zinder	2,316	0	**2,316**	0.00
Maradi	600	0	**600**	0.00
Tahoua	428	0	**428**	0.00
Dosso	465	0	**465**	0.00
Tillaberi	661	0	**661**	0.00
Total	**4,810**	**0**	**4,810**	**0.00**

– All the sera from the six regions, including those from Zinder, proved negative during the 2009 serological tests.

CONCLUSION

– The last confirmed outbreak of rinderpest dates back to 1986. The last use of vaccine was in 1998.
– All legitimate suspected cases of rinderpest led to confirmation of rinderpest-like diseases (foot-and-mouth disease, peste des petits ruminants, bovine viral diarrhoea), either by international reference laboratories or by the Niamey Central Laboratory in the Niger.

DOSSIER

In May 2005, the Niger was recognised as being free from rinderpest disease following evaluation of the application dossier by the World Organisation for Animal Health (OIE) (2).

In June 2009, the Niger submitted a dossier to secure the status of country freedom from rinderpest. The dossier was examined by the relevant OIE Commission (3) and country freedom from rinderpest was accorded to the Niger by the World Assembly of OIE Delegates at its 78th General Session in May 2010.

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CHAPTER 4.5.16

NIGERIA

J. MAINA & K.A. MAYIJAGBE†

Former Chief Veterinary Officers of Nigeria, Abuja, Nigeria

SUMMARY **Nigeria was first infected with rinderpest during the first African pandemic of the 1880s. The last confirmed outbreak of rinderpest in Nigeria was in April 1987 at the Riyawa hamlet in Kaduna state. Under the passive surveillance system, monthly reports were collected from area veterinary offices throughout the country and from private veterinarians. An epidemio-surveillance network, referred to as the National Animal Disease Information and Surveillance (NADIS), involving all stakeholders was established to assess the status of rinderpest and other epidemic diseases in the country. A wildlife epidemio-surveillance programme was part of NADIS.**

Nationwide serological surveillance was conducted using random map coordinates. In 2007, a total of 398 random points were generated, of which 315 were actually visited. From a total of 7,468 animals found at the various locations, 2,487 sera were collected in two phases of the exercise and sent to the laboratory for analysis, where all the samples were negative for rinderpest. In 2008, a further 5,024 animals were visited within the national parks, and 728 serum samples were collected. These samples all tested negative for rinderpest. Another nationwide serological surveillance was conducted in December 2009 using randomly generated numbers and 5,087 sera were collected and analysed. All of the sera were negative for rinderpest.

The World Organisation for Animal Health (OIE) declared Nigeria rinderpest free in May 2010.

KEYWORDS **Nigeria – Rinderpest – Surveillance – Vaccination.**

INTRODUCTION

The Federal Republic of Nigeria is situated in the south-eastern part of West Africa and is bordered to the west by Benin, to the north by the Niger, to the north-east by Chad, to the east by Cameroon and to the south by the Atlantic Ocean (Fig. 1). The livestock industry in Nigeria has an estimated population of 15.24 million cattle, 96.67 million goats, 51 million sheep, 6.87 million pigs and, as of 2008, contributed about 15–20% of the agricultural gross domestic product (GDP) and 5–6% of the country's total GDP.

HISTORY OF RINDERPEST AND VACCINATION IN NIGERIA

Rinderpest probably reached Nigeria from Chad around 1890 during the Great African Rinderpest Pandemic (see Chapter 2.2). It had a devastating effect on the cattle population, killing 80–90%. Following the widespread drought and famine between 1912 and 1913, there was another disastrous epidemic between 1913 and 1914. A subsequent epidemic between 1919 and 1920 caused mortalities in the range of 60–90%.

In this early period, the Veterinary Department lacked the facilities to intervene; however, in 1922, the government began constructing a veterinary laboratory at Vom, with the principal function of producing rinderpest immune serum to treat cases of the disease. This product was made available in 1925. Once the innate conservatism of the cattle owners had been overcome, they began to appreciate the need for early notification and early treatment of rinderpest.

FIG. 1

MAP OF NIGERIA WITH MAJOR ADMINISTRATIVE BOUNDARIES

Source: United Nations, 2014 (1)

Since it was recognised that serum alone conferred a short duration of immunity, prophylactic vaccinations using the serum–virus simultaneous technique was seen as the next step forward.

With immune serum production running at 600,000 doses per annum, 1925–1926 saw the launch of immunisation camps. The serum–virus simultaneous technique caused between 1% and 3% mortality among the Fulani zebu animals, but this was seen as an acceptable trade-off for a long-lived immunity in the remaining cattle. Unfortunately, the same technique caused astonishingly high (100%) mortality in the humpless cattle of the south of the country. To minimise such losses, its use was preceded 14 days earlier by an inoculation of formalinised spleen vaccine.

By 1930, a network programme for voluntary vaccination was established, and this resulted in reduced mortality of 5–20% in the herds involved. The severity of the disease also decreased owing to an increase in the number of animals vaccinated, with most of the mortality occurring in unvaccinated calves from six months to two years of age, as a result of waning maternal immunity. Trade cattle were also routinely vaccinated. Other zoosanitary measures introduced included quarantine and slaughter of infected animals. Legislation was also passed making vaccination compulsory. As rinderpest also affected the neighbouring countries, their migratory cattle served as a source of infection for Nigeria's national herd. In the first year of the campaign, 60,000 head were immunised, but by 1945 close to 700,000 were being added annually to the immune population. At this time, W.W. Henderson (the then Director of Veterinary Services) concluded that rinderpest in Nigeria had been brought under complete control, and, as and when outbreaks did occur, they were sporadic and affected only a few animals: 'In the early days we lived rinderpest – in 1945 it was hard to find a case.'

By 1960, the situation had begun to deteriorate. The disease remained endemic in Nigeria and other countries until Joint Programme 15 (JP15) was introduced in May 1961 and executed in Nigeria between 1962 and 1967 (see Chapter 4.1). JP15 resulted in a reduction in outbreaks of the disease to as low as two per year. During the Nigerian civil war, the number increased again but soon dropped to zero in 1974 (2), after which the country enjoyed six years of freedom from rinderpest.

In the 1970s, as a result of economic constraints and political instability, many countries in Africa, including Nigeria, failed to implement the necessary post-JP15 (vaccination) conservatory measures. This failure led to the persistence of residual foci of infection in a number of traditional cattle-producing areas in Africa. With the population of susceptible stock building up, the preponderance of insecurity in the surrounding countries, and undisciplined and illegal cattle movement and trade, the situation became conducive to the recrudescence of the disease in Nigeria. In 1980, lineage 2 rinderpest entered Nigeria through infected cattle from the Niger that were smuggled into Sokoto state by a trader. This outbreak was controlled by a vaccination campaign that was sponsored by the Food and Agriculture Organization of the United Nations (FAO), the then Organisation of African Unity Inter-african Bureau for Animal Resources (OAU/IBAR), and the British and French governments.

In January 1983, a virulent strain of lineage 1 rinderpest virus emerged from Sudan and entered Nigeria through Dikwa in Borno state via Chad and Cameroon.

Prior to the rinderpest outbreaks during the period 1980–1983, vaccination against rinderpest was not enforced. However, with the reintroduction of the disease in 1980, both the federal government and the state governments launched ring vaccination campaigns. As the severity of the disease escalated, the federal government officially launched a national vaccination campaign in April 1983. This paved the way for a massive national vaccination campaign (see Chapter 4.6), accompanied by publicity on the importance of eradicating the disease.

A total of 11.3 million cattle were vaccinated through the efforts of the federal and state governments (for more details regarding the Sokoto and Dikwa epidemics, see Chapter 2.4).

In 1986, the European Economic Community (EEC) through the OAU/IBAR sponsored the Pan-African Rinderpest Campaign (PARC) to further strengthen the national efforts of African countries in the control and eradication of the disease. With the commencement of PARC in 1986, a National Coordination Office was established in Nigeria with a National Coordinator and six zonal coordination offices. Overall, the PARC programme provided 7 million doses of tissue culture rinderpest vaccine (TCRV), while the Nigerian government provided 25.9 million doses.

This effort was further strengthened under the Programme for Control of Epizootics (PACE) from 2001 to 2007, which strengthened epidemio-surveillance and disease reporting and facilitated Nigeria's processing of the OIE Pathway for rinderpest eradication.

At the start of this period of intensive vaccination in 1983, rinderpest outbreaks were as high as 1,081, with 6,691,428 cattle involved and over 520,000 cattle dying. The number of outbreaks was dramatically reduced by vaccination, so much so that, by 1987, there was only one outbreak involving 507 cattle and 173 cattle dead, after which there was no further outbreak of the disease. This progress is summarised in Table I.

Between 1989 and 1994, seromonitoring was conducted in Nigeria to determine the level of rinderpest immunity in the national herd. Surprisingly, this averaged less than 50%.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Passive surveillance using the NADIS network failed to detect rinderpest after 1987.

Active surveillance was undertaken during the collection of serum samples for use in serosurveillance (see below). In addition, between 2003 and 2009, 24 instances of stomatitis–enteritis were investigated using the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3 and 6.3) or agar gel immunodiffusion (AGID) test. No rinderpest was detected.

Serosurveillance

Three serological surveillance exercises were conducted in 2007, 2008 and 2009.

In 2007, as there was no sampling frame available, a random selection of geographical coordinates was used, and a total of 398 random points were generated. Out of these, 315 points were visited in two phases of the exercise from September to December 2007. Herds found within a 3-km radius of the selected points were considered as a unique herd/sampling unit and sampled accordingly.

At the end of the exercise, a total of 315 herds with a total number of 7,468 animals were visited, and a total of 2,487 serum samples were collected. Three out of the 2,487 sera tested were positive, but on retesting all were found to be negative.

In 2008, targeted serosurveillance was conducted on cattle living within the national parks, where they coexisted with the few rinderpest-susceptible species of wild animals present in Nigeria. This provided an insight into the situation of the disease in

TABLE I
RINDERPEST OUTBREAKS AND VACCINATIONS IN CATTLE, 1980–1996

Year	No. of outbreaks	No. involved	No. sick	No. dead	Vaccination returns
1980	20	5,661	906	478	N/A
1981	11	3,258	831	437	N/A
1982	30	4,786	665	262	N/A
1983	1,081	6,691.428	2,422,835	500,158	11,350,812
1984	329	53,908	16,493	7,659	8,306,048
1985	39	7,547	1,028	520	7,803,633
1986	2	415	85	53	5,897,783
1987	1	507	300	173	7,824,898
1988	–	–	–	–	4,160,267
1989	–	–	–	–	2,290,236
1990	–	–	–	–	4,379,435
1991	–	–	–	–	4,379,435
1992	–	–	–	–	4,243,600
1993	–	–	–	–	3,649,424
1994	–	–	–	–	3,649,424
1995	–	–	–	–	2,697,223
1996	–	–	–	–	1,777,773

the wildlife. Eighty-four herds with a total number of 5,024 animals within the major seven national parks in the country were visited. The sampling procedure and number of animals sampled from each herd was similar to that for the 2007 exercise. A total of 729 sera were collected and sent to the laboratory for analysis. Ten samples initially tested positive, but all were negative when retested.

In December 2009, another nationwide serological surveillance was conducted. Out of a total of 71,060 localities present in the country, 399 random villages were selected using a random number generator. The animals in any selected locality were regarded as a unique herd and sampled in a manner similar to that in the 2007 exercise, described above. At the end of this exercise, a total of 353 villages had been visited and 5,100 sera collected. Out of the total of 5,100 sera collected, 5,087 were analysed at the National Veterinary Research Institute (NVRI). All the samples tested were negative for rinderpest.

In summary, all the samples tested from 2007 to 2009 in the three serological surveillance exercises were negative for rinderpest antibodies.

Wildlife demography

A wildlife capture exercise was also conducted at the Kainji Lake National Park in February 2003. Sera were collected from seven western kobs and one buffalo and analysed for rinderpest. The result of the analysis from both the NVRI and the veterinary laboratory in Dakar (LNERV) indicated an absence of rinderpest antibodies.

CONCLUSION

Nigeria made concerted efforts to follow the OIE guidelines to attain rinderpest infection-free status. Specifically, as Nigeria had stopped vaccination against rinderpest in cattle in 1996 and no disease had been detected since 1987, in 2004, Nigeria submitted a dossier to the OIE for official recognition of its status as disease free. This was granted in May 2005 (3). Based on the surveillance data, in 2009 Nigeria submitted a dossier applying for recognition as free from infection. The OIE declared Nigeria rinderpest-free in May 2010 (4).

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CHAPTER 4.5.17

SENEGAL

A. BOUNA NIANG†

Former Director of Livestock, Ministry of Agriculture, Livestock and Water Resources (MAEH), Dakar, Senegal

SUMMARY **During the French colonial period and the first decade following Senegal's independence in 1960, rinderpest was the deadliest disease for Senegal's cattle population.**

For more than four decades, Senegal implemented a policy to control rinderpest and contagious bovine pleuropneumonia, mainly through mass vaccination campaigns, with the support of the international community. In the 1990s and 2000s, an epidemiological surveillance programme was also developed. Finally, Senegal followed the procedure of the World Organisation for Animal Health (OIE) for rinderpest surveillance, which led to its recognition as a country free from rinderpest infection in May 2005.

KEYWORDS **Outbreak – Rinderpest – Senegal – Surveillance – Vaccination.**

INTRODUCTION

The Republic of Senegal is a Sahelian country in West Africa. It is bordered by the Atlantic Ocean to the west, Mauritania to the north, Mali to the east, and Guinea and Guinea-Bissau to the south (Fig. 1). The Gambia is almost an enclave of Senegal, extending more than 300 km inland.

The Ministry includes a Livestock Directorate supported by a Regional Inspectorate of Veterinary Services in each of the 11 administrative regions of Senegal. In each of the country's 34 departments, there is a Departmental Inspectorate of Veterinary Services supported by veterinary posts.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN SENEGAL

The first recorded rinderpest outbreaks date back to the French colonial period in the early 1940s. The disease was endemic throughout the 1950s and 1960s and associated with heavy morbidity and mortality. Mass vaccination during phase III of Joint Programme 15 (JP15; Chapter 4.1) between 1966 and 1969 succeeded in ending rinderpest endemicity (Table I). The virus reappeared briefly between 1978 and 1979.

The National Laboratory for Livestock Production and Veterinary Research (LNERV) at Dakar-Hann

TABLE I
RINDERPEST OUTBREAKS RECORDED IN SENEGAL PRIOR TO AND DURING JP15

Year	Number of outbreaks	Number of sick animals	Number of deaths
1956	109	406	1,014
1957	332	2,037	4,067
1958	47	1,255	742
1959	267	2,563	1,838
1960	199	1,929	646
1961	200	2,149	1,019
1962	38	501	147
1963	71	460	184
1964	110	930	427
1965	13	71	24
1966	33	471	160
1967 [a]	76	307	52
1968 [a]	9	–	–
1969 [a]	0	–	–

[a] Years when phase III of JP15 was active

FIG. 1
ADMINISTRATIVE MAP OF SENEGAL
Source: United Nations, 2004 (1)

was designed to support the control of animal diseases, in particular diagnosis and vaccine production, to meet the needs of former French West Africa. Production of tissue culture rinderpest vaccine (TCRV) began at LNERV in Dakar in 1964 and, in just a few years, supplanted the caprinised rinderpest virus previously in use.

After a ten-year absence, transhumance brought rinderpest back to the Saint Louis region of Senegal in 1978 and 1979. It was eliminated with a Food and Agriculture Organization of the United Nations (FAO) emergency vaccination programme.

A decade-long mass vaccination programme followed during the Pan-African Rinderpest Campaign (PARC) (Chapter 4.2). Vaccination returns for this period (1986 to 1996) are given in Chapter 4.6. Seromonitoring showed that herd immunity levels averaged 75% throughout this period, as a consequence of which rinderpest did not return. These facts allowed Senegal to cease vaccination and declare provisional freedom from rinderpest in 1997.

CLINICAL AND SEROLOGICAL SURVEILLANCE

Between November 1998 and November 2004, clinical surveillance failed to detect rinderpest but established the presence of 100 foci of peste des petits ruminants and 49 foci of foot-and-mouth disease. Further active clinical surveillance was undertaken during the collection of samples for serosurveillance during 2006; no rinderpest cases were found.

In 2006, serosurveillance was undertaken with the collection of 2,906 samples from 303 herds distributed across ten of the country's administrative regions. The competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3 and 6.3) results from these samples are shown in Table II.

Wildlife surveillance covered buffaloes, warthogs and antelopes in parks (Niokolo Koba), wildlife reserves (Ferlo) and leased hunting areas.

Back-tracing suggested that positive samples arose from sampling previously vaccinated animals.

TABLE II
PREVALENCE OF RINDERPEST C-ELISA ANTIBODIES BY REGION

Region	Number of herds sampled	Number of samples tested	Number of positive samples	Total seroprevalence (%)
Diourbel	27	163	1	0.61
Fatick	31	244	0	0.0
Kaolack	46	452	0	0.0
Kolda	25	271	1	0.037
Louga	55	524	3	0.57
Matam	18	207	5	1.85
Saint-Louis	41	475	12	2.52
Tambacounda	17	164	0	0.0
Thies	26	236	5	2.11
Ziguinchor	17	170	1	0.58
Total	**303**	**2,906**	**28**	**0.94**

With respect to wildlife, 59 warthog sera collected during the 2003–2004 hunting season were negative for rinderpest antibodies.

Dossier

In May 2003, Senegal was found to be a country free from rinderpest disease, following the OIE's evaluation of the application dossier (2).

In November 2004, the Delegate of Senegal submitted a dossier to secure the status of country freedom from rinderpest. The dossier was examined by the relevant OIE Commission (3), and country freedom from rinderpest was accorded to Senegal by the World Assembly of OIE Delegates at its 73rd General Session in May 2005.

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CHAPTER 4.5.18

SOMALIA

H.S.H.H. HAMUD

Former Director of Veterinary Services, Ministry of Livestock, Forestry and Range, Mogadishu, Somalia

SUMMARY **Random serological surveys for rinderpest were carried out in cattle populations from 1999 to 2009, while purposive serological surveys in wildlife were carried out in 2006 and 2009 targeting abundant warthog populations in suspected high-risk locations in southern Somalia. The results of tests on the cattle sera showed a progressive decline in rinderpest antibody prevalence, while the sera of warthogs sampled in 2006 and 2009 were negative for rinderpest antibodies, confirming the absence of rinderpest virus circulation in the warthog populations in the areas sampled. These results were consistent with the results of tests on 1,228 wildlife sera collected from various locations in neighbouring Kenya where rinderpest had not been diagnosed in wildlife since 2001. Based on this evidence, Somalia was declared free from rinderpest in 2010.**

KEYWORDS **Rinderpest – Somalia – Surveillance – Vaccination.**

INTRODUCTION

The Federal Republic of Somalia covers an area of 638,000 km² within the Horn of Africa region between longitude 41°E and 51°24′E and latitude 12°00′ N and 1°40′S. The country shares international borders with Djibouti, Ethiopia and Kenya (Fig. 1). It is bordered to the east and north by the Indian Ocean and has the longest coastline in Africa – 3,025 km.

The landmass comprises mainly arid and semi-arid rangelands and pastoralism is the most appropriate form of land use.

The collapse of the Somali state in January 1991 resulted in the destruction of public and private institutions. Efforts to rebuild operational government institutions started in 1991 with the self-declaration of independence by Somaliland in north-western Somalia. In 1998, Puntland in north-eastern Somalia, declared itself an autonomous regional state of Somalia. Central and southern Somalia remained without functional institutions until 2004 when the establishment of the Transitional Federal Government of Somalia renewed hope that Somali public institutions could be revitalised. However, continued political conflict and the attendant insecurity hampered the operations of the Veterinary Department established by the Transitional Federal Government within the Ministry of Livestock, Forestry and Range. The restoration of these institutions to their full functional capacities was seen as a long-term support process. In the interim, donor-funded programmes implemented through international agencies and non-governmental organisations (NGOs) enabled disease surveillance and response initiatives that supported the progressive elimination of rinderpest virus infection from Somalia.

The livestock sector is the backbone of the Somali economy and provides the main source of Somali livelihoods, engaging about 55% of the population in livestock production. The majority of cattle are reared in central and southern Somalia in the nomadic production system, which relies on rangeland grazing and browsing to sustain livestock.

FIG. 1
COUNTRIES NEIGHBOURING SOMALIA
Source: United Nations, 2011 (1)

HISTORY OF RINDERPEST AND RINDERPEST CONTROL IN SOMALIA

Apart from the 1887 African pandemic, Somalia suffered a severe outbreak in 1928, but rinderpest had been brought under a degree of control by 1930. From 1939 to 1953, however, there was no effective control, and between those dates rinderpest was considered to be widespread in the country and there were intermittent epidemics.

Somalia was involved in the Joint Programme 15 (JP15) campaign from 1968 to 1973, which eliminated rinderpest from the country and no outbreaks were recorded between 1976 and 1982 although subsequent participatory epidemiology results revealed the continuous presence of subacute rinderpest in Somalia between 1980 and 1993, explaining the recognition (but not reporting) of rinderpest in southern Somalia in 1981. This lead to a ban on the importation of cattle from Somalia by Saudi Arabia as a result of which the Food and Agriculture Organization of the United Nations (FAO) project TCP/SOM/2311 (US$250,000) 'Emergency Assistance for Rinderpest Vaccination Campaign', was implemented from October 1983 to December 1984. Between 1985 and 1990, there were again no reports of rinderpest in Somalia. However, published information and reports from the Somali Pan-African Programme for the Control of Epizootics (PACE; Chapter 4.3; Chapter 4.6) and the Somali animal health services projects highlighted suspected rinderpest outbreaks within Somalia, with confirmed outbreaks in the contiguous areas of north-eastern Kenya that may have affected the status of rinderpest in Somalia between 1983 and 2007.

After the completion of the JP15 vaccination campaign in 1973, rinderpest vaccine was used in a sporadic manner within Somalia (see Table I).

In early 1999, there were reports of an outbreak among cattle in southern Somalia and high mortality among warthogs. In the Lower Juba region, clinical signs were observed in cattle, which were suggestive of mild rinderpest, but no deaths were observed. In 1999, vaccination ceased in Gedo and Lower Juba regions; vaccination in Middle Juba region had ceased in 1993.

Between October and November 2001 an outbreak of mild rinderpest was detected and confirmed (by genetic characterisation) in neighbouring Kenya in buffalo in the Meru National Park. In February 2003, participatory disease surveillance was carried out in Middle Juba region. Some cases with signs resembling mild rinderpest were rinderpest positive according to the Clearview penside test, developed by the World Reference Laboratory, Pirbright, United Kingdom of Great Britain and Northern Ireland. However, these results were not confirmed by polymerase chain reaction (PCR) testing at the Kenya Agricultural Research Institute Muguga laboratory in Kenya.

The last vaccination against rinderpest was carried out in Afmadow district of Lower Juba region in southern Somalia in December 2003. This followed positive laboratory results for rinderpest virus RNA in samples collected from suspected clinical cases of rinderpest in October 2003 at Ruga in the contiguous Garissa district of north-eastern Kenya (see Chapter 4.5.12). As a precautionary measure, a total of 50,000 cattle was vaccinated in Afmadow to complement the focused vaccinations of 150,000 cattle in the neighbouring Garissa and Wajir districts of Kenya that were carried out by the Kenyan Department of Veterinary Services.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Passive disease surveillance

Although Somalia lacked a central Veterinary Service during the later stages of the eradication of rinderpest, a passive disease surveillance system nevertheless existed. Pastoralists reported suspicions of disease outbreaks to the veterinary professionals, who in turn reported the disease events to the Somali livestock professional associations, international NGOs and United Nations agencies supporting disease control interventions. The pastoralists further volunteered information on historical trends in the disease through their active participation in focus group discussions and semi-structured questionnaire interviews. After the end of PACE in Somalia, a network of disease reporting focal points comprising community animal health workers (CAHWs), public and private sector veterinary professionals and the livestock professional associations was established in 2006. With support from the European Union, the Somali Animal Health Services Project (SAHSP) enabled the continuous recording and passive reporting of livestock diseases throughout Somalia.

Purposive surveillance

During October and November 2003, a total of 56 sera, 35 lymph node biopsies and 22 eye swabs were collected from cattle with stomatitis–enteritis syndromes. Five sera tested positive for rinderpest virus antibodies, while all the lymph node biopsies and eye swab samples were negative for rinderpest virus, peste des petits ruminants and bovine viral diarrhoea viruses were detected following specific PCR tests.

In January 2006, a participatory disease search was undertaken in central and southern Somalia. Animals with suspicious clinical signs of mild rinderpest were sampled for virus testing. All 221 eye swabs and lymph node biopsies tested negative for

TABLE I
RINDERPEST VACCINATION FIGURES FOR SOMALIA

Year(s)	No. cattle vaccinated	Comments
1989	450,000	PARC
1992–1993	230,000	Vaccinations in Somaliland and parts of central Somalia by the International Committee of the Red Cross (ICRC)
1994	140,000	Vaccinations in Gedo region by ICRC
1996–1997	227,408	Vaccinations in Gedo region by Terra Nuova
1998–1999	127,396	Vaccinations in Gedo and Trans Juba regions by Terra Nuova
2003	50,000	Vaccination undertaken in Afmadow district (Lower Juba region) following confirmation of rinderpest virus infection in cattle in the neighbouring Garissa district in Kenya

rinderpest virus. No suspicions of rinderpest were reported during the surveys, but the pastoralists identified rinderpest as an important historical disease and some recalled that the last outbreaks occurred in 2002.

A survey conducted on wildlife in the Kulbiow area of Badhade district and in the Afmadow district of Lower Juba region between August and September 2006 revealed no suspicions of rinderpest in the abundant warthog population. Serum samples collected from 33 warthogs captured in the survey were negative for rinderpest antibodies.

A country-wide declaration of provisional freedom from rinderpest was made in February 2007.

In June 2008, investigations of stomatitis–enteritis syndromes in sheep, goats and cattle were carried out in Middle Juba region of southern Somalia. Four eye swab samples and 25 sera collected from suspect and in-contact cattle all tested negative for evidence of rinderpest virus infection.

No suspected cases of rinderpest were reported or observed during participatory disease surveillance conducted in March and April 2009 in Gedo, Middle Juba and Lower Juba regions of southern Somalia. However, 543 sera, 4 lymph node aspirates, 89 eye and nasal swabs and 3 mouth scrapings were collected from cattle showing signs of lacrimation and stomatitis. None of these samples indicated rinderpest.

Serosurveillance

In 1998–1999 clinically mild cases of suspected rinderpest were detected in several locations of Afmadow district. In Lower Juba, Middle Juba and Gedo regions of southern Somalia 1,693 serum samples were tested using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3) and 152 were found to be antibody positive (8.9%).

Between 1999 and 2001 serological investigations carried out on unvaccinated young stock aged one to three years showed positive results in various locations in the Hiran and Galgadud regions of central Somalia.

During 2002-2003 a cross-sectional serosurvey based on a two-stage cluster sampling design showed rinderpest seroprevalence in Gedo (18%), Middle Juba (16%) and Lower Juba (17%) regions.

In 2005 a cross-sectional survey demonstrated seropositive results in the same cluster of Gedo (5%), Middle Juba (2%) and Lower Juba (4%) regions. The seroprevalence percentages were lower than those detected in the 2002–2003 survey.

During July and August 2006 a random survey was carried out in southern Somalia concurrently with similar surveys in the Kenyan and Ethiopian parts of the Somali ecosystem. The survey of the entire ecosystem was coordinated by the Somali Ecosystem Rinderpest Eradication Coordinating Unit (SERECU; Chapter 4.4) within PACE. While Kenya and Ethiopia reported zero seroprevalence, the results from testing 8,048 samples collected in Somalia showed some seropositivity especially in Gedo (2.6%), Middle Juba (2.9%) and Lower Juba (1.2%) regions, while Lower Shabele, Bay and Bakool regions in southern Somalia and Middle Shabele region in central Somalia had antibody prevalences of 0.7%, 0.07%, 0.35% and 0.4%, respectively. During this survey, rumours of an outbreak of a stomatitis–enteritis syndrome in cattle at Kulbiow in Badhade district of Lower Juba region were investigated. A total of 62 samples of eye swabs and post-mortem tissues collected from suspect cattle all tested negative for rinderpest virus.

Tests on 3,075 sera collected in March 2007 during a follow-up random serological survey covering Gedo, Lower Juba and Middle Juba regions in southern Somalia detected an overall rinderpest seroprevalence of 2.57%. Gedo region had the highest seroprevalence (4.25%) followed by Lower Juba (1.89%) and Middle Juba (1.67%) regions. No suspicions of rinderpest were reported.

During the consultation meeting of the Global Rinderpest Eradication Programme (GREP; Chapter 6.1) held in Rome in September 2007, concerns were raised about the persistence of antibodies in southern Somalia. In December 2007, a targeted serological survey was carried out in Gedo, Middle Juba and Lower Juba regions where clusters of seropositive cattle herds were repeatedly detected between 2002 and 2006. All of the 602 samples collected from cattle aged between two and three years old tested negative for rinderpest virus antibodies.

Between September 2008 and January 2009, a random serological survey was carried out countrywide (in Somaliland, Puntland and central and southern Somalia). Following the consistent decline in rinderpest seroprevalences in the Gedo, Middle Juba and Lower Juba regions between 2002 and 2007, the sampling design was reviewed in consultation with the African Union Interafrican Bureau for Animal Resources (AU-IBAR) and SERECU. A total of 7,233 sera was collected and only 18 of these sera tested positive for rinderpest virus antibodies. Low rinderpest antibody prevalences were detected in Lower Shabelle (0.74%), Bay (0.14%), Gedo (0.23%), Middle Juba (1.47%) and Lower

TABLE II
RESULTS OF SEROSURVEILLANCE IN SOMALIA BETWEEN 2000 AND 2009

Year(s)	No. samples	Populations surveyed	Estimated population	Survey results
2002-2003	10,448	Gedo, Middle Juba, Lower Juba, Lower Shabelle, Middle Shabelle, Bay, Bakool, Hiran, Galgadud and Mudug	3.9 million	Seroprevalences ranging from 2.5% to 17% detected in unvaccinated populations
2004	1,658	Puntland and Somaliland	745,000	No seroprevalences detected
2005	6,041	Gedo, Lower Juba and Middle Juba	2 million	Seroprevalences ranging from 2% to 5% detected in unvaccinated populations
2006	10,316	All Somalia	3 million	Seroprevalences ranging from 1.02% to 3% detected in unvaccinated populations
2007	3,677	Gedo, Lower Juba and Middle Juba	2 million	Seroprevalences ranging from 1.5% to 2% detected in unvaccinated populations
2008-2009	7,801	Somaliland, Puntland, central and southern Somalia	4.6 million	Seroprevalences ranging from 0% to 1.47% in unvaccinated populations

Juba (0.23%) regions in southern Somalia, while Hiran region in central Somalia had a prevalence of 0.15%. Tests on 1,217 sera collected in Somaliland were all negative for the presence of rinderpest virus antibodies.

The above results are recapitulated in Table II.

To instil confidence in the surveillance undertaken in the Somali ecosystem over the previous five years, FAO (GREP) and AU-IBAR (SERECU) commissioned a study. These researchers used stochastic scenario tree modelling to quantitatively estimate the sensitivity of seven different components of the rinderpest surveillance system in Kenya, Somalia and Ethiopia, from 2004 to 2008, including passive disease reporting and serosurveys for both livestock and wildlife, livestock market surveillance, participatory disease surveillance and zero reporting systems. The researchers (2, 3) found that by combining evidence over multiple time periods, the surveillance system generated a probability of greater than 99% that the three countries did not have a single infected herd. Uneven coverage of the population suggests that caution was warranted, but even in those parts of the population with lowest confidence (wildlife, central Somalia), the normally rapid spread of rinderpest in naive populations meant that, after five years, its chance of remaining hidden was very low (see Chapter 4.4).

Wildlife surveillance

A survey conducted on wildlife in the Kulbiow area of Badhade district and in Afmadow district of Lower Juba region in August and September 2006 revealed no suspicions of rinderpest in abundant warthog populations in these areas. Serum samples collected from 33 warthogs captured in the survey were all negative for rinderpest antibodies. Serological surveys targeting warthog populations in Lower Juba, Middle Juba and Gedo regions were carried out in March and April 2009 and a total of 58 sera was collected from captured warthogs. The samples tested negative for rinderpest antibodies. No clinical signs of rinderpest were observed in any of the captured warthogs.

Somalia also relied heavily on the results of the extensive wildlife surveys conducted in neighbouring Kenya between 1995 and 2009, which clearly demonstrated the absence of rinderpest virus circulation in wildlife populations after 2003. There were no positive sera in wildlife and therefore there was no backtracing of the wildlife serology results.

DOSSIER

In 2009 Somalia placed the above results in a dossier declaring that:

- No clinical rinderpest had been detected for at least seven years.
- No evidence of rinderpest virus infection had been detected for at least five years.
- No rinderpest vaccines had been used for at least six years.
- The country had operated both clinical surveillance and disease reporting systems for rinderpest adequate to detect clinical disease if it had been present.
- All clinical evidence suggestive of rinderpest was investigated by field and laboratory methods (including serological assessment) to refute a possible diagnosis of rinderpest and Somalia should be recognised as a rinderpest-free country. This view was endorsed by the World Organisation for Animal Health (OIE) Commission (4).

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CHAPTER 4.5.19

SUDAN

B.T.M. TAHA

Former Undersecretary, Federal Ministry of Animal Resources and Chief Veterinary Officer, Khartoum, Sudan

SUMMARY **The demonstration of freedom described in this document is related to the country as it stood after the comprehensive peace agreement of 2008 and before the creation of the Republic of South Sudan in 2011. In the early 1960s, Sudan experienced very high numbers of rinderpest outbreaks, which were reduced after participation in Joint Programme 15 (JP15). A resurgence in the number of outbreaks in Korfodan and Dongola provinces in 1983/4 created conditions that allowed the virus to move westwards into Chad. The situation in Sudan was improved firstly under the Pan-African Rinderpest Campaign (PARC) and subsequently under Operation Lifeline Sudan. The final outbreak attributable to lineage 1 rinderpest virus occurred in Torit County, Equatoria province, in 1998. Clinical and serological surveillance undertaken in the north and south of the country from 2005 to 2007 demonstrated that the cattle population was free of rinderpest.**

KEYWORDS **1983/1984 – Clinical surveillance – Last confirmed lineage 1 outbreak – North Kordofan – Rinderpest history – Serosurveillance – Sudan – Vaccination.**

INTRODUCTION

Sudan is the largest country in Africa, covering an area of about 2.5 million km^2. The country lies in the tropical zone between latitudes 3° and 22°N and longitudes 22° and 38°E and is bordered by nine countries, including Egypt and Libya to the north, Chad and Central African Republic to the west, the Democratic Republic of the Congo, Uganda and Kenya to the south and south-west, and Ethiopia and Eritrea to the east.

The livestock sector is an important contributor to the overall national economy. With its vast rangeland area and large animal population, the sector contributes approximately 25% to gross domestic product (GDP) and provides over 20% of the country's foreign exchange earnings. The sector provides employment and sustenance to about 40% of the population, not only nomadic communities but also livestock traders, exporters, animal product retailers, fodder sellers and hide and skin processors.

When Sudan was declared rinderpest free in 2008, the Comprehensive Peace Agreement had established a Federal Government of National Unity and a Government of Southern Sudan (GOSS). The Federal Ministry of Animal Resources and Fisheries (FMAR&F) of the Government of National Unity, in collaboration with the Ministry of Animal Resources and Fisheries of the GOSS, was supervising veterinary activities at the national level.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN SUDAN

Rinderpest first entered the country through the eastern border in 1889 at the outset of the Great African Rinderpest Pandemic (Chapter 2.2), remaining endemic within the country thereafter. One of the first indicators of the extent of the outbreaks was that obtained from the Sudanese authorities during the period 1960–1967, prior to the extension of JP15 (see Chapter 4.1) to eastern Africa (1) (see Chapter 4.6). At this time, the greatest number of outbreaks occurred in North and South Kordofan, North Darfur, Northern province, Khartoum province, Upper Nile province and Blue Nile province, the last two having a common border with Ethiopia.

In the 1930s, the Sudan Veterinary Service produced an inactivated rinderpest vaccine, which was popular with cattle owners. The goat-adapted rinderpest vaccine was introduced from Kenya in 1949. From 1968 onwards, locally produced tissue culture rinderpest vaccine (TCRV) Kabete 'O' strain was used. During the mass vaccination campaign JP15, phases IV (1968–1971) and VI (1973–1976), outbreak numbers were greatly reduced. For a brief period, it appeared that JP15 might have eliminated rinderpest from the cattle in Sudan, as no outbreaks were reported between 1972 and 1974 (although it should be noted that rinderpest was isolated from a reedbuck and an oribi in Dinder National Park in 1972 [2]).

After JP15, vaccinations continued, the peak year for rinderpest control being 1976, when over 4 million cattle were vaccinated. Vaccination numbers then dropped, and outbreak numbers began to increase again. Between 1975 and 1979, almost all of the clinically diagnosed and confirmed cases of rinderpest were east of the Blue Nile. In 1982, Sudan reported to the World Organisation for Animal Health (OIE) that there were a number of outbreaks involving North and South Kordofan and North Darfur and a number of outbreaks around Dongola, and that, while the outbreaks around Dongola were associated with motorised transport, the outbreaks in North Darfur were associated with nomadic movements (see Chapter 4.1 for a reproduction of the report to the OIE). The outbreaks in North Kordofan were the first since 1971. In 1983–1984, an epidemic of rinderpest killed almost 500,000 cattle in Darfur and Kordofan. A Food and Agriculture Organization of the United Nations (FAO) emergency vaccination campaign ensued and stabilised the disease situation in the run up to the commencement of PARC.

Further spread of rinderpest from Korfodan became part of an epidemic that spread across Chad and into northern Cameroon (in trade cattle) to reach the Dikwa control post in Borno State, eastern Nigeria in 1982 – see Chapter 2.4.

In 1989, the Government of Sudan launched PARC (see Chapter 5.4) in Sudan, the first phase of which consisted of a two-year immunisation programme of approximately 21 million cattle. In northern Sudan, the last outbreak of rinderpest was reported in Lagawa province, West Kordofan state, in 1991.

Rinderpest in southern Sudan

There was a civil war in southern Sudan between 1983 and 2005. In 1989, Operation Lifeline Sudan (OLS), a consortium of United Nations agencies and non-governmental organisations, started to provide emergency relief and humanitarian assistance to the war-affected communities; activities included assistance for food relief, water, human health, education, fisheries, crop production and animal health. The OLS southern sector worked in those areas of southern Sudan that were then controlled by rebel groups and gained access to these areas via Kenya and Uganda. The OLS northern sector worked in the areas of southern Sudan that were at that time under the control of the government.

The OLS programme assisted with the overall control and eradication programmes for rinderpest and other priority diseases in southern Sudan. For detailed accounts, see Chapters 3.9 and 5.13.

Although rinderpest had ceased to occur in northern Sudan in 1991, outbreaks were widespread in southern Sudan throughout the early 1990s. Rinderpest vaccination campaigns carried out by the OLS livestock programme from 1993 to 2002 drastically reduced the number of these outbreaks. Vaccination in the southern sector was primarily carried out by teams aligned with the OLS southern sector; after 1996, they were supplemented by teams from the OLS northern sector (vaccination figures are shown in Chapter 4.6. After 1993, TCRV was replaced by a thermo-stable rinderpest vaccine imported from Botswana until vaccination of cattle ceased in June 2002. The thermo-stable vaccine was mainly used in remote areas and in areas where maintenance of the cold chain was difficult. The thermo-stable vaccine proved to be very practical when used by community-based animal health workers (CAHWs), especially in southern Sudan in the community-based delivery system (Fig. 1).

FIG. 1
A GROUP OF COMMUNITY-BASED ANIMAL HEALTH WORKERS TRANSPORTING ANIMAL VACCINES, NORTHERN BAHR EL GHAZAL STATE, SOUTHERN SUDAN
Courtesy of the author

The network of CAHWs and their veterinary coordinators played very important roles in rinderpest control and surveillance. Through their regular contact with the livestock keepers, they became key to the identification of the last foci of rinderpest. Surveillance teams were accepted more readily by the livestock keepers when they recognised their own animal health workers in the team.

After the widespread outbreaks of 1993 to 1995, subsequent vaccination reduced the number of rinderpest reports, most of which were localised and unconfirmed. In early 1998, the Torit County Veterinary Coordinator reported an outbreak of rinderpest-like disease affecting young cattle in the Lopit Hills of Eastern Equatoria (Fig. 2).

FIG. 2
LAST RINDERPEST OUTBREAK, LOPIT HILLS, TORIT COUNTY, EASTERN EQUATORIA

Source: United Nations, 2020 (3)

Investigations by the United Nations Children's Fund (UNICEF), Global Aid for Africa and PARC found classic clinical signs of rinderpest in calves aged 6 to 12 months and a high case fatality rate. Samples submitted to the Pirbright Institute confirmed the cause to be rinderpest lineage 1 virus. A vaccination campaign to prevent the spread of the disease was rapidly mounted to cover Lopit and neighbouring areas in Torit County, as well as Budi County to the east and Labone to the west, where suspected clinical cases had also been seen. The source of the Lopit outbreak was suspected to be Toposa bulls from Riwoto, Kapoeta, that had been bartered for heifers. This outbreak would prove to be the last laboratory-confirmed rinderpest outbreak in southern Sudan and the last confirmed lineage 1 rinderpest outbreak anywhere.

DECLARATION STRATEGY

Sudan made its first declaration of provisional freedom from rinderpest for the northern part of the country in 1996, extending the zone included in this declaration in 2002 (Fig. 3), and then again in 2003 and 2004.

Sudan declared freedom from disease in 2004, again on a zonal basis, but in 2006 it converted this to a country-wide declaration (4).

CLINICAL AND SEROLOGICAL SURVEILLANCE

Clinical surveillance

The National Disease Reporting System

In 1999, 'localities' were identified as the reporting units in the northern part of the country and 'counties' as the reporting units in the southern part of the country. In 2007, all localities and 79 counties were included in the monthly disease reporting system. From 2003 to 2005, the existing disease reporting system was upgraded by introducing the Animal Resources Information System (ARIS), supported by the Pan-African Programme for the Control of Epizootics (PACE), to all 25 federal states of Sudan, thus improving the linking and exchange of relevant data between states and the FMAR&F. Rinderpest was not reported between 1999 and 2007.

Case reports (or rumours) of stomatitis–enteritis were subject to first-hand investigations. Between 2005 and 2006, 37 such incidents were investigated in southern Sudan, with laboratory backing provided by the Kenya Agricultural Research Institute, Muguga. Foot-and-mouth disease (FMD) was a common diagnosis, but rinderpest was not detected.

Active clinical surveillance

Active clinical surveillance was undertaken in high-risk areas, such as livestock markets, check points, areas close to wildlife reserves and border crossings, to examine herds for clinical signs of rinderpest.

As shown in Table I, clinical surveillance performed from 2004 to May 2007 involved 262,179 animals from all federal states in the north (nine) and three states in the south. Out of the 242,690 animals visually inspected, 2,486 (1.02%) were clinically examined for rinderpest. The number of animals that showed signs of ocular discharge, nasal discharge,

FIG. 3

COUNTRY PROGRESS: RINDERPEST ERADICATION STRATEGIES

Final boundary between the Sudan and South Sudan has not yet been determined

Source: D-maps, 2020 (6), modified to indicate rinderpest eradication strategies

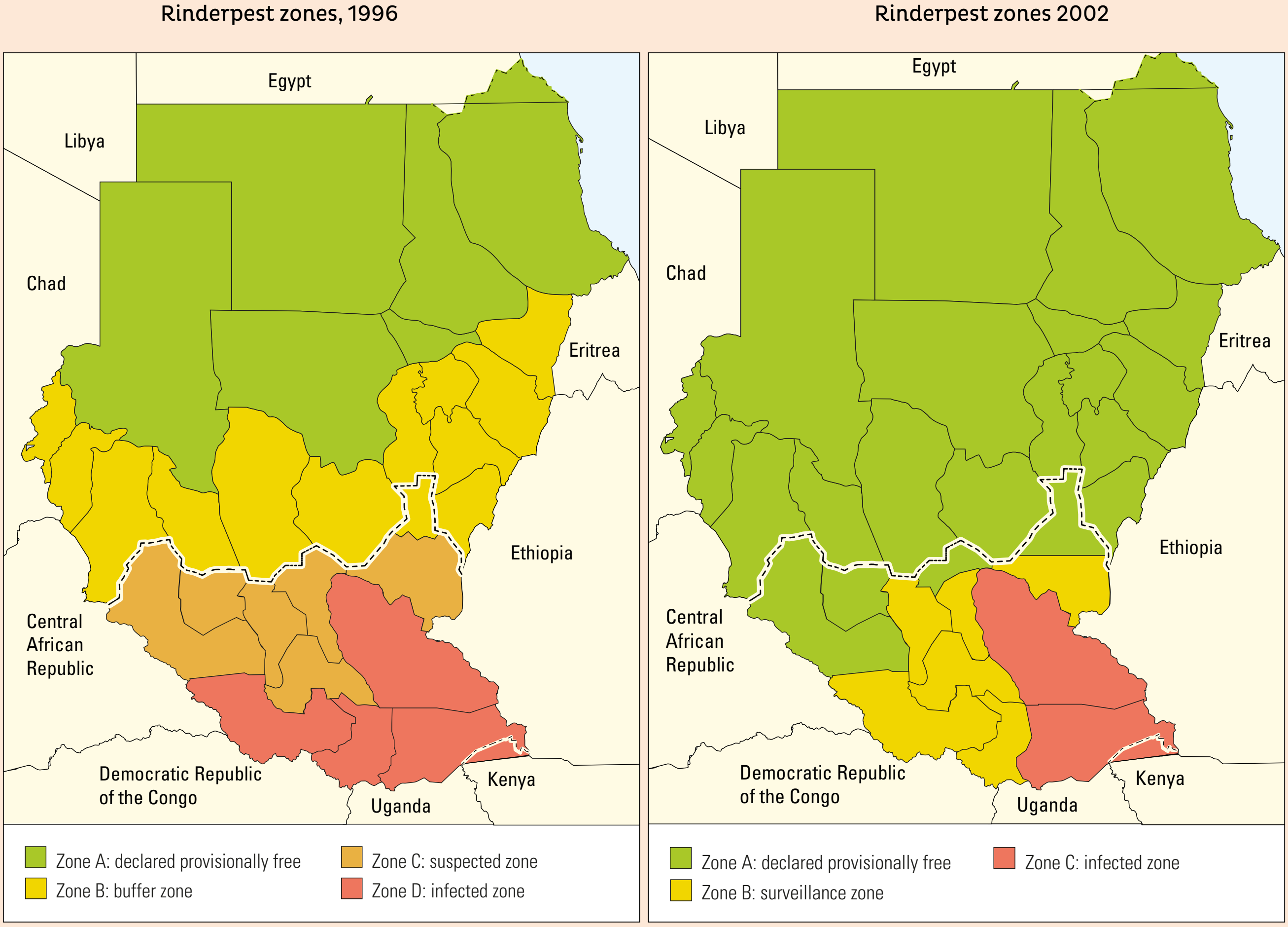

TABLE I

RESULTS OF RANDOM CLINICAL SURVEILLANCE PERFORMED FROM 2004 TO MAY 2007

Year	No. of states	No. of localities/ villages surveyed	Total no. of animals	No. of animals visually examined	No. of animals clinically examined	Clinical signs				Clinical diagnosis
						OD	ND	ML	DI	
2004	7	18	51,850	50,590	1,260	93	36	37	0	FMD in five localities in Upper Nile and western Bahr el Ghazal state
January to June 2005	20	316	44,999	44,944	55	25	38	35	3	FMD in White Nile and West Darfur; East Coast fever in North Kordofan, Unity, western Bahr el Ghazal and northern Bahr el Ghazal; babesiosis in Khartoum and North Darfur; anaplasmosis in Upper Nile
Subtotal 1	**27**	**334**	**96,849**	**95,534**	**1,315**	**118**	**74**	**72**	**3**	
July 2005 to May 2007	13	38	165,590	147,156	1,171	3	11		179	Endoparasites and pneumonia in White Nile, West Kordofan and South Kordofan
Subtotal 2	**13**	**38**	**165,590**	**147,156**	**1,171**	**3**	**11**	**0**	**179**	
Total	**40**	**372**	**262,179**	**242,690**	**2,486**	**121**	**85**	**72**	**182**	
	in percent		**100**	**92.6**	**1.02**					

DI, diarrhoea; ND, nasal discharge; ML, mouth lesions; OD, ocular discharge mouth lesions and diarrhoea is presented in Table I. Rinderpest was not encountered.

In the southern states, clinical surveillance was performed by animal health auxiliaries (AHAs) and veterinarians in cattle camps and at livestock markets. From May 2002 to June 2004, a method for carrying out livestock keeper interviews and clinical surveillance was introduced. AHAs carried out simple interviews with one or more livestock keepers and examined the herd for clinical signs of disease. Livestock keepers were asked about their current disease problems, the causes of any deaths in the previous month and the last time they observed rinderpest in their cattle camp. A measure of the surveillance is given in Table II below.

It was very rare for rinderpest to be mentioned as a problem. In the few cases when it was mentioned, the livestock keeper said that it was not currently present but he feared that it would return to the area. As this area covered the whole of southern Sudan, and as no rinderpest outbreaks were detected, the Veterinary Services were convinced that there were no remaining foci of rinderpest and thus discontinued the activity in June 2004 while continuing with other more targeted active surveillance, such as participatory disease surveillance (PDS).

Participatory disease surveillance

Supported by the European Commission-funded PACE Sudan Project, a total of 45 veterinarians from the various states and headquarters were trained by international trainers on PDS for rinderpest (Fig. 4). Consequently, PDS teams were established in 17 states, to carry out PDS work.

From September 2003 to June 2007, a total of 46 PDS missions were carried out. The PDS teams conducted 902 interviews with 7,311 herders in 701 villages and cattle camps with an estimated cattle population of 766,906 animals (see Table III). Approximately, one quarter were clinically examined.

The PDS teams observed some stomatitis–enteritis cases that were consequently investigated, sampled and tested for rinderpest using the rinderpest Clearview penside test. Rinderpest was not diagnosed.

TABLE II
CATTLE SURVEYED IN CATTLE CAMPS FROM MAY 2002 TO JUNE 2004

Year	No. cattle camps visited	No. supervisors sending forms	No. cattle surveyed
May to December 2002	923	155	709,861
2003	2,138	227	1,519,810
January to June 2004	572	106	348,370
Total	**3,633**	**488**	**2,578,041**

TABLE III
OVERVIEW OF PARTICIPATORY DISEASE SURVEILLANCE MISSIONS CONDUCTED FROM SEPTEMBER 2003 TO JUNE 2007 (NUMBERS)

Period	Area/state	PDS missions	Ethnic groups	Villages/camps	Interviews	Herders	Cattle
September 2003 to June 2005	20 states of stratum A	20	88	310	357	2,882	135,043
July 2005 to June 2007	13 states of stratum A [(a)]	13	82	158	158	1,214	60,700
Subtotal 1	**33**	**33**	**170**	**468**	**515**	**4,096**	**195,743**
February 2003 to December 2004	Eight states of stratum B [(b)]	21	41	207	337	2,881	278,763
2005 to June 2007	Five southern states of stratum B	6	9	26	50	334	39,147
Subtotal 2	**13**	**27**	**50**	**233**	**387**	**3,215**	**317,910**
Total	**46**	**60**	**220**	**701**	**902**	**7,311**	**513,653**

[(a)] Stratum A: north and central states

[(b)] Stratum B: southern states

When asked to list the current disease problems in their herds, very few informants named rinderpest as a problem. However, on further probing it was clarified that rinderpest was not currently present but that they feared its recurrence. No clinical cases of rinderpest were seen, although a range of other common diseases were reported.

Serological surveillance results

Two rounds of random serosurveillance were carried out. The country was divided into stratum A (north of a boundary between Western Equatoria, the Jur river and latitude 10° N) and stratum B (south of stratum A). The first round of the random serosample survey was carried out in the northern and central states of Sudan (stratum A) in 2005. A total of 315 randomly selected villages in 20 federal states or parts of states of stratum A were surveyed during May and June 2005. A total of 7,914 serum samples were collected, and 6,324 samples were tested by enzyme-linked immunosorbent assay (ELISA) at FMAR&F-Khartoum and the Central Veterinary Research Laboratory (CVRL). A similar random serosample survey was conducted in the southern states (stratum B) of Sudan. The second round of random serosample survey in strata A and B was conducted in 2006.

FIG. 4
PDS ACTIVITIES IN WEST KORDOFAN
Courtesy of the author

Of the samples collected during the first round of rinderpest serosurveillance in stratum A, 6,392 cattle sera were tested. In total, 23 samples showed positive competitive ELISA (c-ELISA; see Chapters 3.3 and 6.3) results (0.36%), and 6,473 were negative (99.64%) (see Table IV below).

Epidemiological analysis of the results indicated that the results were not adequate to conclude that the surveyed population was free from disease at

TABLE IV
STRATUM A: LABORATORY RESULTS FOR THE FIRST ROUND OF RINDERPEST RANDOM SEROSURVEILLANCE 2005

Stratum no.	State	Total no. of sera tested	Result			
			No. negative	No. positive	% Negative	% Positive
1	Northern	60	60	0	100	0
2	Red Sea	20	20	0	100	0
3	River Nile	20	20	0	100	0
4	Khartoum	40	40	0	100	0
5	North Kordofan	120	120	0	100	0
6	North Darfur	120	120	0	100	0
7	Kassala	80	80	0	100	0
8	Upper Nile (north of latitude 10° N)	140	140	0	100	0
9	Gedarif	200	200	0	100	0
10	Sinnar	300	294	6	97.96	2.04
11	South Kordofan	500	500	0	100	0
12	White Nile	660	653	7	98.93	1.07
13	Gezeira	440	438	2	99.55	0.45
14	West Darfur	760	758	2	99.74	0.26
15	Blue Nile	780	780	0	100	0
16	South Darfur	780	780	0	100	0
17	West Kordofan	640	639	1	99.84	0.16
18	Unity (northern part)	171	171	0	100	0
19	Western Bahr el Ghazal	235	230	5	97.88	2.12
20	Northern Bahr el Ghazal	326	326	0	100	0
Total / overall		**6,392**	**6,369**	**23**	**99.64**	**0.36**

the expected minimum herd prevalence level of 1%. However, these results were adequate to reject the hypothesis that the surveyed population had a disease prevalence of 1% or more. Backtracing suggested that many of the positive animals might have been vaccinated.

Stratum A: results of the second random serosurvey for rinderpest in 2006

During the second random rinderpest serosurvey, which was held from March to August 2006, 6,606 serum samples and duplicate samples were tested using the c-ELISA. Only one sample tested positive for rinderpest antibodies, while the other 6,605 sera showed negative results (see Table V).

It was concluded that the probability of observing 1 reactor in a sample of 6,606 animals indicated an absence of rinderpest.

TABLE V
STRATUM A: SECOND ROUND OF RANDOM SAMPLE SEROSURVEY FOR RINDERPEST, CONDUCTED IN 2006

State	Total no. of sera tested	Result			
		No. negative	No. positive	% Negative	% Positive
Northern	60	60	0	100	0
Red Sea	20	20	0	100	0
River Nile	20	20	0	100	0
Khartoum	40	40	0	100	0
North Kordofan	120	120	0	100	0
North Darfur	118	118	0	100	0
Kassala	80	80	0	100	0
Upper Nile (north of latitude 10 ° N)	119	119	0	100	0
Gedarif	200	200	0	100	0
Sinnar	300	300	0	100	0
South Kordofan	500	500	0	100	0
White Nile	660	660	0	100	0
Gezeira	440	440	0	100	0
West Darfur	758	758	0	100	0
Blue Nile	780	780	0	100	0
South Darfur	778	777	1	99.87	0.13
West Kordofan	640	640	0	100	0
Unity (northern part)	149	149	0	100	0
Western Bahr al Ghazal	287	287	0	100	0
Northern Bahr al Ghazal	387	387	0	100	0
Warap	150	150	0	100	0
Total /overall	**6,606**	**6,605**	**1**	**100**	**0**

Stratum B: results of the first random serosurvey for rinderpest in 2005/2006 and 2007

A total of 7,998 serum samples were tested twice for rinderpest antibodies as part of the first round in stratum B; the first-round results are presented in Table VI.

It was concluded that the low incidence of sero-positives came from a rinderpest-free population. Nevertheless, a second round was undertaken in 2007, when 7,782 serum samples were tested. Four sera (0.05%) showed positive c-ELISA results (Table VII), substantiating the conclusion of the first survey.

Purposive serosurvey

In addition to the two rounds of random serosample surveys conducted in stratum A and stratum B, the veterinary field mission teams also performed purposive surveillance in identified risk areas, in areas of former rinderpest rumours, at cattle markets, on livestock movement routes and in wildlife concentration areas.

The states of Red Sea and Kassala were selected because of substantial transboundary livestock movement between them and Eritrea and Ethiopia (Ethiopian cattle enter Kassala state via Gedarif state). The results are presented in Table VIII.

The states of Sinnar, Gedarif and Blue Nile were selected for purposive serosurveillance, because they bordered Ethiopia and had significant wildlife populations. The Fulani pastoralists move with their cattle between Ethiopia and the Sudan. The results are presented in Table IX.

The states of Gezeira and White Nile were selected because positive samples were detected in the 2005 serosurvey and because they have main markets where a large number of cattle from different areas congregate. These markets acted as check points for livestock trade. The results are presented in Table X.

The states of South and West Kordofan were selected because the last confirmed rinderpest outbreak was in Lagawa in 1991; in addition, there is substantial seasonal migratory movement and contact with wildlife. The results are presented in Table XI.

South Darfur state was selected because of its significant wildlife populations. In addition, it is a state where livestock populations from different areas meet, and there is substantial cross border trans-boundary livestock movement from Chad and the

TABLE VI
STRATUM B: LABORATORY RESULTS FOR THE FIRST ROUND OF RINDERPEST RANDOM SEROSURVEILLANCE, 2005/2006

State	Total no. of sera tested	c-ELISA results			
		No. negative	No. positive	% Negative	% Positive
Upper Nile (southern part)	514	514	0	100	0.00
Unity (WU – southern part)	637	636	1	99.84	0.16
Jongolei	2,162	2,161	1	99.95	0.05
Warap	1,179	1,178	1	99.91	0.09
Lakes	1,520	1,520	0	100	0.00
Eastern Equatoria	995	994	1	99.90	0.10
Central Equatoria	906	906	0	100	0
Western Equatoria	85	85	0	100	0
Total / overall	**7,998**	**7,994**	**4**	**99.95**	**0.05**

TABLE VII
STRATUM B: LABORATORY RESULTS FOR THE SECOND ROUND OF RINDERPEST RANDOM SEROSURVEILLANCE, 2007

State	Total no. of sera tested	c-ELISA results			
		No. negative	No. positive	% Negative	% Positive
Upper Nile (southern part)	522	522	0	100	0.00
Unity (WU – southern part)	650	649	1	99.85	0.15
Jongolei	2,029	2,028	1	99.95	0.05
Warap	995	994	1	99.90	0.10
Lakes	1,532	1,531	1	99.94	0.06
Eastern Equatoria	968	968	0	100	0
Central Equatoria	986	986	0	100	0
Western Equatoria	100	100	0	100	0
Total / overall	**7,782**	**7,778**	**4**	**99.95**	**0.05**

TABLE VIII
DETAILS OF PURPOSIVE SEROSURVEILLANCE IN RED SEA AND KASSALA STATES, 2006-2007

State	Locality	No. of locations covered	No. of cattle present in the villages covered	No. of samples collected and tested	Results			
					No. positive	% Positive	No. negative	% Negative
Red Sea	Tokar	1	720	25	0	0	25	100
	Port Sudan	1						
Kassala	Kassala	1	560	50	0	0	50	100
	Sitteit	4						
	Atbara River	3						
Total / overall	**5**	**10**	**1,280**	**75**	**0**	**0**	**75**	**100**

TABLE IX

DETAILS OF PURPOSIVE SEROSURVEILLANCE IN GADARIF, SINNAR AND BLUE NILE STATES, 2006-2007

State	Locality	No. of locations covered	No. of cattle present in the villages covered	No. of samples collected and tested	Results			
					No. positive	% Positive	No. negative	% Negative
Gedarif	Gallabat East	10	2,334	50	0	0	50	100
Sinnar	Dindir	4	1,032	50	0	0	50	100
Blue Nile	Rosseires	9	6,464	105	2	1.9	103	98.1
	Gassan	6						
	Damazin	2						
Total /overall	**5**	**31**	**9,830**	**205**	**2**	**0.98**	**203**	**99.02**

TABLE X

DETAILS OF PURPOSIVE SEROSURVEILLANCE IN GEZEIRA AND WHITE NILE STATES, 2006-2007

State	Locality	No. of locations covered	No. of cattle present in the villages covered	No. of samples collected and tested	Results			
					No. positive	% Positive	No. negative	% Negative
Gezeira	Um El Goraa	2	7,840	50	0	0	50	100
	Gezeira East	2						
	Managil	1						
	Gezeira South	2						
White Nile	Aljabelein	3	1,870	100	0	0	100	100
	Kosti	5						
Total /overall	**6**	**15**	**9,710**	**150**	**0**	**0**	**150**	**100**

TABLE XI

DETAILS OF PURPOSIVE SEROSURVEILLANCE IN SOUTH KORDOFAN AND WEST KORDOFAN STATES, 2006-2007

State	Locality	No. of locations covered	No. of cattle present in the villages covered	No. of samples collected and tested	Results			
					No. positive	% Positive	No. negative	% Negative
South Kordofan	Kadogli	4	4,740	98	0	0	98	100
	Dilling	2						
	Rashad	1						
West Kordofan	Abyei	7	1,820	101	0	0	101	100
Total /overall	**4**	**14**	**6,560**	**199**	**0**	**0**	**199**	**100**

Central African Republic. Results are presented in Table XII.

In the western Bahr el Ghazal areas (Jur River County) to the east of Wau town, samples were collected from Fellata cattle present in an area where some rinderpest antibody-positive cattle had been detected in the random sample survey (2005). The results are presented in Table XIII.

For each of these purposive surveys, it was concluded that rinderpest was not circulating in the population surveyed.

Figure 5 illustrates the nature of the sample collection work.

Wildlife surveillance

A wildlife surveillance exercise was carried out in Boma National Park, Jongolei state, from February to March 2004 by Sudan People's Liberation Movement (SPLM) Directorate of Animal Resources and Fisheries, SPLM Directorate of Wildlife, Vétérinaires Sans Frontières (VSF) Belgium Rinderpest Project, VSF Germany, PACE

TABLE XII
DETAILS OF PURPOSIVE SEROSURVEILLANCE IN SOUTH DARFUR STATE, 2006-2007

State	Locality	No. of locations covered	No. of cattle present in the villages covered	No. of samples collected and tested	Results			
					No. positive	% Positive	No. negative	% Negative
South Darfur	Idalfirsan	6	2,650	100	0	0	100	100
	Riheid Albirdi	2						
West Darfur	Aljineina	3	3,230	101	0	0	101	100
	Forparagna	1						
	Garssila	1						
	Zalingi	3						
Total / overall	**6**	**16**	**5,880**	**201**	**0**	**0**	**201**	**100**

TABLE XIII
DETAILS OF THE SAMPLES COLLECTED IN WESTERN BAHR EL GHAZAL STATE

State	Locality	No. of locations covered	Date of survey	No. of cattle present in the villages covered	No. of samples collected and tested	Results			
						No. positive	% Positive	No. negative	% Negative
Western Bahr el Ghazal	Jur River county	2	November 2006	350	58	0	0	58	100
Total		**2**		**350**	**58**	**0**	**0**	**58**	**100**

FIG. 5
PURPOSIVE SEROSURVEILLANCE IN SOUTH DARFUR STATE IN MAY 2005 – BLOOD SAMPLE COLLECTION AND SEPARATION OF SERA

Courtesy of the author

Epidemiology Unit and New Sudan Wildlife Conservation Organization (NSWCO). This area was targeted because it is one of the few areas of wildlife concentration remaining in southern Sudan and because it is one of the places from which rumours of rinderpest in cattle had been received in the last few years.

Samples were collected from 43 white-eared kob, 3 buffalo, 1 eland and 1 roan antelope. This number met the planned target of 30 kob samples and 5–10 samples from other species. Samples were sent to the Kenyan Agricultural Research Institute (KARI), Muguga, and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), France. All samples were negative for antibodies to rinderpest virus, but two out of three buffaloes sampled were positive for antibodies to peste des petits ruminants virus. The 2004 wildlife serosurvey confirmed the absence of circulating rinderpest virus in susceptible wildlife populations.

DOSSIER

In 2007, a dossier was presented to OIE containing an account of rinderpest in Sudan, accompanied by clinical surveillance and serosurveillance data demonstrating its absence from the whole of Sudan, thereby permitting a claim that Sudan was free from rinderpest. This claim was upheld by the OIE, and Sudan was declared free from rinderpest infection in May 2008 (5).

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CHAPTER 4.5.20

TANZANIA (UNITED REPUBLIC OF)

J.O. MOLLEL

Former Acting Director of Veterinary Services, Ministry of Water and Livestock Development, United Republic of Tanzania

SUMMARY **Rinderpest is documented to have been introduced to Tanzania between 1890 and 1892 within the southward spread of the Great African Rinderpest Pandemic. Between 1968 and 1971, the United Republic of Tanzania participated in phase IV of the internationally-coordinated mass vaccination programme, Joint Programme 15 (JP15), which was a great success in the United Republic of Tanzania. During the period of the programme, no cases of either mild or severe rinderpest were recorded in either livestock or wildlife. But rinderpest reappeared in 1982/1983. In retrospect the virus had probably entered the country in 1980, silently, via the Mkomazi Game Reserve (adjacent to the Tsavo National park in neighbouring Kenya). The United Republic of Tanzania's final rinderpest episode occurred in 1997 and was traced to an outbreak in southern Kajiado county, Kenya – a spillover from the Tsavo epidemic of 1994. Rinderpest vaccination ended in 1997 and the country declared provisional freedom from rinderpest in July 1998. The serosurveillance carried out between 1999 to 2006 detected only 40 samples positive for rinderpest antibodies out of 64,822 samples examined. These positive samples were determined to be from vaccinated animals. The United Republic of Tanzania was recognised by the World Organisation for Animal Health (OIE) as being free of rinderpest in 2007.**

KEYWORDS **Freedom – Rinderpest – Serosurveillance – United Republic of Tanzania – Vaccination.**

INTRODUCTION

The United Republic of Tanzania is located in East Africa. The country has borders with Kenya and Uganda to the north, Rwanda, Burundi and Democratic Republic of the Congo to the west, Zambia, Malawi and Mozambique to the south and the Indian Ocean to the east. Administratively, the United Republic of Tanzania, as the United Republic, has been a sovereign democratic republic since 1964 upon the union of Tanganyika with the Revolutionary Government of Zanzibar. The country is subdivided into 31 regions, 26 on the mainland and five on Zanzibar (Fig. 1).

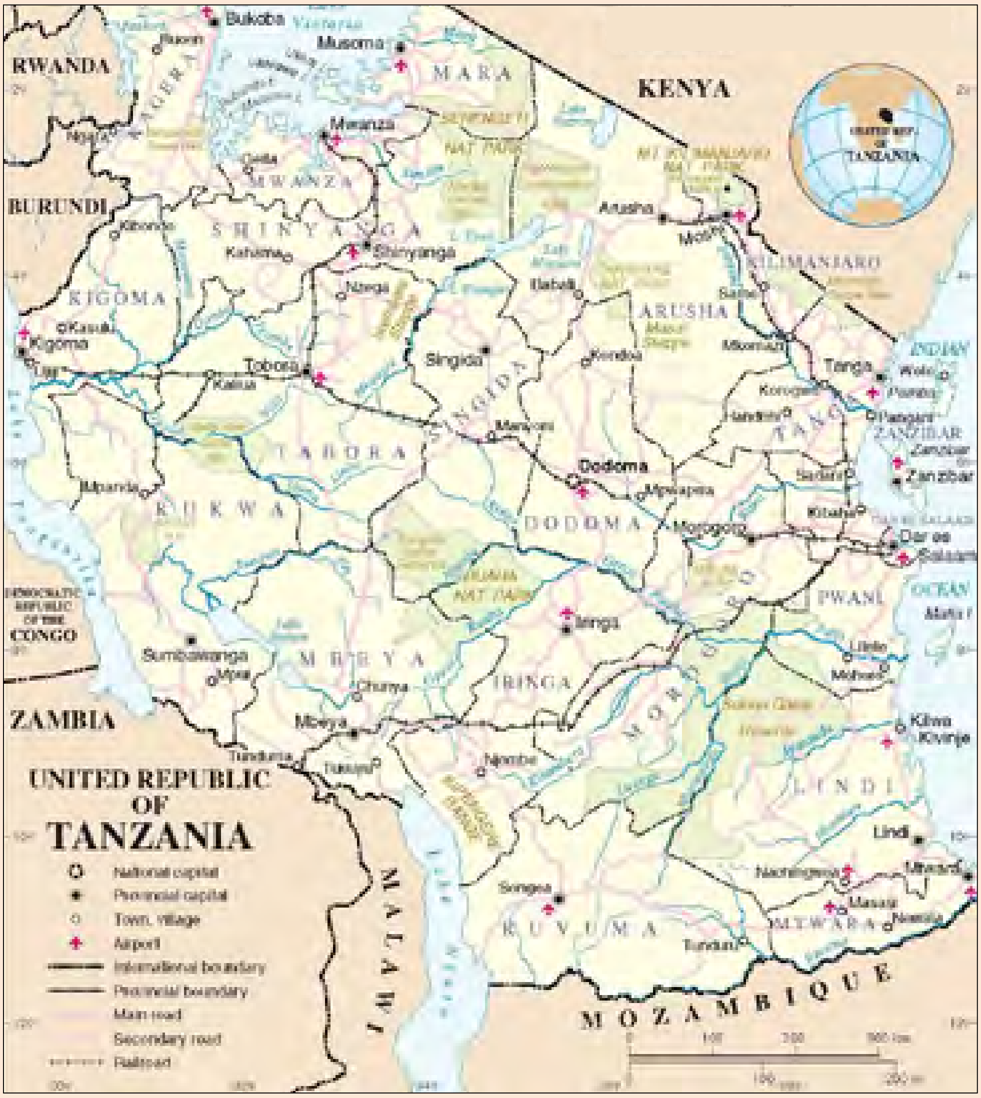
A pertinent feature that runs through the Tanzanian narrative is the central railway line (CRL); this effectively divides the country into northern and southern halves, which have had somewhat different rinderpest histories.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN THE UNITED REPUBLIC OF TANZANIA

Rinderpest disease, known in Swahili as Sotoka, in Sukuma as Lendela, and in the Maasai languages as Lwada, is documented to have been introduced to Tanzania between 1890 and 1892 within the southward spread of the Great African Pandemic (Chapter 2.2). At that time, the country was part of German East Africa. By 1905, countries to the south of Tanzania were probably

FIG. 1
OUTLINE MAP OF THE UNITED REPUBLIC OF TANZANIA SHOWING REGIONAL BOUNDARIES AND CENTRAL RAILWAY LINE

Source: United Nations, 2006 (1)



free of rinderpest (Chapter 2.1), but the disease remained endemic in the country for a number of years.

During the First World War (1914–1918), as British and German forces fought a campaign down the eastern side of Tanzania, rinderpest spread from the north to the south of the country and then into Zambia. In response to this unwelcome spread, the South African Government sent a Commission to Tanzania to create a 15- to 30-km cattle-free strip along the Malawi–Zambia border with Tanzania and, using the virus–serum simultaneous method, an additional belt of immune cattle 50–65 km north of the border. At the same time the Department of Veterinary Services undertook similar immunisation work in areas south of the CRL so that by 1918 southern Tanzania was again rinderpest-free. During the course of a year more than 1 million head of cattle were immunised. The northern area of Tanzania remained endemic for rinderpest with the CRL being the defining line.

After 1918, the emerging Department of Veterinary Services devoted its efforts to containing rinderpest north of the CRL. The control strategy that was employed consisted of an initial standstill of all cattle within 16 km of an infected herd; subsequently, infected herds were moved inwards while uninfected herds were moved outwards to create a cattle-free area around the outbreak. The in-contact animals within the infected herds were then immunised by giving them rinderpest hyperimmune serum and mixing them with the infected animals.

North of the CRL, the disease continued to occur, being constantly recorded from 1922 to 1930. A significant development took place in 1931 when an inactivated rinderpest vaccine began production in the Mpwapwa Veterinary Laboratory. In 1937, rinderpest crossed the CRL again and spread into the Southern Highlands. Its southern drift continued and by 1938 the situation had become so grave that an attempt was made to create a 130-km immune barrier in the face of the epidemic. This did not stop the spread of the virus and when, in 1939, a newly constituted rinderpest intelligence service found rinderpest close to the international border with Zambia, it was decided to create another belt along the border itself, from Lake Nyasa (now Lake Malawi) to Lake Tanganyika. In addition, one million cattle south of the CRL were vaccinated. The year 1940 saw the introduction of Kabete attenuated goat (KAG) vaccine. In 1941, a 2,400-km long game-proof fence along the international border with Zambia was constructed and successfully prevented rinderpest entering the country. By 1942, the Department of Veterinary Services having

BOX 1
HISTORY OF RINDERPEST AND ITS CONTROL IN THE UNITED REPUBLIC OF TANZANIA (1957 TO 1999)

Year	Description
1957 to 1962	Rinderpest outbreaks were recorded in wildebeest and Cape buffalo in the Serengeti ecosystem (SES) and Ngorongoro Highlands.
1959	Rinderpest was recorded in young cattle at Engaruka (Monduli district), introduced by the north-westwards spread of wildebeest, with later spread southwards to Lake Manyara by Cape buffalo.
1960	Mild rinderpest outbreaks in calves in Arusha and Moshi districts occurred as extensions from Lake Manyara and Loliondo.
December 1960 to June 1961	While working at the East African Common Services laboratory at Muguga, Kenya, Walter Plowright managed to isolate seven mild strains of rinderpest virus from cattle and one highly virulent strain from a buffalo. The RBT/1 strain was later identified as Africa lineage 2 rinderpest virus.
1961	Rinderpest outbreaks occurred in Monduli, Arusha and Mbulu districts involving cattle that were not vaccinated.
1962 to 1964	There were no recorded rinderpest outbreaks.
1964	Tissue culture rinderpest vaccine (TCRV), manufactured at Muguga, was used for the first time in East Africa.
1965	Mild rinderpest outbreak was recorded in Olalaa (Loliondo) in cattle that originated from the Ongarika Highlands.
1966	Rinderpest disappeared from the United Republic of Tanzania (until its reappearance in 1980).
1968 to 1971	The United Republic of Tanzania participated in phase IV of the internationally coordinated mass vaccination programme, JP15 (Chapter 4.1). During this period, the United Republic of Tanzania south of the CRL was considered free from the disease in both livestock and wildlife, while the whole area to the north of the CRL was considered to hold endemic rinderpest based upon the presence of sero-positive wildlife and occasional deaths in wildlife with signs suggestive of a mild rinderpest virus infection. On the basis of this assessment, the JP15 vaccination programme targeted young cattle (one to three years of age) using TCRV in districts north of the CRL. This targeted population exceeded 4 million cattle (see Chapter 4.6 for actual vaccination returns). The JP15 programme was a great success in the United Republic of Tanzania in that during the period of the programme no cases of either mild or severe rinderpest were reported or recorded in either livestock or wildlife. At the end of JP15 in 1971, the United Republic of Tanzania continued to vaccinate calves and weaned cattle in the districts north of the CRL, paying particular attention to those adjacent to national parks, game reserves and the border with Kenya.
1981 to 1982 [(a)]	Rinderpest occurred in Cape buffalo at Lobo, Serengeti National Park, in 1981 and in the Mkomazi Game Reserve in 1982. In the Serengeti National Park 2,000 buffaloes died. Cattle in the vicinity were also infected and were held to be the source of the infection in wildlife. In the Mkomazi Game Reserve outbreak, several wildlife species including buffalo, kudu and eland were noted to have died between August and September 1982. Rinderpest was also suspected in the districts of the Arusha region (Same, Mwanga and Ngorongoro). Evidence for the occurrence of rinderpest in Same and Mwanga districts was from serology. The virus was not isolated, but there were positive serological results from 29% of the 106 cattle sera collected from suspected herds that had not been vaccinated. Evidence for occurrence of rinderpest in the wildlife of the Serengeti (Ngorongoro district) was obtained from polymerase chain reaction (PCR)-positive results from clinical samples. In retrospect, the virus had probably silently entered the country in 1980 via the Mkomazi Game Reserve (adjacent to the Tsavo National Park in neighbouring Kenya). The diffuse nature of the outbreak prompted the Food and Agriculture Organization of the United Nations (FAO) to support emergency vaccination. Subsequently, annual vaccination was resumed by the Veterinary Services, under a joint programme with the Southern Africa Development Community (SADC) funded by the European Economic Community (EEC). The programme was designed to prevent the spread of rinderpest into southern African countries (EEC/SADC Rinderpest Control Project) and lasted for three years (1985–1987) with a financial outlay of €4.3 million.
1987 to 1999 [(a)]	Further internationally coordinated mass vaccination came under the remit of the Pan-African Rinderpest Campaign (PARC). Vaccinations during the PARC period were undertaken in the area north and east of the CRL and alternated between the whole of it or districts on the international border with Kenya. Under PARC, the United Republic of Tanzania remained rinderpest-free from 1983 to 1997. The United Republic of Tanzania's final rinderpest episode occurred in 1997 and was traced to an outbreak in southern Kajiado county, Kenya – a spillover from the Tsavo epidemic of 1994 (Chapter 2.5) – which had moved southwards into Monduli, Hai and Ngorongoro districts. The 'immunosterilisation technique' was developed and used to rapidly raise bovine immunity levels to over 85% to eliminate the virus and protect cattle in the districts north of the CRL and prevent further incursions of the disease from Kenya.

[(a)] The locations of outbreaks in the area shown in Figure 2.

made extensive use of the KAG vaccine (2.7 million vaccinations), rinderpest no longer occurred south of the CRL.

Thereafter, good progress continued to be made in controlling rinderpest north of the railway line, so that by 1953 Tanzania reported rinderpest to be almost under control. By 1956, no outbreaks were recorded. The subsequent history of rinderpest and its control in the United Republic of Tanzania is shown in Box 1.

CLINICAL AND SEROLOGICAL SURVEILLANCE

Clinical surveillance

Clinical surveillance began in 1997 and continued for the next seven years. It was at its peak during the African Union Interafrican Bureau for Animal Resources (AU-IBAR)-led Pan African Programme for the control of Epizootics (PACE) (see Chapter 4.3).

PACE had a component that dealt with strengthening and facilitating the epidemio-surveillance system for rinderpest. The protocol had both clinical and serosurveillance for livestock and wildlife and was undertaken in all the years under PACE.

The organisation and implementation of the passive surveillance programme centred on the deployment of local livestock field officers equipped with knowledge and tools to recognise rinderpest. These officers ran routine disease monitoring rounds, took appropriate samples and reported on a monthly basis, or in the case of an abnormal event, immediately. Passive surveillance for rinderpest was for the whole country regardless of the risks and history of previous outbreaks, whereas purposive and active surveillance were mostly done in rinderpest high-risk areas.

From 1999 to 2006 no clinical signs suspicious of rinderpest or any enteritis–stomatitis syndrome were either reported or observed in any of the villages visited.

FIG. 2
RINDERPEST OUTBREAKS IN THE UNITED REPUBLIC OF TANZANIA BETWEEN 1980 AND 1997

Source: D-maps, 2020 (4), modified to indicate rinderpest outbreaks

1 Serengeti NP, 1981
2 Ngorongoro, July 1982
3 Kilimanjaro, July 1982
4 Mkomazi G/R, 1982
5 Monduli, 1997
6 Hai, 1997
7 Karatu, 1997

Regions vaccinated under PARC. Rinderpest vaccination ended in 1997

TABLE I
SUMMARY OF RINDERPEST SEROSURVEILLANCE TEST RESULTS IN CATTLE, 1999–2006

Year	Sampled and tested	Test results	Prevalence (%)
1999	4,751	40/4,751[a]	0.8
2000	12,828	0/12,828	0.0
2001	11,827	0/11,827	0.0
2002	13,705	0/13,705	0.0
2003	9,384	0/9,384	0.0
2004	7,673	0/7,673	0.0
2005	1,812	0/1,812	0.0
2006	2,842	0/2,842	0.0

[a] Backtraced to vaccinated animals

TABLE II
RESULTS OF WILDLIFE RINDERPEST SEROSURVEILLANCE IN CAPE BUFFALO DURING PACE, 2001–2006

Year	Sampled and tested	Test results	Prevalence (%)
2001	139	0/139	0%
2002	156	1/156	0.6 %
2003	47	0/47	0%
2004	24	0/24	0%
2005	23	0/23	0%
2006	18	0/18	0%

Serological surveillance

Using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3 and 6.3), the serosurveillance results for cattle from the PARC and PACE period 1999–2006 are shown in Table I. Out of 64,822 samples only 40 were found positive which were subsequently found to have come from vaccinated animals. During the same period, 19,895 samples were collected from sheep and goats and none of them had detectable antibodies against rinderpest virus.

SEROSURVEILLANCE IN WILDLIFE

The wildlife sampling frame was drawn from national parks and game reserves in the northern areas with a recent history of rinderpest. The PACE wildlife surveillance programme concentrated on Cape buffalo. Clinical observations and serum sampling was done by veterinarians of the Tanzania Wildlife Research Institute (TAWIRI) and the Tanzania National Parks (TANAPA). The results, shown in Table II, indicated that rinderpest was not endemic in the Cape buffalo population of the national parks.

Of the 407 wildlife samples collected between 2001 and 2006 only one sample collected in 2002 had antibodies to rinderpest virus. Follow-up revealed that it was from a 12-year-old buffalo possibly exposed to rinderpest virus before 1997 and not indicative of active rinderpest virus infection in 2002.

DOSSIER

The evidence from clinical and serological surveillance undertaken during the period 2001 to 2006 indicated that the United Republic of Tanzania was free from rinderpest disease. The OIE recognised the United Republic of Tanzania as being free from rinderpest disease in May 2005 (2) and free from rinderpest infection in 2007 (3).

References

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2. World Organisation for Animal Health (OIE) (2005). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 14–19 January 2005. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_Jan05.pdf (accessed on 25 September 2019).
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CHAPTER 4.5.21

TOGO

A. SEIBOU SONHAYE

Former Director of Livestock and Fisheries, Ministry of Agriculture, Livestock and Fisheries, Togo

SUMMARY **Following several successive vaccination campaigns against rinderpest, Togo officially ceased vaccination in 1991 and declared itself provisionally free in 1996. The country embarked on the World Organisation for Animal Health (OIE) procedure for official recognition of rinderpest status and was found to be free from the disease in 2003. The results of the serological campaign conducted in 2003–2004 suggest that the rinderpest virus was no longer circulating in Togo. Country freedom from rinderpest was accorded to Togo by the OIE in 2005.**

KEYWORDS **Rinderpest – Surveillance – Togo – Vaccination.**

INTRODUCTION

The Togolese Republic is a West African country bordered to the north by Burkina Faso, to the south by the Gulf of Guinea, to the east by Benin and to the west by Ghana. It is divided into five administrative regions. Cattle are concentrated in the country's northern regions (Fig. 1).

The central level of the public Veterinary Services is the Directorate of Livestock and Fisheries.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN TOGO

The first occurrence of rinderpest dates back to 1911. Togo recorded several episodes – notably from 1925 to 1952 and from 1960 to 1963 – like most countries in the West Africa region. Togo was involved in phase II of Joint Programme 15 (JP15; see Chapter 4.1), which was conducted between 1964 and 1967 and led to the temporary eradication of rinderpest. However, the disease reappeared in 1972 and in 1980. The latter outbreak was dealt with by an emergency vaccination campaign carried out in 1981 supported by the Food and Agriculture Organization of the United Nations (FAO). Of the country's 205,369 cattle, 156,706 (76.3% of the cattle population) were vaccinated and the disease was eliminated.

Several outbreaks were detected in 1985 and in 1986, in the prefectures of Kozah, Keran, Binah and Kloto. Following these outbreaks, the European Union approved €90,000 of funding for emergency vaccination. Around 60 vaccinators were trained as part of a vaccination team. Vaccination was conducted in two phases:

- Phase one was carried out between November and December 1987 at the borders to create a buffer zone.
- Phase two was implemented in January 1988, covering the rest of the country. This was coupled with the vaccination carried out by FAO. More than 90% vaccination coverage was obtained.

Although there were no further rinderpest outbreaks after 1986, vaccination continued under the Pan-African Rinderpest Campaign (PARC; Chapter 4.2). Vaccination ceased in 1991 (see Chapter 4.6).

FIG. 1
TOGO: ADMINISTRATIVE REGIONS AND NEIGHBOURING COUNTRIES
Source: United Nations, 2020 (1)

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Togo declared itself provisionally free from rinderpest on 1 June 1999 and began epidemiological surveillance of the national herd.

Clinical surveillance

Active and passive surveillance by observation post officers, private veterinarians and other field workers revealed no suspected cases of rinderpest or rinderpest-like lesions (stomatitis, enteritis, etc.) after 1991. A report on active search activities was produced every month.

Serological surveillance

The first blood samples were collected in late 2003 and early 2004. A total of 4,222 sera were collected from animals aged between one and five years and tested using the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3 and 6.3). A total of 114 positives (or 2.7%) were detected. Investigations showed that most of these were trade animals from Sahelian countries that had undertaken vaccination against rinderpest as recently as 1999.

Wildlife

Surveillance was based on the detection of signs arousing legitimate suspicion, followed by serological monitoring. No clinical cases were reported to the livestock service.

CONCLUSION

Rinderpest first occurred in Togo in 1911. Outbreaks were reported between 1925 and 1952 and between 1960 and 1963. Thanks to successive vaccination campaigns, the disease was eradicated. The results of the serological campaign conducted in 2003–2004 suggested that the rinderpest virus was no longer circulating in Togo.

Dossier

In May 2003, Togo was declared free from rinderpest disease following an evaluation of its application dossier by the OIE (2).

In November 2004, the Delegate of Togo submitted a dossier to secure the status of country freedom from rinderpest. The dossier was examined by the relevant OIE Commission (3), and country freedom from rinderpest was accorded to Togo by the World Assembly of OIE Delegates at its 73rd General Session in May 2005.

References

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CHAPTER 4.5.22

UGANDA

E.B. RWAMUSHWA

Former Commissioner, Livestock Health, Ministry of Agriculture, Animal Industry and Fisheries, Uganda

SUMMARY **Uganda was endemically infected with rinderpest during the first half of the 20th century, a situation that ended with mass vaccination during phase IV of Joint Programme 15 (JP15). After an interval of 11 years, the virus reinvaded Uganda and was intermittently reported over the next 16 years. It was finally eradicated by more mass vaccination, delivered by both the Food and Agriculture Organization of the United Nations (FAO) and the Pan-African Rinderpest Campaign (PARC). The last outbreak was in 1994. Clinical and serosurveillance between 2002 and 2007 demonstrated that the virus was no longer present. Uganda was declared free from rinderpest by the World Organisation for Animal Health (OIE) in 2008.**

KEYWORDS **Outbreak – Rinderpest – Surveillance – Uganda – Vaccination.**

INTRODUCTION

The Republic of Uganda is an East African country sharing borders with the Democratic Republic of the Congo, Kenya, Rwanda, South Sudan and the United Republic of Tanzania (Fig. 1).

Livestock production constitutes an important subsector of Uganda's agriculture, contributing about 9% of national gross domestic product (GDP) and 17% of agricultural GDP. Currently, it is estimated that the livestock population consists of 6.5 million cattle, 7.8 million goats, 1.6 million sheep, 1.2 million pigs, 33 million poultry, 100,000 rabbits and 10,000 equines (donkeys, camels and horses). Livestock production systems are mostly open range and extensive.

Veterinary Services are provided by the Directorate of Animal Resources.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN UGANDA

The rinderpest virus is thought to have first infected cattle in Uganda in 1890, having been introduced from Somalia via Kenya. The first outbreak on record was reported to have occurred in the Mbale district in eastern Uganda in 1911. The disease then became endemic in the area and eventually other parts of the country. It was observed that zebu cattle were fairly 'resistant', whereas the Ankole Longhorn and Nganda cattle were highly susceptible.

Efforts by Uganda alone did not yield significant control of the disease, which was endemic up until the inception of phase IV of JP15 between 1968 and 1971. No cases of rinderpest were reported between 1966 and 1978, but the disease reemerged in 1979 in the Karamoja area, as a result of the breakdown in control measures because of war. The disease spread to 11 districts in the north and east of Uganda, persisting up until 1994 (see Chapter 4.6). It affected the districts of Karamoja, Soroti, Kumi, Mbale, Tororo, Iganga and Kamuli as well as the mid-central (Luwero district) and southern regions of Uganda.

An emergency rinderpest vaccination programme was undertaken between 1986 and 1989, with the support of FAO. Thereafter, Uganda continued with mass vaccination under PARC.

In 1999, mass vaccination in the country ceased except in seven districts (Arua, Nebbi, Gulu, Moyo,

FIG. 1
MAP OF UGANDA SHOWING THE DISTRICTS
Source: United Nations, 2020 (1)

Kitgum, Moroto and Kotido) bordering southern Sudan and north-western Kenya.

Vaccination in the remaining districts stopped in December 2001. Uganda declared itself provisionally free from rinderpest, with effect from 1 November 2002, and notified the OIE and its neighbouring countries accordingly.

SURVEILLANCE

Passive surveillance

All stakeholders were trained on recognising the clinical signs of rinderpest, especially the three Ds, (diarrhoea, discharges and deaths), and the importance of reporting any suspicion of the disease.

Following the last case of rinderpest in June 1994, there were no further cases.

Active clinical surveillance

Clinical surveillance for rinderpest commenced in 2002, using district rinderpest search teams. A parish is the smallest administrative unit in Uganda, and there are 4,055 parishes in the country. A list of all parishes was made, and 314 parishes were randomly selected to give a 95% confidence level at an estimated disease prevalence of 0.95%. Fifteen head of cattle were clinically examined per parish at an intra-herd confidence level of 50% and an estimated disease prevalence of 0.50%.

Rinderpest search teams used standardised reporting forms for each parish and animal examined. When necessary, samples were collected from the suspected cases and sent to the Central Diagnostic Laboratory for testing.

A total of 4,710 head of cattle were clinically examined each year between 2002 and 2007 for clinical signs of rinderpest. No rinderpest disease was reported.

Serosurveillance

For serosurveillance of domestic animals, the parish was again selected as the primary sampling unit. A list of all parishes was made, and 314 parishes were randomly selected to give a 95% probability of detecting evidence of rinderpest, if present, at a prevalence of 1% of herds. Twenty head of cattle were sampled per parish at an intra-herd confidence level of 50% and an estimated disease prevalence of 0.50%. All samples were tested using the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapters 3.3 and 6.3) in the central diagnostic laboratory.

Of the 17,863 samples collected from cattle (Table I), 127 samples were found to be positive during 2003, which gave a seropositivity of 3.3%. Further investigations were carried out that revealed that young animals of less than six months old had been sampled (an error in ageing while sampling). These animals had maternal antibodies.

During subsequent years, from 2004 to 2007, the seropositivity ranged from 0.28% to 0.09%. Traceback was carried out on all animals that tested positive. All samples were confirmed negative after retesting. All the 68 samples from sheep and goats tested negative. This indicates that there was no circulating rinderpest virus among the domestic population.

Surveillance of wildlife

Serosurveillance was undertaken in all major national parks and game reserves between 1998 and 2007. A sample fraction of 1–2% enabled disease detection because of the high seroconversion levels among the buffaloes (main species sampled). The age group of one to three years was preferred, as it is this group that is least likely to have been exposed to the rinderpest virus during the outbreaks in domestic species.

The wildlife species sampled included African buffalo, topi, impala, warthog, hartebeest and roan antelope.

Between 1998 and 2002, of the 40 samples from Lake Mburo, 30 samples were from impala, six were from buffaloes, three were from topi and one was from a warthog. During the period 1998–2002, of the nine samples from Pian Upe, six samples were from buffaloes, two were from hartebeest and one was from a roan antelope. All samples tested during the period 2003–2006 were from buffaloes. Out of 446 wildlife samples collected between 1998 and 2006, no sample tested positive. These results indicated that there was no circulating rinderpest virus among the wildlife.

CONCLUSION

Uganda declared provisional freedom from rinderpest with effect from 1 November 2002 and notified the OIE and its neighbouring countries accordingly. Between 1994 and 2007, no clinical occurrence of rinderpest was recorded. From 17,863 sera, 127 samples were found to be positive during 2003, which gave a seropositivity of 3.3%, but this decreased to zero by 2007. After the dossier had been reviewed by the relevant Commission (2), the World Assembly of OIE Delegates recognised Uganda as free from rinderpest disease at its 74th General Session in May 2006. In August 2007, the delegate for Uganda submitted a dossier to secure

TABLE I
RINDERPEST C-ELISA RESULTS FOR DOMESTIC ANIMALS FROM 2003 TO 2007

Year	Species	Number tested	Test results	Proportion	Percentage
2003	Bovine	3,525	127/3,825	0.033203	3.3
2004	Bovine	2,734	3/2,734	0.001097	0.11
2005	Bovine	2,462	7/2,462	0.002843	0.28
2006	Bovine	4,044	5/4,044	0.001238	0.12
2007	Bovine	5,098	5/5,098	0.000981	0.09
2007	Sheep and goats	68	0/68	0	0

the status of country freedom from rinderpest. The dossier was examined by the relevant OIE Commission (3), and country freedom from rinderpest was accorded to Uganda by the World Assembly of OIE Delegates at its 76th General Session in May 2008.

References

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3. World Organisation for Animal Health (OIE) (2008). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 19–21 February 2008. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_feb2008.pdf (accessed on 14 August 2019).

CHAPTER 4.6

REGIONAL TIMELINE FOR AFRICA

Countries in Africa on the Global List of Countries officially recognised as free from rinderpest infection as at May 2011

Source: United Nations (2011). - Map of Africa. Available at: www.un.org/geospatial/content/africa-1 (accessed on 9 June 2021). Modified to indicate those countries on the Global List of Countries officially recognised as free from rinderpest. Final boundary between the Sudan and South Sudan has not yet been determined

YEAR	COUNTRY / CROSS REFERENCE								
	BENIN/CHAPTER 4.5.1			BURKINA FASO/CHAPTER 4.5.2			CAMEROON/CHAPTER 4.5.3		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
1950		+	–		+	–		+	–
1951		+	–		+	–		+	–
1952		+	–		+	–		181	–
1953		+	–		+	–		92	–
1954		1	–		59	–		43	–
1955		10	–		87	–		275	–
1956		7	–		89	–		108	–
1957		21	–		83	–		114	–
1958		4	–		71	–		95	–
1959		9	–		81	–		181	–
1960		26	–		107	–		297	–
1961		22	–		121	–		90	–
1962		5	–		109	–		25	–
1963		0	–		21	–			665
1964		0	–		32	–	V. JP15+I	12	736
1965		0	263		26	1,964		3	674
1966	V. JP15+II	1	325	V. JP15+II	1	2,306		1	–
1967			364		+	2,359		34	–
1968					1			5	233
1969					+	31		14	1,595
1970					74	379		4	1,888
1971		2			44	539			1,866
1972		44			26	414			1,865
1973		+			31	1,221			1,876
1974		5			2	1,246	OIE outbreak reports not in dossier text	1	1,975
1975						783		4	1,835
1976						421			2,000
1977						337			2,453
1978						470			2,907
1979						281			2,919
1980		2	454		10	2,624			2,345
1981		4			11				1,077
1982					10				1,057
1983		3			3			84	1,988
1984		2			+			4	1,006
1985		2			8			2	1,006
1986		1			40			1	2,241
1987		1	671		+	1,523			2,734
1988			508		3	583			2,773
1989			489			1,928			3,124
1990			508			2,095			3,018
1991			574			169	V. PARC		2,985
1992			645	V. PARC		1,691			2,720
1993	V. PARC		554			1,434			3,036
1994			546			1,385			3,208
1995			507			1,777			3,908
1996			458			1,470			3,892
1997			508						3,985
1998			292						3,397

LEGEND

–	*Routine vaccination by Veterinary Services, number of vaccinations not known*		*Unreported*
236	*Vaccination by Veterinary Services funded by international programme, number x 1,000*	+	*Virus endemic: number of outbreaks in the year not recorded*
45	*Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000*	25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
67	*Routine vaccination by Veterinary Services, number x 1,000*		*Virus epidemic: number denotes total outbreaks recorded in the year*

Vaccination	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

YEAR	COUNTRY / CROSS REFERENCE								
	CENTRAL AFRICAN REPUBLIC/ CHAPTER 4.5.4			CHAD/ CHAPTER 4.5.5			CÔTE D'IVOIRE/ CHAPTER 4.5.6		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
1950					565	...		+	...
1951					698	1,046		+	...
1952					343	1,050		+	...
1953					356	1,059		+	...
1954	No information				406	1,269		+	...
1955					401	1,092		+	...
1956					218	864		+	...
1957					224	964		12	...
1958					351	1,057		12	...
1959					367	867		1	...
1960					235	1,145		1	...
1961					324	1,065		30	...
1962					163	1,989		14	...
1963					33	3,195		16	...
1964				V. JP15+I	9	2,236	V. JP15 I & II	22	...
1965		1			ni	1,564		6	45
1966					ni	1,501			43
1967					39	2,662		1	274
1968				V. JP15+III	25	1,597			237
1969					26	1,426			194
1970					19	1,284		8	
1971						1,927			
1972						1,634		12	
1973						1,745		6	
1974						1,539			
1975						1,714			
1976						1,675			
1977						1,184			
1978						0			
1979						0			
1980				Civil war		0			380
1981						0			
1982				Virus moving from Sudan to Nigeria	+	0	V. FAO		
1983	Virus moving from Sudan to Nigeria	1 with V. FAO			218	6,152		3	
1984				V. FAO		2,241		1	
1985						1,734		4	
1986			1,044			1,773		1	
1987			...			2,324			709
1988			654			2,018			802
1989			348			1,985			883
1990			654			1,849	V. PARC		983
1991	V. PARC		538	V. PARC		1,221			630
1992			568			2,323			354
1993			627			1,158			288
1994			690			877			0
1995			607			2,459			551
1996			482			2,185			
1997			448			1,990			
1998			412			1,310			
1999			502			1,462			
2000			404			642			
2001						406			

LEGEND

–	Routine vaccination by Veterinary Services, number of vaccinations not known		Unreported
236	Vaccination by Veterinary Services funded by international programme, number x 1,000	+	Virus endemic: number of outbreaks in the year not recorded
45	Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000	25 etc.	Virus endemic: number denotes total outbreaks recorded in the year
67	Routine vaccination by Veterinary Services, number x 1,000		Virus epidemic: number denotes total outbreaks recorded in the year

Vaccination	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

YEAR	COUNTRY / CROSS REFERENCE								
	DJIBOUTI/CHAPTER 4.5.7			ERITREA/CHAPTER 4.5.8			ETHIOPIA/CHAPTER 4.5.9		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
1950								+	...
1951								+	...
1952								+	...
1953								+	...
1954	Non-endemic			Non-endemic				+	...
1955								+	...
1956								+	...
1957								+	...
1958								+	...
1959								+	...
1960								+	...
1961								+	...
1962					18			18	...
1963					14			75	...
1964								4	2,409
1965								61	1,871
1966								55	1,772
1967								36	2,228
1968								35	2,246
1969								53	3,064
1970							1970-1976 massive outbreak throughout southern and central Ethiopia moving through Arsi into cattle of Afar pastoralists V. JP15 V & VI	13	4,782
1971								+	8,088
1972								+	8,865
1973								+	...
1974								+	...
1975								+	...
1976								+	...
1977						235	JP15 follow-up (calves)	+	...
1978						165		+	...
1979						155		7	...
1980						172		24	...
1981						163		53	...
1982						...		1	...
1983						73		+	...
1984						653		127	...
1985		1				567		+	...
1986						465	In late 1980,s epidemic spread from Sudan-Ethiopian border across north of Ethiopia including Afar region with Wollo isolates as lineage 1 1988-1990 PARC Emergency vaccination 1991-1997 V. PARC 2 & 3	+	...
1987						432		+	...
1988						...		1	...
1989	Conditional entry into PARC		1			414		8	10,269
1990						433		4	25,546
1991				V. PARC		207		7	7,879
1992					Major outbreak	362		5	5,738
1993						477		8	4,060
1994					Minor outbreak	602		4	4,564
1995						668		2	3,864
1996						987		0	3,094
1997						510			2,221

LEGEND

–	Routine vaccination by Veterinary Services, number of vaccinations not known	
236	Vaccination by Veterinary Services funded by international programme, number x 1,000	
45	Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000	
67	Routine vaccination by Veterinary Services, number x 1,000	
Vaccination	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

	Unreported
+	Virus endemic: number of outbreaks in the year not recorded
25 etc.	Virus endemic: number denotes total outbreaks recorded in the year
	Virus epidemic: number denotes total outbreaks recorded in the year

YEAR	COUNTRY / CROSS REFERENCE								
	GHANA/CHAPTER 4.5.10			GUINEA/CHAPTER 4.5.11			KENYA/CHAPTER 4.5.12		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
1950		+	...					34	...
1951		+	...					+	...
1952		+	...					+	...
1953		+	...					+	...
1954		+	...	Non-endemic				+	...
1955		+	...					+	...
1956		+	...					+	...
1957		+	...					+	...
1958		+	...				1958 lineage 1 isolated from Marsabit	15	...
1959		+	...					25	330
1960		3	...					44	...
1961		17	...		36			13	...
1962		34	...			...	Lineage 2 RGK/1 virus isolated	7	...
1963		14	...			...		12	277
1964		1	...		1	...		8	521
1965	V. JP15+II		306			...		2	354
1966			356	V. JP15+III	1	...		+	465
1967			391		3	170		2	547
1968			307			1,043		+	1,024
1969						499	V. JP15 +IV	+	1,436
1970								+	1,200
1971								+	...
1972							1972 outbreak spreading towards Marsabit and Mombasa - offshoot of outbreak in south-east Ethiopia moving NE	5	...
1973		6						+	...
1974		2						+	...
1975								+	...
1976								+	...
1977								+	...
1978			178					+	...
1979			180					+	...
1980	V. FAO		263					+	...
1981			461					+	...
1982		2	395					+	...
1983			57	V. FAO			V. FAO	+	...
1984			536					+	...
1985		26	761					+	...
1986		7	471				1986 lineage 1 isolated from West Pokot	1	2,433
1987		20	310					1	4,968

LEGEND

–	*Routine vaccination by Veterinary Services, number of vaccinations not known*
236	*Vaccination by Veterinary Services funded by international programme, number x 1,000*
45	*Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000*
67	*Routine vaccination by Veterinary Services, number x 1,000*

Vaccination	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

	Unreported
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
	Virus epidemic: number denotes total outbreaks recorded in the year

YEAR	COUNTRY / CROSS REFERENCE								
	GHANA/CHAPTER 4.5.10			GUINEA/CHAPTER 4.5.11			KENYA/CHAPTER 4.5.12		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
1988		12	513	V. PARC		238		3	1,153
1989	V. PARC		617			326	1988 rinderpest in Kiambu District having spread from West Pokot 1988/2000 V. PARC	1	2,257
1990			636			353		10	2,984
1991			588			333			2,112
1992			906			247			1,969
1993			961			80			2,386
1994			430			50	1994-1995 severe outbreak in buffaloes in Tsavo National Park with spread to Amboseli and Nairobi National Parks		1,940
1995			495					2	2,318
1996			1,023					3	1,938
1997									3,518
1998									3,686
1999								1	243
2000									73
2001								1	96
2002									
2003									140

LEGEND

–	Routine vaccination by Veterinary Services, number of vaccinations not known	(yellow)	Unreported
236	Vaccination by Veterinary Services funded by international programme, number x 1,000	+	Virus endemic: number of outbreaks in the year not recorded
45	Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000	25 etc.	Virus endemic: number denotes total outbreaks recorded in the year
67	Routine vaccination by Veterinary Services, number x 1,000	(pink)	Virus epidemic: number denotes total outbreaks recorded in the year

Vaccination	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

YEAR	COUNTRY / CROSS REFERENCE								
	MALI/CHAPTER 4.5.13			MAURITANIA/CHAPTER 4.5.14			NIGER/CHAPTER 4.5.15		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
1950		+	...		+	...		+	...
1951		+	...		+	...		+	...
1952		+	...		+	...		64	...
1953		+	...		+	...		89	...
1954		154	...		+	...		201	...
1955		254	...		+	...		258	...
1956		283	...		224	...		157	...
1957		186	...		245	...		192	...
1958		140	...		129	...		152	...
1959		217	...		117	...		159	...
1960		232	...		31	...		137	...
1961		203	...		49	...		131	...
1962		308	...		52	...		133	...
1963		149	...		102	...		60	1,841
1964		159	...		108	...		60	1,820
1965		71	1,859		54	...		1	4,210
1966	V. JP15 + I & II	82	3,567		48	...		3	3,096
1967		0	3,950		41	1,479	V. JP15 + I & II	4	2,086
1968		13	831	V. JP15 + I & II	2	2,171		9	1,375
1969		8	725		3	2,343		23	1,292
1970		11	...		1	...		9	1,113
1971	JP15 did not eliminate endemic situation	33	...		1	...			1,075
1972		47	...	JP15 did not eliminate endemic situation	1	...		11	2,070
1973		53	...		8	...		6	1,417
1974		23	...		26	...		1	1,868
1975		0	...		1	...			1,298
1976		4	2,095		2	...			1,570
1977		11	2,525		47	...			2,086
1978	Post-JP15 recrudescence	9	...	Post-JP15 recrudescence	13	...			1,805
1979		29	2,583		18	...	Rinderpest spread from Mali to Terra arrondissement		2,140
1980	V. FAO	11	5,834	V. FAO		542		7	2,677
1981		7	2,812			...		+	2,224
1982		21	2,826			...		6	2,927
1983		17	1,959	V. FAO		...	V. FAO	5	2,851
1984		44	2,458		7	...		2	3,411
1985		18	1,672		17	...		2	873
1986		2	1,401		1	642		1	1,249
1987			1,522			569			1,257
1988			1,636			600			1,211
1989			2,330			520			1,342
1990			2,117			482			1,342
1991	V. PARC		1,657			521			931
1992			1,691			480	V. PARC		617
1993			1,685			350			503
1994			1,230			281			635
1995			1,751			596			344
1996			1,483			547			626
1997			680						828
1998									56

LEGEND

–	*Routine vaccination by Veterinary Services, number of vaccinations not known*	
236	*Vaccination by Veterinary Services funded by international programme, number x 1,000*	
45	*Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000*	
67	*Routine vaccination by Veterinary Services, number x 1,000*	
Vaccination	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

	Unreported
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
	Virus epidemic: number denotes total outbreaks recorded in the year

YEAR	COUNTRY / CROSS REFERENCE								
	NIGERIA/ CHAPTER 4.5.16			SENEGAL/ CHAPTER 4.5.17			SOMALIA/ CHAPTER 4.5.18		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
1950		+	...		288				
1951		+	...		+				
1952		+	...		+				
1953		+	...		+				
1954		20	...		+				
1955		404	...		+				
1956		364	...		109				
1957		373	...		332		Game animal species historically implicated in maintaining and spreading infection and probably did so through 1957-1958		
1958		423	...		47				
1959		520	...		267				
1960		336	...		199				
1961		315	...		200				
1962		104	...		38				
1963		7	5,386		71				
1964	V. JP15 + I & II	2	6,528		110				
1965		1	7,101		13				
1966	70 million doses issued between 1965 and 1980	2	4,545		33				Pre-JP15 unknown
1967		17	3,275		76				
1968		15	2,129	V. JP15+ I & II	9				480
1969		45	...					25	1,743
1970		34	...						1,488
1971		49	...				V. JP15+ IV & V		1,256
1972		19	70 million doses issued between 1965 and 1980						...
1973		1						4	...
1974	Outbreaks around Mubi								
1975								6	
1976									
1977			...		8				
1978			...		1				
1979			...						

LEGEND

–	*Routine vaccination by Veterinary Services, number of vaccinations not known*
236	*Vaccination by Veterinary Services funded by international programme, number x 1,000*
45	*Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000*
67	*Routine vaccination by Veterinary Services, number x 1,000*

Vaccination		
	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

	Unreported
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
	Virus epidemic: number denotes total outbreaks recorded in the year

YEAR	COUNTRY / CROSS REFERENCE								
	NIGERIA/ CHAPTER 4.5.16			SENEGAL/ CHAPTER 4.5.17			SOMALIA/ CHAPTER 4.5.18		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
1980	1980 moderately virulent lineage 2 rinderpest introduced from the Niger plus highly virulent lineage 1	20	863	Outbreaks controlled by combined emergency vaccination and national vaccination through FAO				Participatory epidemiology results consistent with presence of sub-acute rinderpest in S. Somalia from 1980 to 1993, the last incident being serologically confirmed	
1981		111	1,326						
1982		55	986						
1983	1980-1986 plus highly virulent lineage 1 rinderpest introduced at Dikwa from Sudan via Chad	1.081	11,351				V. FAO		
1984		329	8,306						
1985		39	7,804						
1986		2	5,898	V. PARC					
1987		1	7,824						616
1988			8,026						
1989			2,957				V. PARC		300
1990			2,198						150
1991			2,345						
1992			4,244				Somaliland and part of Central		230 by ICRC
1993			3,649						
1994			3,649				Gedo		140 by ICRC
1995			2,697						
1996			1,778				Gedo		227 by Terra Nuova
1997									
1998							Gedo and Trans Juba		127 by Terra Nuova
1999									
2000									
2001									
2002									
2003							Afmadow		50

LEGEND

–	*Routine vaccination by Veterinary Services, number of vaccinations not known*	
236	*Vaccination by Veterinary Services funded by international programme, number x 1,000*	
45	*Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000*	
67	*Routine vaccination by Veterinary Services, number x 1,000*	
Vaccination	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

(yellow)	*Unreported*
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
(pink)	*Virus epidemic: number denotes total outbreaks recorded in the year*

YEAR	COUNTRY / CROSS REFERENCE							
	SUDAN/CHAPTER 4.5.19					TANZANIA (UNITED REPUBLIC OF)/CHAPTER 4.5.20		
	Narrative	Number of outbreaks	Vaccinations northern Sudan	Vaccinations southern Sudan		Narrative	Number of outbreaks	Vaccinations
				Southern sector	Northern sector			
1950		+	...					...
1951		+	...				+	...
1952		+	...				+	...
1953		+	...				+	...
1954		+	...				+	...
1955		+	...				+	...
1956		+	...				+	...
1957		+	...				+	...
1958		+	...				+	...
1959		+	...				2	...
1960	Outbreak numbers between 1960 and 1967 computed from Atang and Plowright - BEDA 17. 1969.	213	...				2	...
1961		151	...				3	...
1962		108	...				+	...
1963		196	...				+	997
1964		192	1,349			Last traces found in Loliondo Division, thereafter rinderpest free for next 14 years	1	859
1965	1961 outbreak numbers between 1960 and 1967 computed	536	1,573				5	942
1966		416	1,773	26			5	962
1967		422	11,145					1,119
1968	V. JP 15 + IV	234	1,330					1,346
1969		178	3,026	146				1,315
1970		216	3,043	748				1,431
1971		6	2,161	523				960
1972	Lineage 1 isolated from Reedbuck, Dinder N.P.	ni	2,900	359				...
1973		ni	2,700					Coverage maintained around Serengeti National Park but diminished elsewhere
1974		ni	2,100					
1975		3	2,600					
1976	OIE reports	10	4,000					
1977		+	3,700					
1978	Lineage 1 build up prior to westwards movement to Nigeria within so called 'second African pandemic'	3	2,800					
1979		24	3,300					
1980		36	No data available			1980-1982 Cryptic re-entry from Kenya; confirmed in 1982 in buffaloes at Lobo and in Ngorongoro Conservation Area	7	
1981		65					9	
1982		94	...				8	1,020
1983	V. FAO	65	...			1982-1983 V. FAO 1982 FAO & EU immunosterilised north of Central Railway Line	8	2,854

LEGEND

–	*Routine vaccination by Veterinary Services, number of vaccinations not known*	(yellow)	*Unreported*
236	*Vaccination by Veterinary Services funded by international programme, number x 1,000*	+	*Virus endemic: number of outbreaks in the year not recorded*
45	*Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000*	25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
67	*Routine vaccination by Veterinary Services, number x 1,000*	(pink)	*Virus epidemic: number denotes total outbreaks recorded in the year*

Vaccination	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

YEAR	COUNTRY / CROSS REFERENCE							
	SUDAN/CHAPTER 4.5.19					TANZANIA (UNITED REPUBLIC OF)/CHAPTER 4.5.20		
	Narrative	Number of outbreaks	Vaccinations northern Sudan	Vaccinations southern Sudan		Narrative	Number of outbreaks	Vaccinations
				Southern sector	Northern sector			
1984		8	No data available					1,742
1985		+						6,100
1986		+	1,603					8,794
1987		+	982	Actual number				8,700
1988	1988–1995 V. PARC 1993 disease widespread and active in southern Sudan in early 1990's	+	10,666			1988-1997 V. PARC; emergency vaccination on international border 1995 serological evidence of incursion from Kenya		3,490
1989		3	3,300	116,057				2,700
1990		1	2,831	370,346				1,269
1991		+	3,957	510,249				1,869
1992		+	3,847	140,000				5,980
1993		+	5,593	1,489,706				3,362
1994		+	4,729	1,776,173	Actual number			6,313
1995		+	4,360	1,075,516				778
1996	V. PARC and UNICEF/FAO; thermostable vaccine used	+	4,500	1,152,839	28,021			0
1997		+	1,364	757,280	59,259		4	5,477
1998		+	1,915	518,989	107,018			
1999			999	466,819	98,231			
2000				522,097	199,391			
2001				189,590	439,700			
2002				88,719	654,679			

LEGEND

–	*Routine vaccination by Veterinary Services, number of vaccinations not known*
236	*Vaccination by Veterinary Services funded by international programme, number x 1,000*
45	*Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000*
67	*Routine vaccination by Veterinary Services, number x 1,000*

Vaccination	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

	Unreported
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
	Virus epidemic: number denotes total outbreaks recorded in the year

YEAR	COUNTRY / CROSS REFERENCE					
	TOGO/CHAPTER 4.5.21			UGANDA/CHAPTER 4.5.22		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
1950		+			+	...
1951		+			+	...
1952		4			+	...
1953		+			+	...
1954		3			+	...
1955		1			+	...
1956		1			+	...
1957		4			+	...
1958					+	...
1959		5			+	...
1960					29	...
1961					2	...
1962		1			5	...
1963					12	440
1964					8	564
1965	V. JP15+II				1	410
1966			60		2	385
1967			47			509
1968						1,314
1969				V. JP15+IV		2,855
1970						3,135
1971						2,323
1972		4				...
1973						...
1974						...
1975						...
1976						...
1977						...
1978					+	...
1979					27	...
1980	V. FAO	+	157	V. FAO	+	...
1981					6	...
1982					2	...
1983	V. FAO			V. FAO		...
1984					1	...
1985		5			+	...
1986		3	187		22	514
1987			158		40	1,010
1988			213		61	1,319
1989			198		1	263
1990			186			534
1991					+	2,716
1992				V. PARC	2	1,212
1993					1	1,794
1994					+	1,106
1995						1,404
1996						427
1997						1,755
1998						1,175
1999						...
2000						...
2001						...

LEGEND

–	*Routine vaccination by Veterinary Services, number of vaccinations not known*	
236	*Vaccination by Veterinary Services funded by international programme, number x 1,000*	
45	*Emergency vaccination by Veterinary Services funded by FAO or donor, number x 1,000*	
67	*Routine vaccination by Veterinary Services, number x 1,000*	
Vaccination	in conjunction with PARC	V. PARC
	under JP15 and phase #	V. JP15+#
	FAO emergency vaccination	V. FAO

	Unreported
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
	Virus epidemic: number denotes total outbreaks recorded in the year

CHAPTER 4.7

THE CONTRIBUTION OF THE NEAR EAST ANIMAL HEALTH INSTITUTE (NEAHI) TO RINDERPEST CONTROL

F. NJEUMI [(1)*] & Y. OZAWA [(2)†]

(1) Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy
(2) Former Chief of the Animal Health Service, FAO, Rome, Italy
† Deceased
*Corresponding author: felix.njeumi@fao.org

SUMMARY **Between 1962 and 1972, the Near East Animal Health Institute (NEAHI) was established for countries in the Middle East in two phases, with the coordination body based in Lebanon. In its initial stage, the institutes concentrated on the laboratory research needing to be established and diagnostic test techniques. As this work advanced, the development and production of vaccines began, with a view to manufacturing safe, effective vaccines at a low cost for use in mass vaccination campaigns. Surveys for investigating the incidence of major diseases were also an important aspect of the NEAHI as well as training. The initiatives had their own weaknesses that led to the re-emergence of rinderpest in the region. The initiatives laid the groundwork for effective disease diagnosis and control. The participating governments realised the vital importance of maintaining the existing facilities and expanding the initial objectives to other aspects of livestock production.**

A cost–benefit ratio estimated across ten countries participating in PARC was 1.83:1. The internal rates of return (IRR) varied from 11% for Côte d'Ivoire to 11.8% for Burkina Faso. All of these were well above the opportunity cost of the capital. The total welfare gains from PARC were established at ECU 57.5 million (European currency units, the unit of account for the European Community that preceded the euro), which could be translated into ECU 10.7 million (or US$11.68 million) to consumers.

KEYWORDS **Disease control – Epizootiology – Laboratory – Rinderpest – Vaccines.**

INTRODUCTION

In 1953, the Director General of the Food and Agriculture Organization of the United Nations (FAO), with the support of the Government of the United Kingdom of Great Britain and Northern Ireland, organised the first Near East Meeting on Animal Health in Cyprus (1). It was attended by representatives of the governments of Afghanistan, Egypt, Ethiopia, France, Islamic Republic of Iran, Iraq, Jordan, Libya, Pakistan, Saudi Arabia, Turkey, the United Kingdom and Yemen. The meeting recommended the establishment of the Near East Commission for Animal Health, whose objective would be to promote national and international action with respect to control measures against foot-and-mouth disease (FMD), rinderpest and other contagious diseases (Newcastle disease, sheep pox, brucellosis) of international importance for the region. FAO's second Near East Meeting on Animal Health was held in Damascus in 1956. The meeting considered the provision of full professional training for a sufficient number of veterinarians to meet the requirement of the region through the establishment of permanent training centres and a proposal for the establishment of a regional organisation for animal health. Preliminary discussions among the disease control officials in Damascus in 1958 and in Cairo in 1959 indicated the need for an institute that would control major animal diseases and improve livestock production (2). As delegates at these meetings reported their animal disease problems, a region-wide picture of the most prevalent and economically significant diseases emerged. Although other diseases were mentioned, rinderpest in cattle and buffaloes was a major consideration. Whatever the disease, its control required training, research, manpower, the provision of equipment and vaccines, and a regional coordination mechanism.

In December 1960, the Governing Council of the United Nations Special Fund of the United Nation Development Programme (UNDP) approved individual requests from the Islamic Republic of Iran, Iraq, Lebanon, Sudan and Egypt for support for an initial five-year period and requested that FAO be the executing agency. Consequently, in 1962 a regional project, the NEAHI, was developed by FAO with financial support from the UNDP. The main objective of the project was to strengthen the national animal health institute in each of the five countries (Islamic Republic of Iran, Iraq, Lebanon, Sudan and Egypt). Detailed objectives were presented by Dr Daubney, project virologist (2):

- to undertake research on several disease problems of the region, and to strengthen and improve diagnosis by making the necessary *ad hoc* investigations of related problems, as they occur;
- to act as a reference laboratory on major diseases in the region, particularly in connection with diagnosis;
- to develop a procedure to produce and supply vaccines, sera and standard diagnostic antigens and reagents;
- to assist other countries of the region in diagnosis and, where necessary, to dispatch specialist personnel temporarily to investigate undiagnosed outbreaks of the disease and its control;
- to train counterpart personnel and trainees from other countries as well as holding regular training centres for countries of the Near East region.

The work of the institutes was coordinated on a regional basis by a central office located in Beirut, Lebanon. A regional training centre and a laboratory for rinderpest was established in Abbassia, Cairo (3). The proposal to establish units in connection with the national institutes was accepted in five countries of the region: Islamic Republic of Iran, Iraq, Lebanon, Sudan and the United Arab Republic (UAR) (or currently Egypt) (3, 4).

IMPLEMENTATION

The NEAHI had an international staff of 17 senior scientists and 8 laboratory technicians. The project manager was Dr W.M. Moulton. Each country unit was assigned a team leader, tasked with assisting the project manager and international experts in carrying out laboratory and field research and providing training in laboratory techniques and field survey methods. The five units' main activities (3) were as follows:

- laboratory research and vaccine production;
- field surveys;
- training;
- consultation and collaboration in regional disease control and eradication activities;
- publication.

The project was implemented in two phases.

NEAHI PHASE 1 (1962–1967)

The cash contributions of the UNDP, covering international expenses, amounted to US$3,425,000 for international staff, fellowships and special equipment. The total government contributions for local professional and supporting staff, land, buildings, equipment and supplies amounted collectively to approximately US$2.5 million (Table I). The in-kind contribution represented land, buildings, equipment and supplies. The individual plans of operation were signed early in 1962, and the five projects became operational between August and November 1962 (3).

TABLE I
NATIONAL GOVERNMENTAL CONTRIBUTIONS (US$)

Country	In cash	In kind
Iran (Islamic Republic of)	177,000	445,000
Iraq	30,000	828,000
Lebanon	30,000	454,000
Sudan	30,000	184,000
UAR	30,000	332,000
Total	**297,000**	**2,243,000**

The efforts of the five countries were concentrated on the establishment of research and training centres for selected diseases of economic importance (5) – rinderpest, FMD and African horse sickness were chosen. The regional laboratory for rinderpest was established at the Serum and Vaccine Institute in Abbassia, Cairo, and Dr K.V. Singh was assigned to carry out the following tasks:

- to select a safe and effective vaccine for rinderpest;
- to produce the selected vaccine in a sufficiently large quantity to meet the needs of Egypt and other countries of the region;
- to train the selected laboratory and field staff of the NEAHI member countries on the correct storage and use of the vaccine in the event of a rinderpest emergency;
- to provide training on the diagnosis of rinderpest and rinderpest-like diseases to both field and laboratory personnel.

Achievements of phase 1

The accomplishments of the NEAHI were the close collaboration between counterpart staff of the host laboratory and the team of foreign scientists in designing a work programme, determining equipment needs, providing administrative support and utilising the technical ability and experience of the foreign specialists assigned to the project (3, 4).

Rinderpest vaccine

The Serum and Vaccine Institute in Abbassia, Cairo, established in 1905, was selected as the most suitable place where the NEAHI's research, diagnosis and vaccine production work on rinderpest could be undertaken. This assignment was specifically designed to give effect to the recommendation of the Meetings on Animal Health (Damascus, 1956) that FAO should arrange for the creation of a reserve bank of the rinderpest vaccine to be used in the region in the event of a rinderpest incursion into a hitherto free country or countries. In 1960, two staff members were trained by Professor J. Nakamura using his lapinised–avianised vaccine strain of rinderpest, which was to be used for this purpose.

However, by the inception of the NEAHI, it was becoming apparent that tissue culture rinderpest vaccine (TCRV) would be a more suitable product for large-scale production to meet the needs of the growing cattle and buffalo population of the NEAHI region, and for the creation of a reserve of inexpensive vaccine for use in any type of cattle and buffaloes in the region.

The main task of the Cairo unit (Abbassia Institute) was to establish a laboratory for the large-scale production of this vaccine. Seed virus of the attenuated TCRV of the Kabete 'O' strain (91st passage level) was obtained from Dr W. Plowright in Kenya, and a trial batch of vaccine was produced. This vaccine was tested in local livestock to determine whether it offered more advantages than Dr Nakamura's lapinised–avianised vaccine. On the basis of the laboratory tests and field trials in 200 animals, the National Rinderpest Committee of Egypt approved TCRV as the vaccine to be used in the national vaccination campaigns in Egypt. Mass production of TCRV cut the costs of vaccine from US$1.00 per dose of the earlier vaccine to US$0.35 per dose.

Approximately 4 million Egyptian cattle and buffaloes were vaccinated in 1965 with the TCRV, and a mass vaccination programme started in 1967. By the end of the phase 1 project, the institute had not only met its objective by creating a million-dose reserve of a safe and effective rinderpest vaccine but had also supplied the vaccine to Afghanistan, Ceylon (today Sri Lanka), India, Islamic Republic of Iran, Libya, Nepal, Somalia, Sudan and Thailand. In addition, Dr K.V. Singh visited several countries in the region to train local staff on how to produce the TCRV.

Disease investigations

Investigations were also carried out in the field on rinderpest-like diseases, such as bluetongue and parainfluenza in cattle, for differential diagnoses of rinderpest.

Training and research

In addition to the individual training of counterpart personnel, training courses on rinderpest were held in Cairo for field veterinarians and laboratory specialists of the NEAHI member countries. Training was carried out in epidemiology, virology, serology, vaccine production and use, histopathology, rinderpest diagnosis and differential diagnosis. After the training in Abbassia, a training-of-trainers session was carried out in other countries in the region. Special training on the tissue culture technique was also provided to veterinarians from Somalia and Hungary.

A fellowship programme for counterpart staff was established to supplement practical training available at the institutes through advanced studies outside the region in specialised fields. Forty counterpart officers received fellowships between 1962 and 1967.

Until the establishment of the NEAHI, nothing was known about the exact role of buffaloes as carriers of the disease or whether they should be routinely vaccinated and with what vaccine. Results of virus transmission tests, together with the detection of the rinderpest complement fixation antigen and field observations, gave strong evidence that buffaloes, although they enjoy a certain high level of resistance (especially at an older age), were susceptible to rinderpest virus. Infections in adult buffaloes were usually not apparent, while younger buffaloes, especially sucklings, showed a picture of subacute rinderpest.

In addition, original research was conducted to develop differential diagnostic tests for rinderpest and rinderpest-like diseases; this work was done in collaboration with leading scientists in North America, the United Kingdom and Europe.

Considering the NEAHI's achievement – investigating disease problems to an extent that far exceeded early expectations – in January 1965, discussions were held concerning the continuation of the NEAHI in a phase 2 follow-up project. It was suggested that negotiations should be undertaken and finalised with the animal health authorities of the countries concerned before the project ended in 1967. The project had laid the groundwork for effective disease diagnosis and control, and the participating governments realised the vital importance of maintaining the existing facilities and expanding the initial objectives during a second phase.

NEAHI PHASE 2 (1967–1972)

In the programme drawn up for the NEAHI follow-up project, it was recommended that assistance be given to government services. Specific assistance was recommended in:

- establishing local clinical diagnostic facilities;
- providing veterinary faculties with senior staff and laboratory personnel who could give training in animal husbandry;
- training local veterinary personnel in demonstration and information techniques for extension work;
- expanding or establishing disease reporting, by training government health officers on the modern statistical methods and reporting systems needed to provide rapid, accurate disease reporting;
- coordinating such information between the Near East countries to create a regional disease reporting organisation to supply the livestock statistics and economic data needed by the livestock industry (6).

Early in 1968, the UNDP Governing Council approved a three-year follow-up project for Iran, and Lebanon, plus a five-year project for a new institute in Jordan, with FAO appointed as the executive agency. The Iraq and UAR projects were approved in January 1968. All projects were operational in the summer of 1968, with Cyprus joining later.

The estimated special fund contribution for the three-year phase 2 project (Table II) in Iran, Iraq, Lebanon and the UAR and the new five-year project in Jordan amounted to approximately US$4,335,700. The corresponding government contribution estimated in cash and in kind collectively amounted to approximately US$4.5 million. The special fund earmarked for the central coordinating unit amounted to US$334,600; the Government of Lebanon's estimated contribution amounted to US$175,000; and the other participating countries agreed to cover the remaining finances with funds from their NEAHI budgets (6). Under the operational plan, the individual government contributions, covering national counterpart and service staff, land, buildings, equipment and supplies, were estimated as shown in Table II.

TABLE II
COUNTRIES' CONTRIBUTIONS (US$) TO THE NEAHI PHASE 2 PROJECT

Country	In cash	In kind	Local operating cost
Iran	160,725	1,271,900	86,000
Iraq	21,739	476,800	104,000
Jordan	10,000	436,799	81,600
Lebanon	N.A.	917,244	109,600
UAR	N.A.	753 300	90,700
Total	**192,464**	**3,856,043**	**471,900**

The activities of the NEAHI covered eight countries in the region, namely Egypt, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon (coordination centre) and Turkey. A special emphasis was placed on the extensive training of laboratory specialists of each national institute on subjects such as improving the standards of vaccine production techniques for the control of diseases, such as rinderpest, FMD and poultry diseases, and upgrading the diagnostic capacity of each country.

Results for phase 2

Rinderpest training: diagnostic centres trained and equipped to diagnose rinderpest

The training of national counterpart staff and veterinary personnel and technicians from all countries of the region was one of the project's main objectives. A fellowship programme was established to supplement the practical training available in the institutes through advanced study outside the region in a specialised field. Forty counterpart officers received fellowships from 1962 to 1967 and beyond. Each unit held regional training courses that offered individual training in the fields of the unit's competence for local staff and selected veterinary and technical personnel from all countries of the region. During each phase of operation, 33 trainees from 10 countries attended training for a period ranging from three weeks to one year, for a total of 38 person-months. Short regional training sessions were organised in all the institutes to provide intensive group training, to increase the participants' technical proficiency and to broaden their knowledge in specific fields; 106 participants attended these courses. National refresher training sessions were also organised to acquaint field veterinarians with the latest techniques for rapid and accurate diagnosis of rinderpest. Eleven of these courses were held by the central office in eight countries and were attended by over 100 veterinarians (3).

Disease reporting centres trained and facilitated to report rinderpest

Veterinarians were trained and provided with forms for disease recognition and reporting. The information/data collected were subsequently published from 1963 onwards in the Animal Health yearbooks of FAO, the World Health Organization (WHO) and the World Organisation for Animal Health (OIE).

Rinderpest vaccine production

The Abbassia Institute in Cairo, UAR, the Razi Institute in Iran and the Ankara Institute in Turkey trained their staff on the production of TCRV. Under this phase, the production of TCRV for the region was also assured (Table III). The production was in accordance with the 22nd report of the WHO Expert Committee on Biological Standardization (7). The purchase of freeze-drying equipment assisted in improving vaccine production. The potency of the final product issued to the field by the institutes corresponded to $10^{2.5}$ $TCID_{50}$ (median tissue culture infectious dose) per field dose.

Rinderpest vaccine was exported from Egypt in 1969 (1,234,250 doses) and in 1970 (1,225,400 doses), as well as from Turkey. Mass vaccination was carried out in all participating countries, and, for the first time, the need to assess vaccination efficacy through seromonitoring was introduced (6).

TABLE III
TISSUE CULTURE RINDERPEST VACCINE PRODUCTION, FROM 1968 TO 1970

Country	1968	1969	1970
Iran	200,000	16,419,500	6,920,100
Turkey		5,985,800	29,032,600
Egypt	2,559,400	3,910,400	5,620,000

HANDLING OF THE NEAR EAST EPIDEMIC, 1969–1973

In the absence of movement control at the border and surveillance activities, in late 1970s, the rinderpest situation in the region deteriorated with the fresh entry of rinderpest, probably from Afghanistan. Between 1969 and 1973, the Near East epidemic affected Iran, Turkey, Lebanon, the Syrian Arab Republic and Jordan (see Chapter 2.3). The year of reinfection in several countries is listed in Table IV.

TABLE IV
RINDERPEST OUTBREAKS IN THE NEAR EAST

Country	Year of reinfection
Kuwait	August 1968
Afghanistan	Early 1969
Iran	June 1969
Bahrain	October 1969
Lebanon and Syrian Arab Republic	August 1970
South-eastern Turkey	October 1970
Jordan and Yemen Arab Republic	1971

Adapted from P.J. Moorhead, 1971 (8)

The NEAHI diagnostic facilities in Cairo (Abbassia Institute) confirmed the diagnosis of rinderpest in Jordan, Lebanon and the Syrian Arab Republic.

The main laboratories producing rinderpest vaccines in the region were the Abbassia laboratory in Cairo, Egypt, the Razi Institute in Iran and the FMD laboratory in Ankara, Turkey. All of these produced TCRV in response to the epidemic. In 1970, nearly six million doses of vaccine were produced by the Abbassia laboratory, and nearly a quarter of this was exported to various countries in the region.

The NEAHI vaccine manufacturing facilities in Turkey and Iran produced vaccine for their own use while also assisting Jordan, Lebanon and the Syrian Arab Republic.

A major success was the virtual eradication of rinderpest from the Near East, after a pandemic had swept across the region. Control procedures in the affected countries were coordinated by Dr K.V. Singh, the FAO Regional Rinderpest Laboratory Coordinator stationed in the NEAHI in Beirut.

PUBLICATIONS

The NEAHI handbooks, proceedings of the regional technical meetings, training centre documents and working papers were produced and distributed. In total, 125 documents were prepared during the project's implementation. The NEAHI handbook on rinderpest cell-culture vaccine laboratory techniques, written by Dr K.V. Singh, was revised and updated by the author. It was subsequently widely distributed in the region (9). The information circulated enabled national staff to plan for the optimum level of international staff and facilities. The wide circulation of the meetings' proceedings and technical reports on the occasion of regional training contributed to a great extent to the close regional cooperation between participating countries. Several documents were published (9, 10, 11).

WEAKNESSES

One of the major weakness of the NEAHI was that research was undertaken on several diseases (e.g. for selected diseases of economic importance [5] – rinderpest, FMD and African horse sickness) of the region, rather than concentrating only on rinderpest. In addition, the project aimed to strengthen and improve the diagnosis of important diseases by undertaking necessary *ad hoc* investigations of related problems, as they occurred. Unfortunately, little was achieved in respect to these initiatives.

CONCLUSION

In the initial stage of the NEAHI, institutes concentrated on the laboratory research needed to establish and test diagnostic techniques (3, 5, 6, 12). As this work advanced, the development and production of vaccines began, with a view to manufacturing safe, effective vaccines at a low cost for use in mass vaccination campaigns. Surveys for investigating the incidence of major diseases were also an important aspect of the various phases of the programme. By the end of the projects, the institute had met its initial objectives for training, and the rinderpest bank of safe, effective vaccine against any emergency in the region had been established.

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CHAPTER 4.8

NEAR EAST ANIMAL PRODUCTION AND HEALTH CENTRE (NEADEC), 1973–1975

F. NJEUMI [(1)*] **& Y. OZAWA** [(2)†]

(1) Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy
(2) Former Chief of the Animal Health Service, FAO, Rome, Italy.
†Deceased

*Corresponding author: felix.njeumi@fao.org

SUMMARY **In June 1971, the third meeting of the Food and Agricultural Organization of the United Nations (FAO) Animal Production and Health Commission for the Near East, while appreciating the services rendered to the region by the Near East Animal Health Institute (NEAHI), recommended the integration of animal production into health regional activities through the establishment of the Near East Animal Production and Health Centre (NEADEC). This new project differed from the previous one (NEAHI) in its innovative approaches: cross-border harmonisation through workshops/training; synchronisation of vaccination campaigns; improved systems for identifying vaccinated animals; post-vaccination seromonitoring; and establishing new vaccine-producing laboratories.**

KEYWORDS **NEADEC Near East Animal Production and Health Centre – Rinderpest – Seromonitoring – Vaccination.**

INTRODUCTION

In 1969, rinderpest invaded hitherto free countries of the Near East region during the Near East epidemic (see Chapter 2.3). At this point, the importance of a coordinated regional control programme became increasingly recognised. In June 1971, the third meeting of the FAO Animal Production and Health Commission for the Near East, while appreciating the services rendered to the region by the NEAHI, recommended the integration of regional animal production into health activities through the establishment of the NEADEC. Towards the end of 1972, following the positive replies received from several regional governments to enquiries about their possible interest in the proposed project, the United Nations Development Programme (UNDP) agreed to consider supporting the NEADEC as a two-and-a-half-year follow-up to the NEAHI project. UNDP assistance was contingent upon two conditions. Firstly, from 1973, NEAHI had to expand its programme to include both animal health and animal production and change its name to NEADEC. Secondly, it had to coordinate simultaneous vaccination on both sides of national borders (i.e. between Lebanon and the Syrian Arab Republic, the Syrian Arab Republic and Turkey, and Iran and Turkey) (1, 2, 3). Countries participating in NEADEC included Afghanistan, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon, People's Democratic Republic of Yemen, Saudi Arabia, the Syrian Arab Republic, Turkey, United Arab Republic and Yemen Arab Republic.

The yearly contribution of each of the participating countries, in addition to human resources, was equivalent in the local currency to US$10,000. The UNDP contribution for scientific instrument repair and maintenance was US$207,000 (3). The host country (Iraq) was to provide an in-kind contribution. This chapter focuses only on those project activities contributing to rinderpest control.

PROJECT MANAGEMENT

For staff, in addition to a director and three animal health officers, the project included two animal production specialists. The executive board of the NEADEC was made up of FAO and the directors of Veterinary Services, who were representatives of the participating countries. The plan of operations included an outline of the means by which the board and the project director would administer the project. The project director reported at six-monthly intervals to FAO, which provided technical advice and guidance. The headquarters was in Baghdad, with a number of specialists posted to individual countries or a group of countries (4, 5).

FACTORS TO BE CONSIDERED FOR RINDERPEST CONTROL IN THE REGION

Because of the speed with which the disease escalated, the FAO Regional Animal Production and Health Commission for the Near East convened an emergency meeting in October 1970, at which it was noted that controlling the movement of animals in the Near East was virtually impossible. By this time, the disease was already widespread in Iran and Turkey within the Near East epidemic (see Chapter 2.3), and, in addition to ongoing emergency responses, mass vaccination with indelible identification was recommended for three consecutive years, to be followed by the vaccination of calves in endemic areas at six to eight months of age. In previously disease-free countries, vaccination was recommended at birth, with revaccination within 12 months (2). The project director, in consultation with the executive board, was first to assess the target population to be vaccinated and then the yearly maximum requirements for rinderpest vaccine (Table I) in the region. This led to rinderpest control in the region through a high vaccination coverage of cattle and buffaloes in all participating countries. Such a high vaccination coverage required national veterinary departments to evaluate periodically the efficacy of their vaccination

TABLE I
YEARLY MAXIMUM REQUIREMENTS FOR RINDERPEST VACCINE IN THE REGION

Country	Doses
Afghanistan	3,000,000
Cyprus	Nil
Iran	6,000,000
Iraq	3,000,000
Jordan	50,000–100,000
Kuwait	10,000
Lebanon	250,000
Syrian Arab Republic	650,000
Turkey	15,000,000
United Arab Republic	5,000,000
Yemen, Bahrain, Saudi Arabia and other countries of the Arabian Peninsula	300,000

programmes. Therefore, it was recommended that all governments of the countries within the region involved in the rinderpest vaccination programme should endeavour to conduct post-vaccination immunity surveys. It was also necessary to keep records of vaccinated animals so that they could be recognised in the following annual vaccination campaigns.

PLAN FOR THE VACCINATION CAMPAIGN

The following three steps were taken:

a) The NEADC member governments introduced the systematic identification of all vaccinated cattle and buffaloes over one year old.
b) There was a minimum of two million doses of rinderpest cell culture vaccine kept in reserve by each of the three participating institutes (Serum Institute in Cairo, Egypt, Razi Institute in Iran and the Foot-And-Mouth Disease (FMD) Institute in Turkey).
c) The control of rinderpest was achieved by vaccinating all cattle within and/or entering the region and by implementing other control measures.

The execution plan foresaw at least two vaccination phases. NEADEC countries were faced with low levels of immunity inherited from the NEAHI project. According to Singh (6), the following factors contributed to the low level of immunity achieved during the NEAHI project and should be improved during the NEADEC project:

– the unknown pre-vaccination immunity status of the herd;

- transport and storage of vaccine under adverse conditions;
- a lack of technical competence and suitable training for vaccinators;
- inadequate vaccine to cover the country.

The strategy was modified with innovative approaches. In addition to estimating the target population for vaccination, NEADEC promoted cross-border harmonisation through workshops and training, synchronisation of the vaccination campaigns, improved systems for animal identification, post-vaccination seromonitoring and establishment of new vaccine-producing laboratories (7).

THE ACTUAL CAMPAIGN

The target animal population in the area was estimated to be 30 million head. During phase I, a total of 12 million cattle and buffaloes were vaccinated in Afghanistan, Iran, Iraq, Jordan, Kuwait, Lebanon and Saudi Arabia (but not Turkey).

In phase II, 10 million animals were vaccinated in the Gulf States, Iran and Saudi Arabia. In Afghanistan, according to Dr Van den Bogaard (8), who visited the country between 21 January 1973 and 12 March 1973, a total of 54,500 head of cattle in Laghman were vaccinated, representing about 75% of the total cattle population. More importantly, between the inception of the campaign in October 1972 and 18 October 1973, 350,000 head of cattle were vaccinated. In the provinces where Dr Van den Bogaard worked, 70–80% of the cattle population were vaccinated and had been ear punched for identification.

It was recognised that national vaccination campaigns would be insufficient to obtain a complete eradication of the disease from the region, as the reinvasion of rinderpest from bordering countries would remain unavoidable. In addition, the quantity of available vaccine was very low compared with the target population to be vaccinated. In each country, the veterinary department was responsible for the campaign, but the coordination was done by the regional executive board. This board met regularly to plan future campaign activities and review past achievements. Emphasis was given to cross-border harmonisation and simultaneous vaccination on both sides of national borders. The awareness campaign through various media was undertaken for livestock owners/keepers. It was recommended that drier and cooler periods of the year ought to be selected for an effective mass vaccination programme (9).

SEROMONITORING

In support of the proposed vaccination campaign, it was recognised that serological surveys should be conducted to assess the level of immunity in vaccinated animals. For the purpose of carrying out the proposed surveys, it was agreed that regional reference laboratories could not cope with the requirements on a routine basis and consequently recommended that facilities be made available by the governments concerned to existing national laboratories to enable them to carry out the surveys. Only a few countries, such as Turkey, the Syrian Arab Republic, Iraq and Saudi Arabia, were equipped to assess the efficacy of the vaccination campaigns by the serum neutralisation (SN) test. Even these countries lacked well-planned and -organised surveys, and most of the data available were based on blood samples collected from state farms, big private farms or villages that were easily accessible. These samples were rarely identified in terms of age groups. A series of training courses were carried out on antibody monitoring techniques. Recognising these constraints, FAO reported that the overall seropositivity in cattle following vaccination was between 20% and 85% across the region, with 58% in Jordan and 72% in Lebanon (1). A small assessment study of immunity before and after vaccination was carried out by Bogaard (8) and is presented in Table II.

TABLE II
SUMMARY OF SERUM NEUTRALISATION (SN) TESTS ON CATTLE SERA

Serum samples identification	Total tested	No. of samples positive for SN antibodies (%)
Azis before vaccination (27/02/1973)	14	7 (50%)
Azis post vaccination (07/04/1973)	14	13 (93%)
Laghman before vaccination	31	10 (32%)
Laghman post vaccination	76	67 (88%)

Adapted from Van den Bogaard (8)

MAJOR ACHIEVEMENTS

NEADEC information leaflets describing the substance and operation of the project and matters related to animal health and production were regularly produced for stakeholders. For training veterinarians in epidemiology, 8 counterpart personnel were sent to a short-term training session on data collection and processing; 12 were sent to a group training session on vaccine quality control;

107 received training on diagnostic methods of rinderpest; 19 participated in a group training session on epidemiology of rinderpest and computer data processing; and 25 participated in a group training session on laboratory diagnostic techniques. A training fellowship for a total of nine person-months was used to increase the knowledge of member countries (3, 8).

The 'NEADEC information leaflets' were produced and distributed to stakeholders. The disease was rapidly contained by stamping out sick animals, ring vaccination and paying compensation. However, a hidden focus in Lebanon flared up in 1973. Prompt action allegedly obliterated the focus, but it was not extinguished, because military withdrawals from Lebanon in 1983 introduced rinderpest into the Syrian Arab Republic again and for the first time into Israel.

Intergovernmental coordination of national vaccination campaigns, especially on both sides of international borders, was carried out through cross-border harmonisation bilateral or regional meetings of the veterinary authorities concerned. Training in various laboratory techniques was provided on the spot and through regional rinderpest training courses. Accurate reporting of the incidence of the disease to the international agencies concerned was carried out within reasonable time. Post-vaccination seromonitoring detected antibodies in around 80% of the vaccinated areas.

The major constraints in the campaigns' organisation/implementation (9) were:

- prompt recognition and reporting of the disease;
- restriction of livestock movement;
- the quality and quantity of vaccines – in fact the number of rinderpest vaccines produced was very low compared with the maximum requirement for rinderpest vaccine in the region;
- launching well-planned and -organised sustained vaccination campaigns;
- periodic and systematic evaluation of vaccination campaigns;
- disease surveillance;
- regional networks;
- laboratory diagnosis facilities in all participating countries;
- training;
- funding;
- security – several areas were not accessible;
- coordination.

To ensure a regular supply of effective vaccine, the producing laboratories were visited regularly to ensure the consistency of its production and use in the field in accordance with international requirements (10).

CONCLUSION

The inability to maintain an adequate immunisation rate in young stock was the greatest handicap experienced in most of the countries in the region. Vaccination achieved high levels of immunity in several regions of the participating countries.

The great success of the vaccination programme in these countries led to the belief that rinderpest, for which an effective vaccine was now available, was no longer a serious problem. This belief proved erroneous, as some countries still harboured the disease. The difficulties experienced in such countries in controlling the infection essentially included logistics, communication problems, security, insufficient doses of vaccine for the target population, and the project's administration and short duration. There was a need to formulate a long-term project and provide funding to address the weaknesses mentioned above.

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CHAPTER 4.9

MIDDLE AND NEAR EAST REGIONAL ANIMAL PRODUCTION AND HEALTH PROJECT (MINEADEP)

F. NJEUMI (1)* & Y. OZAWA (2)†

(1) Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy
(2) † Former Chief of the Animal Health Service, FAO, Rome, Italy
† Deceased

*Corresponding author: felix.njeumi@fao.org

SUMMARY **The Middle and Near East Regional Animal Production and Health Project (MINEADEP) was implemented by the Food and Agriculture Organization of the United Nations (FAO) from 1975 to 1991. It succeeded the Near East Animal Health Institute (NEAHI) and the Near East Animal Production and Health Development (NEADEC) programme. It aimed to assist the participating countries in promoting intraregional cooperation between their animal production and health departments. The animal health component addressed the control of rinderpest, improved diagnostics and vaccine production. The MINEADEP successfully promoted technical cooperation in the participating countries and led to a reduction in the incidence of rinderpest in several countries. Unfortunately, the project had to be suspended because of the Gulf crisis in 1990. Its third phase assisted in the formulation of the West Asia Rinderpest Eradication Campaign (WAREC).**

KEYWORDS **Disease reporting – Middle and Near East Regional Animal Production and Health Project – MINEADEP – Rinderpest – Vaccination.**

INTRODUCTION

The MINEADEP came into existence in November 1975 and was the follow-up to two earlier FAO-executed projects implemented between 1962–1975:

- the Near East Animal Health Institute (NEAHI) (see Chapter 4.7) and
- Near East Animal Production and Health Development (NEADEC) (see Chapter 4.8).

The long-term development objective was to assist the participating countries in promoting intraregional cooperation between their animal production and health departments, thereby supporting increased productivity of livestock and intraregional trade of live animals and livestock products. This project was implemented in three phases: the first phase covered the period November 1975 to December 1980; the second phase became operational in January 1981 and ran until 1986; and the third phase ran from 1987 to 1991. This chapter focuses on the animal aspect, specifically activities related to rinderpest. In 1975, the countries of the Near East experienced a major epidemic and managed to halt it. At the start of the MINEADEP, production facilities for tissue culture rinderpest vaccine (TCRV) were installed in Cairo, Ankara and Teheran. Rinderpest diagnostic skills were available in Cairo.

MEMBERSHIP, COORDINATION AND FUNDING

The MINEADEP was a regional trust fund project with a coordination office in Baghdad, Iraq. Its financial contributions were pledged and made, with minor exceptions, during various phases by the governments of the following countries: Afghanistan, Bahrain, Cyprus, Djibouti, Egypt, the Islamic Republic of Iran (from 1982), Iraq, Jordan, Kuwait, Lebanon, Libya, Oman, Pakistan, Qatar, Saudi Arabia, Somalia, Sudan, the Syrian Arab Republic, Tunisia, Turkey, United Arab Emirates and Yemen (previously Yemen Arab Republic and People's Democratic Republic of Yemen). Covering 23 countries, the cost of the project was estimated in the original project document approved in Baghdad (October 1975) at about US$6.9 million, whereas pledges made by participating countries did not exceed US$3.9 million. However, at the end of the project, the total government contributions had amounted to approximately US$9 million (1, 2, 3, 4).

Table I describes the status of expenditure. Coordination was ensured by staff at the headquarters in Baghdad and outposted officers. Dr Amin El-Karib, who was director during phase I, and Dr F.I. El Dessouky, who was director during phase II, were assisted by Dr Thabet El Safar, assistant director, and Dr K.V. Singh, a virologist; the training coordinator was assisted by administrative staff. Outposted specialists were stationed in Cairo, covering Egypt, Libya and Tunisia. Dr Thabet was also the animal health specialist/epizootiologist. He was to organise and lead teams to investigate diseases and to assist the infected countries in the control and eradication of these diseases (4).

OBJECTIVES AND IMPLEMENTATION

The main objective of MINEADEP was to develop animal production and health aspects in a number of countries in the Near East region. The immediate animal health objectives were (1, 3, 6):

- to monitor the incidence of major infectious diseases of livestock (especially rinderpest, foot-and-mouth disease (FMD), brucellosis, blood parasites and contagious bovine pleuropneumonia) and prepare regional action plans for their control or eradication;
- to promote and streamline the animal disease surveillance network in the region.

The MINEADEP was managed by a project director, an animal health officer and an executive board. The latter consisted of representatives of the participating countries (directors of animal health) and FAO. The animal health officer spent a significant share of his time addressing laboratory matters, training and disease control. The MINEADEP functioned from 1975 until 1990, when, owing to the Gulf crisis, its operations were curtailed, with the exception of a few activities based on an *ad hoc* request from some countries. The flow of financial contributions was also interrupted.

With regard to rinderpest, during the MINEADEP period, Sudan (by then a member) experienced a severe epidemic from 1978 to 1984. Egypt experienced a severe epidemic between 1982 and 1986; the Islamic Republic of Iran experienced outbreaks in 1981 and 1987; Iraq experienced an outbreak in 1985; Israel experienced an outbreak in 1983; Lebanon was infected in 1982; Saudi Arabia was infected in 1981; Kuwait was infected in 1980; and Yemen experienced a major epidemic around 1982. Pakistan had endemic undeclared rinderpest in Sindh province. Turkey did not experience an outbreak during the MINEADEP period.

By 1987, almost five million large and small ruminants had been imported into the region every year. Exporting countries included Sudan, Somalia, Ethiopia, India and Pakistan. This large-scale cattle movement brought rinderpest into the area. In August 1970, after killing thousands and thousands of cattle and buffaloes, it moved westwards, invading the Syrian Arab Republic, Jordan and Lebanon through Turkey, and caused tremendous direct and indirect economic losses. Since its introduction, rinderpest, instead of losing ground, gained territory every year. The disease was introduced into Iraq in March 1985 by the importation of Indian buffaloes via Kuwait; many unofficial outbreaks were still being reported from this region (7).

Phase I (November 1975 to December 1980)

Short-term training courses

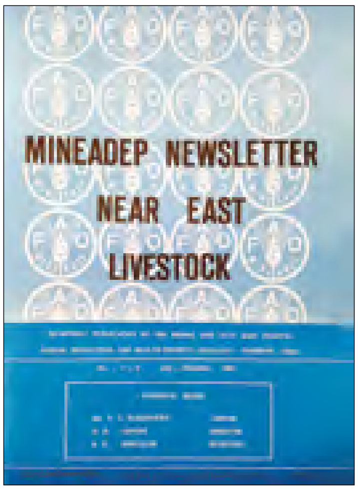
According to FAO (8), one of the major activities was the training courses of two to four weeks, with an average attendance of 15 trainees per course. The courses were organised such that 25% of the time was spent in lectures and 75% of the time was devoted to practical work. The training's focus was on the maintenance and repair of scientific and technical equipment for diagnosis and vaccine production. Several newsletters (Fig. 1) were issued as the outcome of the training and conferences/workshops, to address the implementation of MINEADEP.

TABLE I
STATEMENT OF EXPENDITURE (US$) FROM MINEADEP'S INCEPTION UNTIL 30 APRIL 1993

Country	Pledges			Office/ salary contribution	Total contribution	1992	1991	1990	1989	1988
	Phase I	Phase II	Phase III							
Afghanistan		50,000	10,000	40,909	**19,091**				10,000	
Bahrain	100,000	50,000		0,00	**150,000**					
Cyprus	10,000	20,000	20,000	0,00	**50,000**				20,000	
Djibouti			10,000	10,000	**0.00**					
Egypt	30,000		50,000	13,000	**67,000**				50,000	
Iraq	2,500,000	1,500,000	300,000	104,708.75	**4,195,291.25**				193,548	
Jordan	25,000	50,000	50,000	26,027	**98,973**			6,973		
Kuwait	250,000	200,000	200,000	133,000	**517,000**			67,000		
Lebanon		50,000	20,000	19,502	**50,498**	16,752		144		162
Libya	100,000	750,000		450,000	**400,000**					
Morocco		50,000		50,000	**0.00**					
Oman	10,000	10,000	50,000	0.00	**70,000**			16,667	33,333	
Pakistan	15,000	50,000		30,146.51	**34,853.49**				7,619	
Qatar	250,000	50,000		0.00	**300,000**					
Saudi Arabia	500,000	1,000,000		0.00	**1,500,000**					
Somalia	25,000	50,000	20,000	93,803.83	**1,196.17**					
Sudan	30,000	50,000	30,000	30,000	**80,000**					
Syrian Arab Republic		50,000	50,000	20,000	**80,000**			50,000		
Tunisia	10,000	50,000	50,000	17,500	**92,500**					10,000
Turkey	5,000	50,000	50,000	1,611.23	**106,611.23**					51,442
United Arab Emirates	75,000				**0.00**					
Yemen –Yemen Arab Republic	3,000	50,000	73.50	102,926.50	**29,960**				49,926	
Yemen –People's Democratic Republic of Yemen		50,000		50,000	**0.00**					
Subtotal				1,087,059.36	**7,990,940.64**	16,752	0.00	140,784	364,426	61,604
Interest					**886,194.98**	16,752	30,497.81	39,335	44,587	40,020
Total	**3,938,000**	**4,180,000**	**960,000**	**1,087,059.36**	**8,919,942.89**	**33,504**	**30,497.81**	**180,119**	**409,013**	**101,624**

Adapted from FAO, 1993 (5)

FIG. 1
ONE OF THE MINEADEP NEWSLETTERS
Source: MINEADEP, 1983 (3)



Fellowship training courses

The Executive Board, at its meeting in December 1978, reformulated the fellowship programme. There were 20 fellowships with a duration of three months (one for each participating country), 8 with a duration of four months and 12 with a duration of two months.

Improved diagnostics and vaccine production

Dr K.V. Singh, the project's virologist, was engaged in collecting viral samples for their examination and appraisal, with a practical emphasis on those that may be used for the production of vaccines. He undertook a number of field trips to investigate cases of disease. His observations and diagnoses led to a number of prophylactic and curative

TABLE I CONTINUED

Country	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Afghanistan	9,091				50,000						100,000		
Bahrain											10,000		
Cyprus				20,000									
Djibouti													
Egypt								11,000		6,000			
Iraq		301,581	300,081.25	300,081	600,000	750,000		490,000		10,000	750,000		500,000
Jordan	17,000		16,000		34,000					15,000	5,000	5,000	
Kuwait			70,000	65,000		65,000				125,000	25,000	100,000	
Lebanon	721	3,495	5,929	23,295									
Libya			150,000	150,000					100,000				
Morocco													
Oman						10,000			10,000				
Pakistan	8,185			4,049.49		2,000			5,000				
Qatar					50,000				125,000		125,000		
Saudi Arabia	200,000			300,000	500,000			300,000		100,000		100,000	
Somalia			1,196.17										
Sudan				50,000								30,000	
Syrian Arab Republic			20,000	10,000									
Tunisia	20,000		2,500		2,500	22,500	12,500	12,500		10,000			
Turkey									5,190.23				
United Arab Emirates	15,750	34,229						50,000			25,000		
Yemen – Yemen Arab Republic			50.50	49,950								3,000	
Yemen – People's Democratic Republic of Yemen													
Subtotal	270,747	339,305	409,827.92	955,009.49	1,409,795	849,500	12,500	863,500	245,190.23	266,000	1,045,000	241,000	500,000
Interest	42,728	66,397	115,102	105,350	38,259	18,678	66,549.12	94,746.15	54,258.75	54,753.2	37,502.65	11,462.61	9,216.69
Total	**313,475**	**405,702**	**524,929.92**	**1,060,359.49**	**1,448,054**	**868,178**	**79,049.12**	**958,246.15**	**299,448.98**	**320,753.2**	**1,082,502.65**	**252,462.61**	**509,216.69**

measures taken by national veterinary authorities. He also established a working relationship with prominent veterinary laboratories outside Iraq, such as the Pasteur Institute in France, the United Kingdom of Great Britain and Northern Ireland and Egypt. He was also engaged in training in the region. He assisted in the modernisation of the vaccine-producing laboratories (particularly those prepared on tissues or chick embryos from attenuated virus strain) and in the improvement of diagnostic services. To fulfil the project's objective to strengthen cooperation among countries in the region and coordinate policies and plans, the project arranged a number of meetings and seminars. The greatest attention was given to the production of vaccines against rinderpest, which were either prepared locally (as is the case in several countries) or obtained from within the region (the suppliers in the latter case being the Razi Institute in the Islamic Republic of Iran, and the Abbassia Institute in Egypt, Iraq, Pakistan and Sudan). These laboratories produced TCRVs. As a measure of productivity related to the activities of MINEADEP, in 1976/77, Sudan and Pakistan produced, respectively, 7,744,800 and 2,408,500 doses of TCRV (7, 8). These were successfully used in the respective countries or exported to those within the region to address various rinderpest occurrences.

Phase II (1981–1986)

As the second phase of the MINEADEP was not operational until January 1983, between 1981 and 1982, the project continued its activities on a smaller scale, utilising savings from phase I. This second phase ended in 1986. Although in theory the immediate objectives were never changed, in practice the operational scope of the MINEADEP was drastically reduced during phase II, to focus on selected areas, such as the promotion of cooperative efforts for the control of diseases, especially rinderpest and FMD. During this time, rinderpest had to be mainly dealt with by separate projects, such as the FAO/United

Nations Development Programme (UNDP) projects in Turkey and the Syrian Arab Republic. Other countries that did not have separate projects were supported under the umbrella MINEADEP funds. With regard to rinderpest control, its activities were largely of a fire-brigade nature (3), in the event of any outbreaks.

In Turkey, the Rinderpest Serum Institute, considered the beginning of today's Etlik Central Veterinary Control and Research Institute, used to operate in Eskişehir during the Turkish War of Independence but had to move to Ankara, and then to Kirşehir/Bozkaya, owing to the war. The institute then changed its name to the 'Ankara Serum Production Institution' and moved to its current location in Etlik in December 1921, where it produced rinderpest serum.

The FAO/UNDP project (TUR/024) in Turkey started in 1980 and ran up until 1984. The project was located at the Veterinary Research Institute in Etlik, Turkey. Dr K.V. Singh assisted the laboratory in the mass production of TCRV. In addition, he supported his counterpart staff in improving the procedures for the differential diagnosis of rinderpest and strengthened the control of movement of livestock in the country, with emphasis on international borders. For the vaccination campaign, a national coordinator was appointed, and over 6 million head of cattle in 28 south-eastern provinces in Turkey were vaccinated by September 1982, to prevent the entry of rinderpest from the Islamic Republic of Iran, Iraq and the Syrian Arab Republic. In March 1983, an additional 2.8 million animals were vaccinated. Later, it was decided that all cattle in the same provinces would be revaccinated (9) as a preventive measure.

Vaccine storage facilities at the veterinary provincial centres, as well as the Veterinary Research Institute in Etlik, were improved. The vaccinated animals were not ear-marked, but the number of vaccinated cattle was recorded by the veterinarian responsible. Efficacy of the vaccine and the vaccination campaign were evaluated by statistically sampling cattle sera collected seven months after vaccination, and it was confirmed that the rate of immunity was approximately 75%. Cattle in the provinces where the immunity rate was lower than 60% were immediately revaccinated, and the reasons for poor antibody response were examined and corrected. The laboratory facilities of the Central Laboratory in Ankara were improved, and the laboratory specialists were trained in differential diagnosis of rinderpest by agar gel precipitation tests, in isolation and identification of viruses recovered from sick animals, and in antibody titration of vaccinated cattle. The Turkish campaign was an excellent example of what could be achieved by a country in the Near East (3, 9, 10).

With regard to the Technical Cooperation Programme in the Syrian Arab Republic (1985–1986), in 1985, a short-term consultant was assigned to the country by the MINEADEP when the Syrian Arab Republic was threatened again by rinderpest outbreaks from the neighbouring countries (e.g. Lebanon). Under this project, materials and equipment essential for the production of rinderpest vaccine were provided by FAO, and a new laboratory was established in the Central Veterinary Institute in Damascus. In-service training was provided by Dr K.V. Singh for the laboratory specialists, and three batches of the rinderpest vaccine were produced. The quality of the vaccine and its specificity and safety were tested before the vaccine was used in the field. A manual of standards for rinderpest vaccine production and quality control was prepared for the laboratory specialists (11, 12).

The third conference of the Council of Arab Ministries of Agriculture in the States of the Gulf and Arabian Peninsula (CAMAGSAP) held in Doha, Qatar, in 1978, prior to phase II of MINEADEP, had stressed the pressing need to control rinderpest in the area. It had requested that MINEADEP prepare a plan for eradicating rinderpest and requested that FAO undertake the necessary study. A technical meeting of the representatives of animal health services in the member states was held in Riyadh from 20 to 26 January 1980. The meeting discussed the study presented by FAO and finalised it as a CAMAGSAP project for adoption by the ministerial conference. The project received UNDP funding for four years through FAO trust funds amounting to US$3,663,256, starting in September 1980. It covered the following countries: Bahrain, Iraq, Kuwait, Oman, People's Democratic Republic of Yemen, Qatar, Saudi Arabia, United Arab Emirates and Yemen Arab Republic. The project was entitled 'Rinderpest Eradication Campaign in the Gulf States and Arabian Peninsula' and had similar objectives to those of MINEADEP (5). Laboratory capacities for diagnosis were improved, and the laboratory in Iraq was developed to allow the production of vaccine that was used in several participating countries.

During this phase, the project started to supply countries with vaccines, seed virus and frozen liquid upon request, and all facilities were required to ensure their safe arrival in the countries. Table II shows the material sent to countries (3).

Phase III (1987–1991)

During this phase, many of the activities established in the earlier phases of MINEADEP were continued and strengthened, with particular attention given to surveillance and disease reporting.

TABLE II
MATERIALS SENT TO COUNTRIES DURING MINEADEP

Country	Rinderpest vaccine	Syringes	Seed virus	Samples sent to international laboratory	Training and other materials
Egypt	Not specified	Information not available	Yes	Yes	Yes
United Arab Emirates	Information not available	Information not available	Information not available	Yes	Yes
Iraq	Not specified	Yes	Yes	Yes	Yes
Jordan	10,000 doses	Yes	Information not available	Information not available	Yes
Pakistan	Information not available	Information not available	Information not available	Information not available	Information not available
Qatar	10,000 doses	Yes	Information not available	Information not available	Yes
Sudan	377,500 doses	Yes	Information not available	Information not available	Yes
Somalia	Not specified	Yes	Information not available	Information not available	Yes
Yemen –People's Democratic Republic	Not specified	Yes	Information not available	Information not available	Yes

With respect to rinderpest, this phase of the project was instrumental in providing vaccines to participating countries for emergency needs. Nearly 1.9 million doses of rinderpest vaccines were shipped and used in nine countries: Bahrain, Jordan, Kuwait, Lebanon, Qatar, Sudan, Egypt, Yemen Arab Republic and People's Democratic Republic of Yemen (4).

A vaccine bank (Baghdad, Iraq) was established, not only saving countries considerable operational costs but more importantly providing a centralised stock of vaccines available for outbreaks.

MINEADEP took the lead in the preparation of the special project 'Rinderpest Eradication Campaign in the Gulf States and Arabian Peninsula'; the lessons learnt from this campaign and those from MINEADEP were used to formulate the West Asia Rinderpest Eradication Campaign (WAREC), described in Chapter 4.10.

In general, the vaccines used during these phases were either produced locally in Turkey, Iraq, Egypt, Sudan or Saudi Arabia or imported from Kenya, India, the United Kingdom (Coopers) and France (Mérieux). A few countries, such as Turkey, the Syrian Arab Republic, Iraq and Saudi Arabia, had cell culture facilities and staff to assess the efficacy of the vaccination campaign through serum neutralisation (SN) tests. In general, only 20–30% of the samples from pastoral farms were found to be positive for SN antibodies. On the well-managed state farms, the rate of immunity among adult stock was 80–85%. The low seroconversion in local/pastoral farms may explain the perpetuation of rinderpest in the region (5, 13).

The project increasingly led to the development of laboratory and diagnostic services. The importance of training technical, specialist staff on rinderpest and the services that these staff members provided in expanding veterinary and laboratory services has become increasingly evident (5, 13, 14). It was noted at the time, that the experience gained by MINEADEP in its training programme, should be recognised when formulating any future projects (5, 8, 13, 15).

CONCLUSION

It was clear that, from the start, there was a marked imbalance between the ambitious objectives of MINEADEP and the available resources. Although the stated objectives were never formally changed during the life of the project, in practice its operational scope was drastically curtailed to cover only selected areas, focused on promoting cooperation for the control of diseases, especially rinderpest and FMD.

Although the project maintained a close liaison with regional institutions, such as the Arab Organization for Agriculture Development (AOAD), the Arab Centre for the Studies of Arid Zone and Dry Lands (ACSAD), the Arab Agro-Industry Organization and the Gulf States Cooperation Council (GSCC), MINEADEP was not able to engage in livestock research (breeding, feeding, management, livestock trade and the preparation of feasibility studies) to achieve the broader objectives of the project.

However, in contrast to its limited contribution to livestock research, the project played an important role in controlling the eradication of rinderpest and provided the platform to formulate WAREC.

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CHAPTER 4.10

WEST ASIA RINDERPEST ERADICATION CAMPAIGN (WAREC)

S.C. MATHUR [(1)] & Y. OZAWA [(2)†]

(1) H-28, Sector-11, Noida – 201301, Uttar Pradesh, India (Former Project Coordinator, West Asia Rinderpest Eradication Campaign, Food and Agriculture Organization of the United Nations [FAO] and United Nations Development Programme)

(2) Former Chief of the Animal Health Service, FAO, Rome, Italy

†Deceased

SUMMARY

The West Asia Rinderpest Eradication Campaign (WAREC), a regional project, was implemented from March 1989 to December 1993 in 11 countries of West Asia: Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Syrian Arab Republic, United Arab Emirates and Yemen. Although first recorded in the 1820s and then controlled, rinderpest appeared in all countries of the region in epidemic form in the 1970s and 1980s. For most countries in the region, rinderpest entered as a result of loose quarantine arrangements but it had probably been present in Yemen since at least the early 1970s (see Chapter 4.11.12).

As part of the WAREC project, a regional coordination unit, a regional rinderpest laboratory and a data management cell were established at Baghdad and subregional enzyme-linked immunosorbent assay (ELISA) testing centres were set up in eight countries. Existing facilities for manufacturing around 15.5 million doses of rinderpest tissue culture vaccine were strengthened in four countries. Facilities for diagnosing rinderpest by virus isolation, tissue culture and immunological tests were strengthened in six countries, and basic rinderpest diagnostic tools were established in the remaining five countries. Four consultants were engaged and 187 veterinarians were trained in serosurveillance, ELISA testing, diagnosis, vaccine quality control, animal quarantine and data management and epidemiology. A communication campaign was launched.

Mass vaccination was arranged in 1991 and 1992. Out of a target bovine population of 8.5 million in the West Asia region, 7.5 million were vaccinated in 1991 (88% coverage) and 8.3 million in 1992 (97.6% coverage). However, the coverage varied between 23.5% and 100% among countries. The low coverage was due to the Gulf War of 1990 and 1991, but it was made up for by repeating the vaccination in 1993. About 29,000 serum samples were tested for antibody to rinderpest virus.

The mass vaccination resulted in a progressive reduction in the disease. Yemen and Lebanon became free from clinical rinderpest in October 1992, Iraq in February 1993 and the United Arab Emirates and Oman in March 1993. Thus, no rinderpest was reported in these five countries for periods that ranged from nine months to two years before the WAREC project terminated in December 1993. In the remaining six countries rinderpest-free status was maintained.

However, following clinical surveillance in these countries, some hidden foci of infection were detected and rinderpest reappeared in Oman, the United Arab Emirates and Yemen but was ultimately

controlled in these countries in June, October and December 1995, respectively.

KEYWORDS ***Al-taun al-baqar*** **– Faulty quarantine – Natural desert barriers – Near East Pandemic – Operation Rinderpest – WAREC coordination unit.**

HISTORY OF RINDERPEST IN THE REGION

Livestock rearing is the most important economic activity of low- and middle-income farmers, pastoralists, nomads and Bedouins of West Asia, who rear cattle, sheep and goats for milk, meat and wool. A net exporter of food less than 60 years ago, the West Asian region has become the largest food importing region in the developing world, having to import live animals, meat and dairy products. Against this backdrop, the governments of West Asian countries have initiated various programmes to improve the breeding, nutrition and health of livestock with a view to increasing the indigenous production of milk, meat and wool. Diseases and pests, however, remain a major hurdle to increasing livestock production.

Among the infectious diseases prevalent in the region, rinderpest, or *al-taun al-baqar* in Arabic (meaning plague of cattle), was the deadliest of all. This disease had entered the region in the early 1970s from South Asia and since then it had become established in West Asia. Rinderpest adversely affected the supply of animal protein and was a serious barrier to international trade in livestock and livestock products.

Although West Asian countries mounted individual programmes to control rinderpest in their territories, eradication of the disease from the region required a coordinated effort. The West Asia Rinderpest Eradication Campaign (WAREC) was launched in March 1989 as a regional United Nations Development Programme (UNDP)/Food and Agriculture Organization of the United Nations (FAO) project (RAB/86/024) in 11 countries (Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, the Syrian Arab Republic, United Arab Emirates, Yemen) and continued until December 1993.

Rinderpest was first noticed in Egypt in 1827 in draught cattle of the Egyptian army. In response, a veterinary training centre was established by two French veterinarians, Hamoon and Bruno, and an Egyptian professional, Mohammed Ali, to study and control the disease. Subsequently, rinderpest followed a 20-year cycle, appearing in 1842–1843, 1863, 1880–1882, 1903–1904, 1912–1925, 1945–1947, 1950–1953, 1958 and 1961–1963. In Iraq, rinderpest was first recorded in the period 1918–1923 as a result of the British army bringing cattle and buffaloes from India during the First World War.

The local name for the disease was *abu-hadlal,* meaning 'animal with drooping head and ears'. Thereafter, the country remained free from the disease for six decades. In the Syrian Arab Republic, the first epidemic occurred in the 1920s. By 1934, the disease had been controlled by quarantine, slaughter and inoculation of in-contact cattle. The disease was first reported in Bahrain in 1962 and in 1965 in Saudi Arabia and the adjacent southern part of Yemen.

The other countries in the region were engulfed with rinderpest in the Near East Pandemic of 1969–1973 (see Chapter 2.3) when the disease rolled through Afghanistan, Iran and Bahrain (1969–1973), Turkey (1970) and the Syrian Arab Republic, Lebanon and Jordan (1971). During the 1970s and 1980s rinderpest occurred in all 11 WAREC countries. It was reported in Bahrain in 1976, 1985 and 1988; in Egypt in 1982–1986; in Iraq in 1985; in Jordan in 1971; in Kuwait in 1971–1979, 1980–1981 and 1984; in Lebanon in 1971–1973 and 1977–1991; in Oman in 1979, 1982, 1984, 1986, 1988 and 1991–1993; in Qatar in 1987; in the Syrian Arab Republic in 1971–1974 and 1982 to 1983; in the United Arab Emirates in 1977, 1979, 1984 and 1991–1993; and in Yemen from 1969–1992.

In 1988 the WAREC region had a reported bovine population of 8,446,000 head: 6,000 in Bahrain; 4,520,000 in Egypt; 1,745,000 in Iraq; 29,000 in Jordan; 26,000 in Kuwait; 52,000 in Lebanon; 136,000 in Oman; 8,000 in Qatar; 724,000 in the Syrian Arab Republic; 50,000 in United Arab Emirates; and 115,000 in Yemen. These bovines were mostly cattle, except for 2,300,000 buffaloes in Egypt, 111,000 in Iraq and 1,000 in the Syrian Arab Republic.

The cattle population comprised 30% to 40% exotic and cross-bred dairy cows, which appeared to be more susceptible to rinderpest than indigenous cows. The dairy cows, mostly Holstein–Friesians, were kept in organised farms in all of the WAREC countries. Although some progressive farmers in Iraq had established dairy farms with 20,000 to 30,000 cows and buffaloes, small farmers in the region owned the bulk of the cows and buffaloes and had, on average, holdings of 10–15 cows and 15–200 buffaloes. The animals were kept loose in paddocks or cattle sheds. They were mostly stall fed and occasionally taken to nearby areas for grazing or wallowing. As buffaloes were never tied, it was often difficult to approach or control them for vaccination or veterinary aid.

In the Gulf countries, livestock were mostly kept as a hobby by rich people in their orchards in groups of 10–30 cows.

In Yemen, livestock was deemed a sign of wealth or prestige and was often given as a marriage gift. Animal holdings were small, with an average farmer owning around 2–3 cows and 15–20 sheep and goats. Cows, sheep and goats were kept in separate paddocks at farmers' houses. Cows were hand fed by many farmers.

In Yemen, cattle herds were moved on hoof from one area to another for trade; this was a major way in which rinderpest infection was disseminated. However, in other countries, cows, buffaloes, heifers and calves were moved by truck to cattle markets for trade, each market holding 100–200 animals.

Most WAREC countries imported cattle and buffaloes for meat and the entry of rinderpest was linked to imported animals as a result of inadequate quarantine in Yemen, Lebanon and the United Arab Emirates. Yemen imported stock from Djibouti, Ethiopia, Somalia, Sudan and Kenya; and the United Arab Emirates imported from India, Pakistan, Ethiopia, Kenya and Sudan. In Egypt, immature cattle brought for fattening from Sudan and Somalia also brought the disease. Unrestricted land movement of stock between Yemen, Oman and the United Arab Emirates spread infection. The movement of refugees and military personnel also spread the disease in areas with a common land border, such as the Islamic Republic of Iran, Iraq and Turkey. In Yemen, infection year after year indicated the presence of hidden foci and endemicity.

The WAREC region has several geographical and cultural features that contributed to the eradication of rinderpest. A major part of the region is arid or semi-arid and bovine rearing is confined to agricultural areas. For most of the year the region has a high ambient temperature and bright sunny days, making virus survival difficult. Several countries have wide natural desert barriers, making it difficult to move livestock between countries. There is comparatively little wildlife and nomadic cattle herds are absent.

VETERINARY SERVICES AND VACCINATION CAMPAIGNS

At the time of WAREC, Veterinary Services in the region were provided through veterinary hospitals and dispensaries. There were 18,135 government veterinarians and 12,787 vaccinators/field assistants, and there were another 5,162 veterinarians in laboratories and colleges to provide diagnostic support. Vaccination work was carried out by specially constituted vaccination teams, except in Oman where a contractor was hired for the purpose. There were 60 animal quarantine stations in the region located at airports, seaports and international land borders. Each country had animal quarantine and disease control laws.

The WAREC workplan envisaged a preparatory phase (1989–1990), a vaccination phase (1991–1992) and a surveillance phase (1993 onwards). During the preparatory phase a regional coordination unit, a regional rinderpest laboratory and a data management cell were established in Baghdad (Iraq). For seromonitoring, eight subregional ELISA testing centres were set up in Egypt, Iraq, Jordan, Kuwait, Lebanon, Oman, the Syrian Arab Republic and Yemen. The region already had the capacity to produce 15.5 million doses of rinderpest tissue culture vaccine (Kabete 'O' strain) in Egypt, Iraq, Jordan and the Syrian Arab Republic, which was further strengthened through project funding by supplying new equipment and chemicals. In addition, existing facilities for diagnosing rinderpest by virus isolation, tissue culture and immunological tests (in Egypt, Iraq, Jordan, Oman, the Syrian Arab Republic and Yemen), were further strengthened. Basic rinderpest diagnostic facilities were set up in the national diagnostic laboratories of the remaining five countries. Four consultants were engaged and 187 field veterinarians were trained in rinderpest diagnosis, serosurveillance and ELISA testing, vaccine quality control, animal quarantine and computer processing, data management and epidemiology.

A WAREC communication campaign was launched using posters. The logo used throughout the campaign is shown in Figure 1. Diagnostic photo albums and transparency kits, showing lesions and other clinical signs of the disease, were distributed in all the countries to help field veterinarians identify sick animals. The photo album depicted clinical signs of watery discharge from the mouth, nostrils and eyes (Fig. 2), opacity of the eyes (Fig. 3), watery stools (Fig. 4), erosion of the gums and tongue (Fig. 5), focal necrosis of the mucosa of the abomasum (Fig. 6) and haemorrhagic longitudinal stripes (Fig. 7) and transverse stripes (Fig. 8) of the intestinal mucosa. A WAREC bulletin 'Operation Rinderpest' was published (Fig. 9). Separate materials

FIG. 1
WAREC LOGO
Courtesy of the authors

FIG. 2
DISCHARGE FROM MOUTH, NOSTRILS AND EYES
Courtesy of the authors

FIG. 3
OPACITY AFFECTING THE EYE
Courtesy of the authors

FIG. 4
WATERY STOOLS
Courtesy of the authors

FIG. 5
EROSIONS ON GUMS AND TONGUE
Courtesy of the authors

FIG. 6
FOCAL NECROSIS IN THE ABOMASUM
Courtesy of the authors

FIG.7
HAEMORRHAGIC LONGITUDINAL STRIPES IN THE INTESTINE
Courtesy of the authors

FIG. 8
HAEMORRHAGIC TRANSVERSE STRIPES IN THE INTESTINES
Courtesy of the authors

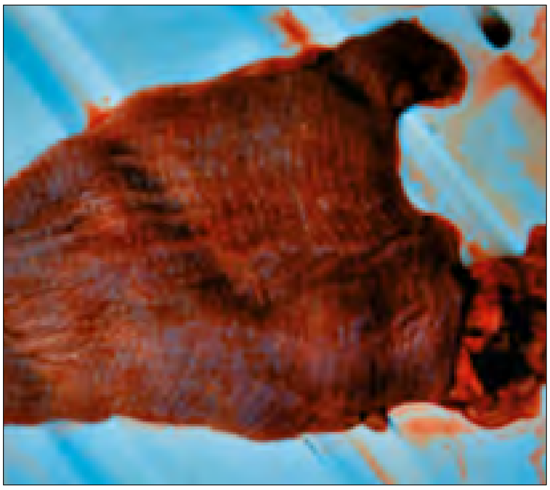
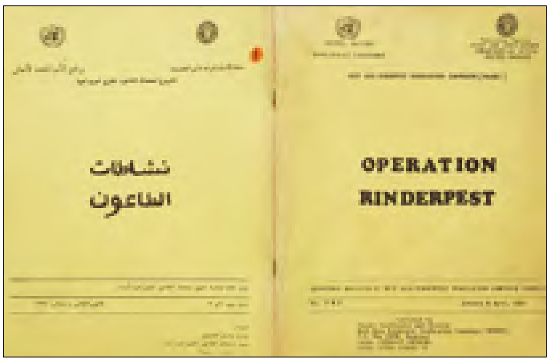


FIG. 9
WAREC BULLETIN: OPERATION RINDERPEST
Source: West Asia Rinderpest Eradication Campaign (WAREC) (1994). – Operation rinderpest. *West Asia Rinderpest Eradication Campaign Bulletin*, Nos 2 & 3, January-April 1994.



were prepared for each country accompanied by information on how the rinderpest eradication programme would be implemented.

The WAREC coordination unit was relocated from Baghdad to FAO headquarters Rome in 1991, as a result of the Gulf War of 1990–1991. After the end of the war, the unit functioned from Amman (Jordan) during 1992 and 1993. In spite of political differences between some member countries following the Gulf War, all countries remained united in implementing the WAREC programme.

After the initial preparatory phase, the vaccination phase was implemented, in which two rounds of mass vaccination of the susceptible cattle and buffalo populations were arranged during 1991 and 1992 (see Chapter 4.12). As some countries could not carry out mass vaccination owing to the Gulf War, an additional round of mass vaccination was conducted in 1993. Out of a bovine population of 8.5 million, 7.5 million vaccinations were carried out in 1991 (88% coverage), 8.3 million in 1992 (97.6% coverage), and approximately 8.5 million vaccinations were conducted in 1993. The percentage coverage by vaccination varied among countries in 1991 and 1992 (Table I).

TABLE I
VACCINATION COVERAGE DURING 1991 AND 1992 (PER CENT POPULATION VACCINATED)

Country	Population vaccinated (%)	
	1991	1992
Bahrain	100.0	50.0
Egypt	100.0	100.0
Iraq	45.0	100.5
Jordan	54.2	40.0
Kuwait	0.0	100.0
Lebanon	55.8	23.5
Oman	13.2	31.0
Qatar	14.0	40.0
Syrian Arab Republic	69.8	76.7
United Arab Emirates	82.7	92.3
Yemen	35.6	30.4

In Bahrain, the low coverage in 1992 was due to the short supply of vaccine. Egypt's coverage was more than 100% in 1991 and 1992 indicating that some animals were vaccinated twice. In Iraq and Kuwait the low vaccine coverage in 1991, which was caused by the Gulf War, was corrected in 1992. Iraq vaccinated 89% of the bovine population between January and June 1993. In Jordan, the low vaccination coverage in both years was due to a shortage of vaccine, and in Lebanon it was due to a lack of financial support in the post-war period. The shortfall in these countries was made up in 1993. In Oman, a vaccination contractor could not be hired in 1991 and 1992, hence vaccination occurred only in 1993. Qatar was rinderpest free and hence did not require higher coverage. The Syrian Arab Republic, although rinderpest free, had coverage of 69.8% in 1991, 76.7% in 1992 and 83% from January to September 1993. Yemen could cover only one-third of the population each year, owing to a shortage of human resources and budgetary and logistics support; however, it attempted to achieve 100% coverage over the three years.

In order to assess the efficacy of vaccination, serum samples were collected randomly in 1991 and 1992 from different age groups of vaccinated cattle and buffaloes from different governorates in Egypt, Iraq, Jordan and Yemen. In all, about 29,000 serum samples were tested and the percentage of immune animals was found to vary from 46% to 91%. Wherever the percentage of immune animals was found to be less than 65%, a target of 100% vaccination was set for 1993.

The mass vaccination resulted in a progressive reduction in the incidence of rinderpest in the region. In Yemen, rinderpest occurred from 1971 to 1992. During the period 1987 to 1989, the annual incidence was 200 outbreaks with 1,000 cases. This fell to 33 outbreaks across the 17 subdistricts affected by 1991, and by September 1993 Yemen was free from clinical rinderpest. In Lebanon, rinderpest was reported from 1971 to 1991. In 1989 there was a major outbreak in which thousands of animals died, but in 1991 only five outbreaks were reported. Thereafter, no rinderpest was reported.

In Oman, sporadic cases of rinderpest were reported during 1979, 1982, 1984, 1986 and 1988. In 1991, out of a total of eight governorates, two were affected with eight outbreaks. In 1992, ten outbreaks were reported. The last outbreak of rinderpest in Oman was reported in March 1993. In the United Arab Emirates, sporadic incidence was reported in 1977, 1979 and 1984 and again in 1991, 1992 and March 1993. In Iraq, where major outbreaks occurred in 1985, affecting all 18 governorates and killing 17,000 animals, only suspected cases of diarrhoea with stomatitis were reported from 14 of the 18 governorates from 1989 to 1992, and since February 1993 no such cases have been reported.

It is important to note that no rinderpest was detected in Yemen, Lebanon, Oman, the United Arab Emirates and Iraq for periods that ranged from nine months to two years prior to the WAREC project terminating in December 1993. In the remaining six countries, rinderpest-free status had been maintained for longer periods: in Bahrain from 1988, in Egypt from 1990, in Jordan from 1971, in Kuwait from 1984, in Qatar from 1987 and in the Syrian Arab Republic from 1983. Clinical rinderpest was therefore controlled in the WAREC region before termination of the project.

Owing to the need for repeat vaccinations during 1993, the surveillance phase was rescheduled for the end of 1993 onwards.

ACTIVITIES CONTINUING AFTER WAREC

After the project ended in December 1993, WAREC circulated plans to each country for clinical, virological and serological surveillance, to fulfil the World Organisation for Animal Health (OIE) criteria for attaining freedom from rinderpest disease and freedom from rinderpest infection. During this exercise some hidden foci of infection were detected across the region. Rinderpest reappeared in Oman, the United Arab Emirates and Yemen, probably resulting from the importation of infected stock from South Asia and the Horn of Africa. The disease was finally controlled in the United Arab Emirates in June 1995, in Oman in October 1995 and in Yemen at the end of 1995. While the last date was two years after the termination of WAREC, the programme had laid the foundation for the eventual eradication of rinderpest in the region.

The WAREC project also assisted in controlling rinderpest in Turkey from October to December 1991, through two FAO Technical Cooperation Programme (TCP) projects (TCP/TUR/C154 [A] and TCP/TUR/0155 [E]).

The UNDP/FAO provided about US$1.75 million to the WAREC programme for equipment, chemicals, consultancy, training, communication campaigns and human resources in the form of a project coordinator, a virologist and an associate professional officer. The bulk of the operational expenses were, however, borne by participating countries by providing about 36,000 veterinary personnel, logistics support, diagnostics, vaccines, chemical and other miscellaneous expenses. WAREC's work was assessed by periodic tripartite meetings of UNDP, FAO and the Veterinary Services of all participating countries. WAREC's final report closed with a message to the West Asian region – 'Good-bye rinderpest, never come again.'

CHAPTER 4.11

INTRODUCTION TO THE RECENT HISTORY OF CONTROL OF RINDERPEST IN EGYPT, THE GULF AND THE MIDDLE EAST

Egypt and the countries of the Middle East could chart their rinderpest history in terms of the epidemics it caused in their naive bovine populations. Thus, Egypt experienced epidemics in 1903–1904 and 1921–1922 following an introduction from Iraq. The country experienced further epidemics between 1945 and 1947, 1961 and 1963 and 1982 and 1985 following an introduction from Sudan.

In the Middle East rinderpest epidemics were recorded in the 1920s in Ottoman Turkey and spread into neighbouring parts of the Ottoman Empire, while another epidemic was reported from Iran between 1924 and 1927. The region was clear of rinderpest in 1932 and remained so for the next 50 years.

In 1969 Iran experienced a major epidemic that spread outside the country in the form of the Near East Pandemic, 1969–1973, which also involved Turkey and the Syrian Arab Republic (see also Chapter 2.3). In 1985 Iraq experienced an epidemic due to the importation of infected buffaloes.

From 1970 onwards countries bordering the Persian Gulf experienced numerous small outbreaks due to the importation of infected slaughter stock from the Indian subcontinent. The virus did, however, become endemic in the dairy cattle population of Saudi Arabia. Yemen also had an underlying endemic situation.

The Veterinary Services of these regions were provided with advice and training in rinderpest control and vaccine manufacture through the series of United Nations programmes outlined in Chapters 4.7, 4.8 and 4.9, which aimed to improve inter-regional cooperation, rinderpest diagnosis and vaccine production. Finally, under the West Asian Rinderpest Eradication Campaign (WAREC), in 1991 and 1992, mass vaccination took place in a number of the participating countries. Chapter 4.12 attempts to demonstrate the simultaneous participation of countries of the Middle East and the Gulf states in these programmes.

Ultimately, only Bahrain, Jordan and the Syrian Arab Republic were admitted to the World Organisation for Animal Health (OIE) global list of rinderpest-free Members on the basis of historical freedom. The remaining countries had continued to use rinderpest vaccine well after the last case of rinderpest had been reported (see Chapter 4.12) and in consequence – once vaccination ended – were required to submit clinical and serological evidence to the OIE Scientific Commission in order to be declared rinderpest-free. Chapters 4.11.1–4.11.12 record the rinderpest history and evidence of freedom from infection of these countries.

CHAPTER 4.11.1

EGYPT

A. TAWFIK

Former Chairman, General Organisation for Veterinary Services, Ministry of Agriculture and Land Reclamation, Egypt

SUMMARY **Rinderpest was imported into Egypt on many occasions, most prominently in 1903 when the virus entered through the Alexandria abattoir. Intermittent epidemics occurred thereafter. An outbreak between 1945 and 1947 arose as a result of the importation of cattle from the Sudan and was combatted with a goat-attenuated vaccine. A severe and final epidemic occurred between 1982 and 1986. This was successfully combatted with a tissue culture rinderpest vaccine. Vaccination against rinderpest ceased in 1996 and subsequent clinical surveillance failed to detect cases. Serosurveillance results from 1996 to 2002 supported the approval of a rinderpest disease-free status in 2003. Additional serosurveillance in 2003–2004 demonstrated that Egypt was also a rinderpest infection-free country, and it was accepted by the World Organisation for Animal Health (OIE) in 2006.**

KEYWORDS **Clinical surveillance – Egypt – Epidemics – Serosurveillance – Vaccination.**

INTRODUCTION

The Arab Republic of Egypt occupies the north-eastern corner of the African continent. It lies between latitude 22° and 31°N and longitude 25° and 31°E. The country is bordered to the north by the Mediterranean Sea, to the south by Sudan, to the east by the Red Sea and to the west by Libya.

Administratively, Egypt is divided into 27 governorates (Fig. 1).

The majority of livestock are kept within a mixed production system. Small numbers of cattle or buffaloes are kept by individual village farmers for draught power, irrigation and milk. Milk is also produced in peri-urban milk colonies. Feedlots also occur and are stocked with locally bought or imported animals. In 2004, Egypt had 1.3 million dairy cattle, 2.2 million buffaloes, 2.5 million sheep, 1.1 million goats and 79,000 camels.

Veterinary Services are the responsibility of the General Organisation for Veterinary Services. Each governorate has a Directorate of Veterinary Medicine, which is responsible for the provision of local veterinary services, for which there are 1,462 clinics distributed throughout the country; these also serve as the basis for the national passive disease reporting system.

HISTORY OF RINDERPEST IN EGYPT

Two outbreaks were recorded in the 19th century (1841–1843 and 1865–1866), both of which apparently died out spontaneously. The source of these outbreaks was taken to be Turkey. Egypt escaped direct involvement in the Great African Rinderpest Pandemic of 1887.

More importantly, an outbreak that started in 1903 had its origins in cattle imported from Asia Minor (the Baghdad region). Although its entry was anticipated, the mildness of the virus allowed it to elude the sanitary precautions put in place in Alexandria (2). On entering the then totally susceptible Egyptian cattle population, the virus apparently

FIG. 1
MAP INDICATING THE LOCATIONS OF THE GOVERNORATES OF EGYPT
Source: United Nations, 2012 (1)

reverted to virulence, spread all over the country and was still causing problems in 1912. From that point onwards, Egypt experienced alternating epidemics and periods of apparent freedom from the disease (Table I).

The outbreak of 1945–1947 began with the importation of cattle from the Sudan (3). There was an unsuccessful attempt to eliminate it in 1946 by introducing the Nigerian sub-strain of Edward's goat-attenuated virus vaccine in place of the inactivated vaccine being used at the time.

The last and most severe epidemic in the 20th century was recorded between 1982 and 1986 when over 11,000 cattle died. Index outbreaks were recorded in neighbouring Fayoum (on a fattening farm) and Beni Suef governorates in early March 1982. By the end of the month, outbreaks had been recorded much further south, in Quena governorate. The epidemic appeared to spread rapidly and, by the end of April, with an additional two governorates becoming involved (Menia and Sohag), the disease had affected the entire centre of the country. It reached the delta governorates by the end of the year. The epidemic lasted for five years, ending only in 1986. The involvement of various governorates across the years is shown in Table II. No outbreaks of rinderpest were recorded in the Governorates of Matrouh, New Valley, Red Sea, South Sinai or North Sinai. The origins of this outbreak could not immediately be back-traced to an external source, but an isolate from this epidemic was identified as African phylogenetic lineage 1 and appeared to contain subpopulations of virus capable of causing either mild or severe clinical disease in cattle. In fact, the presence of such a cryptic-to-virulent endemic focus of rinderpest in Egypt might not have been detected had the virus not been introduced into feedlot cattle under conditions of stress, which lowered their innate resistance. Fortunately, once detected, Egypt was freed of infection by comprehensive vaccination.

RINDERPEST VACCINES AND VACCINATION

A history of the rinderpest vaccines used in Egypt is provided in Table III.

From 1963 onwards, Egypt began the production and administration of the Plowright

TABLE I
OUTBREAKS AND RELATED MORTALITY FIGURES IN EGYPT WITHIN THE BOVINE POPULATION, 1842–1986

Year of the outbreak	Mortalities
1842–1843	665,000
1863	734,000
1880–1882	Not recorded
1903–1904	354,647
1917	500
1921–1922	509
1923	188
1945–1947	831
1950	412
1953	388
1961–1963	315
1982–1986	11,423

attenuated tissue culture rinderpest vaccine (TCRV) in ampoules containing 200 doses, each equivalent to $10^{2.5}$ $TCID_{50}$ (median [or 50%] tissue culture infective dose). At this time, the adopted schedule was vaccination, every second year, for all bovines six months old and over.

Following the recrudescence of the disease in 1982, this schedule was changed to one of blanket annual vaccination to include animals of all ages,

TABLE II
MORTALITY FIGURES AMONG THE BOVINE POPULATION RECORDED YEARLY AND BY GOVERNORATE DURING THE RINDERPEST EPIDEMIC OF 1982–1986

Governorate	Mortality figures during the outbreak/year				
	1982	1983	1984	1985	1986
Cairo	7	82	8	–	–
Alexandria	259	20	303	13	4
Port Said	74	8	106	–	–
Ismailia	–	157	550	82	101
Suez	7	–	–	–	–
Dumyat	–	519	–	–	–
Gharbia	43	129	–	–	–
Qualubia	444	119	124	–	–
Monoufia	57	257	114	4	–
Beheira	1,187	1475	14	–	–
Dakahlia	–	549	35	–	–
Sharkia	100	220	203	8	–
Kafr El Sheikh	22	416	18	–	–
Giza	67	–	1	32	–
Fayoum	568	305	275	10	166
Beni Suef	158	194	90	28	26
Menia	356	96	95	15	–
Assiut	–	31	33	–	10
Sohag	37	189	12	–	–
Quena	743	–	16	–	–
Aswan	–	36	5	–	–
Total	**4,120**	**4,802**	**2,002**	**192**	**307**

TABLE III
HISTORY OF DIFFERENT VACCINES AND THEIR PERFORMANCE IN CONTROLLING RINDERPEST IN EGYPT

Year	Type of vaccine
1903	Injection of infected blood with immune sera obtained from Turkey
1904	Injection of 10 ml bile fluid subcutaneously, as recommended by Robert Koch (not effective)
1906	The Egyptian laboratories processed the immune sera (expensive, immunity of short duration)
1912	Simultaneous dose of infected blood and immune sera (good immunity for six years but expensive, labour intensive and some post-vaccination reactions that spread the disease)
1914–1920	The use of infected nasal discharge with immune sera
1926	A law issued for compulsory vaccination
1936	Formalised (inactivated) vaccine used for foreign breeds of cattle (gave weak immune response)
1945	Goat-attenuated vaccine introduced (severe post-vaccination reaction)
1946	Production of goat-attenuated vaccine in the Egyptian laboratories
1950	Rabbit-attenuated vaccine introduced (milder reaction than goat-attenuated strain)
1951	Egg-attenuated vaccine introduced (no reaction but very low immune response)
1955	Both goat- and rabbit-attenuated vaccines in use. The latter for calves from 12 months of age and for cows that were six- to nine-months pregnant
1963–1981	Production and use of the Plowright attenuated tissue culture rinderpest vaccine (TCRV) Biannual vaccination of buffaloes and cattle at six months old and over; vaccinated animals were identified by coloured ear tags
1982–1993	Same as previous period, but vaccination was annually and at all ages
June 1996	Vaccination ceased countrywide

even newly born calves. The effectiveness of this schedule was borne out by the complete absence of outbreaks of rinderpest during the 11 years that followed. In 1991 and 1992, vaccination was accorded with the Food and Agriculture Organization of the United Nations (FAO) West Asia Rinderpest Eradication Campaign (WAREC) (see Chapter 4.10). After 1993 – by which time Egypt had become part of the Pan-African Rinderpest Campaign (PARC) – it was decided that annual vaccinations should be limited to a total of two per animal. Vaccination of calves was postponed until eight months of age to ensure that maternal immunity had faded. The vaccination record with TCRV from 1972 onwards is included in the regional timeline (see Chapter 4.12). Between 1982 and 1996, the campaign intensity reached a level of around 77% of the population on an annual basis, which ensured that the virus was eradicated. Vaccinations ceased after 1996.

CLINICAL AND SEROSURVEILLANCE RESULTS

Clinical surveillance

A powerful surveillance system was applied by local veterinary officers at the veterinary clinics to detect any stomatitis–enteritis cases. Suspect cases were fully investigated serologically for rinderpest, bluetongue, infectious bovine rhinotracheitis (IBR) and bovine viral diarrhoea (BVD). The surveillance activity was reported periodically to GOVS (Preventive Medicine Department and Epidemiology Unit).

There were several notifications of rinderpest-like diseases (IBR, BVD) during 2003–2004, none of which were confirmed as rinderpest (Table IV).

Serological surveillance

Sampling units were chosen randomly from a single frame containing 1,462 clinics. In total, 320 clinics were chosen according to a surveillance plan. Samples were initially taken from 8- to 12-month-old animals and later changed to 12- to 24-month-old animals. Samples were tested using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3) at the Animal Health Research Institute, Dokki, Cairo.

Serosurveillance results to 1999 are shown below (Table V). These results were included in a dossier submitted in 1999 claiming freedom from rinderpest disease. While a small proportion of the positive results were probably due to collecting samples from vaccinated animals, overall the reduction in the incidence of positives with time was compatible with the absence of rinderpest in the population.

TABLE V
RESULTS OF SEROSURVEILLANCE FOR RINDERPEST OBTAINED FROM CATTLE AND BUFFALOES BETWEEN 1996 AND 1998

Sampling dates	Cattle	Buffalo
November–December 1996	27/1,616 (1.72%)	29/1,062 (2.87%)
April–May 1997	8/1,420 (0.58%)	22/1,051 (2.14%)
October–November 1997	30/3,076 (0.98%)	27/1,852 (1.46%)
September 1998	1/1,689 (0.67%)	0/859 (0.0%)
April 1998	2/971 (0.21%)	2/421 (0.48%)

A further round of serosurveillance across all rinderpest-susceptible village livestock was undertaken

TABLE IV
SUSPECTED CASES OF RINDERPEST-LIKE DISEASES AND DIFFERENTIAL DIAGNOSIS RESULTS

Date of suspicion	Governorate	District	Animal species	Number of diseased	Number of deaths	Lab results
3/5/2003	Menofia	Tala	Cattle	61	61	–ve to RP
1/8/2003	Gharbia	Kafr El Zayat	Cattle	67	0	–ve to RP
27/8/2003	Fayoum	Fayoum	Cattle	8	0	–ve to RP
28/8/2003	Menofia	Berka Elsabe'	Cattle cross-bred	2	2	–ve to virus isolation
4/10/2003	Menia	Menia	Cattle	1	0	–ve to RP, –ve viral infection
22/10/2003	Menia	Abo Korkas	Cattle	2	1	–ve to RP
30/11/2003	Alexandria	America	Cattle	4	0	–ve to RP
7/7/2004	Dakahlia	Mansoura	Cattle	4	0	+ve IBR, BVD
26/7/2004	Qualiubia	Banha	Cattle	5	0	+ve IBR, BVD
4/8/2004	Sharkia	Abokebir	Sheep	2	0	–ve to RP
9/8/2004	Sharkia	Menia El Kamh	Buffaloes	4	0	+ve IBR

BVD, bovine viral diarrhoea; IBR, infectious bovine rhinotracheitis; RP, rinderpest

TABLE VI
RESULTS OF SEROSURVEILLANCE FOR RINDERPEST OBTAINED FROM VILLAGE LIVESTOCK IN 2003 AND 2004

Governorate	Total samples	Buffalo	Cattle	Sheep	Goat	Pig	Camel
Alexandria	**420**	1/90 [a]	3/116	0/54	0/16	0/140	–
Assiut	**480**	0/106	0/253	0/82	0/38	–	0/1
Aswan	**560**	0/50	1/374	0/74	0/61	–	–
Behera	**640**	0/149	0/338	0/100	0/53	–	–
Beni Suef	**560**	0/81	0/335	0/103	0/41	–	–
Cairo	**200**	0/11	0/8	0/15	0/6	0/160	–
Dakahlia	**680**	1/234	0/280	0/104	0/61	–	–
Dumyat	**400**	0/88	0/222	2/54	2/32	–	–
Fayum	**640**	1/165	2/297	0/105	0/68	–	0/2
Gharbia	**760**	0/200	0/369	0/105	0/86	–	–
Giza	**320**	4/83	0/140	0/45	0/46	–	0/2
Ismailia	**440**	0/121	1/196	1/82	1/39	–	–
Kafr El Sheikh	**560**	0/171	1/248	0/89	0/51	–	–
Kaliubia	**240**	0/101	0/78	0/36	0/25	–	–
Luxor	**280**	0/37	0/175	0/43	0/23	–	0/2
Matrouh	**320**		0/24	1/197	0/98	–	–
Menia	**720**	0/158	3/362	0/118	0/77	–	0/2
Monofia	**600**	0/228	1/214	0/104	0/52	–	0/1
New Valley	**560**	0/3	0/391	0/84	0/79	–	0/3
North Sinai	**480**		1/23	2/183	0/266	–	0/5
Port Said	**200**	0/57	8/87	0/36	0/12	–	–
Quena	**280**	0/72	0/133	0/34	0/36	–	0/5
Red Sea	**320**			3/168	0/149	–	–
Sharkia	**1,160**	0/420	0/439	0/217	0/102	–	–
Sohag	**480**	0/127	2/224	1/62	0/54	–	0/10
South Sinai	**400**		0/4	0/167	0/224	–	0/5
Suez	**160**	3/43	4/70	0/30	0/10	–	–
Total	**12,860**	**10/2,777**	**27/5,400**	**10/2,491**	**2/1,805**	**0/300**	**0/38**

[a] Numerator, samples positive for rinderpest; denominator, samples tested

in 2003–2004. The results, by governorate, are presented in Table VI.

Retests were carried out on a number of animals or on animals in the same location. Of 101 retested buffalo samples, none were positive. Similarly, 268 cattle samples, 3 camel samples, 84 goat samples and 104 sheep samples were negative.

In addition, serosurveillance was carried out on suspected cases of stomatitis–enteritis, which were being tested for the rinderpest virus. Again, negative results were obtained from 56 buffalo samples, 274 cattle samples, 22 sheep samples and 48 goat samples.

A number of 300 samples were collected for purposive surveys from Bedou sheep and goats (eligible age only), 100 samples each from North Sinai, South Sinai and Matrouh governorates. None were positive for rinderpest.

CONCLUSION AND DOSSIER

It was concluded that all OIE guidelines concerning rinderpest epidemio-surveillance had been followed and had proved that Egypt was free from rinderpest virus infection through the following:

- No clinical or epidemiological evidence of rinderpest had been confirmed since the year 1986 (18 successive years).
- Suspected cases were negative for the rinderpest virus while positively confirmed in some cases for rinderpest-like diseases (BVD, IBR).

Three rounds of serosurveillance (1999–2000, 2001–2002 and 2003–2005) revealed that there was no circulation of mild strains of rinderpest virus among unvaccinated bovines, sheep, goats, camels and pigs.

On the basis of this submission, Egypt was accepted as a rinderpest infection-free country in 2006 (4).

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CHAPTER 4.11.2

IRAN (ISLAMIC REPUBLIC OF)

H. HASSANI

Former Head, Iran Veterinary Organisation, Ministry of Agriculture and Agrarian Reform (MAAR), Administration of Animal Wealth (AAW), Animal Health Directorate (DOAH), Islamic Republic of Iran

SUMMARY **The first rinderpest outbreak was recognised in 1924; the second rinderpest outbreak was in 1931, and both were reported in the western provinces. Vaccination began in 1931. The next outbreak was in 1949, and for the next decade the country was rinderpest-free. In 1969, however, a major countrywide epidemic arose. From 1970 to 1980 the Islamic Republic of Iran was free from rinderpest, but in 1981 Khorasan province was again infected. From 1965 to 1994 vaccination was restricted to young animals, but from 1994 to 2001 mass vaccination was undertaken in animals of all ages. In 2002, active clinical surveillance was conducted countrywide. Vaccination ceased for rinderpest in March 2003, although the same vaccine continued to be used for peste de petits ruminants (PPR) until September 2004. The Islamic Republic of Iran was declared free from rinderpest in May 2008.**

KEYWORDS **Islamic Republic of Iran – National epidemic – Provincial epidemics – Rinderpest – Serosurveillance – Vaccination history.**

INTRODUCTION

Bordered by the Gulf of Oman, the Persian Gulf and the Caspian Sea, the Islamic Republic of Iran lies between Iraq and Turkey in the west, Armenia, Azerbaijan and Turkmenistan to the north and Afghanistan and Pakistan to the east. The Islamic Republic of Iran is one of the most mountainous countries in the world. The western part is the most populous, while the eastern part consists mostly of desert basins.

Administratively the country is divided into 30 provinces (Fig. 1). Livestock keeping follows a sedentary mixed farming model, with herds being communally grazed in the summer. In 2006 the total bovine population was slightly over seven million.

The control of rinderpest was undertaken by the Directorate of Investigation, Surveillance and Campaigns of Animal disease within the Iran Veterinary Organisation (IVO).

The second National Rinderpest Eradication Programme was adopted in 1998. In 2001 the National Committee for Rinderpest-free Status was established within the IVO.

HISTORY OF RINDERPEST IN THE ISLAMIC REPUBLIC OF IRAN

The first rinderpest outbreak was recognised in 1924 and was alleged to have been introduced across the western border. The disease spread from Azarbayejan province across the north of the country. The second rinderpest outbreak was in 1931 and again was reported in the western provinces. In addition to zoosanitary controls (destruction of affected and in-contact animals), an inactivated rinderpest vaccine was made by the Razi Institute (founded in 1924) and used in at-risk cattle. Figure 2 shows the extent of the spread of infection in these and, except for the Near East Pandemic (Chapter 2.3), all subsequent provincial epidemics.

The next outbreak was in 1949 and was introduced by cattle coming from the east and was similarly controlled. For the next decade the country was rinderpest-free – a situation that ended in 1960 when rinderpest occurred in Khorasan, Sistan and Baluchistan provinces.

Up to this point all outbreaks were restricted to the provinces where they were first reported and

FIG. 1

PROVINCES (ADMINISTRATIVE SUBDIVISIONS) OF THE ISLAMIC REPUBLIC OF IRAN

Source: United Nations, 2020 (1)

failed to reach the central and southern parts of the country. However, in 1969 a major countrywide epidemic arose, causing at least 20,000 cattle deaths and marking the start of the Near East Pandemic, which continued until 1973. It was controlled, with assistance from the army, by the destruction of in-contact animals and mass vaccination across the country with tissue culture rinderpest vaccine (TCRV) as well as an inactivated vaccine.

From 1970 to 1980, the Islamic Republic of Iran remained free from rinderpest, but in 1981 Khorasan province was again infected, ostensibly by illegal movements of infected animals from Afghanistan and Pakistan. After this outbreak, mass vaccination of the national herd was instituted. This was allied to clinical surveillance looking for rinderpest or rinderpest-like diseases. In addition, special sanitary regulations on animal movement, border inspection of trade animals and animal products were adopted throughout the country.

After 1981, the mode of introduction and the source of infection of the rinderpest virus into the country shifted from the eastern borders to the western borders where, in the years before 1950, rinderpest used to occur. Outbreaks were reported in 1987 in Khouzestan and Hamedan provinces in the south-west, and then in 1990 in Kordestan province next to the western borders. The primary outbreak foci were located close to the border with Iraq. These outbreaks of rinderpest were localised and only a few cases were reported.

The final outbreaks of rinderpest occurred in 1994 in western Azarbayejan province, in an area adjacent to a region of rinderpest endemicity involving northern Iraq and Turkey (Chapter 6.1). The disease then spread to the central provinces and became endemic in feedlot cattle farms, while another outbreak was reported in the migratory (unsettled) buffalo farms in the marshy area close to Arvand River (Shat-Al-Arab) in Abadan city, which is located in the south-west of Khuzestan province. This outbreak was controlled by destroying affected and in-contact susceptible animals, and through the vaccination of all susceptible cattle populations. The last cases of rinderpest in Islamic Republic of Iran occurred in 1994.

HISTORY OF RINDERPEST VACCINES AND VACCINATION IN THE ISLAMIC REPUBLIC OF IRAN

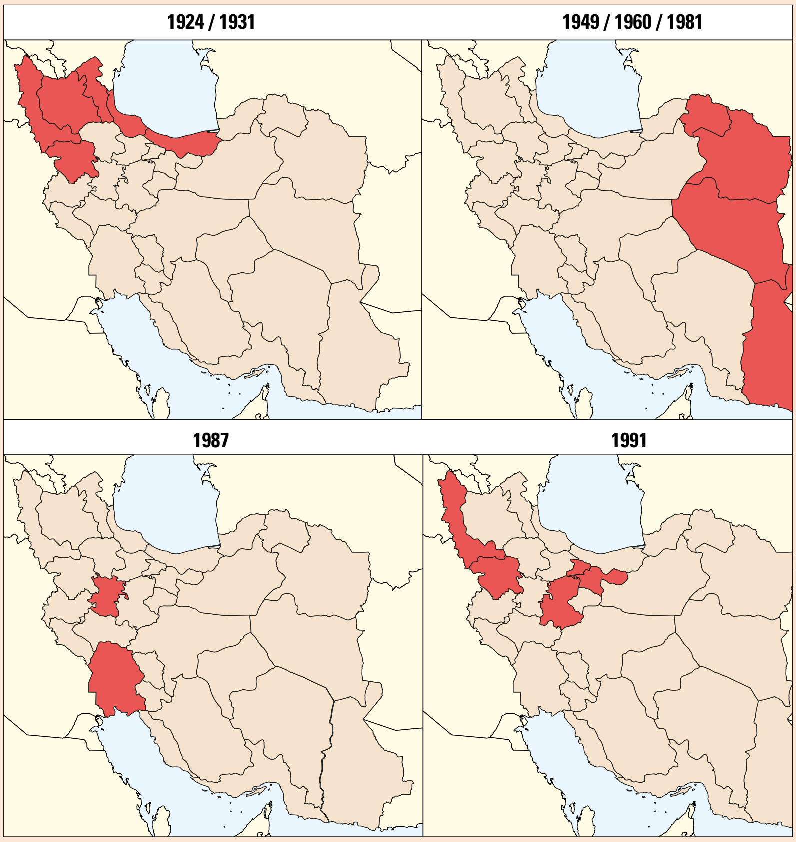
The first vaccination against rinderpest in Iran was in 1931 during the second outbreak of rinderpest, using a killed vaccine made in the Razi Institute. Iran began making TCRV using seed virus provided

FIG. 2

PROVINCES AFFECTED BY RINDERPEST OUTBREAKS

(In the Near East Epidemic of 1969 -1973, rinderpest was widespread in Iran. See Chapter 2.3)

Source: d-maps.com (2020). - Map of Iran. Available at: https://www.d-maps.com (accessed on 9 June 2021), modified to show provinces affected by rinderpest



by the Food and Agriculture Organization of the United Nations (FAO) in 1965. Up to that point vaccination had been undertaken only during outbreaks and involving 'at-risk' (i.e. contact) animals. From 1965 to 1994 vaccination was restricted to young animals. However, from 1994 to 2001 mass vaccination was undertaken in animals of all ages, which included the revaccination of calves under one year of age, in a drive towards eradication. In 2002, vaccination ceased in all but the eastern provinces, ending completely in 2003. On three occasions (1974, 1989 and 1994) vaccine uptake figures exceeded the estimated bovine population, creating immunity levels that effectively prevented the virus from ever becoming endemic within the Islamic Republic of Iran. Seromonitoring between 1994 and 2001 revealed an average immunity level of 67%. Annual vaccination figures are included in the regional timeline (Chapter 4.12). Vaccination ceased in March 2003.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Up until 1996 all mucosal disease outbreaks were reported in monthly reports, but in that year a national disease surveillance system was established (passive clinical surveillance), and all mucosal diseases had to be listed in compulsory daily animal disease reporting lists. District veterinary offices had to send all their reports by fax to the provincial veterinary offices and the IVO.

In 2002, active clinical surveillance was conducted all over the country. The officer in charge of animal disease investigation and surveillance in each district veterinary office randomly chose and visited monthly 3–5% of all epidemiological units, which included villages, farms, pastures and animal markets, and examined at least 50% of cattle and buffalo populations for any clinical signs of disease. Starting in 2005, serological samples were obtained from 5% of non-vaccinated examined animals. These were animals born after the cessation of vaccination.

All suspected outbreaks were investigated by field and laboratory (antigen and antibody detection by enzyme-linked immunosorbent assay [ELISA]) methods (Chapter 3.3). In the course of 19.4 million examinations, only 213 cases of a rinderpest-like condition were detected (Table I). None of these was confirmed as rinderpest.

Some 16,796 serum samples were tested with the rinderpest competitive immunosorbent assay (c-ELISA). Out of the 972 positive samples, 514 were not from animals born since the end of vaccination and were not considered further. None of the 303 animals backtraced was positive when resampled (Table II). No evidence of rinderpest virus circulation was detected.

TABLE I
ACCOUNT OF ACTIVE CLINICAL SURVEILLANCE OF BOVINES

Year	Number of cattle examined	Number of cattle in visited units	Number of affected cattle with rinderpest-like disease	Number of cattle slaughtered/ dead owing to rinderpest-like disease
2003	2,365,275	4,760,298	123	24
2004	4,615,541	9,350,093	49	13
2005	6,417,224	10,335,528	23	23
2006	6,030,188	10,663,400	18	18

There are eight wildlife species considered susceptible to rinderpest in the Islamic Republic of Iran, totalling approximately 122,130 head, and living in 140 limited areas, such as the national parks and protected areas (covering 117,224 km^2, which is only 7% of the entire territory of the Islamic Republic of Iran). In the Islamic Republic of Iran, the Environment Conservation Organisation is responsible for wild animal protection. Because most susceptible wildlife species are rare, their habitats are protected and entry to such areas is forbidden or requires permission for limited entry. Moreover, the size of the population is not significant (122,130 head, compared with 81,268,500 head of susceptible domestic livestock). Therefore, effective contact between wildlife and susceptible domestic species seldom occurs. Accordingly, no wildlife serological samples were collected.

DOSSIER

The Islamic Republic of Iran declared provisional freedom for the whole country in June 2003, at which time it ceased to use rinderpest vaccine in cattle and buffaloes. The Islamic Republic of Islamic Republic of Iran submitted a dossier in December 2006 claiming freedom from rinderpest disease. The dossier presented a persuasive case for freedom from rinderpest disease. However, the dossier stated that rinderpest vaccine continued to be used in small ruminants for the control of peste des petits ruminants until September 2004. Thus, in accordance with the requirements of the *Terrestrial Animal Health Code*, the Islamic Republic of Iran could not be considered eligible for recognition of the status of freedom from disease until September 2007. In October 2007, the Islamic Republic of Iran was considered eligible for accreditation as free from rinderpest in accordance with the *Terrestrial Animal Health Code,* 2007 edition. The World Organisation for Animal Health (OIE) Scientific Commission recommended the recognition of the Islamic Republic of Iran as free from rinderpest infection in March 2008 (2). Resolution XIX, adopted by the World Assembly of the OIE Delegates on 27 May 2008, made this recognition official.

TABLE II
SEROSURVEILLANCE RESULTS FOR 2006 AND 2007

Iran (Islamic Republic of) rinderpest serosurveillance (cattle and buffaloes)								
Time	Number of selected units	Number of cattle and buffaloes		Seropositives	Follow-up investigation of seropositives			
		Units' population	Sampled		Out of reach (sold/ slaughtered)	Outside eligible age	Seronegative in resampling	Unauthorised vaccinated
October 2005 to August 2006	320	50,782	7,538	477	112	276	89	0
October 2006 to August 2007	308	64,160	9,258	495	43	238	214	0

References

1. United Nations (2004). – Map of the Islamic Republic of Iran. Available at: www.un.org/geospatial/content/iran-islamic-republic (accessed on 9 June 2021).
2. World Organisation for Animal Health (OIE) (2008). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 19–21 February 2008. OIE, Paris. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_feb2008.pdf (accessed on 20 April 2019).

CHAPTER 4.11.3

IRAQ

S.J. MOZAN

Former Director-General of Veterinary Services, Ministry of Agriculture, Iraq

SUMMARY **After many rinderpest-free years, the disease entered Iraq in 1985 with an infected consignment of buffaloes. A widespread epidemic ensued. Mass vaccination eventually controlled the disease and the last case occurred in Erbil 11 years later. Nationwide serosurveillance in 2008 demonstrated that the country was free from rinderpest.**

KEYWORDS **Iraq – Outbreak – Rinderpest – Serosurveillance – Vaccination.**

INTRODUCTION

Iraq is a Middle Eastern country situated at the cross-roads of international transport and trade between three continents: Europe, Asia and Africa. The country is bordered by Turkey to the north, the Islamic Republic of Iran to the east, Kuwait and Saudi Arabia to the south, and the Syrian Arab Republic and Jordan to the west. Traditional livestock rearing in Iraq depends mainly on grazing pastures within or close to the defined borders of towns and villages. Most cattle are kept as small dairy herds living in the villages and towns or their environs. Buffaloes are kept in the villages and towns in the southern marshes in the Basrah, Nassriyah and Missan governorates. In 2006 the estimated cattle and buffalo populations were 1,385,256 and 148,577 respectively. The country is permeated by both the Tigris and Euphrates rivers.

Iraq is divided into 18 administrative governorates (Fig. 1). The Veterinary Administration and Authority of Iraq is the Ministry of Agriculture. The Director-General of the State Company for Veterinary Services (SCVS) is the 'Chief Veterinary Officer' and represents Iraq at the World Organisation for Animal Health (OIE). The northern governorates of Sulaimaniyah, Erbil and Dohuk form the 'Kurdish region' with its own Ministry of Agriculture and General Directorate of Animal Resources and Veterinary Services but no separate OIE representation.

THE HISTORY OF RINDERPEST IN IRAQ

From 1924 to 1985 rinderpest did not occur in Iraq.

In March 1985, 600 Indian buffaloes entered through the port of Basra without undergoing quarantine and brought rinderpest to Iraq. The buffaloes were widely distributed and gave rise to an epidemic that involved 15 governorates and led to the death (from disease or emergency slaughter) of 50,000 buffaloes. It was controlled by intensive and repeated vaccination using tissue culture rinderpest vaccine (TCRV) manufactured in the Abu-Graib Laboratory, Bagdad, in spite of which, sporadic outbreaks and minor epidemics continued to occur.

In 1989 the Food and Agriculture Organization of the United Nations (FAO) West Asia Rinderpest Eradication Campaign (WAREC) established its headquarters in Baghdad. The national WAREC programme began in 1991 with a general survey for rinderpest, which found that rinderpest was still widespread and concluded that improved mass vaccination should continue. This was implemented until 1994 and brought about a significant decrease in new outbreaks, and the last case of rinderpest in central and southern Iraq was reported at the end of that year. After 1995 vaccination in central and southern Iraq was restricted to buffaloes and

FIG. 1
MAP OF IRAQ SHOWING THE GOVERNORATES
Source: United Nations, 2014 (1)

cattle over four and a half months of age – a policy maintained until 2003 when the Gulf War made it impossible to continue. Vaccination figures from 1994 onwards are recorded in the regional timeline (Chapter 4.12).

In the Kurdish region, however, disease remained present until 1996 when the last case was recorded at Erbil. The Veterinary Authority in the Kurdish region decided, on advice from FAO, to stop all vaccination against the disease in 1997 and institute serosurveillance.

RINDERPEST SURVEILLANCE

Clinical suspicion

Routine monthly reports submitted to SCVS Baghdad for 2006, 2007 and 2008 showed cases of stomatitis–enteritis syndrome (SES) in cattle and buffaloes in most governorates. These responded to medical treatment and rinderpest was ruled out in cases in which samples were submitted to the Central Veterinary Diagnostic Laboratory (CVDL) in Baghdad and Erbil. Likewise, no emergency reports of rinderpest or rinderpest-like disease were received by the SCVS in Baghdad or in Erbil over the same period. During this period laboratories maintained a rinderpest agar gel immunodiffusion assay (AGID) capability.

Serological surveillance

As there had been no cases of rinderpest since 1996 and as vaccination for rinderpest ceased in 2003, Iraq declared provisional freedom from rinderpest in 2006 in order to begin serosurveillance (2). All subsequent sampling and testing routines were in accordance with the guidelines provided in Appendix 3.8.2 of the OIE *Terrestrial Animal Health Code* (*Terrestrial Code*). Actual tests were carried out using the competitive enzyme-linked immunosorbent assay (c-ELISA) in the CVDL centres in Baghdad and Erbil.

During the period 2005–2006 a survey was carried out in central and southern Iraq, which showed that 21% of the samples from 25 villages were positive for rinderpest antibodies. This was attributed to sampling older animals that had been vaccinated. In a fresh survey carried out in 2008, specifically revisiting villages where positive samples had been detected in 2006, all samples from unvaccinated animals from all villages provided negative results (Table I).

TABLE I
RESULTS OF 2008 SURVEY REVISITING VILLAGES PREVIOUSLY PROVIDING POSITIVE SAMPLES

Governorate	No. of villages visited	No. of samples collected	No. samples rinderpest positive
Neniva	4	60	0/60
Salah Alden	2	30	0/30
Dayala	1	15	0/15
Babil	2	30	0/30
Diwanya	1	15	0/15
Karbala	1	15	0/15
Najaf	4	60	0/60
Nasriyaah	3	45	0/45
Muthanna	1	15	0/15
Missan	3	45	0/45
Basrah	1	15	0/15
Baghdad	2	30	0/30

A national survey of cattle and buffaloes was also carried out in 2008. Three hundred villages were randomly selected from among all the villages in Iraq, but weighted towards those with the largest cattle and buffalo populations in each governorate. Serum samples were collected from 15 young animals in each sampled village. Only animals with two permanent incisors were included in the survey (12–24 months of age). In total 4,497 sera were collected.

This survey was used as an opportunity to search the selected villages for mild rinderpest, stomatitis and enteritis (SES). Some 40 cases of SES were encountered, but they were attributed to either foot-and-mouth disease or bovine viral diarrhoea infection. Rinderpest was not encountered.

The incidence of rinderpest seropositive animals during this survey is shown in Table II. Fifty-three of the samples were positive. There were no antibody clusters and the overall prevalence rate was low – 1.17%. Positive samples were back-traced, owners interviewed and animal ages re-assessed using dentition. Mistakes in assessing age offered one explanation for positive samples. It was suggested that the survey results were incompatible with the presence of rinderpest.

TABLE II
RINDERPEST ANTIBODY OCCURRENCE IN IRAQ NATIONAL SURVEY OF 2008

Governorate	No. of samples	No. of villages	No. of samples seropositive
Sulaimaniyah	540	36	11/540
Neniva	507	34	5/507
Babil	510	34	2/510
Missan	330	22	4/330
Baghdad	300	20	1/300
Erbil	255	17	4/255
Dayala	255	17	7/255
Nasriyah	240	16	2/240
Diwanya	240	16	2/240
Wasit	240	16	1/240
Salah Alden	240	14	1/240
Dohuk	150	10	1/150
Kirkuk	150	10	2/150
Karbala	135	9	0/135
Anbar	120	8	5/120
Basrah	105	7	2/105
Mutthanna	105	7	3/105
Najaf	105	7	0/105
Total	**4,497**	**300**	**53/4,497**

DOSSIER

On 4 April 2006, based on the provisions of Appendix 3.8.2 of the OIE *Terrestrial Code* (version 2006), Iraq declared its country provisionally free from rinderpest to the OIE. In January 2009 Iraq submitted a dossier to the OIE containing the above results and claiming that it should be recognised as free from rinderpest. This claim was upheld by the OIE (1) and Iraq was declared free from rinderpest on 26 May 2009.

Reference

1. United Nations (2014). – Map of Iraq. Available at: www.un.org/geospatial/content/iraq (accessed on 9 June 2021).
2. World Organisation for Animal Health (OIE) (2009). – Public version of the report of the meeting of the OIE Scientific Commission for Animal Diseases, 11–13 February 2009 (indicating that Iraq is declared free from rinderpest; pages 13–54 of the *Ad hoc* Group report only available only to OIE Delegates). Available at: http://www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_Feb_2009_pourPUBLIC.pdf (accessed 3 May 2019).

CHAPTER 4.11.4

ISRAEL

M. CHAIMOVITZ

Former Director, Veterinary Services and Animal Health, Ministry of Agriculture and Rural Development, Israel

SUMMARY **Outbreaks of rinderpest occurred in Israel between 1903 and 1927. Although neighbouring countries were affected during the Near East epidemic (1969–1973), Israel excluded the infection by vaccinating all cattle. There were cattle infected with rinderpest in Israel for a short time in 1983, the disease having entered from Lebanon. Vaccination continued until 1989. Negative results were obtained in a national serum survey undertaken between 2008 and 2009.**

KEYWORDS **1983 outbreaks – Israel – Near East epidemic – Serosurveillance – Vaccination.**

INTRODUCTION

Israel is located at the eastern end of the Mediterranean Sea (Fig. 1) and is bounded by Lebanon to the north, the Syrian Arab Republic to the north-east, Jordan to the east, and Egypt to the south-west. The Palestinian Authority (PA) is located in the centre of the country (the West Bank) and in the south-west of the country (the Gaza strip). There are six main administrative districts: Central, Haifa, Jerusalem, Northern, Southern and Tel Aviv (Fig. 1).

Geographically, Israel is divided into four regions. A narrow coastal strip extends along the Mediterranean Sea and includes many of Israel's major cities and much of its agricultural land. Inland mountain ranges run north to south, while further inland much of the Rift Valley lies below sea level. To the south there is the Negev Desert.

Estimates of livestock numbers in 2009 indicated the presence of 330,000 cattle and 300 buffaloes. At that time, the majority of dairy cattle were held by collectives (kibbutzim) or cooperatives (moshavim).

The Israeli Veterinary Services and Animal Health (IVSAH) is an independent unit within the Ministry of Agriculture and Rural Development. The IVSAH administrative offices are located at Bet Dagan, along with the largest of the IVSAH branches – the Kimron Veterinary Institute (KVI).

HISTORY OF RINDERPEST AND ITS CONTROL IN ISRAEL

Historical outbreaks of rinderpest occurred in 1903, 1915, 1918, 1926 and 1927. Coincident with the Near East epidemic (1969 to 1973; see Chapter 2.3), Israel undertook precautionary vaccination of all cattle commencing in 1970 and continuing until 1975. While Lebanon, Jordan and the Syrian Arab Republic all experienced rinderpest outbreaks at this time, none occurred in Israel.

Nine outbreaks were reported in 1983, the virus having entered from Lebanon. Thanks to extensive vaccinations undertaken in 1982 and 1983, the outbreaks were limited and confined to beef herds in nine different locations. Movement restrictions were applied, and the last outbreak occurred in August 1983 (see Timeline, Chapter 4.12).

Vaccination of cattle on the border with Lebanon commenced in 1982 and quickly extended countrywide, an activity that was maintained until 1985 and then continued along Israel's borders

FIG. 1
POLITICAL MAP OF ISRAEL

Source: United Nations, 2004 (1)

until 1989. Initially tissue culture rinderpest vaccine (TCRV) was imported from the Pirbright Institute, and it was later substituted with the same product made locally.

RINDERPEST SURVEILLANCE

Although a notifiable disease, no notifications of rinderpest were received after 1983.

Virological and serological investigations on rinderpest in Israel were performed immediately after the outbreaks of the disease in 1983. Serum neutralisation tests were conducted on the blood of wild pigs and deer from the area where the disease appeared, and they were found to be negative. The possibility that sheep could be infected or be carriers of the virus and serve as a source of reinfection was also studied; sera from flocks in the affected areas were tested and all the samples were negative (2).

TABLE I
RESULTS OF NATIONAL SURVEY OF ISRAELI CATTLE, 2008–2009

Veterinary field district	Number of settlements sampled	Number of rinderpest positive samples/ number of samples tested
Rosh Pina	20	0/262
Acco/Tsfat	13	0/92
Afula	47	0/367
Hadera	18	0/172
Kanot	47	0/549
Beer Sheva	40	0/561

Rinderpest virus could not be isolated in tissue culture or detected by immunoperoxidase staining of cells from cattle involved in three outbreaks of haemorrhagic diarrhoea in 2008.

In preparation for the submission of the dossier, a survey was conducted across all veterinary field districts. Samples were tested by the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3). The results are shown in Table I. No positive sample was found.

DOSSIER

In September 2009 the Israeli Veterinary Services and Animal Health Service submitted a report including the clinical and serological results contained in this chapter; as a result, in 2010 Israel was accepted as a rinderpest-free country (3) and was declared free from rinderpest on 25 May 2010.

References

1. United Nations (2004). - Map of Israel. Available at: www.un.org/geospatial/content/israel (accessed on 9 June 2021).
2. Abraham A. & Label E. (1984). – Virological and serological investigations on rinderpest in Israel. *Refuah Vet.*, **41,** 112–121.
3. World Organisation for Animal Health (OIE) (2010). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 2–5 March 2010, Paris. OIE, Paris. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_march2010_public.pdf (accessed on 8 May 2019).

CHAPTER 4.11.5

KUWAIT

N. AL KHALEEL

Former Deputy Director-General for Animal Resources, Public Authority for Agriculture Affairs and Fish Resources, Kuwait

SUMMARY **The last outbreak of rinderpest was in 1985 after which clinical surveillance failed to detect further evidence of rinderpest. Likewise, serosurveillance from 2004 to 2009 failed to detect evidence of rinderpest.**

KEYWORDS **Kuwait – Passive surveillance – Rinderpest – Serosurveillance.**

INTRODUCTION

Kuwait is located in the Middle East. It has a coastline bordering the Arabian Gulf and land borders with Iraq and Saudi Arabia (Fig. 1). The country is flat and the climate is hot. Livestock keeping is highly restricted and food supplies are largely dependent on imported animals, there being a considerable deficit regarding beef and milk. In 2008 some 23,000 head of cattle were imported through the quarantine system.

There are two main cattle production systems in Kuwait. A total of about 40 dairy farms represent the commercial production system in the country. It is estimated that there are more than 3,000 cattle herds (*jahoors*) reared in an extensive system. However, the average size of herd in this kind of production system is not more than five animals. The extensive system also applies to sheep, goat and camel rearing.

HISTORY OF RINDERPEST IN KUWAIT

Rinderpest was first confirmed in Kuwait in 1968, and between 1971 and 1983 it was reported annually (see Chapter 4.12). The last report of rinderpest in Kuwait was in 1985.

In 1992, 100% of the local cattle population was vaccinated against rinderpest, and vaccination continued until 2002.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Disease surveillance

Monthly passive surveillance reports on livestock diseases from private veterinary practices, public clinics and surveillance teams are submitted to the epidemiology unit of the Animal Health Department. These monthly reports are used to compile a database for further epidemiological analysis.

Whenever a transboundary disease is suspected in animals, the information is immediately relayed to the epidemiology and surveillance section of the Animal Health Department for further investigation. Appropriate samples are then collected for confirmation by laboratory investigation.

Following self-declaration of provisional freedom from rinderpest in July 2003, surveillance was strengthened to capture any condition with resemblance to rinderpest. Data collection formats that described the case definition for rinderpest suspicion were distributed to surveillance field units and veterinarians working on farms. It was underlined that any animal showing any of the following clinical signs should be suspected of having rinderpest and swabs should be submitted to the national veterinary diagnostic laboratory to confirm or refute rinderpest: nasal discharge, ocular discharge, mouth lesions and diarrhoea.

During clinical surveillance of rinderpest carried out from 2007 to 2009, no animal was suspected of

FIG. 1
MAP OF KUWAIT

Source: United Nations, 2010 (1)

having rinderpest. As a result, no samples were submitted for virus detection and isolation of rinderpest.

Serosurveillance

Rinderpest serosurveillance was conducted in 2004, 2005, 2006 and 2008. The surveillance covered cattle and small ruminants in 2004; however, only cattle were sampled thereafter. All cattle older than 1 year that were born after July 2002 were included in the survey. Competitive enzyme-linked immunosorbent assays (c-ELISAs) were carried out in the national veterinary diagnostic laboratory.

A stratified two-stage sampling technique was used for rinderpest surveillance. The two production systems (mentioned earlier) were used as strata, as there are differences in management and other aspects between the two systems. Herds of cattle (farms) were the primary sampling units and were selected systematically, as there is no herd sampling frame for random selection. The secondary sampling units were individual animals, which were selected systematically from each selected herd due to the practicality of this technique. The survey results presented in Table I indicate the absence of rinderpest in Kuwait since the cessation of vaccination in 2002.

TABLE I
RESULTS OF RINDERPEST SEROSURVEILLANCE FROM 2005 TO 2008/2009

Year	Species	Total tested	Total positive	Percentage positive
2005	Cattle	3,009	0	0.0
2006	Cattle	1,049	0	0.0
2008	Cattle	1,753	2	0.1

As there are no wild animals susceptible to rinderpest in Kuwait, no rinderpest surveillance was undertaken in wildlife.

DOSSIER

A dossier containing the above information was submitted in 2009 and was approved by the World Organisation for Animal Health (OIE) in 2010 (2). Kuwait was declared free from rinderpest on 25 May 2010 by the World Assembly of OIE Delegates.

Reference

1. United Nations (2010). – Map of Kuwait. Available at: www.un.org/geospatial/content/kuwait (accessed on 9 June 2021).
2. World Organisation for Animal Health (OIE) (2010). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 2–5 March 2010. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_march2010_public.pdf (accessed on 18 May 2019).

CHAPTER 4.11.6

OMAN

A. ABDULLAH AL-SAHMI

Former Assistant Director General for Animal Health, Ministry of Agriculture, Oman

SUMMARY **Between 1979 and 1995, Oman experienced a series of discrete rinderpest outbreaks due to the importation of live infected animals. These were controlled by vaccination and quarantine procedures. Vaccination work continued until 2001 as a commitment to the West Asia Rinderpest Eradication Campaign (WAREC). Serosurveillance between 2005 and 2007 demonstrated that the bovine population was free from rinderpest.**

KEYWORDS **Oman – Outbreaks – Rinderpest – Serosurveillance – Vaccination.**

INTRODUCTION

The Sultanate of Oman lies in the extreme south-eastern corner of the Arabian Peninsula. It shares a land boundary with Yemen to the south-west, Saudi Arabia to the west and the United Arab Emirates to the north (Fig. 1). It has a coastline of approximately 1,700 km that stretches along the Gulf of Oman and Musandam Peninsula in the north and along the Arabian Sea in the east.

A significant number of the population are involved in the livestock sector, especially in the Dhofar and Wusta regions where nomadic and semi-nomadic livestock production systems are practised. Settled livestock farming is widespread, and, in recent years, intensive farming has been practised, especially for dairy and poultry production. According to a livestock census conducted in 2004–2005, the livestock population numbers were 301,588 cattle, 1,557,148 goats, 351,066 sheep and 117,299 camels.

There are a number of institutions within the country that are involved in the delivery of Veterinary Services. Within the Ministry of Agriculture, these are covered by the Directorate-General of Animal Wealth, which deals with livestock health, including national disease control policies. The Veterinary Research Centre comes under the Directorate of Agriculture and Livestock Research and deals mainly with diagnostics and animal disease surveillance activities. There is a total of 62 government veterinary clinics and one veterinary hospital dealing with both therapeutic and vaccination activities, as well as other veterinary activities.

HISTORY OF RINDERPEST IN OMAN

In the 1970s rinderpest was considered an exotic disease in Oman; however, the highly contagious nature of the disease and the risk of introduction into the country through legal importation and smuggling of live cattle from infected countries was recognised. In 1979, the first case of rinderpest was reported at Ibri, Dhahira, following the introduction of an infected animal from a neighbouring country. The disease then spread through cattle markets to the surrounding areas of Dhahira and Dakhilia, and approximately 1,200 cattle were reported either sick or dead before the outbreaks were contained by vaccination and quarantine procedures. Rinderpest failed to become endemic, but over the following years further outbreaks occurred, associated with the importation of live cattle (Table I). The outbreaks were reported and controlled by vaccination and strict quarantine measures. The last incidence was in 1995.

FIG. 1
MAP OF OMAN
Source: United Nations, 2004 (1)

HISTORY OF RINDERPEST VACCINATION IN OMAN

Rinderpest vaccinations began in 1979, using tissue culture rinderpest vaccine (TCRV) imported from the (then) Institute of Animal Health, Pirbright, United Kingdom of Great Britain and Northern Ireland. In 1989, Oman joined the United Nations Development Programme (UNDP)/Food and Agriculture Organization of the United Nations (FAO) West Asia Rinderpest Eradication Campaign (WAREC), continuing to vaccinate until 2001 and administering some 678,000 doses (details are provided in the regional timeline – see Chapter 4.12).

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Clinical surveillance

When suspected clinical cases were encountered at the veterinary clinics in different regions, samples

TABLE I
OUTBREAK HISTORY

Year	Outbreaks	Cases	Location
1979	Not known	1,200	Dharia and interior
1980	0	0	
1981	0	0	
1982	1	Not known	Dharia
1983	1	86	Risail Quarantine, Sohar, Samail, Nizwa
1984	0	0	
1985	1	12	Muscat
1986	1	5	Buraimi
1987	0	0	
1988	2	3	Muscat, Buraimi
1989	3	183	Muscat, Buraimi, Munuma
1990	0	0	
1991	0	0	
1992	10	90	Barka, Izki, Samail, Sohar
1993	1	9	Liwa
1994	0	0	
1995	16	124	Saham, Sohar, Buraimi, Barka, Liwa, Suweiq, Rustaq

were dispatched to the Veterinary Research Centre (VRC) at Rumais for laboratory confirmation using the agar gel immunodiffusion test (AGID) and attempts at virus isolation in tissue culture (primary calf kidney cells and Vero cells).

All specimens submitted after the last outbreak in 1995 were negative by AGID.

Serosurveillance

A total of 2,733 randomised cattle serum samples from different regions of the country were collected during the period 2005–2007. They included samples from Musandam (55), Batinah (475), Muscat (183), Dhahira (278), Dakhilia (396), Sharqiya (239), Wusta (13) and Dhofar (1,094). These specimens were subjected to the competitive enzyme-linked immunosorbent assay (c-ELISA; Chapter 3.3) technique at the VRC and were all found to be negative for rinderpest antibodies and indicative of the absence of rinderpest within the Omani bovine population (Table II).

TABLE II
RESULTS OF RINDERPEST C-ELISA TEST ON BOVINE SERA COLLECTED AS PART OF THE ACTIVE SEROSURVEILLANCE CAMPAIGN

Year	Serum samples	Test results	
		Negative	Positive
2005	996	996	0
2006	844	844	0
2007	893	893	0
Total	2,733	2,733	0

CONCLUSION

On 14 July 2004 and based on the provisions of Appendix 3.8.2 of the World Organisation for Animal Health (OIE) *Terrestrial Animal Health Code* (*Terrestrial Code*) (version 2014), Oman was declared provisionally free from rinderpest, as vaccinations had stopped in 2001. After more than four further years of vigilant surveillance and based on the requirements of the OIE *Terrestrial Code* – Oman was compliant within the framework of the stipulated OIE *Terrestrial Code*.

DOSSIER

Based on the above results, the OIE Scientific Commission endorsed the report and recommendation for the recognition of Oman as a rinderpest-free country in February 2009 (2).

Reference

1. United Nations (2004). - Map of Oman. Available at: www.un.org/geospatial/content/oman (accessed on 9 June 2021).
2. World Organisation for Animal Health (OIE) (2009). – Public version of the report of the meeting of the OIE Scientific Commission for Animal Diseases, 11–13 February 2009 (indicating that Oman is declared free from rinderpest; pages 13–54 of the *Ad hoc* Group report only available to OIE Delegates). Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_Feb_2009_pourPUBLIC.pdf (accessed on 17 October 2019).

CHAPTER 4.11.7

QATAR

K. NASSER AL-QAHTANI

Former Director of Animal Resources Department, Ministry of Environment, Doha, Qatar

SUMMARY **Qatar was never endemically infected with rinderpest. The last recorded outbreak occurred in 1987. Qatar participated in the Food and Agriculture Organization of the United Nations (FAO) West Asian Rinderpest Eradication Campaign (WAREC) and began vaccinating cattle in 1991, continuing until 2003. Clinical and serological surveillance undertaken in 2009 and 2010 did not disclose evidence of the presence of rinderpest.**

KEYWORDS **Clinical surveillance – Qatar – Rinderpest vaccination – Serosurveillance.**

INTRODUCTION

The State of Qatar is an independent state in the southern Arabian Gulf bordered by Saudi Arabia and close to neighbouring Bahrain and the United Arab Emirates. The coastline is 550 km long and bounds the country to the west, north and east (Fig. 1). Doha is the capital and the major administrative, commercial and population centre. In 2009 the rinderpest-susceptible livestock population consisted of 9,900 cattle and buffaloes, 327,000 small ruminants, 42,000 camels and 1,200 Arabian oryx. The Veterinary Services were established in 1958. An animal identification system was introduced in 2004.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN QATAR

Rinderpest was always an exotic disease, occasionally introduced with legally imported cattle from rinderpest-infected countries. The last recorded outbreak occurred in Al Rayyan municipality in 1987. Since then the country has been rinderpest-free.

Within the FAO WAREC programme (Chapter 4.10), vaccination was undertaken in 1991 and 1992 (Chapter 4.12). Vaccine use was concentrated on domestic farm stock, but some trade animals were also vaccinated. All rinderpest vaccination ceased in May 2003.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Passive surveillance failed to find rinderpest after 1987.

Combined active clinical and serological surveillance was undertaken between 2008 and 2009. To detect evidence of rinderpest, at a prevalence of 1% and with 95% certainty, 180 villages were visited. In each village, between 15 and 20 animals, aged between two and five years old, were sampled. Sera were examined using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; Chapter 3.3).

The results are shown in Table I. The overall seroprevalence rate was 0.26%. None of the positive samples fell within a cluster, and

FIG. 1

GENERAL TOPOGRAPHICAL MAP OF QATAR

Source: United Nations, 2004 (1)

TABLE I

RESULTS OF CLINICAL AND SEROLOGICAL SURVEILLANCE WORK UNDERTAKEN IN 2009 AND 2010

Region	Number of villages visited	Clinical surveillance		Number of samples collected	c-ELISA result	
		Number of cattle examined	Number of cattle showing stomatitis/ enteritis		Number of positive samples	Number of negative samples
Ash Shmal	37	753	0	753	5	748
Um Slal	15	558	0	558	0	558
Al Rayyan	67	1,251	0	1,251	0	1,251
Shahanyia	28	511	0	511	3	508
Wakrah	15	198	0	198	0	198
Khour	18	559	0	559	3	556
Total	**180**	**3,830**	**0**	**3,830**	**11**	**3,819**

further investigation suggested that four of the positive samples might have represented maternal antibodies.

WILDLIFE

A total of 331 samples was collected from various wildlife species, but laboratory testing did not detect any antibody to rinderpest virus.

CONCLUSION

Based on the absence of clinical rinderpest after 1987 and the failure to detect serological evidence of rinderpest in the village cattle when examined six years after the end of vaccination, in 2009 the Government of Qatar applied to the World Organisation for Animal Health (OIE) for consideration as a rinderpest-free country. This evidence was accepted by the OIE (2), and Qatar was officially declared free from rinderpest in May 2010 during the General Session of the World Assembly of the OIE Delegates

Reference

1. United Nations (2004). - Map of Qatar. Available at: www.un.org/geospatial/content/qatar (accessed on 9 June 2021).
2. World Organisation for Animal Health (OIE) (2010). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 2–5 March 2010, Paris. OIE, Paris. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_march2010_public.pdf (accessed on 14 June 2019).

CHAPTER 4.11.8

SAUDI ARABIA

ABDUL GHANIY Y.M. AL FADHL

Former Director of Animal Quarantine, Ministry of Agriculture, Saudi Arabia

SUMMARY **Saudi Arabia can be considered to have been endemically infected with rinderpest from the 1960s to the 1990s. Eradication followed the adoption of a stamping out policy, rigorous quarantine and vaccination of imported animals. The last case occurred in 1999. Serosurveillance undertaken in 2009 demonstrated the absence of infection.**

KEYWORDS **Clinical surveillance – Outbreak history – Saudi Arabia – Serosurveillance – Vaccination.**

INTRODUCTION

The Kingdom of Saudi Arabia is bordered to the east by the Arabian Gulf, the United Arab Emirates, Qatar and Bahrein. To the north lie Kuwait, Iraq and Jordan. The Red Sea lies to the west and to the south lie Yemen and Oman (Fig. 1).

Saudi Arabia is the largest country in the Arabian Peninsula, with a human population of 17 million, but, because of the harsh environment, its cattle population is very small. In 1993 it was estimated that there were 7 million sheep, 4 million goats, 413,000 camels and only 202,000 cattle. The principal areas for agricultural production are in the centre of the country, in Riyadh and Al Qassim provinces, and in the south-west, in Jizan (which borders Tihama in Yemen), Hail and Makkah (Fig. 2).

Cattle production can be divided into two types: traditional production of meat from native zebu animals and specialised production of dairy products from exotic Friesian/Holstein cows. Most traditional production occurs in the south-west in Jizan, Asir and Makkah, where goat production is also important, although some is also undertaken in the central provinces of Riyadh and Al Qassim. Specialised cattle production is confined to Riyadh and Eastern provinces, where, in the latter, breeding animals are produced and male calves from the dairy herds are fattened.

The Ministry of Agriculture is responsible for the supervision of all animal Veterinary Services. There is a total of 42 governmental veterinary clinics dealing in therapeutic, vaccination and other veterinary activities. In addition, private clinics are responsible for reporting infectious diseases to governmental authorities and for the implementation of programmes combating epidemic diseases.

HISTORY OF RINDERPEST IN SAUDI ARABIA

Rinderpest was first reported in Saudi Arabia in 1964 (see Timeline, Chapter 4.12), and the disease became endemic in Saudi dairy farms during the 1960s and 1970s (2), persisting until the mid-1990s in feedlots in Al Qassim province and Al Hoffuf governorate (3). Rinderpest was seen in fattening calves in Al Qassim province in the latter part of 1994 after an interval of four years (4). The last case occurred in 1999. A peracute strain belonging to the Asiatic lineage was isolated from an outbreak in Riyadh in 1981.

Vaccination was undertaken between December 1982 and October 2004.

Eradication of rinderpest was achieved by developing a rapid disease reporting system. When

FIG. 1
OUTLINE MAP OF SAUDI ARABIA
Source: Nations Online Project, 2021 (1)

FIG. 2
POLITICAL MAP OF SAUDI ARABIA SHOWING PROVINCES
Source: d-maps.com (2020). - Map of Saudi Arabia. Available at: https://www.d-maps.com (accessed on 9 June 2021), modified to show the political map of the provinces

rinderpest was encountered, the disease was controlled by stamping out, by the introduction of strict quarantine measures and, until 2004, by the vaccination of imported animals at the point of entry.

Outbreak and vaccination data is summarised in Chapter 4.12.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Clinical surveillance

Clinical surveillance consisted of examining oral swab samples from animals showing signs of stomatitis or enteritis suggestive of rinderpest using the agar gel immunodiffusion (AGID) test. In the period between 2004 and 2007, 151 samples were examined, all with negative results. Tests were performed in the Riyadh Veterinary Laboratory.

Serological surveillance

In 2009, 4,080 randomised serum samples were collected from different provinces and governorates of Saudi Arabia (Table I). These samples were examined with the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; Chapter 3.3) test; all gave negative results.

CONCLUSION

The above evidence was accepted by the World Organisation for Animal Health (OIE) after analysis of the report sent in May 2010 by Saudi Arabia (5). The country was officially recognised as a rinderpest-free country in May 2011.

TABLE I
PROVINCES AND GOVERNORATES OF SAUDI ARABIA SAMPLED FOR SEROLOGICAL EVIDENCE OF RINDERPEST TOGETHER WITH THE NUMBER OF SAMPLES COLLECTED

Administrative area	No. of small ruminant samples	No. of cattle samples
Riyadh province	50	100
Jizan province	210	420
Al Taif governorate	50	100
Hail province	20	40
Al Magmaah governorate	30	60
Al Kharj governorate	30	60
Al Jawf province	10	20
Al Zoulfi governorate	20	40
Najran province	40	80
Asir province	50	100
Ad Dawadimi governorate	10	20
Al Afallaj governorate	10	20
Besha governorate	40	80
Qurayat governorate	20	40
Asharqiyah governorate	80	160
Wadi El Dwasser governorate	20	40
Al Ahssaa governorate	120	240
Al Bahah province	30	60
Al Hudud Al Shamaliyah (Northern Borders) province	10	20
Tabuk province	10	20
Makkah province	140	280
Al Madinah province	20	40
Shaqraa governorate	110	20
Al Qassim province	120	240
Unayzah governorate	210	420

References

1. Nations Online Project (2021). - Map of Saudia Arabia. Available at: www.nationsonline.org/oneworld/map/saudi-arabia-map.htm (accessed on 9 June 2021).
2. Hafez S.M., Abou-Zeid A.A., Osman F.S., Fadle N.E. & Abdul-Rahim S.A. (1985). –Factors contributing to the occurrence of rinderpest in Saudi dairy farms. *Proc. Saudi Biol. Soc.*, **8**, 309–322.
3. Roeder P.L., Taylor W.P. & Rweyemamu M.M. (2006). – Rinderpest in the twentieth and twenty-first centuries. *In* Rinderpest and peste des petits ruminants (T. Barrett, P.-P. Pastoret & W.P. Taylor, eds). Elsevier-Academic Press, Oxford.
4. Wilsmore A.J. (1955). – An epidemiological assessment of rinderpest in the Arabian Peninsula. Findings and recommendations. Food and Agriculture Organization of the United Nations, Rome, and, PAN Livestock Services Ltd, Reading, UK.
5. World Organisation for Animal Health (OIE) (2010). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 7–10 September 2010, Paris. OIE, Paris. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_sept2010.pdf (accessed on 11 June 2019).

CHAPTER 4.11.9

SYRIAN ARAB REPUBLIC

Z. NAMOUR

Former Director of Animal Health, Ministry of Agriculture and Agrarian Reform, Syrian Arab Republic

SUMMARY **The Syrian Arab Republic experienced isolated outbreaks of rinderpest in 1970 and again in 1982–1983. These were controlled, and the infection was eliminated by mass vaccination combined with zoosanitary controls. Vaccination ended in 1994. Twenty-five years of passive surveillance plus two rounds of serosurveillance established the absence of infection.**

KEYWORDS **Mass vaccination – Passive surveillance – Rinderpest – Serosurveillance – Syrian Arab Republic**

INTRODUCTION

The Syrian Arab Republic is located in the Middle East. It is bordered by the Mediterranean Sea and Lebanon to the west, by Iraq to the east, by Turkey to the north and by Israel, the West Bank and Jordan to the south (Fig. 1).

From west to east the country consists of a coastal plain, a mountain belt and a large eastern plateau traversed by the Euphrates river.

In 2007 the country maintained 1.1 million cattle, 22 million sheep and 1.5 million goats.

Over the last two decades the livestock industry has improved significantly, mainly due to large investments made by the government and farmers to improve the production potential and to try to meet local market requirements and exports.

The dairy herd is mostly Friesian; in addition, there are about 2,000 local Shami cattle, concentrated in governmental establishments or owned by farmers.

THE HISTORY OF RINDERPEST IN THE SYRIAN ARAB REPUBLIC, INCLUDING VACCINATION

The first recorded cases of rinderpest occurred in the 1920s. By 1934 the disease had been eradicated by quarantine, slaughter and vaccination of in-contact cattle. As a consequence of the epidemic of rinderpest that swept rapidly across the Near East from Afghanistan in 1969, rinderpest was reported in Aleppo and Damascus from August to October 1970. The response was immediate, and mass vaccination was carried out with the assistance of the Food and Agriculture Organization of the United Nations (FAO).

After 13 years of freedom, rinderpest was reintroduced in 1983 after Lebanon had become reinfected in 1982. The ensuing outbreak involved cattle in eight of the counties and 14 of the governorates, with 468 deaths and more than 1,000 animals slaughtered. The outbreak was successfully controlled by vaccination allied with movement controls. The Syrian Arab Republic became free from rinderpest in 1983.

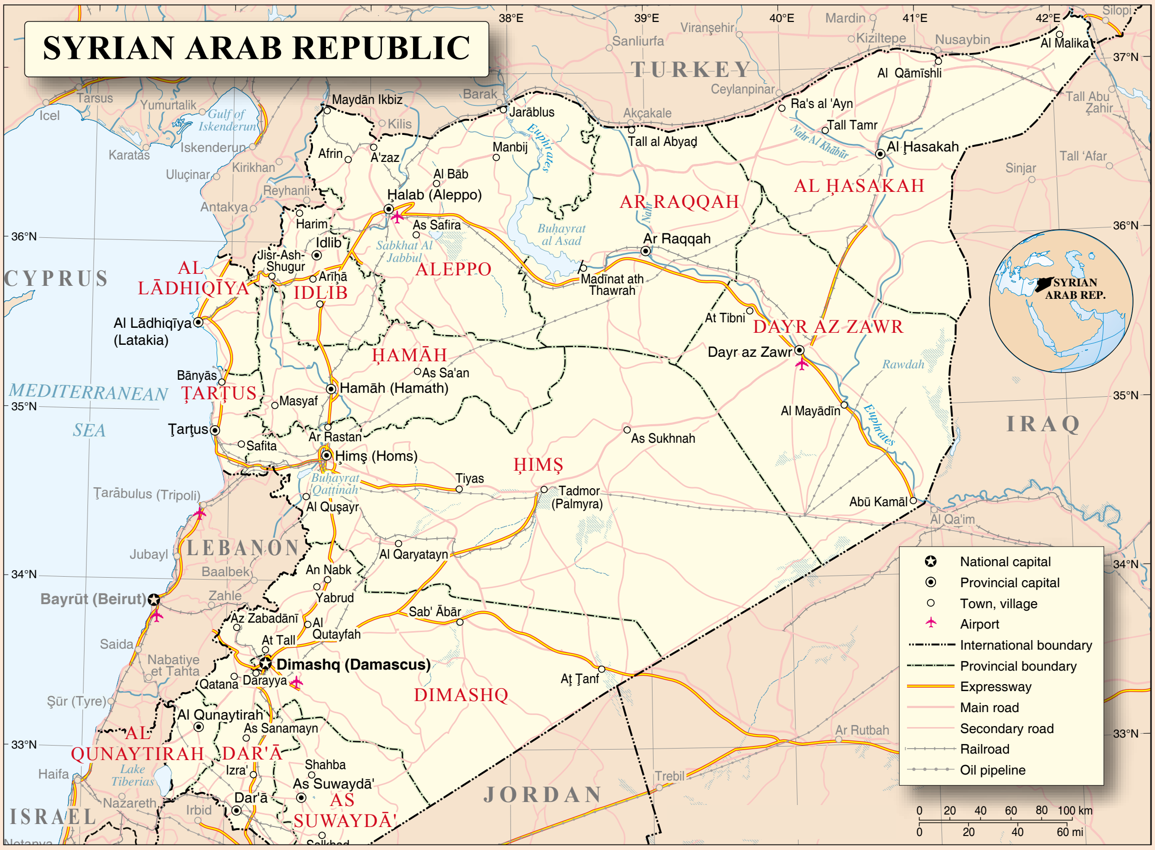
VACCINES AND VACCINATION

Mass vaccination of cattle and buffaloes began in 1984 and continued under the national West Asia Rinderpest Eradication Campaign (WAREC) in 1991 and continued until 1993 (see Chapter 4.10) – even though a general survey for rinderpest in 1991 had failed to find the disease.

Vaccination was disrupted in the first half of 1991 when war affected the Gulf countries. In

FIG. 1
MAP OF THE SYRIAN ARAB REPUBLIC

Source: United Nations, 2012 (1)



1992, vaccination was carried out as per the recommended schedule. In view of the disruption to vaccination in 1991, an additional mass vaccination was carried out in 1993. Thereafter, as a preventive measure, mass vaccination was continued until 2004. Table I gives details of the number of animals vaccinated; see also Chapter 4.12.

The national laboratory produced the vaccine but ceased production in 2005. Subsequently all vaccine stocks were withdrawn from use and in 2007 were destroyed.

ACTIVE SURVEILLANCE FOR RINDERPEST

Rinderpest surveillance in the Syrian Arab Republic was directed towards establishing substantial evidence that rinderpest infection had been verifiably eradicated from the country. This was done through a combination of directly searching for the presence of cases and indirectly looking for hidden circulating virus in the apparently healthy susceptible population. This included clinical surveillance, passive reporting and serosurveillance in susceptible domestic animals.

TABLE I
VACCINATION RETURNS FOR THE PERIOD 1991 TO 2004 AND ESTIMATES OF THE PERCENTAGE OF THE CATTLE POPULATION COVERED

Year	Number of animals vaccinated	Estimated % of cattle population covered
1991	510,000	69.8
1992	560,000	76.7
1993	560,000	76.7
1994	561,874	78
1995	582,400	80
1996	872,574	86
1997	859,657	82
1998	737,976	97
1999	716,437	96
2000	810,855	94
2001	882,588	97
2002	812,532	95
2003	833,470	97
2004	923,445	98

Routine monthly reports of diseases confirmed by each governorate's major veterinary clinic and by laboratories and other departments were routinely sent to the Department of Animal Health. From 1983 to 2009 no suspicion of rinderpest was reported.

A random countrywide serological survey was carried out in 2006. In total 1,500 samples were collected in 150 villages based on the density of their cattle population. Between 5 and 15 samples were collected from each visited village. The seroprevalence of rinderpest was 13.8%. Follow-up investigation was undertaken which established that the positive animals were more than two years old and had probably been vaccinated; no clinical rinderpest was found.

Between 2008 and 2009, a serosurvey was carried out, targeting animals between one and two years old. A total of 300 villages were selected randomly from the country's list of 10,000 villages but in proportion to the cattle population of the 14 governorates. In total, 4,400 blood samples were collected. The sera were analysed for antibodies to rinderpest at the central laboratory in Damascus using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3) kit. Collection and testing of samples strictly followed the recommendations of the World Organisation for Animal Health (OIE) on rinderpest eradication and those in the OIE *Terrestrial Animal Health Code*.

Overall, 3.02% (133) of the samples were found to have antibodies against rinderpest. In areas where seropositive results were found, further investigations were carried out to reassess the age group and other factors that might have led to seropositivity. The investigation found that 103 of the 133 positive samples (77.4%) were from animals that were either less than one year or more than three years old and considered ineligible. This reduced the overall seroprevalence in the Syrian Arab Republic to 0.7%. This figure was considered to be due to non-specific reactions.

At the time of the surveys, there were no concentrations of wild animals in the Syrian Arab Republic that required specific surveillance for evidence of infection with rinderpest virus.

CONCLUSION AND DOSSIER

There have been no cases of rinderpest in the Syrian Arab Republic since 1983. Mass vaccination against rinderpest was carried out as a preventive measure but ended in 2004. Serological evidence indicated that the Syrian Arab Republic could consider itself free of rinderpest, and on this basis, in 2009, the Syrian Arab Republic requested recognition as a rinderpest-free country. This request was accepted by the OIE (2) and the Syrian Arab Republic was declared free from rinderpest on 25 May 2010.

Reference

1. United Nations (2012). - Map of the Syrian Arab Republic. Available at: www.un.org/geospatial/content/syrian-arab-republic (accessed on 9 June 2021).
2. World Organisation for Animal Health (OIE) (2010). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 2–5 March 2010, Paris. OIE, Paris. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_march2010_public.pdf (accessed on 8 May 2019).

CHAPTER 4.11.10

TURKEY

N. PAKDIL

Former Director General, General Directorate of Protection and Control, Ministry of Agriculture and Rural Affairs, Turkey

SUMMARY Endemic rinderpest was eliminated from Turkey in 1932. Rinderpest spread from Iran to Turkey in October 1969, and over the next two years spread widely across Turkey. Rinderpest was eradicated in 1972. Between 1972 and 1991, Turkey was free from rinderpest, but the disease reappeared in 1991 and again in 1993 and 1994. The last outbreak was recorded in January 1996. Based on further surveillance activities and negative results, Turkey was declared an infection-free country on 25 May 2005.

KEYWORDS Outbreak history – Rinderpest – Serosurveillance – Turkey – Vaccination.

INTRODUCTION

The Republic of Turkey occupies a unique geographical and cultural position at the crossroads between Europe and Asia. It is bounded by the Black Sea to the north, the Aegean Sea to the west and the Mediterranean Sea to the south. It shares land borders with Greece, Bulgaria, Georgia, Armenia, Azerbaijan, the Islamic Republic of Iran, Iraq and the Syrian Arab Republic (Fig. 1).

There are 81 provinces in the country. In 2001, there were over 3 million holdings, of which some 2 million were engaged in crop production and animal husbandry, while in 2002 there were 9.8 million cattle but only 121,000 buffaloes.

Veterinary affairs are the responsibility of the Ministry of Agriculture and Rural Affairs. At the country level, livestock health issues are dealt with by the General Directorate of Protection and Control in conjunction with Provincial Directorates of Agriculture.

HISTORY OF RINDERPEST IN TURKEY

Endemic rinderpest was eliminated from Turkey in 1932. In 1969, the so-called Near East Pandemic (1969–1973) began in Afghanistan, affected almost all countries in the region, spread from Iran to Turkey in October 1969 and over the next two years spread widely across Turkey, involving 20 provinces. Some 10,750 animals were slaughtered and 2,059 died of the disease (2). In each of the three successive years, all the cattle and buffalo population (about 14 million) were vaccinated against rinderpest, and by 1972 this incursion was completely eradicated (see Chapter 2.3 for a detailed account and map of distribution). Vaccination figures are shown in the regional timeline (Chapter 4.12).

Between 1972 and 1991, Turkey was free from rinderpest, but in September 1989 it reappeared in the Islamic Republic of Iran – and the Turkish authorities in the border regions were advised accordingly (3). Two years later in September 1991, rinderpest was detected in Van and Hakkari, cities in eastern Turkey, having entered from the Islamic Republic of Iran. Subsequently, the disease spread rapidly westwards and north-westwards (towards Istanbul), so much so that, within two months, 44 municipalities including 516 herds were affected.

A further upsurge in infection in an area straddling neighbouring parts of Iraq, the Islamic Republic of Iran and Turkey occurred during the period 1993–1994.

FIG. 1
MAP OF TURKEY
Source: United Nations, 2021 (1)

The disease recurred in Ardahan province in 1994. The last outbreak of rinderpest in Turkey was recorded in Diyarbakır in January 1996.

The extent of the final outbreaks is shown in Table I.

The disease was controlled by appropriate measures, such as compensation for destroying sick and in-contact animals, animal movement controls, vaccination and clinical surveillance.

HISTORY OF RINDERPEST VACCINATION IN TURKEY

Tissue culture rinderpest vaccine (TCRV) was manufactured by the Etlik Central Veterinary Control and Research Institute in Ankara.

Mass vaccination was undertaken during the Near East Epidemic and during the incursions of 1991 to 1996. The last vaccination was done in 1998.

TABLE I
RINDERPEST OUTBREAKS 1991–1996

Year	Month	No. of outbreaks	Province	No. of cases	No. of destroyed
1991	October	2	Adana	440	440
		4	Afyon	1,000	1,000
		4	Diyarbakir	1,301	1,301
		1	Hakkari	39	39
		2	Konya	443	443
		3	Sakarya	161	161
		1	Van	100	100
	November	2	Van	299	299
Total 1991		**19**		**3,783**	**3,783**
1994	April	1	Ardahan	8	8
1996	January	1	Diyarbakır	24	24
Grand total		**21**	**3,815**	**3,815**	**3,815**

Latterly, this activity was resolved through a strong emergency vaccination response from the Food and Agriculture Organization of the United Nations (FAO).

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Clinical surveillance

In 2003, a report was prepared by Turkey's Ministry of Agriculture and Rural Affairs General Directorate for Protection and Control and submitted to the World Organisation for Animal Health (OIE), requesting freedom from rinderpest disease status. As a result of this report, on 21 May 2003, Turkey was declared rinderpest disease-free.

After obtaining the freedom from rinderpest disease status in 2003, continuous active clinical surveillance was carried out, particularly in border regions and provinces where animal movement was intensive (Van, Gaziantep, Adana, Osmaniye, Kayseri, Tokat, Amasya, Afyon, Kocaeli, Erzurum) and during periods when animal movement was intensive. No rinderpest outbreaks were detected.

Serological surveillance

At the laboratory level, cases of rinderpest-like disease continued to occur. Between 1999 and 2001, 108 samples were examined. Of these, 31 samples were examined as samples belonging to rinderpest-suspected cases. All samples were inoculated to sensitive cell cultures for virus detection. Four of these were found to be positive with respect to bovine virus diarrhoea/mucosal disease (BVD/MD). None were positive for rinderpest. Among the remaining 77 samples examined for rinderpest-like diseases (infectious bovine rhinotracheitis, BVD/MD, etc.), none of them were positive for rinderpest.

Serosurveillance results for 2001, 2003 and 2004

All samples were tested using the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3). In a nationwide rinderpest serosurvey in 2001, sera were collected from a total of 7,827 head of animals that were born after vaccination had been stopped and that were older than one year old within the 13–30 months group. Of these, 110 were positive.

In 2003, serosurveillance was carried out in 37 provinces. Sera were collected from 1,531 animals, among which 21 were positive.

Among a sample of 10,934 sera collected from eligible animals, 165 were positive.

CONCLUSION

As a result of the efforts of the Veterinary Service and all the data obtained, Turkey was declared free from rinderpest disease after 2003. Based on further surveillance activities a dossier was submitted in November 2004; this was accepted by the OIE (4). Turkey was declared an infection-free country on 25 May 2005.

References

1. Nations Online Project (2021). - Map of Turkey. Available at: www.nationsonline.org/oneworld/map/turkey-map.htm (accessed on 9 June 2021).
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CHAPTER 4.11.11

UNITED ARAB EMIRATES

S. AL RAIS

Former Head of Animal and Plant Health, Ministry of Environment and Water, United Arab Emirates

SUMMARY **The United Arab Emirates recorded occasional rinderpest outbreaks between 1979 and 1995, but it is unlikely that the condition was ever endemic. The United Arab Emirates subscribed to the Food and Agriculture Organization of the United Nations (FAO)'s Middle and Near East Regional Animal Production and Health Project (MINEADEP) and the West Asia Rinderpest Eradication Campaign (WAREC), and vaccinated cattle between 1987 and 2004. Serosurveillance in 2009 and 2010 demonstrated that the bovine population was free from rinderpest. The United Arab Emirates was declared free of rinderpest by the World Organisation for Animal Health (OIE) in May 2011.**

KEYWORDS **Rinderpest – Serosurveillance – United Arab Emirates.**

INTRODUCTION

The United Arab Emirates is a federation of seven independent emirates: Abu Dhabi, Dubai, Sharjah, Ras Al Khaimah, Ajman, Umm Al Quwain and Al Fujairah. Abu Dhabi is the capital and the largest emirate. The country is located in the southern corner of the Arabian Peninsula and bordered by the Persian Gulf to the north, Saudi Arabia to the south and west, Qatar to the north-west and Oman and the Gulf of Oman to the east (Fig. 1).

In 2010, there were 65,000 cattle including 23,000 milking cows held on 25 farms. Approximately half of the cattle population is found in the Western Region.

HISTORY OF RINDERPEST IN THE UNITED ARAB EMIRATES

Rinderpest was a notifiable disease in the United Arab Emirates; the recorded incidence of outbreaks from 1979 to 2010 is shown in Table I. The condition was never considered endemic, and the last outbreak was recorded in 1995.

Vaccination against rinderpest began in 1987 under FAO's MINEADEP and continued under WAREC (see Chapter 4.12). The vaccine coverage in 1991 and 1992 amounted to 82.7% and 92.3% of the cattle population, respectively. Vaccination ended in 2004.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Passive surveillance failed to find rinderpest after 1995.

Serosurveillance was undertaken between 2009 and 2010 by targeting unvaccinated animals between one and four years of age. While sera were randomly collected, the sampling frame attempted to consider the distribution of the population. Using the competitive enzyme-linked immunosorbent assay (c-ELISA; Chapter 3.3), the results are shown in Table II.

FIG. 1
REGIONS OF THE UNITED ARAB EMIRATES
Source: D-maps, 2020 (2), modified to indicate regions

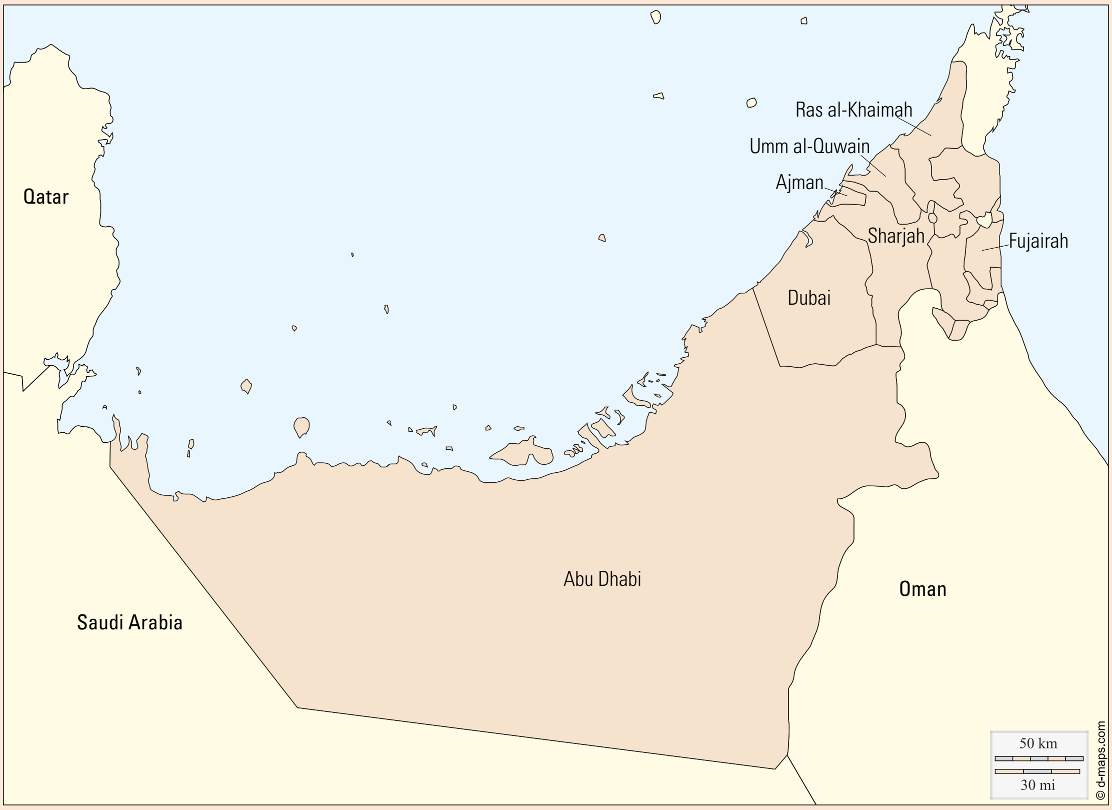

TABLE I
INCIDENCE OF RINDERPEST IN THE UNITED ARAB EMIRATES BETWEEN 1979 AND 2010

Year	Outbreaks	Cases	Location
1979–1985	0	–	–
1986	1	13	Western Region
1987	1	112	Al Ain
1988	2	22	Al Ain, Al Ruwiyeh
1989	1	13	–
1990	0	–	–
1991	0	–	–
1992	1	9	Al Ain
1993	0	–	–
1994	0	–	–
1995	1	2	Western Region
1996–2010	0	–	–

CONCLUSION

Based on the absence of clinical rinderpest after 1995 and the absence of serological evidence in 3,475 samples collected four years after the end of vaccination, the United Arab Emirates claimed freedom from rinderpest in June 2010. This evidence was accepted by the OIE (1), and the United Arab Emirates was officially declared free from rinderpest in May 2011, during the General Session of the World Assembly of the OIE Delegates.

TABLE II
RESULTS OF SEROSURVEILLANCE WORK UNDERTAKEN IN 2009 AND 2010

Region	Cattle population	Number of samples collected	Number of positive results	Number of negative results
Eastern	6,922	419	0	419
Northern	5,888	1,000	0	1,000
Central	19,219	956	0	956
Western	33,150	1,100	0	1,100
Total	**65,179**	**3,475**	**0**	**3,475**

Reference

1. World Organisation for Animal Health (OIE) (2010). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 7–10 September 2010. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_sept2010.pdf (accessed on 13 June 2019).
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CHAPTER 4.11.12

YEMEN

M. AL-QADASI

Former Director of Veterinary Services, Ministry of Agriculture and Irrigation General Directorate for Animal Health and Veterinary Quarantine, Sana'a, Yemen

SUMMARY **Two epidemics of rinderpest occurred between 1971 and 1979 and a further epidemic occurred in 1981. Outbreaks were controlled by ring vaccination. From 1982 to 1995 rinderpest remained endemic within the country. An Asian lineage virus was isolated on two occasions. The passive disease surveillance system operating from 1995 to 2009 failed to identify rinderpest. Dedicated disease investigations over the same period yielded similar results. Four rounds of serosurveillance between 2001 and 2009 demonstrated low and progressively declining levels of immunity. The Yemen dossier of 2009 was accepted by the World Organisation for Animal Health (OIE) as evidence that the country was rinderpest free.**

KEYWORDS **Clinical surveillance – Disease investigation – Epidemics – Rinderpest – Serosurveillance – Vaccination – Yemen.**

INTRODUCTION

The Republic of Yemen is situated at the south-western corner of the Arabian Peninsula. It is bordered to the west and south by the Red and Arabian Seas, respectively, to the east by Oman and to the north by Saudi Arabia. Yemen possesses a number of islands, including Socotra. Administrative boundaries are shown in Figure 1.

The country is naturally divided into four main regions: the western coastal plains or Tihama; the southern coastal plains; the eastern semi-desert hills and sand deserts, including Al-rub Al-khali and the central highlands separating the coastal lowlands from the eastern deserts and hills. The highlands include extensive inter-mountain plains that are important for agriculture and animal grazing, rearing and nomadic settlement.

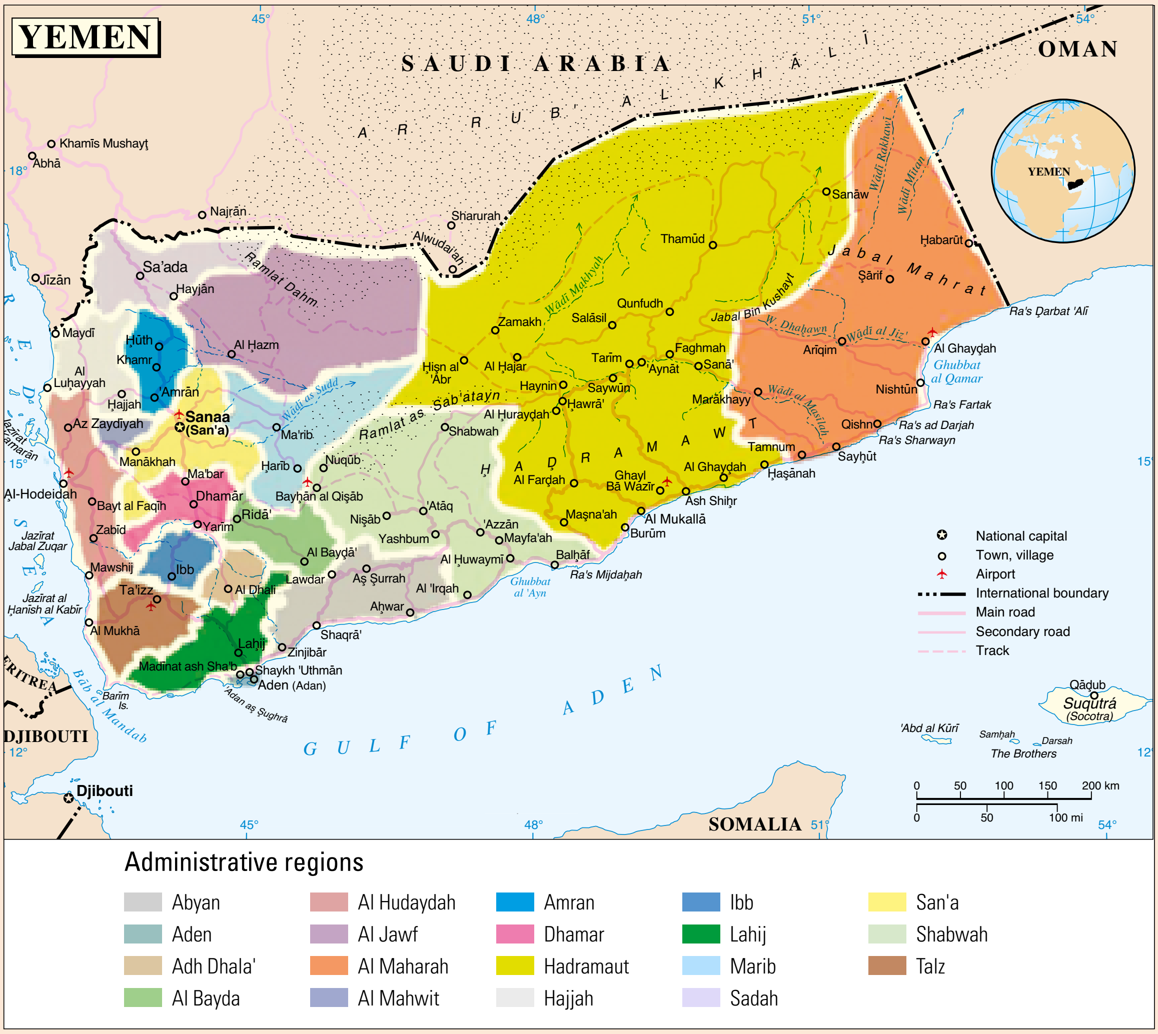
Yemen has two livestock industries: an indigenous one, in which animals are bred, reared and used in the country as a source of milk and some meat, and another which imports large numbers of cattle, sheep and goats from other countries, predominantly those in the Horn of Africa. The two systems operate almost independently of each other, indigenous livestock being owned and managed largely by small-scale farmers while the imported industry is managed by traders. Most cattle live in the highlands or the Tihamas (the Red Sea coastal plains).

There are no wildlife populations in Yemen that might have assisted in the maintenance of rinderpest.

The General Directorate of Animal Health and Veterinary Quarantines (GDAH&VQ) is the authorised veterinary administration. The GDAH&VQ operates from Sana'a with field offices in all of the country's 19 governorates. The Central Veterinary Laboratory is also situated in Sana'a. In 2009 it was capable of diagnosing rinderpest by the agar gel immunodiffusion test and of detecting antibodies to rinderpest by the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3). Disease surveillance operated through monthly reporting from the

FIG. 1
ADMINISTRATIVE BOUNDARIES OF YEMEN

Source: United Nations, 2004 (1), modified to show the administrative regions of Yemen



governorates, augmented by emergency reports of possible outbreaks of major notifiable diseases such as rinderpest.

Community animal health workers were trained to assist the delivery of veterinary services in the more isolated areas.

HISTORY OF RINDERPEST IN YEMEN

The disease was first confirmed in Yemen in the highlands and the Tihama between 1971 and 1973. It was characterised by a moderate mortality rate (10–20%) and controlled through vaccination of animals at risk. The outbreak attracted international assistance with vaccination teams supplied by the Egyptian Government, by the Food and Agriculture Organization of the United Nations (FAO) and the Yemen Ministry of Agriculture. A British veterinary team vaccinated throughout 1973 and 1974.

The next occurrence of rinderpest was at Al-Hojaryah (Taiz governorate) in the second half of 1976. Despite ring vaccination the disease spread rapidly through the highlands and by September involved not only Taiz but Ibb, Dhamar and Sana'a governorates. In the first quarter of 1977 the disease spilt on to the Tihama. A major vaccination campaign at that time visited 2,351 villages and administered 232,287 rinderpest vaccinations. During these visits the staff counted 1,246 sick animals and 717 carcasses. Continuing vaccination during 1977 brought the epidemic to a close but the disease remained present throughout 1977 and into 1978 in the form of scattered outbreaks in mountainous areas, and it continued to spread northwards into Hajjah and Sa'ada governorates. A steep and continual rise in the incidence of clinical rinderpest was noted in 1979 with some outbreaks being traced back from Dhamar to Ibb. Sporadic outbreaks of the disease were present during 1980.

In June 1981 a fresh epidemic began. The disease reappeared in Sana'a with very high mortality in remote unvaccinated areas: some 166 outbreaks involved more than a thousand animals. This epidemic appeared to originate in the north and then swept down the Tihama. Subsequently, Dhamar reported the disease spreading from Ibb. This epidemic continued until the end of 1981 and involved at least 2,500 cases. A sample from this outbreak was submitted to the FAO World Reference Laboratory for morbilliviruses at Pirbright, United Kingdom of Great Britain and Northern Ireland, where the virus was isolated and confirmed as virulent rinderpest, and subsequently shown to belong to the Asiatic lineage of rinderpest viruses.

In 1982 two separate outbreaks occurred in Sana'a and Al-Hodeidah governorates and soon the disease became endemic with outbreaks regularly reported from most of the cattle-keeping governorates. Characteristic of the ongoing situation was the high mortality in imported cattle moving within the livestock trading system. Rinderpest control was maintained through vaccination in affected and surrounding villages, supported with routine annual mass campaigns. The number of outbreaks peaked in the mid-1980s, although by this time an outbreak report might be initiated by a single case. The response to the continuing endemic situation was increasingly intense vaccination as a result of which the number of reported outbreaks decreased in the 1990s. With particular attention paid to ring vaccination around outbreaks, the last reported cases occurred in Gabal Jehaf, in Al Dhali governorate, and Medi, near Haddar in Hajjah governorate, both in 1995. Virus isolated from the Al Dhali outbreak was again typed as an Asian lineage virus.

The clinical disease seen in Yemen was always classic and severe with clearly visible oculo-nasal discharges, erosions of the oral mucosa, frequent diarrhoea and high mortality rates. At post-mortem examination classic erosions and congestion were found in the oesophagus and abomasum and throughout the intestines. Mild rinderpest was never detected. Outbreaks of disease were as severe in indigenous cattle as in imported stock.

Rinderpest outbreak or case numbers, together with vaccination figures, are presented in Chapter 4.12. Vaccination ended in 2000.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Passive clinical surveillance

Animal health teams in the governorates' agriculture offices were required to submit monthly disease surveillance reports. None of the 1,454 reports submitted between 1999 and 2009 mentioned rinderpest.

Purposive surveys for clinical rinderpest

Veterinarians participating at a national workshop in 2000 were asked to identify the areas of Yemen where they believed rinderpest might have persisted, if at all, since the last confirmed outbreaks in 1995. The results identified the areas where rinderpest was last confirmed in Yemen in 1995: the northern Tihama and Al Dhali and eastern Ibb in southern Yemen. Based on these results a rapid search for cattle with oculo-nasal discharges, stomatitis and/or enteritis (i.e. a rinderpest-like syndrome) was made in 100 villages in the Tihama in 2000, and 120 villages in Ibb and Al Dhali in 2001. An additional rapid search was made in 35 villages in and around Sana'a in 2001 because of the frequency with which rinderpest was reported there when the disease was common in the country, due to its role as the final market for cattle in the country. Within the target areas the survey teams defined a route through villages with the most cattle populations or with a known history of rinderpest and then drove that route stopping at every third or fourth village to talk with livestock owners and village elders. The search was rapid, with each team visiting five to eight villages a day, and often carried out without advance warning. No clinical cases or recent reports of rinderpest or rinderpest-like disease were found in any village. After enquiring about the presence of the symptoms mentioned above the investigating teams then asked specifically about the history of rinderpest in the villages. One or more people in most villages could clearly remember when the disease had last been present.

A nationwide active rinderpest disease survey, both clinical and serological, was undertaken between 2001 and 2003. Livestock owners were asked to show the surveillance teams any sick animals that concerned them, including cases of oculo-nasal discharge, stomatitis and diarrhoea. A total of 477 randomly selected villages were searched during which no cases of rinderpest or rinderpest-like disease were found.

Further purposive searches for disease were conducted in 2007, and in 2009 they were conducted as part of three major surveys for serological evidence of rinderpest infection in Yemen. No cases of rinderpest or rinderpest-like disease were found.

Disease investigations

Two possible rinderpest outbreaks were investigated in 1999 and not confirmed by the CVL or in duplicate samples submitted to the World Reference Laboratory at Pirbight, United Kingdom. Similarly, there was a suspected case in November 2000 in a bull calf at Hamdan, north of Sana'a, which was not confirmed. In August 2002 a calf born on a dairy farm near Sana'a was reported as suspected of having rinderpest but proved negative after intensive reinvestigation, including sending 23 samples to the World Reference Laboratory for polymerase chain reaction (PCR) analysis.

Between 2004 and 2009 there were 44 investigations of suspected rinderpest. A number of duplicate specimens were submitted to the World Reference Laboratory for rinderpest at Pirbright and no virus found.

Serological survey of 2001–2003

The sampling strategy followed the international procedures recommended by the Global Rinderpest Eradication Programme (GREP) and the OIE for surveillance for antibodies to rinderpest with the result that 490 (13.3%) of the 3,771 samples were positive. Analysis of the results showed that positive animals were widespread throughout the highlands and Tihama and that antibodies were more prevalent in older animals (which should have been excluded from the survey).

Serological survey of 2007

In 2007 a survey was carried out in the 10 governorates deemed at highest risk of retaining endemic rinderpest. The sampling frame followed the procedure recommended by the GREP with random selection of 300 villages in the governorates. The result showed that 141 of 1,922 samples had antibodies to rinderpest, giving an overall prevalence of 7.34%. When analysed by different age groups it was found that the positive animals were distributed across all age groups and across all governorates with some clustering in certain villages. Detailed investigation and resampling were carried out in many of the villages that had clusters of antibody-positive cattle. Unfortunately this took place nearly a year after the collection of samples and data, making it difficult to find and rebleed the original animals. However, where specific individuals were found, many had been significantly under-aged, often by several years. Of 98 sera collected from these re-examined animals and from others on their farms, 12 had antibodies of which 9 were either young enough to have had maternal antibodies or old enough to have been vaccinated.

Serological survey of March–April 2009

A national survey was undertaken in 2009, selecting 330 villages at random. However, as in 2007, it proved difficult to find sufficient younger animals in the villages and the overall finding of 125 positive samples in 3,834 samples (3.26%) again included many older animals. The positive animals were found in 82 villages in 14 governorates in the highlands and Tihama; 56 villages had 1 positive animal, 17 had 2, 3 had 3, 4 had 4, and 2 had 5 positive animals (of which 3 were old animals). There did not appear to be any clustering of positive villages.

Serological survey of December 2009

A final survey was made in three governorates in or partly in the Tihama (Al-Hodeidah, Hajjah, Al Mahwit) and two governorates in the central highlands (Ibb and Taiz) all of which had villages with clusters of antibody-positive cattle in the March–April survey. Out of 897 samples collected during the field survey four samples were not tested as they were outside the targeted age range, one sample was recorded as uncertain by the collector and gave a positive result and all remaining samples tested negative.

A summary of the results of the various serological surveys is given in Table I. All samples were examined using the c-ELISA (see Chapter 3.3).

TABLE I
RESULTS OF SEROLOGICAL SURVEYS CARRIED OUT AFTER ENDING RINDERPEST VACCINATION

Year	Region sampled	No. samples collected and tested	Positive samples (%)
2001/2003	Nationwide	3,771	13.30
2007	Highlands and Tihama	1,992	7.34
2009 (March–April)	Nationwide	3,834	3.26
2009 (December)	Tihama, Taiz, Ibb	893	0.11

CONCLUSIONS AND DOSSIER

The diminishing proportion of positive animals in the four surveys undertaken after vaccination ceased was taken as evidence of the absence of rinderpest within the surveyed population.

Because there were no reports of the presence of rinderpest in the seven-year period from January 1996 to December 2002 the Government of Yemen made a declaration of provisional freedom from rinderpest in October 2003.

In the period between January 1996 and December 2009 the passive disease surveillance system failed to report any instances of rinderpest. In the period from 1999 to 2009 the combined field and laboratory service investigated 48 cases of suspected rinderpest but failed to confirm any of them. From 2001 an active village search programme visited 777 villages and found no evidence of rinderpest in any of them.

On the basis of the above findings the Government of Yemen submitted a dossier of evidence to the OIE claiming freedom from rinderpest infection. This claim was upheld by the OIE (2) and Yemen was declared free from rinderpest on 25 May 2010.

Reference

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CHAPTER 4.12

TIMELINE FOR EGYPT, THE GULF AND THE MIDDLE EAST

Egypt and countries in the Gulf and the Middle East on the Global List of Countries officially recognised as free from rinderpest infection as at May 2011

Source: d-maps.com (2020). - Map of Middle East. Available at: https://www.d-maps.com (accessed on 9 June 2021), modified to show countries covered in this section

YEAR	COUNTRY / CROSS REFERENCE								
	BAHRAIN			EGYPT/CHAPTER 4.11.1			IRAN (ISLAMIC REPUBLIC OF)/CHAPTER 4.11.2		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
Background notes				Prior history of intermittent epidemics			History of intermittent epidemics; 1969–1973 epidemic began the Near East Pandemic		
1960						...**	In eastern provinces		0.4*
1961						...			89
1962						...			...
1963						...			...
1964						...			...
1965				NEAHI phase I		...	NEAHI phase I		...
1966						...			...
1967						...			185
1968						...			2
1969						...	NEAHI phase II		14,007
1970				NEAHI phase II		...			4,287
1971						...		130 outbreaks, 20,000 deaths	4,654
1972						2,157			3,390
1973						...			4,731
1974				NEADEC		...	NEADEC		8,350
1975						2,061			3,234
1976	MINEADEP phase I					2,208			2,485
1977						2,113			1,718
1978				MINEADEP phase I		2,300			1,142
1979						2,095			1,266
1980			10*			2,582			1,229
1981	MINEADEP phase II		5		4120 dead	2,738			6,065
1982			10		4802 dead	4,845			1,385
1983				MINEADEP phase II	2002 dead	3,920			1,018
1984					192 dead	3,920			1,349
1985					307 dead	4,654			6,536
1986						5,385			6,313
1987						5,597			3,961
1988						5,776			3,999
1989	WAREC					5,405			7,976
1990				MINEADEP phase III + WAREC		5,044	From Iraq		5,856
1991						5,322***			5,932***
1992						4,611***			4,603***
1993						3,418			5,524
1994						847			9,885
1995						717			8,123
1996						64	Final outbreak in west, close to Turkey/Islamic Republic of Iran borders		7,748
1997									8,805
1998									7,816
1999									7,999
2000									7,321
2001									4,604
2002									1,081

LEGEND

MINEADEP	*Middle and Near East Animal Production and Health Project implemented by FAO*
NEADEC	*United Nations Development Programme implemented Near East Animal Production and Health Centre*
NEAHI	*United Nations Development Programme implemented Near East Animal Health Institute*
WAREC	*FAO implemented West Asia Rinderpest Eradication Campaign*
FAO	*Food and Agriculture Organization of the United Nations*
10* etc.	*Vaccination by Veterinary Services, number × 1,000*
...**	*Vaccination by Veterinary Services, number × 1,000*
5,322*** etc.	*Vaccination under FAO WAREC programme × 1,000*

	Unreported
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
	Discrete reintroductions
130 etc.	*Discrete reintroductions and associated number of outbreaks or bovine deaths*

YEAR	COUNTRY / CROSS REFERENCE								
	IRAQ/CHAPTER 4.11.3			ISRAEL/CHAPTER 4.11.4			JORDAN		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of ofoutbreaks	Vaccinations
Background notes	Eliminated in 1923, reintroduced in 1985 with buffalo importation to Basra			Prior history of intermittent epidemics			History of intermittent epidemics; 1969–1973 epidemic began the Near East Pandemic		
1960									
1961									
1962	NEAHI phase I								
1963									
1964									
1965									
1966									
1967									
1968	NEAHI phase II								
1969									
1970						227	NEAHI phase II		
1971				Precautionary vaccination continuing until 1975		...			31
1972						...			31
1973	NEADEC					...			31
1974						...	NEADEC		31
1975						...			31
1976	MINEADEP phase I								31
1977									31
1978							MINEADEP phase II		...
1979									...
1980									...
1981	MINEADEP phase II								...
1982						...			...
1983					Entered Israel from Lebanon	...			...
1984			600			...			...
1985			3,908			...	MINEADEP phase II		...
1986		Lingering infection in central and southern governorates and near Basrah and Baghdad	1,524			...			...
1987	MINEADEP phase III + WAREC		1,722			...			...
1988			1,402			...			5
1989			1,534			...			19
1990			1,672				MINEADEP phase III + WAREC		14
1991			1,858***						70***
1992			1,392***						18***
1993			1,705						'''
1994			2,042						...
1995			2,089						...
1996		Last case	1,195						9
1997			1,337						
1998			1,410						
1999			228						
2000			830						
2001			791						
2002			866						
2003			153						

LEGEND

MINEADEP	*Middle and Near East Animal Production and Health Project implemented by FAO*
NEADEC	*United Nations Development Programme implemented Near East Animal Production and Health Centre*
NEAHI	United Nations Development Programme implemented Near East Animal Health Institute
WAREC	FAO implemented West Asia Rinderpest Eradication Campaign
FAO	Food and Agriculture Organization of the United Nations
10* etc.	*Vaccination by Veterinary Services, number × 1,000*
...**	*Vaccination by Veterinary Services, number × 1,000*
5,322*** etc.	*Vaccination under FAO WAREC programme × 1,000*

	Unreported
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
	Discrete reintroductions
130 etc.	*Discrete reintroductions and associated number of outbreaks or bovine deaths*

YEAR	COUNTRY / CROSS REFERENCE								
	KUWAIT/CHAPTER 4.11.5			LEBANON			OMAN/CHAPTER 4.11.6		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
Background notes									
1960									
1961									
1962									
1963									
1964									
1965				NEAHI phase I					
1966									
1967									
1968	NEAHI phase II								
1969				NEAHI phase II					
1970									
1971									
1972				NEADEC					
1973	NEADEC								
1974									
1975									
1976	MINEADEP phase I	Annually reported in cattle but unlikely to have been endemic							
1977									
1978							MINEADEP phase I		
1979								1	...
1980									...
1981	MINEADEP phase II			1981-1986 MINEADEP phase II					...
1982						...		1	...
1983				1983 Infection began with importation of Pakistani buf-faloes by road		...	MINEADEP phase II	1	
1984						...			
1985						...		1	
1986			5			...		1	21
1987	MINEADEP phase III + WAREC		5			...			0,6
1988			...			...		2	42
1989			...	Infection began with importation of Pakistani buffaloes by road		19		3	51
1990			...			8	MINEADEP phase III + WAREC		59
1991			...			510***			18***
1992			...			560***		10	43***
1993			...			560		1	57
1994			...			562			88
1995			...			582		16	116
1996			...			873			41
1997			...			860			10
1998			...			738			38
1999			...			716			18
2000			...			811			74
2001			...			883			1
2002			...			813			
2003						833			
2004						923			

LEGEND

MINEADEP	*Middle and Near East Animal Production and Health Project implemented by FAO*
NEADEC	*United Nations Development Programme implemented Near East Animal Production and Health Centre*
NEAHI	United Nations Development Programme implemented Near East Animal Health Institute
WAREC	FAO implemented West Asia Rinderpest Eradication Campaign
FAO	Food and Agriculture Organization of the United Nations
10* etc.	*Vaccination by Veterinary Services, number × 1,000*
...**	*Vaccination by Veterinary Services, number × 1,000*
5,322*** etc.	*Vaccination under FAO WAREC programme × 1,000*

(yellow)	*Unreported*
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
(pink)	*Discrete reintroductions*
130 etc.	*Discrete reintroductions and associated number of outbreaks or bovine deaths*

YEAR	COUNTRY / CROSS REFERENCE								
	QATAR/CHAPTER 4.11.7			SAUDI ARABIA/CHAPTER 4.11.8			SYRIAN ARAB REPUBLIC/CHAPTER 4.11.9		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
Background notes				Endemic and epidemic periods			1970, entered the Syrian Arab Republic/ during Near East Pandemic; disease free until 1983 when reintroduced from Lebanon		
1960									
1961									
1962									
1963									
1964				First report					
1965									
1966									
1967									
1968									
1969									
1970					+				
1971					+				
1972					+				
1973					+				
1974				NEADEC	+		NEADEC		...
1975					+				...
1976					+				...
1977					+				...
1978	MINEADEP phase I			MINEADEP phase I	+				...
1979					+				
1980					+				
1981					+	...			
1982					+	...			
1983	MINEADEP phase II			MINEADEP phase II	+	...			
1984					+	....			...
1985					+	...			...
1986					+	...			...
1987					+	...			...
1988					+	...			...
1989					+	...			...
1990					+	...			...
1991			1.4***			...			510
1992			4.0***	WAREC		...	WAREC		560
1993			5.0			....			560
1994			...			...			562
1995			...			...			582
1996			...			...			873
1997			...			...			860
1998			...			...			738
1999			...			...			716
2000			...			...			811
2001			0.7			...			883
2002			1.2			45			813
2003			0.5			15			833
2004									923

LEGEND

MINEADEP	*Middle and Near East Animal Production and Health Project implemented by FAO*
NEADEC	*United Nations Development Programme implemented Near East Animal Production and Health Centre*
NEAHI	United Nations Development Programme implemented Near East Animal Health Institute
WAREC	FAO implemented West Asia Rinderpest Eradication Campaign
FAO	Food and Agriculture Organization of the United Nations
10* etc.	*Vaccination by Veterinary Services, number × 1,000*
...**	*Vaccination by Veterinary Services, number × 1,000*
5,322*** etc.	*Vaccination under FAO WAREC programme × 1,000*

	Unreported
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
	Discrete reintroductions
130 etc.	*Discrete reintroductions and associated number of outbreaks or bovine deaths*

YEAR	COUNTRY / CROSS REFERENCE								
	TURKEY/CHAPTER 4.11.10			UNITED ARAB EMIRATES/CHAPTER 4.11.11			YEMEN/CHAPTER 4.11.12		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
Background notes	1970, entered Turkey from Iran during Near East Pandemic			Prior history of intermittent epidemics			After 1971, waves of outbreaks from an underlying endemic situation		
1960									
1961							Case level to 1980; outbreaks thereafter		
1962									
1963									
1964									
1965									
1966									
1967									
1968									
1969		19	2,484						
1970	NEAHI phase II	1	11,686						
1971		1	10,591					Disease widespread to March	...
1972			8,265						...
1973									20
1974	NEADEC						NEADEC		12
1975									2
1976								1,884 cases	257
1977								2,388 cases	245
1978	MINEADEP phase I			MINEADEP phase I			MINEADEP phase I	564 cases	122
1979								286	127
1980			8,817					24	28
1981			On border with the Islamic Republic of Iran					2,500 cases	159
1982	MINEADEP phase II						MINEADEP phase II	71	633
1983								99	167
1984								111	235
1985								128	199
1986					1			193	398
1987					1	11		179	739
1988					2	12		35	340
1989	MINEADEP phase III				1	12		232	422
1990						12	MINEADEP phase III + WAREC	35	246
1991		19	11,870	WAREC		12		68	397
1992			11,179		1	12		43	367
1993			10,635			13		45	357
1994		1	11,664			11		79	389
1995			14,457		1	9		23	367
1996		1	15,277			9			193
1997			8,082			9			37
1998			7,613			9			83
1999						8			120
2000						7			58

LEGEND

MINEADEP	*Middle and Near East Animal Production and Health Project implemented by FAO*
NEADEC	*United Nations Development Programme implemented Near East Animal Production and Health Centre*
NEAHI	United Nations Development Programme implemented Near East Animal Health Institute
WAREC	FAO implemented West Asia Rinderpest Eradication Campaign
FAO	Food and Agriculture Organization of the United Nations
10* etc.	*Vaccination by Veterinary Services, number × 1,000*
...**	*Vaccination by Veterinary Services, number × 1,000*
5,322*** etc.	*Vaccination under FAO WAREC programme × 1,000*

	Unreported
+	*Virus endemic: number of outbreaks in the year not recorded*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
	Discrete reintroductions
130 etc.	*Discrete reintroductions and associated number of outbreaks or bovine deaths*

CHAPTER 4.13

INTRODUCTION TO RINDERPEST ERADICATION ACROSS SOUTH ASIA

To follow the history of rinderpest eradication in the South Asia region it is probably best to commence in the post-1947 period, when India and Pakistan became separate nations. At this time endemic rinderpest was present in India, Nepal and Pakistan but not in Bangladesh (then called East Pakistan), Bhutan or Sri Lanka (then called Ceylon). After some initial epidemics, Pakistan quickly controlled rinderpest and then claimed to be rinderpest-free, a situation that was subsequently shown to be overly optimistic – capped by the realisation that the virus was endemic in Sindh province – a possible chronic source of the virus for countries to the west of Pakistan. In addition Pakistan's northern areas experienced a large virgin population epidemic in 1993–1994 (described in Chapter 2.6).

In the period between 1956 and 1985, and in the absence of any regional considerations, the Government of India decided to pioneer rinderpest eradication by the mass application of vaccination. Initially highly successful, this initiative eventually stalled just short of the mark and a rethink was required. By the time India's second eradication attempt got under way around 1990, international donors (and the relevant international authorities, the Food and Agriculture Organization of the United Nations [FAO] and World Organisation for Animal Health [OIE]) had begun to envisage global rinderpest eradication as an achievable objective. Good progress in Africa (Pan-African Rinderpest Campaign) and the Middle East (West Asia Rinderpest Eradication Campaign) contributed to this optimism and so, inevitably, a regional project for South Asia (South Asia Rinderpest Eradication Campaign) was proposed. However, this last project could not find donor support for international management and was substituted with bilateral programmes directed at strengthening Veterinary Services with the support of the European Union. Thus, the revitalising measures that contributed to rinderpest eradication and proof of eradication from Bhutan, India, Nepal and Pakistan were implemented at national level. Latterly the FAO Global Rinderpest Eradication Programme (Chapter 6.1) provided a forum for neighbourly exchanges. Bangladesh and Sri Lanka only really came into the picture when it became necessary for them (along with their neighbours) to end vaccination against rinderpest and (with Myanmar) accumulate clinical and serological evidence to provide an international demonstration that they were free from infection with the virus.

Chapters 4.13.1–4.13.9 provide accounts of the countries' varied experiences with rinderpest – either in epidemic form or in the form of a deeply entrenched endemicity. An overview of these contrasting experiences up to the point of ending vaccination is given in Chapter 4.14, but the data-gathering exercises to prove freedom from infection are described only in the individual chapters.

CHAPTER 4.13.1

SOUTH ASIA RINDERPEST ERADICATION CAMPAIGN AS A PART OF THE COORDINATED ACTIONS TOWARDS THE GLOBAL ERADICATION OF RINDERPEST

M. SASAKI

Former Food and Agriculture Organization of the United Nations (FAO) Regional Animal Production and Health Officer, FAO Regional Office, Bangkok, Thailand; and Former Livestock Development Specialist, Japan International Cooperation Agency (JICA), Tokyo, Japan

SUMMARY **It was expected that the South Asia Rinderpest Eradication Campaign (SAREC) would evolve in a similar way to the eradication campaigns in Africa (PARC) and West Asia (WAREC). Although the fully fledged regional coordination unit never materialised, because of the difficulty in finding financial resources from external donor agencies, the Food and Agriculture Organization of the United Nations (FAO) Animal Production and Health Commission for Asia and the Pacific (APHCA) played a key regional role in organising and coordinating rinderpest eradication activities in the countries in South Asia. The last recorded outbreak of rinderpest in the SAREC region was in 2000 in Pakistan. The last SAREC country to receive international recognition from the World Organisation for Animal Health as being 'free from infection' was Sri Lanka in the year 2011. Rinderpest eradication was successfully achieved through appropriate control measures applied to animals crossing international borders, active field surveillance and thorough seromonitoring, all of which were well coordinated both bilaterally and regionally.**

KEYWORDS **Animal movement – Animal Production and Health Commission for Asia and the Pacific – APHCA – International border – Regional coordination unit – Regional livestock commission in Asia and the Pacific – South Asia – SAREC – South Asia Rinderpest Eradication Campaign.**

THE SOUTH ASIA RINDERPEST ERADICATION CAMPAIGN

In 1992, FAO convened an expert consultation to propose a strategy for the global eradication of rinderpest (1). The consultation recommended launching the Global Rinderpest Eradication Programme (GREP) as a secretariat within FAO, providing advice and guidelines, rather than as a campaigning organisation becoming directly involved in control measures. Indeed, GREP would be executed through three regional eradication campaigns: the Pan-African Rinderpest Campaign (PARC; Chapter 4.2), the West Asia Rinderpest Eradication Campaign (WAREC; Chapter 4.10) and the South Asia Rinderpest Eradication Campaign (SAREC). In 1992, PARC had been operational for five years, WAREC for three years and SAREC was still under discussion. GREP started in 1994 (see Chapter 6.1).

SAREC was initially proposed in 1983, when the FAO organised an expert consultation in Izatnagar, India, on the requirements for a rinderpest eradication campaign in South Asia (2). It should be noted that at this expert consultation the representatives from Bangladesh, Bhutan, Nepal, Pakistan and Sri Lanka each indicated that their country had been free from rinderpest since 1983. Nevertheless, a time-bound (five-year long) action plan for regional eradication was recommended, including the creation of a coordinating group, set up by the FAO Animal Production and Health Commission for Asia and the Pacific (APHCA), and a regional coordinator.

Subsequently, in 1985–1986, FAO launched a study of the rinderpest disease control situation in Bangladesh, Bhutan, India, Nepal and Pakistan. In 1987, the results of this study were used to compile an FAO/UNDP (United Nations Development Programme) pipeline project 'Coordination of Rinderpest Eradication Campaign in South Asia' but no project ensued. In 1990, FAO hosted another expert consultation regarding what had now become known as SAREC (3). The FAO meeting envisaged Bangladesh, Bhutan, India, Myanmar, Nepal, Pakistan and Sri Lanka as being the constituent countries of SAREC, each with a national coordinating unit, with overall project coordination being based in New Delhi under the South Asian Association for Regional Cooperation (SAARC). The expert consultation recommended the reformulation of the 1987 FAO/UNDP proposal. By this time, however, the Government of India was reviewing the results of its second attempt to eradicate rinderpest (Operation Rinderpest Zero) and had forwarded a project proposal to the European Union for bilateral assistance to introduce technology for large-scale serosurveillance (see Chapter 4.13.5). In addition, both Bhutan and Nepal were concluding similar bilateral project agreements with the European Union aimed at strengthening Veterinary Services as well as eradicating rinderpest.

Intent upon launching SAREC despite previous failures, a third FAO expert consultation was held at the FAO Regional Office, Bangkok, from 1 to 4 September 1992 (4). By this time, India had developed a fresh strategy that would align rinderpest eradication activities with the World Organisation for Animal Health (OIE) Pathway and had embarked upon the third rinderpest eradication project (National Project on Rinderpest Eradication). In addition, it was becoming clear that little mass vaccination would be required to eliminate rinderpest from the South Asian region, although there would still need to be a considerable amount of disease and serological surveillance work to prove that eradication had been achieved. Pakistan did not attend this meeting.

Nevertheless, the conclusion and recommendations of this third consultation were as follows:

1. All member countries concerned with SAREC were urged to renew their full commitment to the eradication of rinderpest as the target under a time-bound and regionally coordinated campaign.
2. FAO was strongly urged to renew contact with possible potential donor agencies to seek financial and material support to establish the fully fledged Regional Coordination Centre, which was absolutely essential to coordinate all national-level eradication programmes and bring uniformity to the Campaign activities in the long term and coordinate the eradication programmes.
3. Bearing in mind that regional campaigns in another two regions, i.e. PARC in Africa and WAREC in the Near East, were already ongoing, the earliest implementation of the proposed SAREC activities was a must to proceed with the concomitant eradication campaign at the global level. Therefore, until a fully fledged unit was established with substantial financial support from external donor(s), a provisional unit was to be created at the FAO Regional Office, Bangkok, and initiate the coordination activities immediately and as much as possible.

The 1992 meeting was the final SAREC expert consultation. While the coordination centre never materialised, over the following decade, it became accepted that the countries of the SAREC region preferred to follow a different model without the involvement of a regional coordination unit but with an appropriate degree of coordination being provided by attendance at GREP expert consultations in Rome, also attended by APHCA.

While, the SAREC initiative did not fully succeed, it created a number of major benefits for the South Asia Region, including the following;

- capacity building in the field of animal quarantine and control along international borders;
- information exchange, particularly on animal movements across international borders;
- strengthening diagnostic facilities (at both central and local level);
- production of tissue culture rinderpest vaccine.

As for animal movement in this region, it is well known that, for economic reasons, a large number of ruminants move both legally and illegally from one country to another, e.g. cattle from India to Bangladesh and buffaloes from Nepal to India. During the SAREC period (1983–1993), considerable effort was made to facilitate such trade by establishing internationally acceptable animal

TABLE I
CHRONOLOGICALLY IMPORTANT STEPS TOWARDS RINDERPEST ERADICATION IN SAREC COUNTRIES

Country	Recorded last outbreaks	Last vaccination	OIE recognition: free from infection
Bangladesh	1958	1999	2009
Bhutan	1969		2005
India	1995 in North Arcot, Tamil Nadu district	2000	2005
Nepal	1990		2002
Pakistan	2000 in Sindh province	2000	2007
Sri Lanka	1987 in Eastern province	1997	2011

movement and quarantine measures on both a bilateral and a regional basis.

The last recorded rinderpest outbreak in the SAREC region was in 2000, at Memon Ghot township, Karachi district, Sindh province, Pakistan. The last countries to stop rinderpest vaccination were India and Pakistan in 2000. The last SAREC country that was recognised internationally by the OIE as 'free from infection' with rinderpest was Sri Lanka in the year 2011 (Table I).

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CHAPTER 4.13.2

AFGHANISTAN

A. OSMANI

Former Chief Veterinary Officer, General President, Animal Husbandry and Veterinary Services, Ministry of Agriculture, Animal Husbandry and Food, Kabul, Afghanistan

SUMMARY **The first outbreak reported was in Kabul province in 1942. Intermittent outbreaks occurred up until 1995. The outbreaks were eliminated through vaccination campaigns and other zoosanitary procedures, including animal movement control. The use of rinderpest vaccine ceased in 1997, with a view to using serosurveillance to detect possible residual infection. After 1997, no further clinical cases of rinderpest were detected. The 600 veterinary field units were directed to be vigilant in searching for clinical signs of rinderpest in cattle and buffaloes and to report any suspected cases to the veterinary authorities immediately. In 2005, the country declared itself provisionally free from rinderpest. Between 2005 and 2007, participatory disease surveillance was used to search for the presence/absence of the disease. Definitive national serological surveys were undertaken in 2006 and 2007, sampling 20 large ruminants per village in randomly selected villages. These visits generated 6,700 and 6,005 samples, respectively, none of which was positive. In 2008, a dossier including the surveillance data was accepted by the World Organisation for Animal Health (OIE) as proof that Afghanistan was free from rinderpest.**

KEYWORDS **Afghanistan – Outbreak – Participatory disease surveillance – PDS – Rinderpest – Vaccine.**

INTRODUCTION

The Islamic Republic of Afghanistan – a mountainous country in central Asia – shares its borders with Turkmenistan, Uzbekistan, Tajikistan, China, Pakistan and the Islamic Republic of Iran (Fig. 1). The Afghan Veterinary Department comes within the purview of the Ministry of Agriculture and Irrigation. Provincial Veterinary Services provide treatments and disease monitoring activities. Disease surveillance is undertaken by veterinary field units working with non-governmental organisations (NGOs) active in the veterinary field in Afghanistan. There are regional diagnostic laboratories and one central veterinary diagnostic and research laboratory. During the period leading up to the declaration of freedom from rinderpest, all laboratories were equipped to undertake the agar gel immunodiffusion test for rinderpest, while the central laboratory was able to perform the rinderpest differential immunocapture enzyme-linked immunosorbent assay (ic-ELISA; Chapter 3.3).

RINDERPEST HISTORY

The first report of the disease in Afghanistan was recorded in 1942 at a governmental farm in Ali Abad village of Kabul province. In 1944, the disease was observed in the northern provinces of Takhar, Kunduz and Baghlan, where it killed about 7,200 head of cattle. At the same time, rinderpest

FIG. 1

PROVINCES OF AFGHANISTAN (IN GREEN) SEARCHED BY PARTICIPATORY DISEASE SURVEILLANCE (PDS) FOR THE PRESENCE/ABSENCE OF RINDERPEST AND OTHER IMPORTANT DISEASES BETWEEN 2005 AND 2007

Source: United Nations, 2009 (1), modified to show the provinces in Pakistan searched by PDS in the period specified. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

outbreaks were observed in other areas, such as Kabul, Kandahar and Nangarhar. As a result of these outbreaks, the government decided to establish a modern animal vaccine production facility in the country. The first rinderpest vaccine produced in Afghanistan was in 1945. In 1946, about 1,945 cattle were vaccinated with this vaccine. In 1947, 12,684 animals were vaccinated in the southern province of Paktya.

In 1949, rinderpest entered the country from the Pakistani province of Baluchistan via the Afghan province of Farah, and then spread to Hirat and Kandahar. Production of the rinderpest vaccine was started in Hirat with the help of an ex-Soviet expert, and 11,840 animals were vaccinated that year. The Food and Agriculture Organization of the United Nations (FAO) started its activity in Afghanistan in 1950 and updated the production method of the rinderpest vaccine in Kabul (caprinised rinderpest vaccine). This vaccine was said to produce a two-year immunity. The laboratory in Hirat provided vaccine for the northern province of Farya and its adjoining areas, with 28,500 cattle being vaccinated in 1950. In 1951, rinderpest was witnessed in Hazarajat province and 18,000 cattle were vaccinated. Overall, between 1950 and 1951, about 93,000 head of cattle were vaccinated against rinderpest. In 1952, lyophilised vaccine was produced in this laboratory for the first time.

In 1970, outbreaks occurred in the western province of Farah bordering Iran, and similarly in Hirat province in 1976 and between 1981 and 1983. Rinderpest was recorded in the eastern provinces near to their borders with Pakistan, in Kapisa between 1960 and 1961, in Logar in 1973 and in the southern province of Hilmand in 1988. Outbreaks in the eastern provinces bordering Pakistan were often more virulent than outbreaks in the western provinces. Outbreaks were attributed to the importation of infected animals from neighbouring countries and were generally controlled by emergency vaccination.

The final outbreak of rinderpest in Afghanistan started in September 1995 in three villages in the Lacan district in Khost province, close to the eastern border with Pakistan (2). Clinical cases were confirmed by the examination of samples at the (Pakistan) National Agriculture Research Council's ELISA laboratory in Islamabad. The disease continued to occur in the province until 1997 but did not spread more widely. Its elimination was achieved through vaccination campaigns and other zoosanitary procedures, including animal movement control. In these activities, Afghanistan was supported by FAO, through its Technical Cooperation Programme, the United Nations Development Programme (UNDP) and several NGOs, with funding from other donors, including the United Kingdom's Department for International Development, the European Union, the Netherlands and Sweden. Following this outbreak, the active disease search system was strengthened so that it involved both public and private veterinarians and applied throughout the country. After 1997, no further clinical cases of rinderpest were detected. In addition, and with a view to using serosurveillance to detect possible residual infection, the use of rinderpest vaccine ceased in 1997.

CLINICAL AND SEROLOGICAL SURVEILLANCE

Clinical surveillance

In the years after 1995, the 600 veterinary field units were directed to be vigilant in their search for clinical signs of rinderpest in cattle and buffaloes and to report any suspected cases to the veterinary authorities immediately. By 2002 (five years after ceasing vaccination), no such report had been made, and in 2005 Dr Azizullah Osmani, General President of Animal Husbandry and Veterinary Services, Ministry of Agriculture, Animal Husbandry and Food, declared the country provisionally free from rinderpest (3).

Subsequently, participatory disease surveillance (PDS) was introduced. The PDS teams consisted of six veterinarians, split into two groups (three in each), who visited about 212 villages in 20 provinces. Rinderpest was not reported by farmers in any of these provinces (Fig. 1). Emphasis was given to Khost province, where rinderpest was last reported in 1995. PDS led to the conclusion that the rinderpest infection found in Khost in 1995 was the last rinderpest outbreak to occur in Afghanistan. In 2005, active surveillance provided strong evidence for the absence of rinderpest in the country. An active search was conducted in 20 northern and eastern provinces out of 34 provinces (security risks precluded the inspection of the other provinces). However, local veterinarians and NGOs were present in all provinces and had responsibility for informing and sending samples to the local veterinary department and to the laboratory in Kabul for confirmation of any notifiable disease, particularly suspected cases of rinderpest. At that time, there were about 600 veterinary field units located in all 398 districts in the country.

Serological surveillance

Using the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3), randomised serosurveillance exercises were conducted in 1998 and again in 2001. In the survey conducted in 1998, 11.8% of 951 unvaccinated cattle were seropositive (4). In the period 2000–2001, a more thorough survey of almost 20,000 cattle conducted under the auspices of the FAO Technical Cooperation Programme project TCP/AFG/0065 disclosed only 0.25% positive reactions. These findings confirmed the absence of rinderpest disease.

Definitive national surveys were undertaken in 2006 and 2007, sampling 20 large ruminants in randomly selected villages. Samples were only collected from animals with one, two or three pairs of permanent incisor teeth and therefore aged between two and six years old, with no possibility of having been vaccinated. In 2006, 335 villages from 67 districts of 27 provinces were visited, and in 2007 a further 340 villages from 66 districts of 28 provinces were visited. These visits generated 6,700 and 6,005 samples, respectively, none of which were positive for antibodies to rinderpest virus.

DOSSIER

In 2008, a dossier including the above surveillance data was accepted by the OIE as proof that Afghanistan was free from rinderpest (5).

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CHAPTER 4.13.3

BHUTAN

P. TSHERING

Head, Epidemiology Unit, National Centre for Animal Health, Department of Livestock, Ministry of Agriculture and Forests, Thimphu, Bhutan

SUMMARY **Bhutan experienced rinderpest outbreaks between 1948 and 1971 that affected almost the whole of the country. Vaccination had been practised to control the disease between 1970 and 1976 when the country had been threatened by an outbreak in the state of West Bengal in India. After ceasing the vaccination programme in 1986, Bhutan applied for the status of 'provisional freedom from rinderpest' in 1992. After conducting numerous clinical and serological surveys between 1995 and 1999, including the nationwide statistically designed two-stage random sampling in 1999 and 2000, Bhutan was conferred 'freedom from rinderpest disease' status in 2001 by the World Organisation for Animal Health (OIE). Annual clinical and serological surveys were performed, targeting the high-risk districts in the south, bordering India. Following the documented absence of clinical disease and circulating rinderpest antibodies in the samples tested over several years, Bhutan was conferred the status of 'freedom from rinderpest infection' in 2005.**

KEYWORDS **Antibodies – Bhutan – Clinical survey – Random sampling – Rinderpest – Surveillance.**

INTRODUCTION

The northern border between Bhutan and China is characterised by high snow-covered mountains that act as a natural barrier for both animal movement and trade. In contrast, Bhutan has a long open southern border with India and a long history of trade in animals and animal products. Rinderpest was first recorded in Bhutan in 1948. Irregular vaccination was practised along the southern border in the early 1960s but failed to prevent a second outbreak, which began in 1969 and continued until 1971. This outbreak affected Paro, Thimphu, Punakha, Trongsa, Haa, Gelephu (Sarpang), Trashigang and Mongar districts, killing over 4,000 animals. It was controlled by ring vaccination and mass vaccination in these vulnerable areas and by developing immune belts along the international borders (Fig. 1).

Goat tissue vaccine (GTV) was used on local cattle and tissue culture rinderpest vaccine (TCRV) was used on cross-bred cattle, yaks (*Bos grunniens*), mithuns (*Bos frontalis*) and mithun crosses. Regular vaccination was practised between 1970 and 1976, following an outbreak in West Bengal in India, which shares a common international border with Bhutan. An immune belt was created along the whole of the southern border. Vaccines came from the Indian Veterinary Research Institute and Bhartiya Agro-Industries Foundation (BAIF), an Indian non-governmental organisation. Vaccination ended in 1986. Based on the results of clinical surveillance confirming the continuing absence

FIG. 1

MAP OF BHUTAN SHOWING PARO, THIMPHU, PUNAKHA, TRONGSA, HAA, GELEPHU (SARPANG), TRASHIGANG AND MONGAR DISTRICTS INVOLVED IN RINDERPEST OUTBREAK BETWEEN 1968 AND 1971

Source: Nations Online Project, 2021 (1), modified to show areas of rinderpest outbreaks (in green)

of clinical rinderpest, in 1992 Bhutan registered a status of 'provisional freedom from rinderpest' with the World Organisation for Animal Health (OIE) (2).

SURVEILLANCE RESULTS

Between December 1995 and January 1996, 3,000 serum samples were collected from the southern region of the country. In 1998 and 1999, a serological survey was conducted for rinderpest using a two-stage stratified random sampling procedure. More than 6,200 samples were collected from bovines, tested and the results analysed. Whenever small ruminants were encountered in the sampled villages, samples were also collected from these species. Using the data from these surveys, Bhutan submitted an application to the OIE declaring itself 'free from rinderpest disease', a status that was

TABLE I

RESULTS OF THE SEROLOGICAL SURVEILLANCE OF BOVINES FROM VILLAGES OF THE EASTERN AND SOUTHERN REGIONS OF BHUTAN, BORDERING WITH THE INDIAN STATES OF ARUNACHAL PRADESH, ASSAM AND WEST BENGAL

Region	Dzongkhag (bordering states in India)	Number of villages sampled	Tested against rinderpest (number positive/number tested) [(a)]
Eastern	Samdrup Jongkhar (Assam)	20	0/240
	Trashigang (Assam and Arunachal)	14	0/444
	Lhuentse (Arunachal)	4	0/180
Southern	Samtse (West Bengal)	9	0/180
	Chuka (West Bengal)	3 [(b)]	0/172
	Sarpang (West Bengal)	17	0/122

[(a)] Samples were tested at the Royal Veterinary Epidemiology Centre, Bhutan, using the indirect enzyme-linked immunosorbent assay (ELISA) test

[(b)] Includes Phuntsholing slaughter house approved by the International Committee during the 69th General Session of the OIE in May 2001.

Bhutan applied for freedom from rinderpest infection status in 2004 based on the absence of clinical disease over the previous 33 years and the serological evidence indicating the absence of circulating rinderpest antibodies from the numerous surveys conducted from 1998 onwards (Table I) in the villages along the southern international border with India. Bhutan's freedom from rinderpest infection was accorded by the OIE in 2005 (3).

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CHAPTER 4.13.4

INDIA'S RINDERPEST CONTROL PROGRAMME BETWEEN 1947 AND 1984

P.K. UPPAL

Sector 17A, House No. 770, Gurgaon-122001, Haryana, India
(Former National FAO Expert on Rinderpest, Government of Punjab, Department of Animal Husbandry, Dairying and Fisheries)

SUMMARY **Between 1956 and 1985, India made a serious and concerted effort to eradicate rinderpest by immunising a large proportion of its bovine population with attenuated rinderpest vaccines. This required expansion of vaccine production across the nation and the introduction of a vaccination plan to be implemented by the state Veterinary Services, which was sponsored mostly by central government through its cycle of five-yearly national development plans. Although initially successful in significantly reducing the number of outbreaks, the programme eventually failed to eliminate the endemic virus in the states in the south of the country. A thorough investigation was undertaken towards the end of the campaign by the Government of India to establish why eradication remained elusive despite intensive activities for 35 years. This review developed parameters for a revitalised scheme, i.e. the National Project on Rinderpest Eradication (NPRE), which is described in this chapter and which eventually achieved the eradication.**

KEYWORDS **Goat tissue vaccine – GTV – India – National Rinderpest Eradication Programme – NREP – Operation Rinderpest Zero – ORZ – Regions – Rinderpest – Rinderpest Task Force – Tissue culture rinderpest vaccine – TCRV.**

INTRODUCTION

The livestock wealth of India is rich in terms of genetic diversity. It currently accounts for 15% of the world cattle population, 53% of the buffaloes, 20% of the goats and 4% of the sheep (1). In 1984, 74% of India's population lived in villages, where 73% of households owned livestock of one kind or the other. The rural population depends on livestock and their products both for nutrition and for income, and livestock is a major source of draught power for agricultural operations. The organic fertilisers produced by the sector is an important input into crop production. Beside this, cow/buffalo dung cakes have been used extensively as a fuel in rural areas. Livestock production in India is characterised by widely distributed small stock holdings, averaging two to ten cattle per household, except in the case of nomadic herds in Rajasthan and Gujarat. Besides this, there are some medium and large-scale dairies in villages as well as in peri-urban and urban areas. The population density of animals is high in villages compared with towns, and their health care is managed by Veterinary Services through mainly government veterinarians, stock men and pharmacists. Animals after their productive life are mostly sent to *gausalas* (animal shelters), where they are housed and some are left to stray. In India, by and large, there is no slaughtering of cows and it is one of the reasons that India adopted a socio-ethical means for the control of rinderpest, as described in this chapter, rather than stamping out the affected animals. Before the start of the national vaccination programme, the disease had a crippling effect on the national agriculture-based economy; thus, the eradication of rinderpest was considered of immense importance to improve the economy of livestock farmers. This chapter describes the efforts made by the Government of India over the period 1954–1984 to eradicate rinderpest through vaccination. A subsequent chapter will describe the international cooperation during the 1990s that expedited the successful eradication by the Government of India (Chapter 4.13.5).

THE HISTORY OF RINDERPEST CONTROL IN INDIA PRIOR TO THE FIRST NATIONAL VACCINATION PROGRAMME

Rinderpest control in India was initiated in 1868 with the constitution of the Indian Cattle Plague Commission by the Government of India (2). Subsequently, the Indian Civil Veterinary Department was established in 1891, and an initial report by the department revealed that rinderpest was endemic in every district of India. In 1893, the Imperial Bacteriological Laboratory (later the Indian Veterinary Research Institute [IVRI]) was established at Mukteshwar to undertake research on rinderpest, and in 1899 a rinderpest antiserum was developed, conferring passive immunity to the disease. In 1927, J.T. Edwards developed an attenuated strain of the virus by serial passaging in goats, which could be used as a live vaccine for protection of cattle (see Chapter 3.4).

When India attained independence in 1947, efforts to develop a realistic rinderpest control programme began. Edwards considered that the eradication of rinderpest in India was a practical possibility, if vaccination coverage was adequate within a time-bound period and traders' movement of cattle suspected of carrying rinderpest was controlled (3). A focused approach towards control and eradication of rinderpest was adopted in the early 1950s. The incidence of rinderpest prior to the 1950s was high in northern and western India. In March 1951, a scheme for the eradication of rinderpest was conceived by the Government of India following a meeting held at IVRI, Izatnagar, after the problem of rinderpest control in the country had been highlighted (4, 5). The scheme was to be known as the National Rinderpest Eradication Programme (NREP). It was resolved that the vaccine for the majority of animals would be the goat-adapted Mukteshwar strain, which conferred immunity for 14 years, but for highly susceptible cattle breeds lapinised rinderpest vaccine (Nakamura strain) could be used. It was proposed that a mass vaccination programme should be undertaken in two phases. In phase I, the aim was to vaccinate all cattle and buffaloes and, in phase II, vaccination of all sheep, goats and other species, as well as the progeny of cattle and buffaloes that would have been born in the meantime. This meeting envisaged the vaccination of the national large ruminant herd of some 320 million animals over a period of five to ten years during phase I.

A Central Rinderpest Eradication Committee (CREC) was formed under the chairmanship of the Vice President of the Indian Council of Agriculture Research (ICAR) and included the Animal Husbandry Commissioner, Government of India, New Delhi, the Director of IVRI, Food and Agriculture Organization of the United Nations (FAO) experts, some state directors, and the Animal Husbandry Commissioner of the state of Uttar Pradesh. The committee was responsible for planning, coordinating and monitoring the progress of the rinderpest disease control campaign.

India is composed of various states and union territories (UTs) as shown in Figure 1. Under the federal constitution, each state or union territory is responsible for internal management of animal health issues, based on the guidelines issued by the central government's Department of Animal Husbandry and Dairying. Because of their territorial uniqueness, union territories are controlled centrally by an administrator appointed by the President of India. The states were expected to have eradication committees mirroring that of the central one. In the early stage of the campaign (1954) for rinderpest control, the country organised itself into four regions: northern, eastern, southern and central (5) but left out several states in the south and east of the country, possibly because there was no rinderpest being reported from those states. These four regions were later realigned by CREC in 1979, as shown in Figure 1. The alignment of states in the four regions in 1979 was as follows: eastern comprises the states of Arunachal Pradesh, Assam, Bihar, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura and West Bengal; western comprises the Daman, Diu (UT) and the states of Goa, Gujarat, Maharashtra and Rajasthan; northern comprises Chandigarh (UT), Delhi (UT) and the states of Haryana, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Punjab and Uttar Pradesh; and southern comprises Pondicherry (UT) and the states of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu.

These regions were created mainly for the administrative functioning of the district authorities with respect to the movements of animals, holding of exhibitions and livestock trade fairs. The states in each region developed a common plan and decided to obtain freeze-dried vaccine from their regional vaccine-producing centres as well as from the IVRI.

FIG. 1

MAP OF INDIA SHOWING THE STATES AND UNION TERRITORIES, 1979–1980

Source: United Nations, 2011 (6), modified to show the state and union territory borders, and four regions of India. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

VACCINE MANUFACTURING IN INDIA

The first step for the control and eradication of rinderpest in India was taken when freeze-dried rinderpest vaccine became available for field use in 1936. Prior to that rinderpest antiserum produced in buffaloes was used mainly for bulls and cows of high value. Prior to independence in 1947, the IVRI, Mukteshwar, developed, produced and supplied limited quantities of wet rinderpest goat-adapted vaccine (viable for three months) and dry powder (viable for one year), both of which were subsequently replaced by freeze-dried vaccine. The first field use of vaccine was in Punjab during the period 1936–1940. In September 1951, FAO and the Government of India jointly signed an agreement for the improvement and large-scale production of freeze-dried rinderpest goat tissue vaccine and facilitated the supply and delivery of one large 48P freeze-dryer, three Edwards 3P freeze-drying machines and a large secondary dryer to IVRI, Izatnagar. Similarly, one freeze-dryer was made available at Lucknow Badshabagh Vaccine Institute under the provincial administration of Uttar Pradesh. By 1954–1956, Uppal and Seetharaman (7) had improved the technicalities of large-scale production of freeze-dried rinderpest vaccine and provided training programmes to various officials of the state vaccine production centres.

Vaccine production institutes were established in various states of India, namely Karnataka (1926), Tamil Nadu (1932), Uttar Pradesh (1945), Orissa (1946), Andhra Pradesh (1947), Maharashtra (1947), Bihar (1954), Rajasthan (1954), Assam (1956), Kerala (1959), Jammu and Kashmir (1963), Madhya Pradesh (1964), West Bengal (1965), Punjab (1973) and Gujarat (1975). These centres were strengthened to produce mainly rinderpest goat tissue vaccine (GTV), which was subsequently replaced by tissue culture rinderpest vaccine (TCRV). The production staff of all these institutes were trained at IVRI, initially in the production of GTV and later in the manufacture of TCRV. Whenever required, IVRI provided these institutes with seed virus for both vaccine production as well as virulent challenge virus for potency testing. A licence for manufacturing vaccine was given by the Drug Controller of India, and the quality of vaccines was monitored by IVRI, Izatnagar. All the batches of rinderpest vaccine referred by the state biological institutes to IVRI were tested for safety, viability and potency. Rinderpest batches not meeting the requirement laid down by the Indian Pharmacopoeia were rejected. A vaccinating dose for GTV was required to contain 40 cattle ID_{50} (median infectious dose) per millilitre and for TCRV, 300 $TCID_{50}$ (median tissue culture infectious dose) per millilitre. In the course of the NREP, 11 state veterinary biological production centres were producing GTV and 7 were producing TCRV. The target for vaccine doses to be produced each year was fixed by the federal government following a consultative process with the State Directors of Veterinary Services. During the period 1956–1961 (the period of the second five-year plan of the Government of India), the target for production was set at 100 million doses and for the period 1961–1966 (the third five-year plan) at 125 million doses.

The vaccines were used by about 34,000 veterinary hospitals, dispensaries and aid centres across the country, which were in the public sectors of various states and centrally governed union territories. Considering the need for better coverage of vaccine use among livestock, more emphasis was given to strengthening the state biological products institutes. A centrally sponsored scheme was specifically introduced during the Government of India's fifth five-year plan, which started in 1974, by providing these institutes with additional aid of 27.9 million Indian rupees (equivalent to US$0.93 million) in 1974. In 1985, the Ministry of Agriculture addressed the constraints on rinderpest vaccine production, specifically the availability of an adequate number of large freeze-dryers, a specialised workforce and provision for maintaining the cold chain. Each biological vaccine institute procured its own freeze-dryers, funds for which were provided by the Ministry of Agriculture. Training programmes on vaccine production, particularly freeze-drying methods, were conducted at the biological products division of IVRI, Izatnagar, and financed by the Ministry of Agriculture of the Government of India

IMPLEMENTATION OF THE NATIONAL RINDERPEST ERADICATION PROGRAMME, 1956–1984

Organisation of the campaign

By 1954, India had gained sufficient confidence in GTV and its Veterinary Services to embark on a publicly financed vaccine-based campaign for rinderpest eradication. The National Rinderpest Eradication Programme (NREP) started in 1956–1957, during the first year of the second five-year plan, with the objective of immunising at least 80% of adult cattle and buffaloes of the relevant state during an initial period of five to ten years. The rinderpest eradication programme was coordinated by the federal government. The Department of Animal Husbandry and Dairying (DAHD) formulated the projects and policy guidelines for implementation by the state Veterinary Services through public funds and support from the Government of India. At the beginning, targets were based on the production of rinderpest vaccine and its availability, which was decided by the federal government. Each state undertook its own vaccination programme. Periodic assessment of the disease situation of each state was done by CREC, which was constituted by the Government of India in the initial phase of the programme and advised the Government of India on all aspects of the rinderpest control programme.

All arms of the Veterinary Services were involved in the implementation of the NREP. Services were provided through a network of veterinary hospitals/dispensaries/polyclinics (27,562), veterinary aid centres and mobile dispensaries (25,195) and stockpeople. Approximately 250 disease diagnostic laboratories supported these activities.

The mass immunisation campaign was adopted almost throughout the country except in the majority of the eastern states of India and the three southern states of Karnataka, Kerala and Tamil Nadu, as they were free from rinderpest at that time. The mass vaccination programme in the country ran for about ten years from 1954 and remained in place until 1964. Around 1964, it became apparent that the virus was also present in the southern states of India, possibly introduced with sick animals from West Bengal state. In response, the mass vaccination programme was extended in 1964 to the states of Karnataka, Kerala and Tamil Nadu and continued until 1974.

To strengthen the mass vaccination campaign in India, a series of activities were commenced with the aim of wiping out the infection from the country. The follow-up programme included vaccination of pregnant animals, newborns and other susceptible populations that were not included earlier where goat-adapted vaccine was used. Vaccination of sheep, goats and other species planned in phase II did not materialise. To prevent the entry of the disease across the international land frontiers, immune belts of vaccinated cattle together with stations at border crossings for vaccinating migratory stock were created between 1966 and 1969. The follow-up programme entailed the vaccination coverage of one-fifth of the cattle population annually.

The National Commission on Agriculture in 1976 reviewed the progress of the NREP (8). Consequently, the Government of India launched additional programmes and replaced the CREC with four regional rinderpest committees: eastern, northern, western and southern, for the efficient implementation of the programmes (9). The programme that succeeded the mass vaccination programme was regarded as a model scheme for rinderpest containment vaccination (see letter no. 51-25/75-LDT (RP), dated 10 December 1976, of the Government of India) and was renamed in 1980 as the Implementation of Rinderpest Surveillance and Containment Vaccination Programme (see letter no. 51-6/79-LDT (RP), dated 30 January 1980). The main features of the programme involved active surveillance and a mandatory search for clinical rinderpest disease in each state/union territory. The field teams comprised one veterinary assistant surgeon, ten vaccinators, two attendants and a driver. In all, 423 government establishments of various capacities with defined functions and a command chain were in place for the rinderpest vaccination programme.

For the effective implementation and monitoring of the above programmes, the hierarchical structure generally followed was that the Director/Commissioner of State Veterinary Services controlled the districts through district veterinary officers under whom the above 'rinderpest officer' worked with the help of assistant rinderpest officers and a group of stockpeople to scout the villages.

The search and operation area included 40 villages to be covered by one stockperson and had to be completed within two months. He or she was required to visit weekly on village market day and to contact teachers and children in the village and other prominent people. Incentives were paid to informers for reporting disease that was later confirmed as rinderpest, based on laboratory confirmation, both in endemic or non-endemic areas. Clinical cases were destroyed and were followed by zoosanitary control measures aimed at limiting the distribution of virus. Carcasses were disposed of under strict supervision, and compensation was paid. Monthly progress reports of this programme were consolidated by the directors of the states/union territories and forwarded to the Government of India for central compilation by including reports from all the states and union territories. Performance reports were submitted before the financial year for the release of funds to each state.

In 1982, concern was expressed that rinderpest had not been eradicated from India despite the extensive efforts described above (10, 11, 12). As a result, increased funding was made available for surveillance and containment and for the purchase of equipment for the field diagnosis of rinderpest.

Dimension of the campaign

In the initial stages (1956–1957) of the eradication programme, the production capacity of the existing vaccine units was the limiting factor. Initially, a target of ten million doses was proposed, which was mainly supplied by IVRI (13) and could cover less than 20% of the cattle population. Subsequently, most of the states developed their own production capacity through which a coverage of 60–80% could be reached (Table I).

The progressive downwards trend reported in the number of outbreaks from the start of the eradication programme was disrupted for a brief period between 1964 and 1968 because of a surge in the number of outbreaks reported from the states of Andhra Pradesh (59), Bihar (101), Haryana (30), Gujarat (506) and the appearance of the disease in the southern states of Karnataka (33), Kerala (37) and Tamil Nadu (85). Nevertheless, the decade of the 1960s, by and large, marked a sharp decline in the number of rinderpest outbreaks reported from the country. The rate of decline was proportional to the increase in the number of animals vaccinated. The absolute number of affected animals came down from 5,938 in 1965–1966 to 2,834 in 1974, except in the year 1967, when about 10,833 animals were affected. During the first decade of the campaign (1954–1964), 184.60 million vaccinations had been undertaken, while in the following decade (1964–1974) a further 352.16 million vaccinations were carried out. Thus, in total, approximately 536.76 million vaccinations had been carried out over the 20 years, and yet the virus remained

TABLE I

VACCINATION COVERAGE VIS-À-VIS NUMBER OF RINDERPEST OUTBREAKS IN THE COUNTRY BETWEEN 1956 AND 1985 (14)

Total vaccine doses used: 1,106 million

National development plan period [(a)]	Duration	Number of doses used (in millions)	Number of outbreaks reported	States covered
Second five-year plan	1956–1961	100	4,368	Assam, Bihar, Orissa, West Bengal, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh, Jammu Kashmir, Madhya Pradesh, Punjab, Uttar Pradesh, Andhra Pradesh
Third five-year plan	1961–1966	120	791	Assam, Bihar, Orissa, West Bengal, Gujarat, Maharashtra, Rajasthan, Haryana, Himachal Pradesh, Jammu Kashmir, Madhya Pradesh, Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka [(b)], Kerala [(b)], Tamil Nadu [(b)]
Annual plan periods	1966–1969	89	774	Assam, Bihar, Orissa, West Bengal, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh, Jammu Kashmir, Madhya Pradesh, Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka, Kerala, Tamil Nadu
Fourth five-year plan	1969–1974	207	237	Assam, Bihar, Orissa, West Bengal, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh, Jammu Kashmir, Madhya Pradesh, Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka, Kerala, Tamil Nadu
Fifth five-year plan	1974–1979	268	124	Assam, Bihar, Orissa, West Bengal, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh, Jammu Kashmir, Madhya Pradesh, Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka, Kerala, Tamil Nadu
Annual plan period	1979–1980	55	120	Assam, Bihar, Orissa, West Bengal, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh, Jammu Kashmir, Madhya Pradesh, Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka, Kerala, Tamil Nadu
Sixth five-year plan	1980–1985	267	142	Assam, Bihar, Orissa, West Bengal, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh, Jammu Kashmir, Madhya Pradesh, Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka, Kerala, Tamil Nadu

[(a)] In 1950, the Planning Commission of India was established by the Government of India and assigned the task of framing centralised and integrated national economic developmental programmes. Most of these spanned a five-year period starting with the first five-year plan from 1951 to 1956, but at certain times annual plans were followed
[(b)] Vaccination started in 1963–1964

widespread even if no longer present in epidemic proportions.

The introduction of TCRV in 1966–1967 greatly strengthened the ongoing Government of India eradication programme. The earlier vaccines, GTV and lapinised vaccines, were gradually replaced with TCRV in most of the biological production centres in India, although there had been sporadic reports of the use of GTV in indigenous breeds of cattle in certain far-flung areas until the early 1990s. Freeze-drying and cold chain facilities were improved and there was a steady increase in the coverage of vaccinations in the 1980s. Data by state on the details of actual vaccination vis-à-vis targets, including bovine population, annual targets, actual vaccinations carried out and percentage and coverage of targets for the years 1981–1982, 1982–1983 and 1983–1984 are given in Table II.

During the year 1982/1983, more than 95% vaccination coverage was achieved in the states of Andhra Pradesh, Bihar, Gujarat, Haryana, Madhya Pradesh, Tamil Nadu, Uttar Pradesh, West Bengal, Maharashtra and the union territory of Delhi. In Jammu and Kashmir, Karnataka, Kerala, Mizoram, Rajasthan and Pondicherry, vaccination coverage was between 50% and 90%. In Assam, Arunachal Pradesh, Himachal Pradesh, Manipur, Meghalaya, Nagaland, Orissa, Punjab and Goa, it was less than 50%. The total vaccination during this period exceeded 50 million doses per year.

Impact of the campaign

Prior to its eradication, rinderpest had devastating effects on the livestock production of India. The Royal Commission on Agriculture (15) gave an account of deaths due to rinderpest between 1923 and 1927, when it was estimated that 182,000 cattle died of the disease. Deaths due to rinderpest were estimated during the period 1938–1939 to be 124,885, against an estimated bovine population of 148.837 million. The only control measure at that time was the serum–virus simultaneous method of immunisation, which had its own limitations. During the year 1956–1958, 25.93 million vaccinations were carried out using GTV, which increased to 53 million during the years 1958–1960, out of an estimated 215 million cattle and buffaloes. The results were encouraging, as the number of reported outbreaks declined dramatically from 8,156 before 1956–1957 to 1,960 in 1960–1961 and then declined further to 545 by 1964. The number of outbreaks finally fell to 93 by 1985, possibly because of the adoption and application of Plowright's TCRV in the field.

Although the link between the use of vaccine and a reduction in the number of reported outbreaks was rapidly established, there was, in fact, no detailed understanding of the level or distribution of the herd immunity achieved in different regions of the country. It was generally presumed that a herd immunity level of around 80% maintained over

TABLE II
DATA ON RINDERPEST VACCINATION BY STATE IN FOUR REGIONS VIS-À-VIS THE TARGETS FOR 1981–1984

Regions State/ union territory	Bovine population (× 100,000)	Annual target (× 100,000)	Actual vaccinations (× 100,000)			Percentage coverage of targets		
			1981–1982	1982–1983	1983–1984	1981–1982	1982–1983	1983–1984
Eastern								
Arunachal Pradesh	2	0.20	NA	0.50	NA	NA	25.0	NA
Assam	64	20.00	14.02	4.21	1.97	70.1	21.1	9.8
Bihar	194	40.00	42.53	38.44	14.85	106.3	96.1	37.1
Manipur	3	0.50	0.27	0.09	0.14	54.0	18.0	28.0
Meghalya	5	1.00	1.39	0.27	NA	139.0	27.0	NA
Mizoram	0.5	0.005	0.03	–0.03	60.0	60.0	60.0	–
Nagaland	1	0.50	NA	0.14	NA	NA	28.0	NA
Orissa	129	30.00	13.69	14.28	10.01	45.6	47.6	33.4
Sikkim	2	0.50	NA	NA	NA	NA	NA	NA
Tripura	5	0.50	NA	NA	0.59	NA	NA	118.0
West Bengal	130	30.00	24.04	30.22	15.32	80.1	100.7	51.1
Western								
Goa, Daman, Di	2	0.50	0.13	0.18	0.07	26.0	36.0	14.0
Gujarat	95	30.00	28.07	31.79	28.45	93.6	105.9	94.8
Maharashtra	180	40.00	40.21	49.14	53.45	100.5	122.9	133.6
Rajasthan	180	45.00	48.96	32.02	19.93	108.8	71.2	44.3
Northern								
Chndigarh	0.2	–	NA	0.02	NA	–	–	–
Delhi	2	1.00	1.55	1.47	0.92	155.0	147.0	92.0
Haryana	54	20.00	9.16	34.24	8.00	45.8	121.2	40.0
Himachal Pradesh	27	5.00	1.15	0.17	1.18	23.0	3.4	23.6
Jammu and Kashmir	26	5.00	2.71	2.34	3.77	54.2	46.8	75.4
Madhya Pradesh	321	95.00	105.48	104.97	71.94	111.0	110.5	75.7
Punjab	77	15.00	6.28	5.92	3.49	41.9	39.5	23.3
Uttar Pradesh	386	65.00	70.01	67.00	8.44	107.7	103.1	13.0
Southern								
Pondicherry	1	0.25	0.33	0.22	0.43	132.0	88.0	172.0
Andhra Pradesh	192	70.00	48.58	84.72	69.26	69.4	121.0	98.9
Karnataka	131	25.00	21.64	12.77	22.79	86.6	51.1	91.2
Kerala	32	10.00	6.10	6.67	7.52	61.0	66.7	75.2
Tamil Nadu	135	50.00	67.54	57.30	43.82	135.1	114.6	87.6
Grand total	**2,377**	**600.00**	**551.8**	**579.12**	**386.34**	**92.00**	**96.5**	**64.4**

NA, information not available; – vaccination not undertaken.

several years would serve as a basis for eradication, but it was also realised that achieving such a level could take as long as eight years. Nevertheless, continued application of vaccination, in some cases at greatly increased levels (e. g. in Madhya Pradesh and Uttar Pradesh), should certainly have maintained high immunity and should have been able to achieve eradication. Unfortunately, vaccine coverage was always based on target figures achieved without any feedback in terms of actual measured immunity level among the vaccinated population of livestock.

Mindful of the possible role of traders in spreading disease (see Chapter 2.8), vaccination zones were created 15–20 km on either side of interstate borders, and cattle movement routes across interstate borders were monitored. Vaccination was mandatory for all cattle transported by rail as well as at cattle fairs and markets. Vaccinated animals were identified by branding, and appropriate records were maintained.

In the initial stages, the mass vaccination campaigns did not address the field operational problems of cold chain maintenance and unauthorised movement of animals. There was also little education of the livestock owners who, on occasion, resisted vaccination and branding of their animals. As soon as the above operational problems were addressed, the inadequacy of the epidemiological information, specifically on the efficacy of vaccination and its correlation with the occurrence of rinderpest, became apparent. Post-vaccination seromonitoring and serosurveillance were hampered by the lack of any sampling strategy and the limitations imposed by the laborious serum neutralisation test. Application of the enzyme-linked immunosorbent assay (ELISA) in the later stages of the campaign made the task of post-vaccination seromonitoring and serosurveillance much simpler and more accurate, as discussed in the next chapter (Chapter 4.13.5).

GENESIS OF THE TASK FORCE AND ITS REPORT

After the submission of a country report on the surveillance and control of rinderpest (1981–1982), the Government of India realised the inadequacies of the sustained mass vaccination campaign that had been followed up to that point. It had to be admitted that at the conclusion of nearly 30 years of mass and follow-up vaccination (in the course of which approximately a billion doses of rinderpest vaccine had been administered), rinderpest had not been eradicated from India. In 1983, the Government of India commissioned a rinderpest task force, which called for the inception of a new revitalised national campaign known as Operation Rinderpest Zero (ORZ) with the following terms of reference:

- to assess the availability of manpower and technical resources available at state and union territory level;
- to make detailed recommendations for the eradication of rinderpest across India within a scheduled time frame.

The task force delivered its report and pointed out that sound strategies were in place, especially based on village searches for rinderpest followed by securing the outbreak site with a mix of sanitary prophylaxis, e.g. ring vaccination, isolation of sick animals, segregation of in-contact animals, disinfection and provision for feed and fodder. It also stated that coordinated mass vaccination undoubtedly suppressed the disease considerably and even cleared large areas of rinderpest, but it did not prevent periodic resurgences in an epidemic form or eliminate reservoirs of infection. Invariably, the origin of rinderpest in a new focus of infection was linked to an introduction from an established outbreak. It was proposed by the task force that if spillage of infection from an outbreak could be prevented, there would be no further spread of infection.

The task force noted that eight states had remained rinderpest free from 1980 to 1983. No particular epidemiological reasons could be given to explain outbreak patterns in the states where the disease was still occurring. In principle, it was accepted by the task force that prolonged mass vaccination could reduce the number of outbreaks but could not eradicate the disease altogether. Therefore, the task force recommended the launching of a new eradication programme based on a return to mass vaccination for a period of three consecutive years. However, it was decided that this would apply only to those states in which the virus was heavily endemic. These were identified as Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Orissa and Tamil Nadu. While every district of Andhra Pradesh and Karnataka was to be included, in the remaining states only those districts with a history of persistent outbreaks were included. It was expected that within the target population, a 90% prevalence of herd immunity would be achieved. In the remaining states, surveillance and containment (by vaccination) was to be applied.

In their review the task force team recommended the acquisition of a new vehicle fleet with which to implement the programme and the addition of a programme control unit within the Ministry of Agriculture of the Government of India, attached to the office of the Animal Husbandry Commissioner. It was also recommended that there should be a dialogue with the neighbouring countries through FAO and the Animal Production and Health Commission for Asia (APHCA).

At that point, the first of India's eradication programmes effectively ended. It can be said that the NREP of India provided the impetus for FAO to take the initiative to hold an expert consultative meeting at IVRI, Izatnagar, in December 1983, with the underlying idea of launching a regional rinderpest eradication programme. This meeting was attended by six countries of South Asia (16) that saw the need for the establishment of a regional South Asia Rinderpest Eradication Campaign (SAREC).

Recognising the importance of eradicating rinderpest, in 1990 the Government of India, with support from FAO, the World Organisation for Animal Health (OIE), the International Atomic Energy Agency and the European Union conceived a timely, multipronged approach and a results-oriented national programme known as the National Project on Rinderpest Eradication (NPRE), The next chapter describes the implementation of the NPRE and the role of international partners in successfully eradicating rinderpest by following the OIE Pathway, within FAO's late 20th century Global Rinderpest Eradication Programme (GREP), while the South Asia timeline (Chapter 4.14) provides outbreak and vaccination figures for the entire period.

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CHAPTER 4.13.5

INDIA

M.P. YADAV [(1)]* & W. TAYLOR [(2)]

(1) H. No 365, Sector-45, Gurugram-122003 Haryana, India (Former Director, Indian Veterinary Research Institute, Izatnagar, India).
(2) 16 Mill Road, Angmering, West Sussex BN16 4HT, United Kingdom (Former EU-Technical Assistant, National Project for Rinderpest Eradication).

*Corresponding author

SUMMARY **The mass vaccination campaign running from 1956 to 1984 has been described in the previous chapter. Its efforts were closely scrutinised by a Task Force on Rinderpest, which reviewed the epidemiology of the virus and the mechanics of its persistence and made a series of recommendations. A fresh campaign was introduced, to be known as Operation Rinderpest Zero (ORZ). Its operations were to be time bound in as much as it would be financed only from 1984 to 1990. ORZ was highly successful and brought an end to endemic rinderpest across all but a small group of states located in the south of the country.**

Even as ORZ was drawing to a close, the international institutions – the World Organisation for Animal Health (OIE) and the Food and Agriculture Organization of the United Nations (FAO) – were attempting to develop the Global Rinderpest Eradication Programme (GREP), not only to reduce the rinderpest incidence rate to zero but also to introduce an elaborate series of clinical and serological checks (the OIE Pathway) in order to verify that eradication had been achieved. In India, this was accomplished through the introduction of the National Project for Rinderpest Eradication (NPRE) (1990–2000) as a partnership between the Government of India, the state Veterinary Services and the European Union.

States where rinderpest had ceased to be endemic were put under pressure to end vaccination and institute surveillance and be declared provisionally free from rinderpest. The small number of states where the virus still occurred were encouraged to maintain a high level of vaccination and eliminate the virus; this they duly did. High levels of clinical surveillance sufficed to have India pronounced free from rinderpest disease, but it required an equally high level of serosurveillance using enzyme-linked immunosorbent assay (ELISA) technology to have the country pronounced free from infection – in 2006.

KEYWORDS **Disease-free zones – ELISA Training and Data Management Centre – ETDMC – European Union – Infection free 2006 – National Project for Rinderpest Eradication – NPRE – OIE Pathway – Operation Rinderpest Zero – ORZ – India.**

INTRODUCTION

During the journey of about a century for the containment, control and eradication of rinderpest in India, the country passed through several ups and downs in understanding the epidemiology, pathology, pathogenesis and immune response of the disease and in the development of improved vaccines, sensitive and specific diagnostic tests, and effective strategies for preventive immunisation of large and small ruminant species. These research and development efforts in the development and standardisation of vaccines and diagnostics, either developed indigenously or obtained from outside, could be divided into appropriate time frames, action plans and methods of implementation over a period of 100 years. A fully fledged national mass vaccination programme was launched by the Government of India (GoI) in 1955–1956; its progress through to 1984 (when it ended) has been described in Chapter 4.13.4. At its conclusion, the incidence level of rinderpest across the country had been greatly reduced, but it seemed that no amount of mass vaccination could achieve a zero incidence level – at which point the GoI proposed a major review of the programme and recommendations for further action. The review body – the Task Force – foresaw the need for more vaccination but in a more focused manner linked to an understanding of the 'pockets' in which the virus was persisting. This was to be accomplished (and to a great extent was) during the period from 1984 to 1990 under the banner 'Operation Rinderpest Zero'. By 1990 the OIE had introduced the OIE Pathway, which bound a member country such as India to accept that freedom from rinderpest, when attained, had to be proved. The proof would be the continuing absence of clinical disease and the continuing absence of serological evidence of its occurrence. As far as India was concerned, this was expected to involve the introduction of new technology. To that end the GoI introduced a new programme, the National Programme for Rinderpest Eradication. In this undertaking India was partnered by the European Union and introduced ELISA technology, not available in India at the time, to allow the country to proceed along the OIE Pathway. The progress of this final programme is described in this chapter.

TASK FORCE ON RINDERPEST

In March 1983, to consider why rinderpest remained in India in spite of the fact that over one billion vaccinations had been carried out, the Ministry of Agriculture, GoI, constituted the Task Force on Rinderpest, headed by Dr C.M. Singh, the newly retired Director of the Indian Veterinary Research Institute (IVRI), to review the 27-year-long control programme in hand, with the objectives:

(i) to assess the existing resources in the technical workforce and infrastructure available within various states and union territories;
(ii) to recommend a detailed action plan for the eradication of rinderpest from the country within a time-bound schedule (1).

The Task Force reviewed the then concluding National Rinderpest Eradication Programme (NREP) and its impact on the incidence of the disease in various parts of the country and held consultations with the departments/organisations concerned.

Subsequent to the launch of mass vaccination in 1956 and follow-up vaccination in 1969, by the mid-1970s the incidence of the disease had been reduced from a level of 1,960 cases per million head of the bovine population to a level of around 11 or 12, reflecting an overall fall in the national outbreak incidence rate. At the same time the number of cases and deaths per outbreak remained broadly similar, suggesting that the virus was being maintained in groups of similarly susceptible animals and was uninfluenced by the increasing amounts of vaccine being administered across the country. Furthermore, statistics for the decade prior to the constitution of the Task Force indicated that there had been little improvement in reducing the national incidence level (2), although, in fact, a number of states had actually managed to attain a high degree of freedom from the disease.

In attempting to rationalise the inability of the NREP to move from a situation in which a high degree of control had been achieved to one of eradication, the Task Force analysis looked at the various components of the mass vaccination and follow-up work undertaken by the various State Veterinary Services over the preceding 25 years.

Most tellingly, they found a lack of simultaneous mass vaccination among all states coupled with under-resourcing, which meant that the campaign was too prolonged and either failed or took too long to achieve the 80% vaccination level considered necessary to eliminate endemicity. As a result, there were always pockets of susceptible livestock within which the virus could survive. Other issues included the limitations imposed by goat vaccine, which was not suitable for pregnant stock or exotic breeds and their crosses. There were also under-resourcing problems during the follow-up period, during which the 20% annual additions to the population should have been immunised, but the workforce resources assigned to different vaccination tasks were inadequate.

In identifying specific issues, the Task Force observed that the programme had failed to eradicate the disease because of a lack of cohesiveness between the various parties involved in the follow-up processes. It observed that in some places the vaccination work claimed to have been undertaken had not. An allied factor was the abandonment of animal marking (cold branding), which (in the absence of seromonitoring) was the only means of assessing the vaccination status of the animals. It was also critical for the teams responsible for the detection and elimination of the outbreaks and to ensure the absence of secondary outbreaks. Apart from ring vaccination and movement control, their report was critical too of the failure to isolate sick animals and in-contact animals, despite the availability of subsidies to compensate for the sequestration (or destruction) of sick animals.

An earlier study of the pattern of outbreaks had suggested that, while the disease had been substantially controlled in the interior parts of various states, outbreaks were still occurring along the interstate borders. This was in spite of an earlier introduction of special 'vigilance units' required to develop immune zones up to a distance of 15–20 km on either side of the interstate borders. Similarly, 'check posts' and 'vaccination stations' had been established on important cattle movement routes across interstate borders to ensure that only rinderpest-free and vaccinated and branded animals were allowed to enter the state (the Task Force also presumed that movement of animals for trade or migratory purposes might have been responsible for the low-level persistence of the disease). The active disease surveillance foreseen in the sixth five-year plan period (1980–1985) had not been happening. The report considered that 'seepage' from outbreaks was the biggest reason for the perpetuation of rinderpest. While discussing all scientific aspects and the epidemiology of rinderpest, the Task Force also pointed out a poor record with regard to forward- and backtracing of the outbreaks – effectively the lack of zoosanitary discipline.

The Task Force in its report submitted in December 1983, recommended the GoI to refocus its efforts and eradicate the disease within a limited period through the revitalised programme to be known as Operation Rinderpest Zero, or ORZ, to be implemented within the seventh five-year plan period (i.e. 1985–1990), incorporating the various combinations of surveillance and vaccination that it recommended into a strategy designed to bring the incidence of rinderpest to zero within three years – i.e. within a 'time-bound' programme. Regarding vaccination, the Task Force recommended that the state biological production units switch from goat tissue vaccine (GTV) to tissue culture rinderpest vaccine (TCRV) to ensure that all species, breeds and other categories of animals, including pregnant animals, could be covered with the same vaccine during vaccine campaigns.

The epidemiological analysis of rinderpest prevalence conducted by the Task Force in 1983 indicated that the disease was widely endemic in six states, partially endemic in seven states, only present by importation in a further four states and absent from eight states. This led to the introduction of one of its most radical recommendations – that the states could be given a 'risk' status that was based on outbreak incidence levels and could be provided with variable action plans from the programme that they would subsequently propose (see below).

OPERATION RINDERPEST ZERO 1985–1990

To be successful, the strategies introduced under ORZ placed a heavy emphasis on active disease surveillance and appropriate vaccination.

High-risk states

In the heavily endemic states (known as high-risk states) of Andhra Pradesh, Karnataka and Tamil Nadu, vaccination took place across the entire population, but in Gujarat, Maharashtra and Orissa it was limited to areas of known endemicity (districts with persistent outbreaks) and was coupled with surveillance across the remainder of the state, with vaccination wherever infection was found. It was envisaged that as a result of three years of vaccination work, some 90% of the bovine population should have been covered.

In Andhra Pradesh, Karnataka and Tamil Nadu, six years of vaccination failed to reduce the incidence level of outbreaks. Conversely, in Maharashtra, Orissa and Gujarat, where vaccination was undertaken only in restricted areas, the programme brought the incidence level to zero.

Medium-risk states

In the weakly endemic states (designated as medium risk) of Assam, Bihar, Haryana, Kerala, Madhya Pradesh, Rajasthan and West Bengal, the entire state was surveyed and vaccination was invoked only where the disease was found. With the exception of Kerala, the outcome in each instance was a reduction to zero outbreaks.

Low-risk states

In the low-risk states of Arunachal Pradesh, Meghalaya and Punjab, surveillance sufficed. As far as Arunachal Pradesh and Meghalaya were concerned, neither state undertook vaccination or reported rinderpest during ORZ, whereas Punjab retained a good level of vaccination and only reported rinderpest once during the ORZ period.

Rinderpest-free states

The group of states deemed rinderpest-free maintained a buffer zone along international borders and undertook surveillance. In this group, Jammu and Kashmir vaccinated throughout the ORZ period, experienced a single outbreak of rinderpest in each of 1984 and 1985 but remained rinderpest-free for the remaining period of ORZ. Nagaland experienced an outbreak in 1988, but the other states in the north and north-east of the country, i.e. Himachal Pradesh, Manipur, Mizoram and Tripura, remained rinderpest-free.

To a very large degree, ORZ accomplished what it set out to do and, at its conclusion, endemic rinderpest had been effectively confined to the three southern states of Andhra Pradesh, Karnataka and Tamil Nadu. As trade of cattle from Tamil Nadu was responsible for the continuing reintroduction of the disease to Kerala, that state would continue to be infected until Tamil Nadu was cleared. The estimated cost of ORZ was 120 million Indian rupees (INR) (equivalent to US$3 million).

THE INTRODUCTION OF INTERNATIONAL COOPERATION IN RINDERPEST ERADICATION IN INDIA

While the Task Force was deliberating the way ahead in India, FAO convened an international meeting in December 1983 in India at IVRI, Izatnagar, to discuss rinderpest eradication across the South Asian region. The meeting recommended a time-bound, unified, coordinated regional action programme (3), referred to as the South Asian Rinderpest Eradication Campaign (SAREC). The FAO organised the 'Expert Consultation on Global Strategy for Control and Eradication of Rinderpest' in Rome in February 1987 to discuss practical plans and strategies for the global eradication of rinderpest (4). The South Asian countries were urged to launch SAREC as soon as possible to coordinate the global campaign with African and Middle Eastern countries, but ultimately FAO was unable to mobilise donor finance and SAREC never materialised (see Chapter 4.13.1). Nevertheless, countries of the region were urged to participate in what was rapidly becoming a global drive to eradicate rinderpest (GREP, Chapter 6.1) and, if necessary, to organise external support on a bilateral basis.

In 1988 the GoI was invited to submit a proposal to the European Union requesting financial assistance for the control of livestock diseases. The document submitted sought finance for the eradication of rinderpest and contagious bovine pleuropneumonia (CBPP) and the control of foot-and-mouth disease (FMD). In 1989 a revised proposal, omitting FMD, was accepted as the basis of a memorandum of understanding between the GoI and the European Union for the provision of additional finance and technical assistance to achieve these objectives under a fresh initiative, namely the National Project on Rinderpest Eradication (NPRE), which, appreciative of the results of ORZ, was given a similar short-term (six-year) framework within which to succeed, beginning in January 1990. At the time, no evidence of CBPP could be found and this component was never funded under NPRE (later surveillance conducted in Assam by the Department of Animal Husbandry, Dairying and Fisheries of the GoI led to a successful submission of freedom from CBPP to the 75th General Session of the OIE in 2007).

DEFINING THE NATIONAL PROJECT FOR RINDERPEST ERADICATION

In 1990, the GoI, in bilateral collaboration with the European Union, launched project ALA/89/04 on 'strengthening of Veterinary Services for livestock disease control in India'. The overall objective of the project was to strengthen Veterinary Services. A total budget of INR3,860 million (approximately US$220 million at the prevailing conversion rate in 1990) was made available for this project, including the EU share of INR2,610 million (40.30 million European Currency Units) from May 1992 to July 1998 and the GoI share of INR1,250 million (approximately US$72 million) (2) during the 8th, 9th, 10th and 11th five-year plan periods (1992–2012).

The GoI was aware that rinderpest was still present in India but to a considerably reduced extent and that further intensive vaccination would be needed in southern India. It was also aware that should it succeed in eliminating rinderpest entirely and, should it then wish to trade in livestock as a rinderpest-free country, India had to fulfil the surveillance guidelines of the OIE Pathway (see Box 1), and that initiating these required a formal declaration of provisional freedom. For the next six years, the NPRE strategy sought to move India to that point.

The first action of NPRE was an attempt to study the epidemiology of the virus across the country to understand how an accommodation could be reached within the demands of the OIE Pathway, namely sound disease surveillance and reporting, reaching a point where two years had elapsed since the last report of the disease, ending vaccination and declaring provisional freedom.

This resulted in an appreciation of the fact that ORZ had enjoyed considerable success and that there was now a large number of states that either fulfilled or came close to fulfilling the conditions for being declared provisionally free, while a third group of states still faced further intensive vaccination. However, to encourage countries to become engaged, the OIE Pathway provided for regions of a country to be nominated as zones and to commence the OIE Pathway process at different times. In 1990 the NPRE decided that this opportunity suited India well and in May 1992 submitted its first work plan and budget, proposing four zones.

Between 1990 and 1992 NPRE reviewed the post-ORZ rinderpest situation across the country. It found that the contiguous states of the north-east of the country (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura) appeared to have been free from endemic rinderpest for at least a decade. Only Nagaland had experienced a recent outbreak, and this had been due to the introduction of infection into the state. It was therefore proposed that this group of states might comprise zone A (Fig. 1). Vaccination was still being undertaken along the international border with Myanmar, and so the zone was not immediately eligible to declare provisional freedom.

In north-central India the so-called Indo-Gangetic states (Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Orissa, Punjab, Rajasthan, Uttar Pradesh and West Bengal) also fitted a zonal profile regarding both geographic contiguity and rinderpest situation. Although three of the states, Gujarat, Maharashtra and Orissa, had been given a high-risk categorisation by the Task Force, by 1990 vaccination during the ORZ period had eliminated the disease. The same was the case with the remaining states, these having been deemed at medium risk by the Task Force. In 1992 NPRE was ready to designate this group of states as zone B (Fig. 1). Moving forward, the main issue would be to end vaccination in order to qualify the zone as provisionally rinderpest-free.

Appendix 1 traces the number of outbreaks and the vaccination figures reported by the different states over the entire period during which rinderpest eradication schemes were in progress (1956–1998), concluding with their declaration(s) of provisional freedom. Although it is configured in terms of the zones under consideration for the NPRE, an analysis of its data was particularly helpful in determining that ORZ had all but eliminated endemic rinderpest from zone B states but had not eliminated it from southern India. Accordingly, Andhra Pradesh, Karnataka, Kerala and Tamil Nadu had to be classed in the third zone (zone C, see Fig. 1) on the basis of both geography and rinderpest situation; a further period of mass vaccination was anticipated under NPRE for this zone.

BOX 1
THE OIE PATHWAY

In 1989, OIE announced that it would require and evaluate evidence put forth by a member country requiring international recognition of having eradicated rinderpest (see OIE Pathway, Chapter 7.1). It proposed a series of steps for taking a country (or a discrete part of a country) from a point where the disease no longer appeared to a point of proven freedom from the disease/infection. The essence of the OIE Pathway approach was that countries were expected to use vaccine to eliminate clinical rinderpest, then to end vaccination, then to verify, both clinically and serologically, that the virus had been eliminated from the national herd.

For the sake of completeness, the off-shore islands were designated as a fourth zone (zone D) even though they had never been infected nor conducted vaccination against rinderpest.

With these issues in mind, the NPRE submitted its first work plan and budget in May 1992, proposing four zones and the immediate objectives to be accomplished. From then onwards, annual work plans and budgets were drafted, outlining the financial commitment of the three partners, namely the GoI, the European Union and the state Veterinary Services (SVS), to strengthen the infrastructure needed to demonstrate eradication following the OIE Pathway. These included vaccine quality and production capability across nine state biological production units; vaccine transport, storage and administration; and improved clinical and serosurveillance capability, backed by diagnostic capability. In addition, a project management unit was established with responsibility for devising strategies, launching budgets and work plans, directing the surveillance routines, and monitoring the outcome of the cessation of vaccination or the intensification of vaccination in specific endemic states. The financial commitment of the European Union to NPRE ended on 15 September 1997, and thereafter NPRE continued the above activities with support from the GoI and the SVS until freedom from and eradication of the disease were achieved.

ORGANISATIONAL STRUCTURE IN SUPPORT OF THE NATIONAL PROJECT FOR RINDERPEST ERADICATION

The development and subsequent implementation of the strategy described above required the identification of a project management unit that

FIG. 1

MAP OF INDIA SHOWING THE OUTLINES AND COMPONENT STATES OF ZONES A, B, C AND D DURING NPRE

Source: United Nations, 2011 (5), modified to show India's state and union territory borders and, courtesy of data provided by Professor P.K. Uppal, to indicate NPRE zones. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

was responsible to a project steering committee, firstly for proposing a strategy, secondly for identifying the various elements required to implement it, thirdly – in conjunction with the SVS – for devising annual work plans and budgets to bring it to fruition, and finally for monitoring progress and capturing the data required for dossier development. The partners in this endeavour were the EU Department of External Affairs, represented locally by the EU Delegation; the Department of Animal Husbandry and Dairying (DAH&D) of the GoI; the Departments of Animal Husbandry of the states and union territories; the Indian Council of Agricultural Research and several research institutes, including the IVRI, Izatnagar; the Project Directorate on Animal Disease Monitoring and Surveillance, Bangalore; the Indian Institute of Science, Bangalore; and the Tamil Nadu Veterinary and Animal Science University, Chennai.

PROGRESSING TO PROVISIONAL FREEDOM FROM DISEASE

Although it took about four years of work plans and budgets for the NPRE to begin to reduce vaccination and implement surveillance procedures, the historic decision taken by Shri K. Rajan in October 1995, as the Secretary to the Department of Animal Husbandry and Dairying, GoI, in declaring zones A, B and D 'provisionally free from rinderpest' (6), confirmed the advantage of a zoning policy (i.e. enrolling the whole country into the OIE Pathway but permitting those zones that were not vaccinating to commence surveillance work while vaccination was being pursued in other zones).

The history within each of the zones preceding this declaration

Zone A

Although an outbreak had occurred in Nagaland in 1988 that had originated from interstate trade, otherwise the zone had been without an endemic focus for the previous decade. The vaccination that had been practised within the zone until 1994, aimed at preventing the entry of rinderpest from Myanmar, had ended. This had been facilitated by an Animal Production and Health Commission for Asia and the Pacific (APHCA) meeting in New Delhi in 1993, during which the delegate from Myanmar indicated that his country was not rinderpest infected. This information had been accepted by the Department of Animal Husbandry and Dairying, so that from 1 April 1994 a 'no-vaccination' policy had been adopted throughout zone A, allowing it to qualify for a declaration of 'provisionally free from rinderpest'.

Zone B

In 1992, the respective states ended follow-up vaccination, making the zone eligible to enter the OIE Pathway. To that end they adopted an interim vaccination programme aimed at vaccinating on either side of district boundaries and along international borders, thereby creating an increasingly susceptible indicator population within the respective states. Endemic rinderpest did not emerge as a consequence and, in June 1994, in order to facilitate a declaration of provisional freedom, they agreed to suspend all further vaccinations except those along international borders. In the four years between 1990 and 1995, the only outbreak in zone B had occurred in Orissa, and, following ring vaccination, there had been no secondary outbreak.

Zone C

Maharastra had initially been placed in zone B, but, for a time, the state had been placed in zone C because of outbreaks between 1991 and 1993 and the need for further vaccination to bring the incidence to zero, but in 1996 it was reallocated to zone B, along with Goa (7).

Zone D

Rinderpest had never been recorded nor had vaccination been used in this zone, and its status remained the same until India had eradicated rinderpest.

The status of zone C at the time when zones A, B and D were declared provisionally free from rinderpest

In 1995, because rinderpest was still being reported, this zone was far from being able to declare provisional freedom. However, having failed to eliminate rinderpest under ORZ, but continuing to vaccinate heavily throughout the NPRE period, the incidence level eventually reached zero in 1996.

In 1998, the zone C states ended vaccination and declared provisional freedom from rinderpest, bringing each of the zones to the same status (8).

PROGRESSING TO FREEDOM FROM DISEASE

To declare freedom from disease, each state in each zone needed to remain free from rinderpest (and vaccination) for a minimum of three years following the declaration of provisional freedom. At the same time there needed to be extensive surveillance to substantiate the absence of the disease.

Clinical surveillance and disease reporting

India does not have a federal Veterinary Service. The SVS act as implementing agencies in fulfilment of their own as well as centrally determined objectives, supported by state/centrally allocated funds. The SVS are represented throughout each state and provide a public service to the livestock farmers through their veterinary hospitals and polyclinics; veterinary dispensaries, including mobile ones; veterinary aid centres; and rinderpest units.

During the period in question the number of veterinary institutions across the country with a disease reporting responsibility was around 57,344, including 7,462 veterinary hospitals/polyclinics, 17,251 veterinary dispensaries and mobile dispensaries, 32,160 veterinary aid centres, and 417 institutions created for the rinderpest surveillance and control programme (2). On a national basis, each disease reporting unit on average had 2.28 veterinary personnel and covered about 11 villages with an average population of 3,465 bovines and 1,910 sheep and goats (2). These disease reporting units effectively covered the entire country.

The 417 institutions created specifically for rinderpest control included 227 check posts sited at interstate borders; 32 immune belt teams; 34 vaccination stations with a mandate to vaccinate along the international borders with China, Bhutan, Nepal, Bangladesh, Myanmar and Pakistan; and 124 'vigilance units, which conducted clinical surveillance of rinderpest and other infectious diseases.

The active surveillance programme undertaken in pursuance of the declaration of freedom from disease was based on village searches, stock route searches and institutional searches. All categories of search results were channelled through the state rinderpest officer to the NPRE office in New Delhi on a monthly basis.

Village searches were made by the state veterinary/animal husbandry departments, which undertook a physical search for rinderpest-like disease in every village. Trained paraveterinary staff enquired about the occurrence of any disease resembling rinderpest during their regular village visits within the administrative jurisdiction of the local veterinary hospital. The report/records of paraveterinary staff were endorsed by the prominent person/authority of the village. The submitted report was examined by higher officials for scrutiny. Each village in the country was searched at least once. Institutional searches were undertaken by the senior veterinary officers, who examined the outpatient registers/day books in veterinary hospitals and dispensaries to find out if there were any cases showing at least two symptoms of rinderpest, and collected and dispatched clinical specimens for laboratory examination. Each such institution was visited six times on average without detecting any signs of rinderpest.

Stock route searches were conducted in the areas having livestock movement for trade and migration in search of grazing, sale, etc. This work was the responsibility of the staff of the check posts, which had been exclusively established for rinderpest surveillance activity along the interstate borders. Each village on both sides of a stock route was visited seven times on average.

Other requirements, such as disease reporting, differential diagnosis from peste des petits ruminants (PPR) and other clinically similar diseases, legal support for animal disease reporting, and quarantine regulations for border control for infectious diseases, were also undertaken and completed successfully.

The entire programme was accomplished under the direct supervision of a state-level rinderpest officer, who had total responsibility for all rinderpest-related activity in the state. This activity was institutionalised with the appropriate pro forma and schedule of reporting to be submitted to the NPRE headquarters as well as to the Animal Health Wing of the Department of Animal Health and Dairying of the GoI in Delhi.

During the years 1995–2001, 1,514,048 village searches were carried out. Given that there were only 579,688 villages, it follows that each village was visited at least twice. In addition, 179,026 villages on stock routes were searched, each being visited at least seven times. Finally, all of the 49,801 veterinary institutions were visited at least six times. None of these searches revealed the presence of rinderpest (2). Furthermore, a total of 5,818 clinical samples collected from bovines, sheep and goats were tested for rinderpest and PPR by competitive ELISA developed at the morbillivirus laboratory of IVRI, Mukteswar (Fig. 2). All the samples were found to be negative for rinderpest. PPR was detected in a few samples from small ruminants.

The states of zone A declared disease freedom in 1998, three years after provisional freedom. In zone B the situation was complicated by the

FIG. 2
THE INDIAN VETERINARY RESEARCH INSTITUTE (IVRI)

The Mukteswar building housing the rinderpest laboratory where goat tissue vaccine was developed in the 1930s by J.T. Edwards and a competitive ELISA test by Singh et al. in 2000 (9)

Courtesy of the authors

maintenance of an immune belt in Jammu and Kashmir, Punjab and Rajasthan, which was finally ended in 2000. Whereas other states in zone B had declared themselves disease-free in 2001, Punjab could not reach the same point until 2002 and Rajasthan and Jammu and Kashmir until 2003.

In zone C, freedom from disease was declared in 2001.

The OIE recognised the whole of India as disease-free in 2004 after evaluation of the information presented to the Specialist Commission (10).

BOX 2
PD-ADMAS AND INDIA'S ELISA TEST

An internationally validated ELISA test for the detection of antibodies to rinderpest virus was not available in India at the start of the NPRE Programme. Nor was there a programme in place for the collection and testing of large numbers of serum samples from unvaccinated animals. Responsibility for creating a network consisting of 33 state laboratories equipped and trained in undertaking the rinderpest competitive ELISA test (see Chapter 3.3) was devolved to PD-ADMAS, Bangalore, through the establishment of the ELISA Training and Data Management Centre.
A monoclonal antibody-based c-ELISA kit for the detection of antibodies to rinderpest virus in cattle, buffalo, sheep and goat sera samples was developed at IVRI, Mukteswar (Fig. 2), by Singh et al. (9). This kit, suitable for serosurveillance and seromonitoring of antibodies specific to rinderpest virus, was validated by the World Reference Laboratory on Rinderpest, Institute for Animal Health, Pirbright, United Kingdom, and approved by the OIE for use in rinderpest serosurveillance in India and neighbouring countries.

PROGRESSING TO FREEDOM FROM INFECTION

Introduction

Moving from freedom from disease to freedom from infection required the successful completion of a serosurveillance programme across the four zones, using an internationally standardised ELISA test. India adopted surveillance for rinderpest as per the OIE *Terrestrial Animal Health Code*, using an annual sample size sufficient to provide 95% probability of detecting rinderpest at a prevalence of 5% within the herds of the village, and 1% infection between villages for three successive years; no village could be visited more than once (2).

A statistical sampling design was developed at the Project Directorate on Animal Disease Monitoring and Surveillance (PD-ADMAS), Bangalore (Box 2), by preparing a consolidated registry of all 641,169 villages in the country, specially designed to classify the villages at taluka, district and state levels. Its validity of correctness was confirmed by the authorities of respective state animal husbandry and Veterinary Services departments. Village-related livestock databases were included in the registry to make it more useful to develop national sampling frames not only for rinderpest but also for other diseases. The ELISA Training and Data Management Centre (ETDMC) used the prevalence analysis programme available in the survey toolbox software developed by Dr Angus Cameron of the Australian Centre for International Agricultural Research for working out the number of villages to be sampled per stratum. The number of animals to be sampled per village was worked out from a statistical table provided by Dr Andrew James of the Department of Epidemiology, University of Reading, United Kingdom of Great Britain and Northern Ireland (11).

An innovative random sampling design covering wide areas and involving large numbers of villages, districts and states of the country was used for three consecutive time periods (termed phases). In each village samples were to be collected from 15 each of cattle and buffaloes, although the 50/50 ratio could be adjusted according to stock availability within the fixed total. Eligible animals were those above one year of age and born after the cessation of vaccination. The same rules applied to sheep and goats.

The ETDMC coordinated the plan for the collection of samples at village level. More than 166,000 serum samples were screened under the ETDMC ELISA laboratory network. The state laboratories tested all the samples collected by them and sent one set of samples to the ETDMC laboratory at Bangalore, which counter-checked and tested at least 10% of the samples drawn from 10% of the villages, on its own or in partnership with the IVRI morbillivirus laboratory at Mukteswar.

Whenever positive reactors were detected, subsequent samples were collected from the same animal(s) for assessment of seroconversion/persistence of antibodies against rinderpest virus. If these animals were not available at the time of the second sampling because they had been slaughtered or for any other reason, more samples from other animals, preferably from the same species and from the same village/place, were included for testing.

The NPRE provided the SVS with mobility support vehicles for serum collection, including funding for mobile laboratories and essential equipment.

SAMPLING PLAN, TESTING AND RESULTS

For serosurveillance sampling, the states were allocated to one of the three strata in line with the Task Force designation of zones during 1983 as low risk, medium risk and high risk, based on the incidence of rinderpest (number of outbreaks), with the objective of examining the remotest possibility that rinderpest virus infection might be lurking somewhere in the country:

- Stratum I comprised 22 low-risk and zero-risk states/union territories (as per the classification of the Task Force in 1983) in the north, north-east and eastern parts of the country, namely Arunachal Pradesh, Assam, Manipur, Mizoram, Meghalaya, Nagaland, Tripura, Jammu and Kashmir, Chandigarh, Delhi, Haryana, Himachal Pradesh, Punjab, West Bengal, Orissa, Sikkim, Goa, Daman and Diu, Dadra and Nagar Haveli, Pondicherry, Andaman and Nicobar, and Laskhadweep.
- Stratum II comprised seven high-risk states in western and southern India, namely Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka and Kerala.
- Stratum III comprised six medium-risk states of central India and north-west and northern parts of the country, namely Uttar Pradesh, Uttaranchal, Bihar, Jharkhand, Madhya Pradesh and Chhatisgarh.

Each stratum was subjected to three rounds of serosurveillance designated as phases 1, 2 and 3 (Tables I, II and III). The number of villages to be sampled had been calculated to provide a 95% probability of detecting a 1% prevalence of rinderpest between herds (villages) and a 5% prevalence within the herds (village), provided all eligible animals in a village (or at least 60) were sampled. Using the national sampling frame of villages throughout the country, the ETDMC randomly selected the villages where serosurveillance had to be undertaken.

Results obtained during phase 1: 1 November 2001 to 31 October 2002

The sampling frame had identified 1,162 villages to be visited, out of which 1,159 villages were actually sampled. Samples were obtained from 23,581 cattle; 11,562 buffaloes; 4,110 sheep; and 17,919 goats. By stratum, the results are shown in Table I.

In stratum I, among the positive samples from Arunachal Pradesh were ten cattle, four goats and one mithun (a semi-domesticated gayal) – sampled in lieu of buffaloes. The sampled animals were not available for rebleeding, but further samples from cattle, goats and mithuns from the same villages all tested negative. Only 2/2,338 samples from Assam were deemed false positives. In Orissa, 2/5514 samples were positive, one each from a sheep and a goat. They also tested negative when retested in the ETDMC laboratory.

In stratum II, of the total 19,747 samples tested, all tested negative except three from Rajasthan (one each of cattle, buffalo and goat) that were deemed false positives.

In stratum III, of the total 18,343 samples tested, all tested negative except one sample from Uttaranchal that was deemed a false positive.

In as much as the sampling locations and sample sizes were in keeping with the limits set for detecting rinderpest, phase 1 sampling had failed to detect the continuing presence of rinderpest.

Results obtained during phase 2: 1 November 2002 to 31 October 2003

The results are given in Table II.

TABLE I
DETECTION OF ANIMALS POSITIVE FOR ANTIBODIES TO RINDERPEST VIRUS IN DIFFERENT STRATA DURING PHASE 1

Stratum	No. of samples collected	State laboratory results	ETDMC cross-checked results	States with positive samples
I	19,082	17,861 tests; 4 positives	7,597 tests; 15 positives	Arunachal Assam; Orissa
II	19,747	19,559 tests; 3 positives	4,825 tests; 0 positives	Rajasthan
III	18,343	16,842 tests; 1 positive	3,351 tests; 0 positives	Uttaranchal

ETDMC, ELISA Training and Data Management Centre

Backtracing in Arunachal Pradesh failed to find rinderpest; the 64 positive samples from Punjab were found to have come from animals vaccinated as part of the border immune belt. A follow-up took 36 samples from known unvaccinated animals in the same location; all tested negative. A single positive sample from Assam was deemed a false positive.

Results obtained during phase 3: 1 November 2003 to 31 October 2004

The results are given in Table III.

Stratum I. Samples from two cattle from Himachal Pradesh, four cattle from Assam and one goat from Goa were deemed false positives. There were three positive samples from Arunachal Pradesh where backtracing was instituted with negative results.

Stratum II. From Maharashtra samples from three cattle, one buffalo and one goat were positive. From Rajasthan samples from one sheep and two goats were positive. Backtracing provided negative results. Positive samples from Karnataka were deemed false positives.

Stratum III. Backtracing in Madhya Pradesh did not yield evidence of rinderpest.

Additional *ad hoc* results

In the 1970s rinderpest was present in the Bandhavgargh game sanctuary in Madhya Pradesh, and in 1982 rinderpest was observed in the Kaziranga game sanctuary in Assam (2). Otherwise India had seldom reported the disease in wildlife during the previous 50 years. However, as suggested in the OIE recommended standards for epidemiological surveillance for rinderpest (11), sampling domestic stock in areas adjacent to large game populations could enhance the possibility of detecting the virus in wildlife. To that end some 13,609 samples were collected from villages in the proximity of wildlife reserves. A total of 10,777 samples were tested by state laboratories, with one positive result, while 4,224 were tested at the ETDMC, with 13 positive results. All positive samples were rationalised as false, suggesting an absence of hidden reservoirs of rinderpest in the wildlife population. Except for two sera from deer, no sera were examined from other wildlife species.

As pigs had occasionally been reported as contracting rinderpest in the southern states, specific surveillance of this species was undertaken in Andhra Pradesh, Karnataka and Tamil Nadu. In total 158 pigs sampled from the villages having the disease in the past were tested, with negative results.

TABLE II

SEROSURVEILLANCE RESULTS IN DIFFERENT STRATUM DURING PHASE II

Stratum	No. of samples collected	State laboratory results	ETDMC cross-checked results	States with positive samples
I	19,862	18,446 tests; 2 positives by IVRI; 65 by state laboratories	6,858 tests; 0 positives	Arunachal; Pradesh; Punjab; Assam
II	20,238	20,238 tests; 0 positives	3,861 tests; 0 positives	
III	18,572	16,977 tests; 0 positives	4,089 tests; 0 positives	

ETDMC, ELISA Training and Data Management Centre

TABLE III

SEROSURVEILLANCE RESULTS IN DIFFERENT STRATUM DURING PHASE III

Stratum	No. of samples collected	State laboratory results	ETDMC cross-checked results	States with positive samples
I	19,553	18,064 tests; 3 positives	6,380 tests; 7 positives	Arunachal Pradesh; Assam; Goa; Himachal Pradesh
II	21,125	20,965 tests; 0 positives	3,980 tests; 15 positives	Rajasthan; Maharashtra; Karnataka
III	18,994	17,497 tests; 0 positive	3,808 tests; 2 positives	Madhya Pradesh

ETDMC, ELISA Training and Data Management Centre

TABLE IV

SERUM SAMPLES TESTED FOR RINDERPEST FROM DIFFERENT SPECIES OF ANIMALS

Particulars	Cattle plus yak	Buffalo plus mithun	Sheep	Goat plus deer
Samples tested	80,956 (including some yaks)	36,594 (including 129 mithuns)	13,093	58,482 (including 2 deer)

Conclusion

For serum samples, the required numbers were 34,860 for each of the four domestic livestock species (total 139,440), whereas 189,125 were actually collected (Table IV). A shortfall in the number of sheep samples was compensated for by increasing the number of goat samples. Across the three years of serosurveillance, the required number of villages to be visited was 2,324, whereas the number of villages actually visited was 3,488, with a distribution across the entire country.

Thus, under serosurveillance in phases 1, 2 and 3 a total of 189,283 serum samples from bovines, sheep, goats, pigs, mithuns and other species were tested for rinderpest infection, with negative results.

In 2005 the serological and clinical results were incorporated into a dossier claiming that India had fulfilled the statistical criteria for demonstrating the absence of clinical reports of rinderpest for the past decade and serological reports across each of three years and was free from rinderpest infection (2). This claim was accepted by the OIE in 2006 (12), a milestone reflecting the sustained efforts of stakeholders for more than 50 years. In celebration, a memorial pillar was erected in Mukteswar (Fig. 3).

FIG. 3
RINDERPEST ERADICATION MEMORIAL PILLAR ESTABLISHED AT MUKTESWAR IN FRONT OF THE BUILDING HOUSING THE RINDERPEST LABORATORY
Courtesy of the authors

POSTSCRIPT

National Project for Rinderpest Eradication as a pioneer

By the time India's third eradication programme got under way around 1990, international donors and the relevant international authorities (FAO and OIE) had begun to envisage global rinderpest eradication as an achievable event. Consequently, the successful measures to strengthen the Veterinary Services that contributed to the successful eradication of rinderpest from India under NPRE were internationally recognised as a pioneering example of adherence to the OIE Pathway and the adoption of a zoning policy that reflected the epidemiology of the disease.

Emergency preparedness

As a sequel to the eradication, India established the National Animal Disease Emergency Committee and the National Emergency Task Force to tackle any situation arising as a result of the re-emergence of rinderpest or the occurrence of any other exotic disease. The surveillance infrastructure available/created during the NPRE period to achieve rinderpest eradication has been maintained and is used for surveillance of rinderpest and other diseases. The project is now named the National Project on Rinderpest Surveillance and Monitoring.

Benefits of rinderpest eradication

Major benefits to India from the eradication of rinderpest have been in the form of enhanced food and nutritional security and livelihood security of landless, small and marginal livestock farmers, who keep about 70% of the total livestock population of the country. Milk production increased by 2.99 times from 1955 to 1995, while export of meat and other livestock products increased by 17.99 times from 1959 to 1995 (13).

The initiatives that led to the control and eradication of rinderpest provided a strong platform and much needed push for India to become the 'number one country' in milk production in the world, which has been the case since 1998, and also for enhancing the export potential of livestock and livestock products. The impact of rinderpest eradication on the value of milk and on beef and buffalo meat in India has been substantial. The value of milk increased 83 times and the value of beef increased 126 times from 1950/51 to 1995/96 (13). Considering the figures from 2006 onwards, when India totally gained freedom from rinderpest, as notified to the OIE, the value of milk alone amounts to about US$15,563.56 million and beef and buffalo meat about US$435.11 million. There has been and buffalo meat over a 100-fold increase in income from milk and a 164-fold increase from buffalo meat (13). A detailed economic impact analysis of the global eradication of rinderpest, including a case study of India showing the losses India would have incurred by 2030 had it not been eradicated from the country, has been provided in the Chapter 6.4.

The expenditure incurred by rinderpest research in India, related to the development of diagnostic tests/kits, vaccine research/production, surveillance and monitoring of the disease, personal emoluments and the establishment/working of laboratories, has been calculated to be approximately US$1063.46 million over a period of about 90 years between 1913 and 2005 (14). Similarly, the overall investment incurred by the rinderpest vaccination campaign in India has been estimated at US$33,357 million from 1955 to 1993 (13). Thus, considering the overall expenditure of about US$34,420 million, savings on recurring vaccination costs are sizeable and would be written in golden letters in the history of Indian veterinary science research and development as an unparalleled achievement. These gigantic efforts towards the eradication of rinderpest involving over 480 million susceptible livestock populations (2) in a vast country like India, particularly without adopting a stamping out policy, are creditable and exemplary.

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APPENDIX 1

A summary of the reduction of rinderpest outbreak levels to zero across all the states of India, brought about by the three mass vaccination campaigns, NREP, ORZ and NPRE.

INDIA									
Eradication Programme	Operational period	ZONE - A / STATE							
		ARUNACHAL		ASSAM		MANIPUR		MEGHALAYA	
		Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination
NREP	1956-1960	0		74	3,811	0		0	
NREP	1961-1965	0		0	2,996	0		0	
NREP	1966-1968	0		83	3,093	0		0	
NREP	1969-1973	0		67	5,238	0		0	
NREP	1974-1979	0		0	6,257	0		0	
NREP	1980-1984	3	179	8	6,764	0		0	
ORZ	1985	0		0	1	0	1	0	
ORZ	1986	0		0	1,533	0	20	0	
ORZ	1987	0		0	1,045	0		0	
ORZ	1988	0		0	488	0		0	
ORZ	1989	0		0	20	0		0	
ORZ/NPRE	1990	0	30	0		0	41	0	126
NPRE	1991	0	33	0		0	20	0	189
NPRE	1992	0	52	0		0	62	0	34
NPRE	1993	0	54	0		0		0	11
NPRE	1994	0		0		0	2	0	
NPRE	1995								
NPRE	1996								
NPRE	1997								
NPRE	1998								

INDIA							
Eradication Programme	Operational period	ZONE - A / STATE					
		MIZORAM		NAGALAND		TRIPURA	
		Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination
NREP	1956-1960	0		0		0	
NREP	1961-1965	0		0		0	
NREP	1966-1968	0		0		0	
NREP	1969-1973	0		0		0	
NREP	1974-1979	0		0		0	
NREP	1980-1984	3		2	88	0	
ORZ	1985	0		0	...	0	...
ORZ	1986	0		0	...	0	
ORZ	1987	0		0	...	0	
ORZ	1988	0		26	...	0	
ORZ	1989	0		0	...	0	
ORZ/NPRE	1990	0	7	0	19	0	
NPRE	1991	0	2	0	11	0	
NPRE	1992	0	5	0	13	0	
NPRE	1993	0	7	0	9	0	
NPRE	1994	0	4	0	7	0	
NPRE	1995						
NPRE	1996						
NPRE	1997						
NPRE	1998						

LEGEND			
(green)	*Number of rinderpest outbreaks reported*	(grey)	*Vaccination along international border*
Vaccination	*All figures are x 1,000*	...	*Vaccination ongoing but amount unreported*
(red)	Intensive vaccination under ORZ		
(yellow)	*Ring vaccination around outbreaks under ORZ*	(blue)	*OIE status: year of self declared provisonal freedom*

INDIA									
Eradication Programme	Operational period	ZONE B / STATE							
		BIHAR & JHARKHAND		GUJARAT		HARYANA		HIMACHAL PRADESH	
		Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination
NREP	1956-1960		14,256			0		0	576
NREP	1961-1965	138	8,096	138	3,926	0		0	152
NREP	1966-1968	184	11,786	184	4,114	38	2,295	0	88
NREP	1969-1973	15	12,852	15	10,577	79	9,383	0	698
NREP	1974-1979	27	14,026	27	7,611	0	10,751	0	1,993
NREP	1980-1984	11	18,200	11	18,576	4	10,883	0	2,466
ORZ	1985	3	2,859	3	3,384	3	912	0	
ORZ	1986	13	4,283	13	3,352	11	1,125	0	27
ORZ	1987	2	3,444	2	4,857	0	853	0	
ORZ	1988	0	5,320	0	4,290	0	1,267	1	
ORZ	1989	0	2,962	0	5,250	0	300	0	
ORZ/NPRE	1990	0	4,262	0	5,390	0	...	0	
NPRE	1991	0	2,552	0	2,785	0	...	0	
NPRE	1992	0	...	0	2,395	0	...	0	
NPRE	1993	0	2,203	0	2,556	0	...	0	
NPRE	1994	0	105	0	...	0	1,252	0	
NPRE	1995	0	1,813	0	...	0	203	0	
NPRE	1996								
NPRE	1997								
NPRE	1998								

INDIA									
Eradication Programme	Operational period	ZONE B / STATE							
		JAMMU & KASHMIR		MADHYA PRADESH		MAHARASHTRA		ORISSA & CHHATTISGARH	
		Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination
NREP	1956-1960	0	1,186	3,672	6,435	3,786	10,419	511	5,123
NREP	1961-1965	0	1,825	1,136	17,583	411	7,109	857	9,067
NREP	1966-1968	0	771	281	9,866	89	4,151	107	4,766
NREP	1969-1973	0	1,478	201	32,224	78	12,535	103	7,575
NREP	1974-1979	0	1,732	80	49,652	148	19,670	81	18,145
NREP	1980-1984	1	2,635	10	65,176	28	29,790	55	6,472
ORZ	1985	1	420	3	713	9	5,497	6	...
ORZ	1986	0	...	6	4,135	62	6,652	7	1,221
ORZ	1987	0	1,552	1	...	6	6,902	19	1,147
ORZ	1988	0	293	0	2,778	19	6,861	12	824
ORZ	1989	0	...	0	...	0	7,200	3	741
ORZ/NPRE	1990	0	432	0	13,480	0	5,694	0	779
NPRE	1991	0	464	0	13,675	1	5,230	0	1,133
NPRE	1992	0	588	0	12,245	2	7,738	0	1,770
NPRE	1993	0	197	0	111,099	1	...	1	1,416
NPRE	1994	0	25	0	2,658	0	5,099	0	1,071
NPRE	1995	0	250	0	646	0	1,548	0	114
NPRE	1996								
NPRE	1997								
NPRE	1998								

LEGEND			
(green)	*Number of rinderpest outbreaks reported*	(grey)	*Vaccination along international border*
Vaccination	*All figures are x 1,000*	...	*Vaccination ongoing but amount unreported*
(red)	*Intensive vaccination under ORZ*		
(yellow)	*Ring vaccination around outbreaks under ORZ*	(blue)	*OIE status: year of self declared provisonal freedom*

INDIA									
		ZONE B / STATE							
Eradication Programme	Operational period	PUNJAB		RAJASTHAN		UTTAR PRADESH & UTTARAKHAND		WEST BENGAL	
		Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination
NREP	1956-1960	551	7,645	322	2,859	4,791	15,795	1,485	10,423
NREP	1961-1965	0	8,153	306	11,361	112	24,017	37	7,006
NREP	1966-1968	0	2,652	172	5,825	36	13,204	44	6,623
NREP	1969-1973	3	4,771	33	14,993	33	39,951	29	8,740
NREP	1974-1979	1	4,744	5	17,550	9	25,845	23	11,403
NREP	1980-1984	0	5,293	8	23,300	6	40,552	21	14,104
ORZ	1985	1	1,295	2	2,665	3	...	7	2,154
ORZ	1986	0	756	0	2,665	2	3,702	11	2,145
ORZ	1987	0	1,607	0	1,286	2	6,361	6	1,973
ORZ	1988	0	503	0	373	2	4,245	1	2,196
ORZ	1989	0	45	0	...	0	...	0	1,562
ORZ/NPRE	1990	0	1,168	0	3,386	0	...	0	1,842
NPRE	1991	0	1,141	0	2,883	0	...	0	285
NPRE	1992	0	1,665	0	2,061	0	...	0	1,827
NPRE	1993	0	2,063	0	1,553	0	...	0	2,325
NPRE	1994	0	692	0	731	0	1,404	0	1,507
NPRE	1995	0	...	0	256	0	494	0	
NPRE	1996								
NPRE	1997								
NPRE	1998								

INDIA									
		ZONE C / STATE							
Eradication Programme	Operational period	ANDHRA PRADESH		GOA		KARNATAKA		TAMIL NADU	
		Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination	Outbreaks	Vaccination
NREP	1956-1960	226	20,235			0	2,672	0	466
NREP	1961-1965	116	12,641			61	162	227	5,364
NREP	1966-1968	153	7,009			5	2,733	293	7,153
NREP	1969-1973	203	15,645			179	10,408	75	12,776
NREP	1974-1979	147	34,938			116	11,442	41	26,409
NREP	1980-1984	106	4,658			54	2,164	5	6,717
ORZ	1985	19	8,388			19	3,792	15	5,253
ORZ	1986	38	9,628			49	5,524	7	3,346
ORZ	1987	33	10,685			62	6,137	4	4,539
ORZ	1988	8	10,200			96	4,052	15	5,254
ORZ	1989	8	8,624	1		40	2,866	83	4,955
ORZ/NPRE	1990	23	9,057	0	12	32	5,805	46	4,656
NPRE	1991	9	8,505	0	13	28	6,364	22	6,193
NPRE	1992	3	6,706	0	10	44	7,167	43	6,758
NPRE	1993	1	5,115	0	17	65	6,139	30	4,772
NPRE	1994	3	4,891	0	9	4	5,512	18	2,858
NPRE	1995	1	4,815	0		1	2,618	10	2,472
NPRE	1996	0	5,795	0		0	1,771	0	6,858
NPRE	1997	0		0		0		0	
NPRE	1998	0		0		0		0	

LEGEND			
(green)	*Number of rinderpest outbreaks reported*	(grey)	*Vaccination along international border*
Vaccination	*All figures are x 1,000*	...	*Vaccination ongoing but amount unreported*
(red)	Intensive vaccination under ORZ		
(yellow)	*Ring vaccination around outbreaks under ORZ*	(blue)	*OIE status: year of self declared provisional freedom*

INDIA			
		ZONE C / STATE	
		KERALA	
Eradication Programme	Operational period	Outbreaks	Vaccination
NREP	1956-1960	0	
NREP	1961-1965	0	215
NREP	1966-1968	76	2,248
NREP	1969-1973	2	4,099
NREP	1974-1979	13	4,902
NREP	1980-1984	0	610
ORZ	1985	2	828
ORZ	1986	2	918
ORZ	1987	4	1,083
ORZ	1988	10	1,395
ORZ	1989	14	437
ORZ/NPRE	1990	7	851
NPRE	1991	3	949
NPRE	1992	3	786
NPRE	1993	1	863
NPRE	1994	1	535
NPRE	1995	0	564
NPRE	1996	0	6,858
NPRE	1997	0	
NPRE	1998	0	

LEGEND			
(green)	*Number of rinderpest outbreaks reported*	(grey)	*Vaccination along international border*
Vaccination	*All figures are x 1,000*	...	*Vaccination ongoing but amount unreported*
(red)	*Intensive vaccination under ORZ*		
(yellow)	*Ring vaccination around outbreaks under ORZ*	(blue)	*OIE status: year of self declared provisonal freedom*

CHAPTER 4.13.6

MYANMAR

U. MAUNG MAUNG NYUNT

Former Director-General, Livestock Breeding and Veterinary Department, Ministry of Livestock and Fisheries, Insein 11011, Yangon, Myanmar

SUMMARY **The last outbreak of rinderpest in Myanmar occurred in 1956 in Kyun Hla township in central Myanmar, and the disease was considered eradicated in 1957. Mass vaccinations continued until 1961. Follow-up rinderpest vaccinations along the borders with Thailand, China, India and Bangladesh were stopped in 1994. Myanmar operated an efficient disease reporting and disease surveillance system throughout this time and undertook extensive clinical and serological surveillance to prove the absence of rinderpest.**

KEYWORDS **Clinical surveillance – Myanmar – Rinderpest – Serosurveillance – Vaccine.**

INTRODUCTION

Myanmar is a South Asian country bordering the Bay of Bengal and the Andaman Sea. It shares borders with Bangladesh, India, China, Lao People's Democratic Republic and Thailand. The country is divided into seven states and seven divisions (Fig. 1). From a total of 324 townships, 287 have veterinary posts.

In 2005, the livestock population of Myanmar included 11.6 million cattle, 2.6 million water buffaloes, 1.8 million sheep and goats, and 4.5 million pigs. The majority of cattle are used for draught power and the dairy sector is still relatively modest (1.4 million cattle). There is a seasonal migration of cattle in the central areas of Myanmar but there is no cross-border migration.

There are also populations of about 30,000 mithuns (*Bos frontalis*) in the north-western parts of the country – which are under foot-and-mouth disease (FMD) surveillance in the local townships. Other potentially susceptible domestic or wildlife species of the order Artiodactyla are insignificant: gaur (*Bos gaurus*) 2,000; banteng (*Bos banteng*) 2,000; hog deer (*Axis porcinus*) 2,000; samber deer (*Cervus unicolor*) 6,000; brow antler deer (*Cervus eldi thamin*) 500; musk deer (*Moschus moschiferus*) 1,500; and barking deer (*Muntiacus muntijae*) 10,000. There is a sizeable population of wild boar in the country, but there is no evidence that they were ever involved in the transmission of rinderpest.

HISTORY OF RINDERPEST IN MYANMAR

Rinderpest was first recorded in Burma in 1925 when nearly 20,000 cattle were killed by the disease, but it could have existed before. During that time the disease reached a mortality of 80%. In the following years the mortality was even higher in some years. The post-Second World War record of outbreaks is shown in Table I.

The last outbreak of rinderpest in Myanmar began in 1956 in Kyun Hla township in central Myanmar and finally ended in 1957.

HISTORY OF RINDERPEST VACCINES AND VACCINATION IN MYANMAR

After the first outbreaks of rinderpest in Myanmar were recorded in 1925, rinderpest immune serum was imported from India. Apart from movement control and stamping out, this remained the principal

FIG. 1

ADMINISTRATIVE STRUCTURE OF MYANMAR: STATES AND DIVISIONS

Source: United Nations, 2016 (1)

method of control until 1935 when a rinderpest desiccated goat spleen (RDGS) vaccine developed in 1935 by Dr D.T. Mitchell and Col. G. Pfaff came into use. Previous attempts by Mitchell to use goat spleen vaccine from a local rinderpest strain preserved in glycerine saline had to be abandoned because of its virulence. Further goat passages and further adaptation carried out by Pfaff in 1935/1936 and drying of the goat spleen pulp in a desiccator resulted in a vaccine that was widely used.

After the Second World War, each vaccination team produced its own vaccine. An emulsion of goat spleen in saline from the Mukteswar (India) rinderpest strain was used. It was freshly harvested from goats at the peak of pyrexia. After independence in 1948, the use of RDGS vaccine was reinitiated. It was now beyond its 410th passage and had lost some of its original virulence, and it was now successfully used to eradicate the disease from Myanmar. The use of the lapinised Nakamura strain, which was used for some time on a limited scale, particularly in mithuns and buffaloes, had to be abandoned again because of a lack of suitable rabbits.

In 1982, the RDGS vaccine was replaced by the much milder tissue culture rinderpest vaccine with a strain of lapinised–avianised vaccine developed by Furutani (2).

Mass vaccinations continued until 1961 and the follow-up vaccinations along the borders with Thailand, China, India and Bangladesh were stopped in 1994. Detailed figures are given in the regional timeline (Chapter 4.14).

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Reporting rinderpest was mandatory for all veterinary staff in Myanmar. Based on routine clinical surveillance, monthly disease reports, including all recorded disease events, were sent through township veterinary offices to district offices and from there to the office of the Director of Research and Disease Control. Rinderpest was not reported after 1957.

Using a two-stage randomised sampling frame, between 1994 and 1998 some 5,836 sera were tested using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA), with negative results (Table II).

In addition, 403 sera from investigations into erosive diseases, primarily foot-and-mouth disease, produced negative results for rinderpest.

TABLE I
RINDERPEST OUTBREAKS FROM 1951 TO 1957

Year	No. of outbreaks	No. of bovine deaths
1951	73	2,011
1952	18	491
1953	16	193
1954	7	40
1955	0	
1956 into 1957	2	29

TABLE II
SERA (CATTLE, BUFFALOES) COLLECTED AND TESTED USING A TWO-STAGE RANDOMISED SAMPLING FRAME

Division/state	No. of townships sampled	No. of sera tested
Yangon	9	1,800
Bago	4	319
Mandalay	6	884
Sagaing	10	844
Magway	3	216
Tanintharyi	2	275
Ayeyarwaddy	2	108
Chin	1	40
Rakhine	4	205
Kayin	3	205
Shan	8	557
Mon	5	304
Kaya	1	35
Kachin	2	44

DOSSIER

Based on the above results the World Organisation for Animal Health (OIE) Scientific Commission recommended recognition of Myanmar as a rinderpest-free country in September 2005 (3).

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CHAPTER 4.13.7

NEPAL

G. GONGAL [(1)*], N. PRAKASH SINGH KARKI [(2)] & K. CHAND THAKURI [(3)]

(1) Former Chief Veterinary Epidemiologist, Veterinary Epidemiology Centre, Directorate of Animal Health, Kathmandu, Nepal
(2) Former Director General, Department of Livestock Services, Harihar Bhavan, Lalitpur, Nepal
(3) Former Deputy Director General, Department of Livestock Services, Harihar Bhawan, Lalitpur, Nepal

*Corresponding author

SUMMARY **Rinderpest was considered a livestock disease of great economic importance in a country such as Nepal where the cattle population density is high, particularly in the Terai region, and the livestock sector plays a vital role in the agriculture-based national economy. Nepal shares a long porous border with India, where frequent animal movement is observed in both directions. Fortunately, both countries were actively engaged in eradicating this disease in the 1960s. Rinderpest eradication campaigns contributed to the establishment and expansion of modern Veterinary Services and quarantine systems around the world, and Nepal was not an exception. Two successive mass vaccination campaigns against rinderpest during the 1960s and 1970s in Nepal helped to eliminate rinderpest, but a relaxation in campaign intensity and the reintroduction of rinderpest in the 1980s reminded the veterinary authorities that eradication of the disease was essential. A resurgence of rinderpest in 1984 in Kathmandu, due to importation of buffaloes from India, was a great challenge for the veterinary authorities in Nepal because a large number of cross-bred dairy cattle and buffaloes were involved. Subsequently the support of an EU-funded project on strengthening of Veterinary Services and livestock disease control (1996–2002) provided a concrete foundation to declare freedom from rinderpest in 2002 in accordance with the World Organisation for Animal Health (OIE) guidelines. This chapter describes the 50-year struggle, first to control and later to eradicate rinderpest in Nepal.**

KEYWORDS **Control – Eradication – FAO – Nepal – OIE – Outbreak – Rinderpest – Surveillance – Terai – United Nations Food and Agriculture Organization – Vaccination – Veterinary – World Organisation for Animal Health.**

INTRODUCTION

Nepal is a small, landlocked country, situated between Tibet (China) to its north, and India to its east, west and south. Livestock farming is an integral part of the agricultural system in Nepal, as cattle and buffaloes are used in the Terai region for ploughing and pulling carts, while their dung is used as manure to enhance the soil fertility. Cattle and buffaloes are an important source of livelihood, with milk and milk products being the primary source of animal protein among vegetarians. Cattle and buffaloes are the largest group of livestock in terms of animal mass units. Although subsistence livestock farming was a common feature in the past, a growing demand for milk and meat products accelerated commercialisation of livestock farming through the introduction of high-yielding cross-bred animals. At the same time attention was given to improving animal nutrition and Veterinary Services. Therefore, progressive control and subsequent eradication of transboundary animal diseases, such as rinderpest and foot-and-mouth disease, became increasingly important.

A HISTORICAL PERSPECTIVE OF RINDERPEST CONTROL

The first recorded incidence of rinderpest in Nepal was in 1939 in the Kathmandu valley (mid-hills), causing heavy mortality, and was dealt with by the segregation of affected animals, the use of herbal medicine and the propitiation of the divinities. No further outbreak was recorded until 1953. The outbreak in question occurred in the Pokhara valley (mid-hills), and was controlled with wet (non-freeze-dried) attenuated goat tissue vaccine and also with rinderpest hyperimmune serum (1).

Apparently, Nepalese farmers were greatly impressed by this allopathic method of combating a disease. In effect a case–control study was happening on the ground in rural Nepal. When villagers opposing rinderpest vaccination could see results with their own eyes, i.e. no cattle dying in the vaccinated area and all cattle dying in the non-vaccinated area, they started to cooperate with the vaccination teams. Subsequently, there was fierce competition among villagers to attract a vaccination team by any means. Nevertheless, the disease remained rampant in Nepal, but particularly in the Terai districts bordering India, until the early 1960s and killed thousands of cattle and buffaloes. Farmers faced famine in rural Nepal because oxen used for ploughing paddy fields were killed by rinderpest epidemics.

ESTABLISHMENT OF VETERINARY SERVICES AND INSTITUTIONALISATION OF A NATIONAL RINDERPEST CONTROL PROGRAMME

These early encounters with rinderpest prompted the Nepalese authorities to request the Food and Agriculture Oraganization of the United Nations (FAO) for assistance in establishing a Veterinary Service. The resulting FAO report of 1957/1958 recommended:

- the establishment of a Veterinary Service that would be easily accessible to farmers;
- the creation of a rinderpest immune belt (comprising vaccinated cattle and buffaloes) along the Terai belt with India;
- the creation of check posts at important livestock passing points between the Terai and the mid- and high hills.

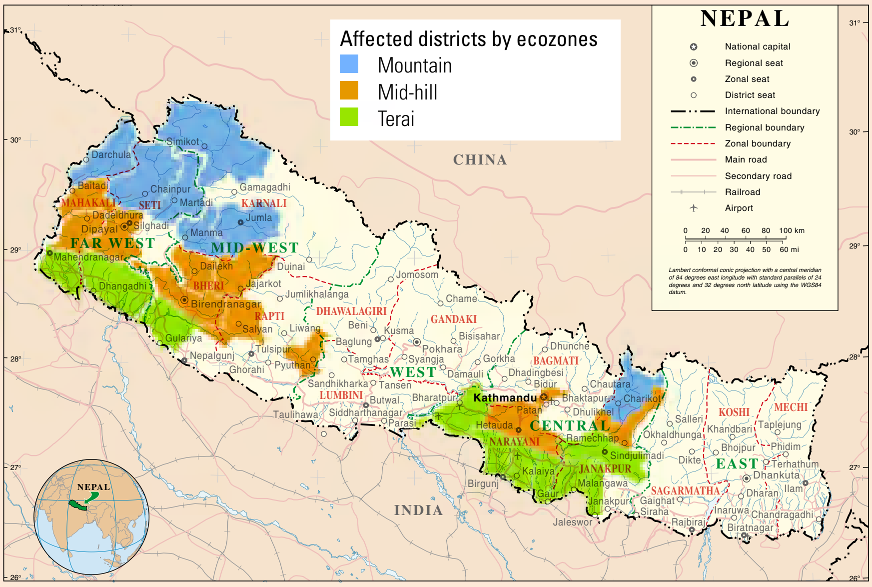
Around 1956 a national rinderpest control programme was being initiated in India (see Chapter 4.13.4) and – as a means of attaining a mutual improvement in disease security – the Government of India (GoI) offered to assist His Majesty's Government of Nepal (HMG-N) in the development of a Veterinary Service, by providing Colombo Plan scholarships for undergraduate and post-graduate training in India. In addition, the Indian Cooperation Mission in Nepal helped to increase the number of veterinary hospitals from 22 to 33 and built an additional 21 dispensaries and 18 check posts, mainly for rinderpest control. Finally, in 1964, FAO posted an expert at Kathmandu and established a functional veterinary laboratory in preparation for vaccine production and the creation of the immune belt. The ensuing programme was jointly implemented by HMG-N, the Oxford Committee for Famine Relief (OXFAM), FAO and the GoI. Between 1963 and 1969 the programme endeavoured to establish an immune belt at a depth of 20–30 km along the Nepalese side of the Indo-Nepal border. This belt was some 800 km in length. The work of mobile teams was supplemented by the creation of 14 vaccination posts in the border area and four vaccination check posts on routes from the Terai into the mid-hills.

The creation of vaccination posts and the mobilisation of vaccination teams for ring vaccination in the Terai districts helped to uncover an endemic rinderpest situation. In 1963/1964, a total of six outbreaks were dealt with by ring vaccination. The five districts involved were contiguous and consisted of four border districts (Parsa, Bara, Rautahat and Chitwan) and the adjoining mid-hill district of Makwanpur. The subsequent presence of vaccination teams and vaccination check posts in strategic locations probably led to an improved recognition of the presence of rinderpest because, between 1965 and 1969, a total of 34 further outbreaks were recorded. On the basis of the reports of ring vaccination work undertaken to control these outbreaks (1), it would seem that outbreaks were found in as many as 25 different districts (Fig. 1). Furthermore, the extent to which rinderpest was widely distributed across each of the three ecozones became much more apparent. The far- and mid-western regions were particularly badly affected. Clearly the virus had a much greater hold in the country than had been previously thought. However, rinderpest was effectively controlled by vaccinating a total of 2,970,636 animals, representing a coverage of 70%. Initially it was necessary to import vaccine from Egypt, Pakistan and India, but goat tissue vaccine production was initiated in Kathmandu in 1965. Unfortunately, there was no subsequent

FIG. 1

REGIONS AND DISTRICTS INVOLVED IN RINDERPEST RING VACCINATION FROM 1964 TO 1969

Source: United Nations (2007) (2), modified according to data provided by the Veterinary Epidemiology Center to indicate regions involved in rinderpest ring vaccination



follow-up vaccination, as a rinderpest outbreak had become a rare event by 1969.

TRANSBOUNDARY OUTBREAK OF RINDERPEST IN 1973 AND NEED FOR MASS VACCINATION CAMPAIGN

After an interval of some four years, rinderpest was again reported in 1973 in districts on the border with India. Seromonitoring at this time revealed that the prevalence of immunity to rinderpest had fallen as low as 5–7%, and an epidemic cycle of rinderpest ensued. While restricted to the Terai, the outbreaks appeared in two far-western districts (Kanchanpur and Kailali), in three central districts (Bara, Rautahat and Dhanusha) and in four eastern districts (Siraha, Saptari, Sunsari and Morang). Vaccination, this time by the staff of the Veterinary Division of HMG-N, controlled the outbreaks. The outcome of these outbreaks was the launch of a fresh mass vaccination campaign – again aimed at creating an immune belt along the Terai. Thus, between 1974 and 1979, a total of 4,490,765 vaccinations were undertaken without the support of any outside agency.

After 1979 no further mass vaccination was possible, as financial support was not available to continue vaccination in the absence of rinderpest in the Terai district. A seromonitoring exercise carried out in 1982 showed a rinderpest immunity prevalence of only 19%. Against such low levels of protective immunity it would be more than likely that, if challenged, the defences would soon be found wanting. This happened in 1984 in Kathmandu when animals brought in from Bihar state, India, caused a focal rinderpest outbreak in which 25–30 male buffaloes died. It was controlled by ring vaccination.

In February 1986, aware of a threatening situation in Bihar, HMG-N issued 100,000 doses of its own freeze-dried goat tissue vaccine for use in local cattle and imported a further 10,000 doses of Indian tissue culture rinderpest vaccine (TCRV) for use in cross-bred animals. A further 20,000 doses of TCRV were imported from Pakistan with support from FAO. In spite of these precautions 42 rinderpest deaths were recorded at Fatepur, in Banke district, in March 1986, and a further 8 deaths were recorded in Rajapur, in neighbouring Bardia district, as a result of low vaccination coverage and uncontrolled movement of livestock. These outbreaks were confirmed at both the Central Veterinary Laboratory and the Indian Veterinary Research Institute.

In April 1986, another outbreak was seen, this time in Kathmandu, in cross-bred cattle imported from Ludhiana (Punjab state, India) via Bihar. Eight of nine affected animals died. A further 12 animals were lost in an outbreak reported in June of that year in Kailali district, in western Terai. Ring vaccination and strict livestock movements brought this outbreak to an end. Although not reaching epidemic levels, these outbreaks served as a reminder that the Indo-Nepalese border was porous to transboundary animal diseases.

In the period between 1986 and 1990 there were only four more reported instances of rinderpest in Nepal. In September 1988, an outbreak was reported from Kudhahar dairy pocket area (or dairy farming area) of Pokhara valley; the index case was seen in a buffalo apparently imported for slaughter from India. The infection spread to local cattle grazing near Rambazar area and then to stall-fed cross-bred cattle with which they were in subsequent contact. The majority of the 150 deaths were in cross-bred cattle, but a few buffaloes also died. The outbreak was confirmed by the post-mortem appearance of the animal and by the agar gel immune diffusion (AGID) test in the laboratory. In November 1988, a second outbreak occurred in Kristi Nachhnechur Veterinary Diagnostic Centre, Kaski district, and the senior author was involved in the outbreak investigation as shown in Figure 2; this outbreak was traced to the September outbreak and involved the death of around 50 buffaloes.

FIG. 2
SAMPLE COLLECTION DURING RINDERPEST OUTBREAK INVESTIGATION IN 1988 AT KRISTI NACHHNECHUR, KASKI DISTRICT
Courtesy of the authors

A further outbreak of rinderpest in a remote Bharatipur village in Nawalparasi district occurred in July 1989; the origins of this outbreak was traced to a pair of bullocks moved from the Kaski district to Nawalparasi. Some 50 bullocks died. Again, confirmation was by post-mortem appearance and the AGID test. Finally, in 1990, the last recorded outbreak of rinderpest was in Dailekh district, in which two buffaloes died. A post-mortem was performed, but no confirmatory test was undertaken.

OIE PATHWAY: ROADMAP FOR DECLARING RINDERPEST-FREE STATUS

Following the resurgence of rinderpest in 1984, HMG-N was determined to get rid of rinderpest forever. Unfortunately, the concept of a regionally coordinated South Asia Rinderpest Eradication Campaign (SAREC) as envisaged by the Global Rinderpest Eradication Programme (GREP) did not materialise. To streamline subregional cooperation for the eradication of rinderpest, the European Union extended technical and financial support to Bangladesh, Bhutan and Nepal through the EU-funded Strengthening of Veterinary Services and Livestock Disease Control (SVSLDC) project in the respective countries. The SVSLDC project was designed to follow the OIE Pathway for declaring freedom from rinderpest, by strengthening veterinary legislation, epidemiological surveillance, laboratory investigation, animal quarantine, and field veterinary and extension services. Initially, it was thought that a mass vaccination campaign against rinderpest should be launched. On reflection, because Nepal had been free of rinderpest for more than five years and a network of functional Veterinary Services was well established, even at subdistrict level, it was decided to omit a mass vaccination campaign. At the same time, the GoI and the European Union were developing a national project for rinderpest eradication in India. The several projects mentioned here cooperated and collaborated through the aegis of the Animal Production and Health Commission for Asia and the Pacific (APHCA) but without the need for an international management umbrella.

The chronology of rinderpest outbreaks, vaccination campaigns and the OIE Pathway for eradication is presented in Figure 3.

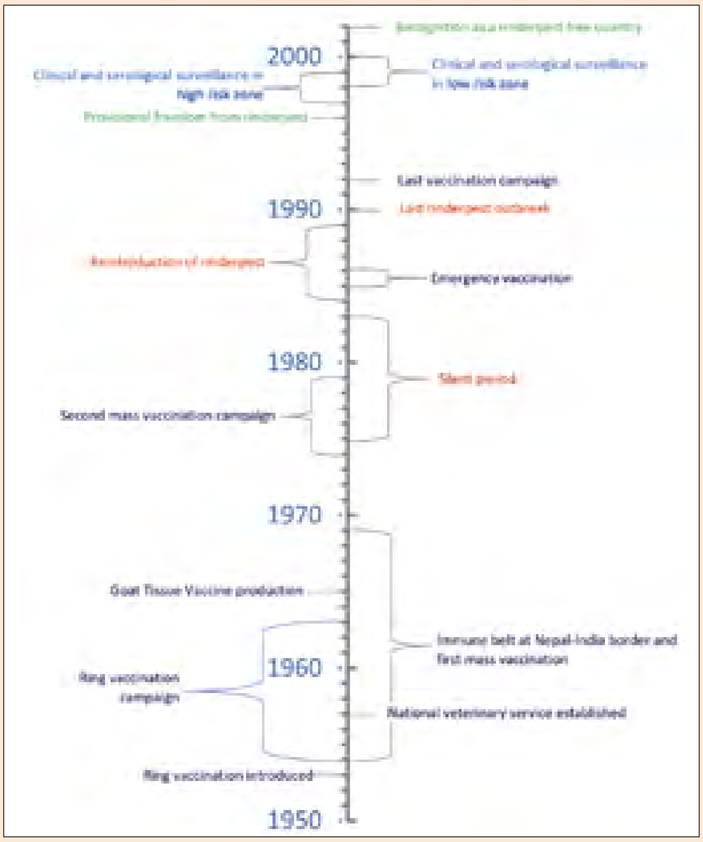
As mentioned earlier, the last outbreak of rinderpest in Nepal was recorded in 1990 (3). Rinderpest vaccine was used for the last time in 1995 to vaccinate 30,000 cattle and buffaloes in the Rupandehi district bordering with India, but, to allow for the better development of appropriate surveillance mechanisms, a declaration of provisional freedom was withheld until August 1996.

The SVSLDC project was designed to prepare the groundwork for detailed epidemiological surveillance under the OIE Pathway. In designing the surveys for Nepal, it was important to consider whether the entire national livestock population had to be examined and, if so, whether there were divisions within the population in which the surveillance burden could be reduced without compromising the overall result. Gongal and others (3) reported that in earlier years the infection was present throughout the country, but for the last 20 years when outbreaks were recorded they were invariably associated with the entry of infection from the Indian states of Uttar Pradesh and Bihar. It was clear from the previous history of the disease, from the pattern of livestock movements and from the geography of the country that some parts of Nepal were at far greater risk than others. Pokhara valley and the districts involved in the 1988–1990 outbreaks, i.e. Kaski, Nawalparasi and Dailekh,

FIG. 3

CHRONOLOGY OF RINDERPEST OUTBREAKS, CONTROL AND ERADICATION IN NEPAL

Courtesy of the authors

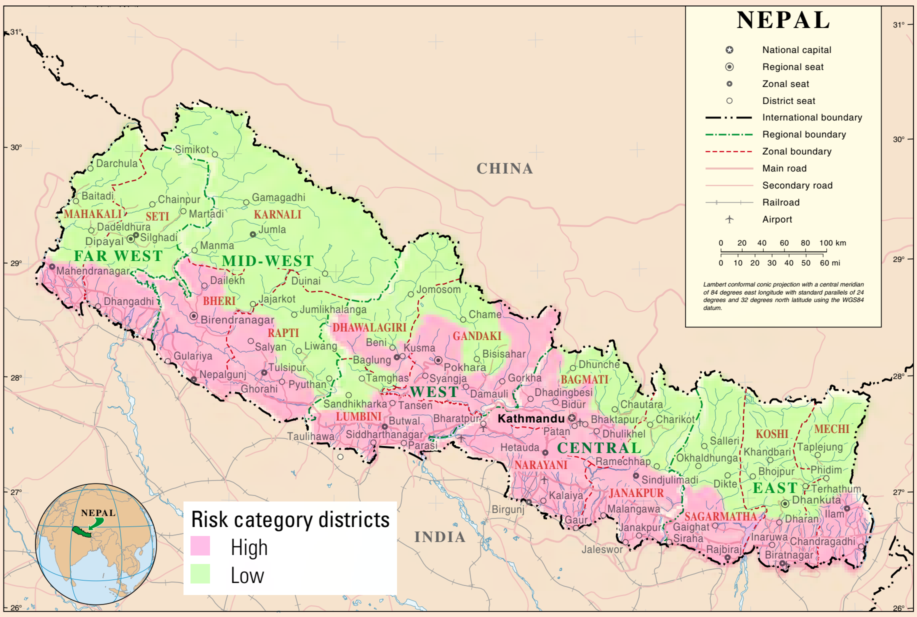


were taken into consideration for risk categorisation. Based on these observations, it was decided that surveillance work had to have a national outline but with respect to detecting rinderpest endemicity, Nepalese districts could be divided into high and low risk. The country was divided into two zones, high-risk and low-risk, as shown in Figure 4.

FIG. 4

RISK CATEGORISATION FOR RINDERPEST CLINICAL AND SEROLOGICAL SURVEILLANCE, NEPAL, 1996

Source: United Nations (2007) (2), modified according to data provided by the Veterinary Epidemiology Center to indicate risk categorisation



The high-risk zone comprised the 40 districts along the southern border with India, along trade routes, and in the Kathmandu valley where most imported animals end their journey. The low-risk zone comprise the remaining 35 districts. Laboratory diagnostic facilities were developed at the Central Veterinary Laboratory with staff experienced in the standard rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA) and AGID tests.

Active clinical and serosurveillance programmes were developed and implemented on the basis of the OIE Pathway. Some modifications were made in designing clinical and serosurveillance for rinderpest because of the absence of any clinical manifestation of the disease for the past seven to eight years (at the very least) without vaccination. It was decided to proceed simultaneously with both clinical and serosurveillance programmes.

A total of 101,182 cattle, 58,382 buffaloes, 127,392 goats and 11,904 sheep were clinically examined in 300 wards in high-risk districts between 1997 and 1999. No animal was observed with clinical signs of rinderpest. This indicated that at a 95% level of probability, rinderpest was not present in the population at a prevalence of 1% over the two-year period from mid-1997 to mid-1999, which implied that cumulatively it was not present at a 0.1% level within the population.

Serosurveillance was conducted from 1997 to 2000 to detect, with 95% confidence, infected sampling units at a prevalence of 1% at a within-unit prevalence of 20% in accordance with the existing guidelines. Additional purposive serosurveillance was undertaken at sites that were thought to be particularly at risk on the basis of prior experience. A total of 37,500 serum samples were tested using the c-ELISA test (the OIE-approved test). Where serum samples produced a positive result after retesting, the location of the positive animal was revisited, and animals living in the same locality were subjected to a detailed clinical and serological assessment. Of 34 rinderpest-positive samples sent to the FAO/OIE World Reference Laboratory for rinderpest testing, 17 showed a positive reaction to rinderpest virus when tested by ELISA and virus neutralisation. At approximately 0.02% of the 71,181 sera originally tested, this result was within the expected performance of the test, which had a specificity estimated to be approximately 99.5% (unpublished paper, Gongal *et al.*, Clinical and serological surveillance to demonstrate Nepal's freedom from rinderpest). No evidence of rinderpest viral activity was detected during active seroepidemiological and clinical surveillance. Passive surveillance activities were carried out on a regular basis. On 28 May 2002, at the 70th General Session of the OIE, the International Committee placed Nepal on the list of countries considered free from rinderpest, in accordance with the provisions of Chapter 2.1.4 of the OIE *Terrestrial Animal Health Code*.

ACKNOWLEDGEMENTS

Special thanks go to the field veterinarians and technicians working in the 75 districts of Nepal for their outstanding contribution in implementing surveillance activities under diverse ecological and climatic conditions. We would thank Mr. Tika Ram Sedai for helping us in graphic design and producing quality maps.

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CHAPTER 4.13.8

PAKISTAN

M. HUSSAIN [(1)*] & M. ABUBAKAR [(2)]

(1) Control of Transboundary Livestock Diseases Project, Food and Agriculture Organization of the United Nations, National Agricultural Research Centre, Islamabad, Pakistan
(2) National Veterinary Laboratory, Park Road, Islamabad, Pakistan

*Corresponding author: manzoor.hussain@fao.org

SUMMARY **In 1983, regarding itself free of rinderpest, Pakistan did not subscribe to a five-year plan for eradicating rinderpest from the region and did not become directly involved in the South Asia Rinderpest Eradication Campaign initiative. Over the succeeding 17 years, Pakistan experienced a number of unrelated rinderpest outbreaks including a major episode in the Northern Areas. For much of this period, endemic rinderpest was acknowledged as being present in the Landhi Cattle Colony in Karachi and was controlled with rinderpest vaccine. With the development of the technique of participatory disease surveillance, the existence of a poorly defined, but nevertheless long standing, endemic situation in interior Sindh province was brought to light. It was concluded that the movement of infected animals from this endemic focus was responsible for constantly introducing infected animals to the Landhi Cattle Colony in Karachi and also for initiating outbreaks in other parts of the country. Rinderpest vaccination across Sindh province brought endemicity to a close. The last case of rinderpest was recorded in 2000 in South Karachi district, and Pakistan was officially declared a rinderpest-free country in 2007. Results from disease surveillance undertaken between 2003 and 2006, together with serosurveillance results generated in 2003, 2004 and 2006, were successfully combined into a dossier claiming that Pakistan was free from rinderpest.**

KEYWORDS **Endemic rinderpest in Sindh province – Outbreaks – Participatory disease surveillance – Rinderpest in Landhi Cattle Colony – Vaccination.**

INTRODUCTION

Although Pakistan came into existence only in 1947, across the country familiarity with rinderpest extended back over several centuries (1). Almost immediately after independence, two epidemics of rinderpest broke out – the first lasting from 1947 until 1950 and the second lasting from 1956 until 1962. Rinderpest featured continuously in the Landhi Cattle Colony (LCC) in Karachi almost from its beginning, while making intermittent appearances at the provincial level until the year 2000. In the early 1980s, with growing pressure for global eradication, regional programmes became the vehicles for international cooperation and collaboration wherever the virus still occurred.

The 1983 meeting at the Indian Veterinary Research Institute (IVRI), Izatnagar, Uttar Pradesh, India, sponsored by the Food and Agriculture Organization of the United Nations (FAO) Animal Production and Health Commission for Asia (APHCA), launched the South Asia Rinderpest Eradication Campaign (SAREC) (2). The meeting recommended that countries should systematically plan to accomplish rinderpest eradication within the region within five years. At this meeting, the Pakistan delegate acknowledged the occurrence of two major outbreaks of a 'rinderpest-like disease' but classified the country as one where outbreaks did not generally occur (similarly classified were Bangladesh, Bhutan, Burma, Nepal and Sri Lanka). This group of countries was expected to intensify its surveillance and disease reporting, but Pakistan effectively neglected to make such a contribution.

At the SAREC meeting in Bangkok in 1990, Anwar Khan (the representative from the Government of Pakistan) reported that Pakistan had been free from rinderpest since 1981 but was vaccinating along its international borders (3). The same message was relayed at the SAREC meeting of 1992 (4). Thereafter, Pakistan, while actually harbouring endemic rinderpest, remained a long-term threat to the region and fell a decade behind other regional members in dealing with it. This situation was subsequently corrected, after an outbreak in LCC was reported to the World Organisation for Animal Health (OIE) in 1993, with assistance from FAO and the European Union to the national Veterinary Services (5).

RINDERPEST IN THE KARACHI AREA OF SINDH PROVINCE IN THE 1980S AND 1990S

Although intermittent outbreaks occurred across the country during the 1980s and 1990s, rinderpest was mostly seen in the dairy colonies of Karachi and in Sindh province's second metropolis, Hyderabad.

Karachi's milk was historically supplied by urban dairy farms scattered throughout Karachi city and named in accordance with their location, e.g. Jacob-lines, Lalukhait, Delhi, Ghizri, Bakra-Piri, Baldia, Mahajar Camp and Kaimari. Lactating animals, mainly buffaloes, but with some cattle, were brought to Karachi from the interior Sindh and Punjab provinces. Usually, freshly calved animals were purchased and kept in the farms to supply milk to the Karachi metropolitan area. As the human population of Karachi started to grow, it was decided to relocate milk production away from the city. Accordingly, in 1958 some 750 acres were allocated for the establishment of what subsequently became known as the LCC in a project jointly supported by the Karachi Municipal Corporation, FAO and the Government of West Pakistan (and, after 1971, by the Government of Sindh). In addition to stockyards, the colony incorporated a slaughter house, a disease diagnostic laboratory, a veterinary hospital and a livestock market. Dr Qayyum Qazi was Project Director. The LCC was designed to house 15,000 animals, but the population increased at the rate of 15–20% annually. According to an estimate (Dr W. Mughal, a private practitioner at LCC), the livestock population of LCC was 40,000 in 1967, 70,000 in 1982, 92,000 in 1992, 240,000 in 2001 and about 350,000 in 2010. In order to fulfil contractual obligations in the supply of milk, freshly calved animals were constantly introduced into the LCC and other dairy colonies (in Karachi and Hyderabad) from livestock markets and breeding areas in Punjab and Sindh provinces.

At LCC, these milk animals were kept only for one lactation and most of the dry animals were either slaughtered (about 40%) or returned to provincial farmers for rebreeding. Replacement of these animals mostly took place from August to December (the calving period) and to a lesser extent from January to July; the continuous arrival of rinderpest-susceptible animals served as fuel for the survival of the rinderpest virus. This statement is well supported by the mortality rate as given in Table I. As a result of the constant turnover of animals at LCC, it was never possible to determine if the virus was endemically maintained in the colony or whether it

TABLE I

ESTIMATED LIVESTOCK POPULATION AND PATTERN OF MORTALITY DUE TO RINDERPEST AT LANDHI CATTLE COLONY FROM 1958 TO 2011

Source: Government of Pakistan dossier submitted to OIE in 2006/07

Years	Average livestock population (per year)	Total estimated population during the period	Total mortality of infected animals [a]		
			Nov–Feb	Mar–June	July–Oct
1958–1963	20,000	100,000	10,000	3,000	2,000
1964–1968	40,000	200,000	20,000	6,000	4,000
1969–1973	70,000	350,000	35,000	10,500	7,000
1974–1978	90,000	450,000	31,500	9,000	4,500
1979–1983	120,000	600,000	42,000	12,000	6,000
1984–1988	150,000	750,000	52,500	15,000	7,500
1989–1993	200,000	1,000,000	40,000	15,000	5,000
1994–1998	220,000	1,100,000	5,500	1,100	110
1999–2003	250,000	1,250,000	0	0	0
2004–2008	300,000	1,500,000	0	0	0
2009–2011	350,000	1,750,000	0	0	0

[a] About 70% of the animals were slaughtered because they were infected

was being constantly reintroduced, although the presence of long-term endemic foci in Sindh province makes the latter suggestion entirely possible.

After 1969 the number of rinderpest cases in the LCC became a major national concern. Between 1970 and 1974 the use of goat tissue vaccine reduced the average number of cases, and after 1975 tissue culture rinderpest vaccine, manufactured at the Veterinary Research Institute (VRI), Lahore, further reduced the incidence. During this period, external confirmation of the presence of virus was made twice, once in 1977 at the Department of Agriculture Laboratories at Plum Island, United States of America, and once in 1985 at the Pirbright Institute, United Kingdom of Great Britain and Northern Ireland (6).

By using vaccine to wage a continuous war against the virus, the incidence rate in LCC was gradually brought under control so that by 1992 and 1993 there were five- and seven-month periods, respectively, when no outbreaks were reported. The last outbreaks in LCC were recorded in 1997, and the last outbreaks in the satellite colonies in Karachi were recorded in 2000 (7).

THE ENDEMIC AREA IN INTERIOR SINDH PROVINCE DURING THE 1980S AND 1990S

Although less obvious than in the LCC, the virus was also endemic in a group of contiguous districts in the interior of Sindh province (most probably caused by the purchase of animals for re-breeding, particularly from the dairy colonies in Karachi and Hyderabad), and these districts served as the reservoir of the virus from which rinderpest-infected animals were again sold to the dairy colonies.

During this period, the presence of rinderpest in Sindh province was recorded locally but not at the international (OIE) level. Examination of the provincial annual administrative reports showed that, although most outbreaks were reported from Karachi, outbreaks were also reported from a number of districts in Sindh province (9 in Dadu between 1983 and 1984, 31 in Larkana between 1983 and 1984, 11 in Nawabshah between 1987 and 1988, 25 in Thatta between 1992 and 1993 and one in Badin between 1992 and 1993). As it was never the subject of a comprehensive investigation and because of an underperforming surveillance system, the full extent to which rinderpest was endemic at village level within these districts was unacknowledged, even although, with a 40% case fatality rate, the virus appeared to be maintaining a high degree of virulence. Perhaps this was because individual outbreaks seldom involved large numbers of animals.

Participatory disease surveillance (PDS), based on the recollections of village livestock keepers (8), was introduced in the country from 2002 to 2006. The results showed that, as far back as 1980 (Tables II and III), villages in Sindh province had had regular experience of rinderpest. For Sindh, the history of rinderpest in terms of outbreaks ascribed to particular years and districts, covering the period 1980 to 1999, is given in Tables II and III.

Based on the continuous presence for five or more consecutive years, rinderpest was probably endemic in Jacobabad, Khairpur, Larkana, Nausharo Feroze, Nawabshah, Sanghar, Shikarpur and Sukkur districts of Sindh province during the 1980s and 1990s. At the same time it was intermittently present in Badin, Dadu, Ghotki, Hyderabad, Mirpur Khas, Tharparkar and Thatta districts. The fact that the administrative data support the PDS data indicates that a number of districts, perhaps occasionally increasing and then contracting in number, had served to maintain, over many years, an endemic cycle of rinderpest in Sindh province and, in all probability, had fuelled the constant presence of the virus in the LCC. The fact that, up until 2000 (when the last case in Karachi occurred in South Karachi district) (9), the most constantly implicated districts fell into a contiguous group. Figure 1 supports this belief.

VACCINATION RECORD IN SINDH

Since the first detection of rinderpest in Pakistan, vaccination was the usual means of keeping the disease under control. Beyond the early national campaign, routine vaccination programmes were undertaken by district administrations. With the exception of an EU–FAO–Government of Pakistan emergency rinderpest vaccination programme in the Northern Areas between 1994 and 1996 and an FAO cyclone relief programme in Sindh in 1999, district administrations were never engaged in a coordinated national mass vaccination campaign against rinderpest. Since 1975, all vaccination was carried out using tissue culture rinderpest vaccine made with the attenuated variant of the Kenyan Kabete 'O' strain distributed in freeze-dried form within a cold chain. This vaccine was made by the VRI, Lahore (established in 1963).

It took up to seven years to vaccinate a number of animals that equated to the total large ruminant population of the province (Table IV). Nevertheless, through the judicious use of vaccine where it was most needed, this incremental vaccination policy succeeded in breaking the transmission chain within the interior of Sindh. PDS results for the province indicated that outbreaks at village level ceased

TABLE II
SINDH PROVINCE: NUMBER OF RINDERPEST OUTBREAKS ASCRIBED TO PARTICULAR YEARS AND PARTICULAR DISTRICTS BETWEEN 1980 AND 1991
(data derived from PDS)

District	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Badin				7			3		1			
Dadu	7	6		6	3	6						1
Ghotki			3			2		2	2		3	
Hyderabad							1		1		1	
Jacobabad			2	2		2			2	2	2	6
Khairpur	1			2	2	4	2	2			3	1
Larkana	7	10		10	1	6	1	1	3	1	1	2
Mirpur Khas									1			
Nausharo Feroze	30			2			3	1		2		5
Nawabshah			1	6	1	3	1	1		2	3	6
Sanghar	2	2	1	1	2	3			1	1		
Shikarpur				2	2	1	1	2	5	1	3	5
Sukkur	1		1	3	1	1	1	1	3		4	5
Tharparkar									3			
Thatta	1			1					2			
Total	**49**	**18**	**8**	**42**	**12**	**28**	**13**	**10**	**24**	**10**	**20**	**31**

TABLE III
SINDH PROVINCE: NUMBER OF RINDERPEST OUTBREAKS ASCRIBED TO PARTICULAR YEARS AND PARTICULAR DISTRICTS BETWEEN 1992 AND 2003 (DATA DERIVED FROM PDS)

District	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Badin	1				1							
Dadu	4	6			1							
Ghotki		3	1	7	4							
Hyderabad	2	1			2			1				
Jacobabad	7	4	2	1	6							
Khairpur	5	4	3	2								
Larkana	5	5	2									
Mirpur Khas	3				6							
Nausharo Feroze	2	4	7	5	1	2						
Nawabshah	3	15	13	4	2							
Sanghar	5	5										
Shikarpur	3	5		1	1							
Sukkur	4	6	5	7	3	1	1					
Tharparkar	3											
Thatta	2	1	2				1	1				
Total	**49**	**59**	**35**	**27**	**27**	**3**	**2**	**2**	**0**	**0**	**0**	**0**

in 1999. In addition, in and around Karachi, annual vaccine uptakes between 1996 and 1999 equalled three times the colonies' nominal large ruminant population (Table IV). This probably reduced the threat of secondary outbreaks starting there, which had happened following the last incursion of rinderpest into Karachi in 2000 at an isolated farm in Malir district, Karachi (10).

FIG. 1
DISTRICTS OF SINDH WHERE RINDERPEST WAS ENDEMIC (COLOURED RED) BETWEEN 1980 AND 1999

Source: D-maps, 2020 (13), modified to indicate rinderpest endemicity

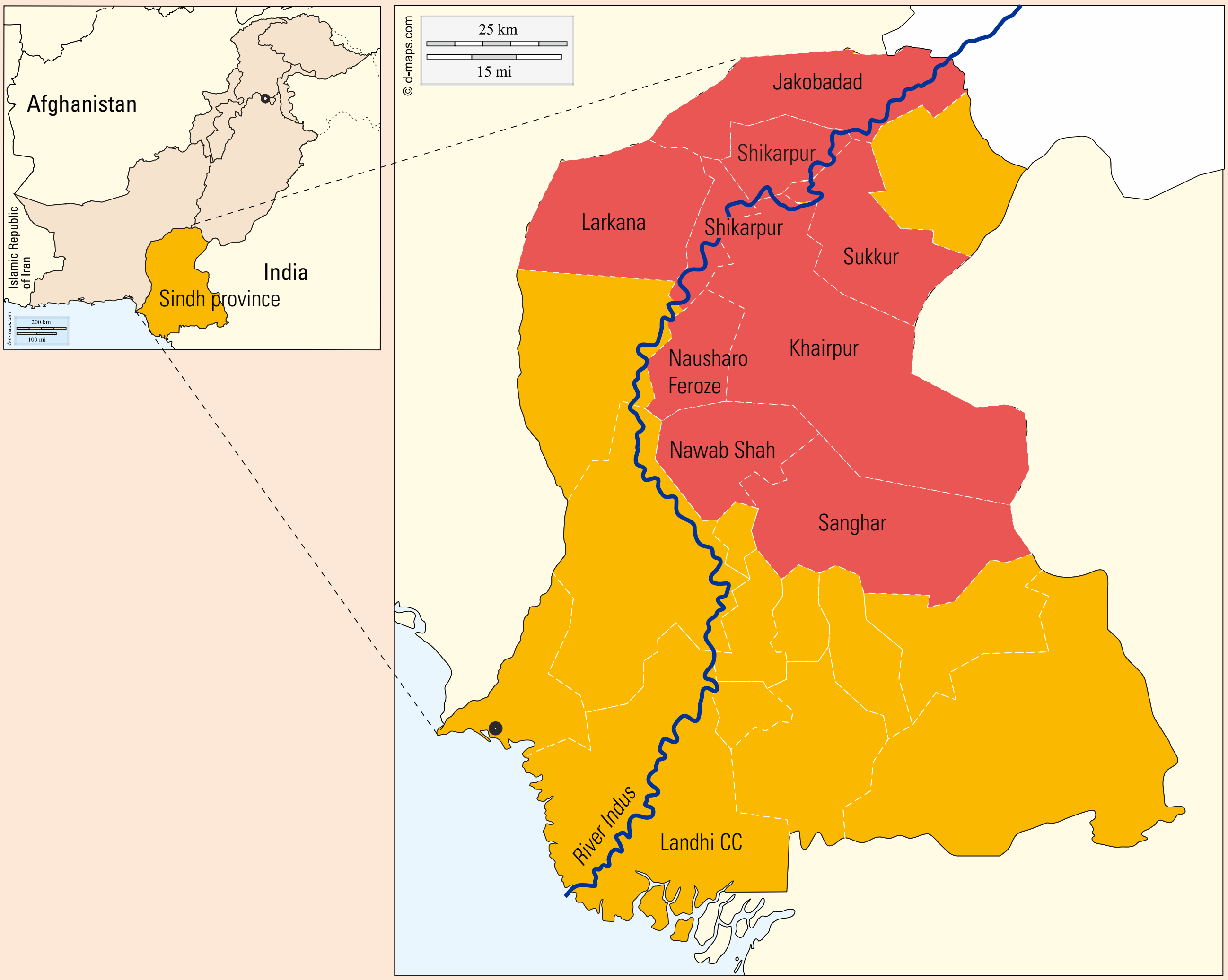

TABLE IV
RINDERPEST VACCINATION CAMPAIGNS IN SINDH PROVINCE, 1989–2000

Vaccination year	Estimated large ruminant population of Sindh	Vaccine uptake	Large ruminant population covered at district level (cumulative %)
1989–1990	7,093,057	979,624	13.8
1990–1991		985,921	27.7
1991–1992		1,151,559	43.9
1992–1993		1,451,577	64.4
1993–1994		1,099,549	79.8
1994–1995		862,326	92.0
1995–1996		1,190,239	108.8
1996–1997	11,079,657	1,376,277	121.2
1997–1998		1,289,251	132.8
1998–1999		803,126	140.1
1999–2000		2,599,584	163.6

POINT EPIDEMICS, 1980 TO 1999

Occasionally, localised epidemics of rinderpest were recorded in other parts of the country (Fig. 2).

In Balochistan, an outbreak occurred in the autumn of 1987 (11) involving 25 farms in and around Quetta. It affected 819 animals but only killed 23. Backtracing suggested that the disease had been introduced with infected buffaloes from the Shikarpur and Jacobabad districts of Sindh. In 1991, cases of rinderpest were present on Quarry Road, Quetta (W. Taylor, unpublished observations). A further outbreak was reported in Quetta in 1995 (8).

In Punjab province several easily controlled point outbreaks were seen, such as one near Lahore in 1994 and one in Rawalpindi in 1997 (5). One of these was back-traced to the south of the province. Most of these individual outbreaks were controlled by restricting livestock movements and then by ring vaccination; none ever led to the establishment of an endemic situation.

In March 1994, presumably through the movement of infected livestock transported from Punjab province by road, rinderpest broke out in the Northern Areas, giving rise to an extremely severe rinderpest epidemic (see Chapter 2.6).

SURVEILLANCE

Active disease searching in villages

Large ruminants (cattle, buffaloes, yaks and yak–cattle crosses) have always been regarded as the stratum within which rinderpest has existed

FIG. 2

EPIDEMIOLOGICAL SITUATION OF RINDERPEST IN PAKISTAN AS OUTLINED IN 2001

Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

Source: Schajee, 2010 (14), modified to indicate the prevalence of rinderpest in Pakistan

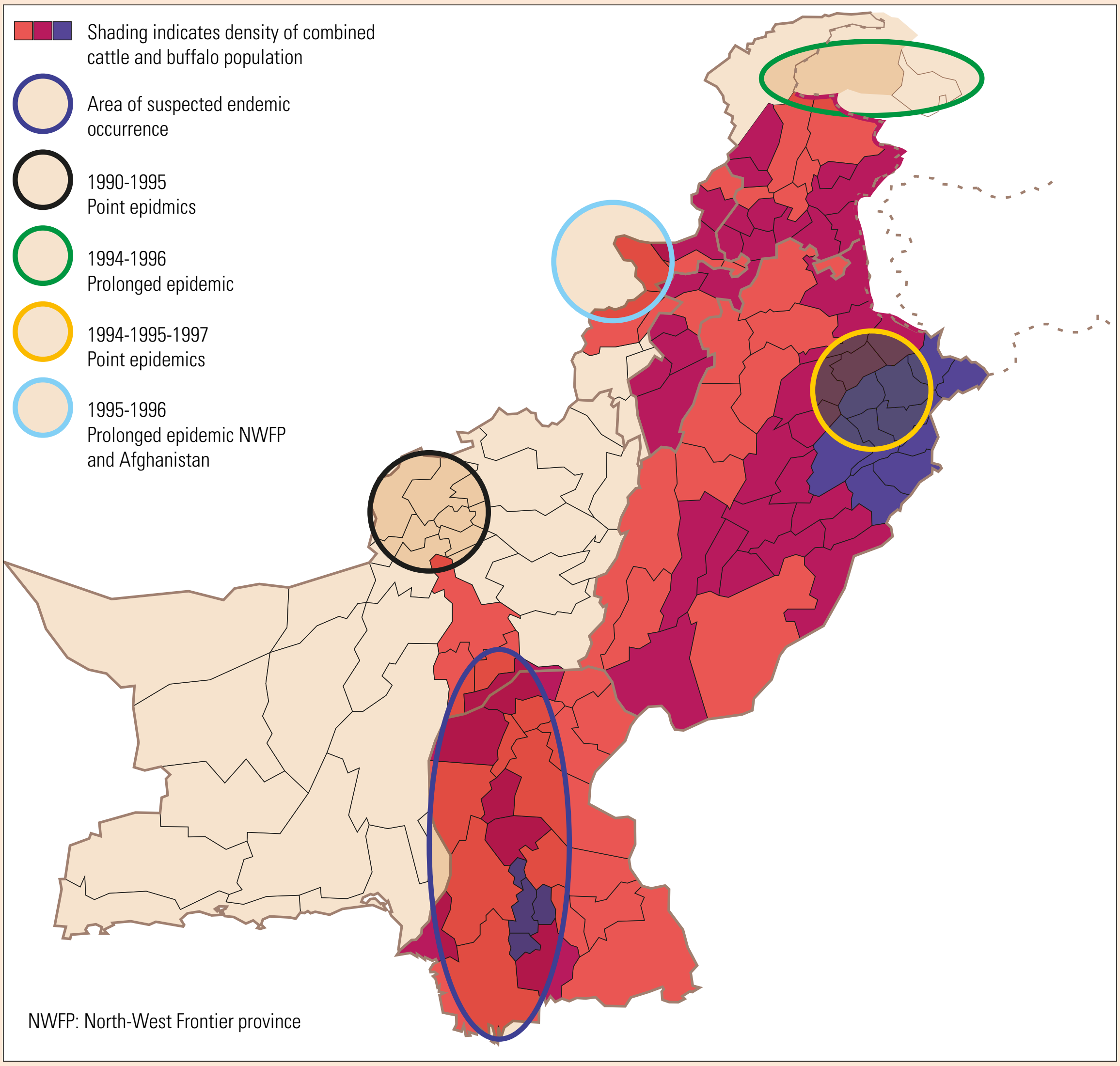

TABLE V
NUMBER OF PROVINCIAL VILLAGES SEARCHED FOR RINDERPEST BETWEEN 2003 AND 2006

Province	Total number of villages in province	Number of villages searched in given year				Total number of searches
		2003	2004	2005	2006	
Azad Kashmir	1,644	203	451	334	100	1,088
Balochistan	7,586	174	309	159	246	888
Islamabad Capital Territory	150	13	30	156	52	110
Northern Areas	566	127	596	0	100	823
North-West Frontier	14,325	285	415	380	248	1,328
Punjab	26,174	659	1,385	579	350	2,973
Sindh	25,000	793	1,214	730	405	3,142
Total	**75,445**	**2,254**	**4,400**	**2,197**	**1,501**	**10,352**

in Pakistan. Large ruminant keeping is essentially a village-based undertaking, and owners have considerable concern for the well-being of their charges.

In 2002, a year ahead of the declaration of provisional freedom from rinderpest, it was decided to commence a nationwide, four-year active surveillance programme to determine whether or not there was a continuing presence of rinderpest disease within Pakistan. To provide a valid framework within which such searches could be conducted, the PDS technique was adopted. The programme became fully operational throughout the country in 2003 and continued until 2006. Veterinary officers trained in PDS techniques (8) visited over 8,000 randomly selected villages representing all administrative districts of the country. The primary objective of the search was to interact with livestock keepers, allowing them to recount their current disease problems. On no occasion was rinderpest mentioned as a current problem. According to the prescribed methodology, the farmers familiarity with the clinical signs of rinderpest was then assessed and, if satisfactory, the farmers were then asked to recall the year of the last occurrence of rinderpest in their village.

By province, the number of village searches undertaken during each of the four active search programmes, each failing to record the presence of rinderpest, is given in Table V.

Serosurveillance

The use of rinderpest vaccine ended in 2000, permitting the development of a serosurveillance programme. This ran throughout the country in 2003, 2004 and 2006.

In each survey, the sampling units were village populations of large ruminants. At district level, the villages to be visited were selected at random from a sampling frame consisting of a list of all villages in the district. In each village 20 large ruminants of specified ages were sampled, if possible collecting ten samples from each species, but otherwise according to the predominant species.

Based on information on the ages of cattle and buffaloes provided by the Global Rinderpest Eradication Programme (GREP), it was determined that cattle with one pair of permanent incisor teeth were aged more than two years old but less than three years old. For buffaloes the age was more than two years old but less than four years old. Animals with two pairs of permanent incisor teeth were taken to be, for cattle, three years old but less than four years old and for buffaloes, four years old but less than five years old.

A preliminary survey was undertaken in 2003 to test the ability of field teams to collect samples from cattle and buffaloes of a specific age (eligible animals) and the ability of the laboratory staff to process samples using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3). Full national surveys were conducted

TABLE VI
THE INCIDENCE OF POSITIVE SAMPLES, BY SURVEY AND BY PROVINCE

Province	Incidence of c-ELISA-positive samples		
	2003	2004	2006
Azad Kashmir	0/760	1/2,394	2/2,960
Balochistan	7/1,000	13/6,101	2/6,960
Islamabad Capital Territory	2/507	4/452	0/1,000
Northern Areas	2/760	55/2,462	12/2,949
North-West Frontier	4/1,000	7/6,000	0/6,974
Punjab	4/2,107	6/6,068	8/7,022
Sindh	13/2,455	16/5,939	23/8,000
Total	**32/8,589 (0.4%)**	**102/29,416 (0.3%)**	**47/35,865 (0.1%)**

in 2004 and again in 2006. The results are shown in Table VI.

In 2003, the survey was carried out late in the year, approximately three years after vaccination had stopped. Thus for cattle it was fairly certain that animals with one pair of erupted permanent incisors would not have been vaccinated, but for buffaloes the situation was less absolute. The 2004 survey was carried out late that year, whereas the 2006 survey was early in the year. Both of these surveys tried to include equal numbers of animals with one and two pairs of permanent incisors showing. All tests were carried out within Pakistan in five dedicated ELISA units using the OIE-approved c-ELISA test.

Backtracing

As a result of the 2003 survey, the villages in Punjab and Sindh provinces, from which positive samples came, were visited by a senior provincial disease investigation officer who determined that the samples probably came from previously vaccinated animals and that there was no evidence of rinderpest in the village. Similar rationalisations were applied to the small number of positive samples seen in the 2004 surveys of Balochistan, North-West Frontier province, Punjab and Sindh. In the Northern Areas a surprisingly high number of positive samples were found; here it appeared that many animals outside the eligible categories had been sampled. Again backtracing demonstrated that there was no evidence of rinderpest in the villages concerned, and the results were deemed to be due to earlier vaccination work.

The 2006 results from Sindh include a dedicated survey of 1,000 samples from Karachi. Here 13 positive samples were found. Uniquely, in one shed a cluster of five positive samples was found in animals of between one and three years of age. Backtracing determined that no rinderpest vaccine had been used on these animals and that they had never suffered clinical rinderpest. However, it came to light that the animals had been suffering from foot-and-mouth disease (FMD) at the time of sampling. Further bleeding was undertaken four months after the initial sampling. Two animals were tested at both sampling times. In each, the initial sample was positive in ELISA and the second sample was negative in ELISA. Samples from a further 30 animals that had remained in the shed since the time of the first sampling were similarly negative. Clearly, therefore, these results reflected the presence of a non-specific cluster, possibly associated with the presence of FMD, but clearly not associated with rinderpest.

The compiled results were included in a dossier submitted to the OIE in 2007 and were judged to provide evidence that Pakistan was free from rinderpest (12).

ACKNOWLEDGEMENTS

During the process of rinderpest eradication, the veterinary authorities, particularly Dr Rafaqat Hussain Raja (Animal Husbandry Commissioner/ Chief Veterinary Officer), directors-general and transboundary animal disease officers, designated by each provincial livestock department, worked in close collaboration and their efforts are highly acknowledged. FAO and the European Commission mainly provided technical and financial assistance. The Government of Pakistan also contributed financially and materially during the rinderpest eradication process. Coordination with neighbouring countries came about by attending and contributing to the FAO Global Rinderpest Eradication Programme.

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CHAPTER 4.13.9

SRI LANKA

R. HETTIARACHCHI
Additional Director-General (Veterinary Research), Department of Animal Production and Health, P.O. Box 13, Getambe, Peradeniya, Sri Lanka

SUMMARY **Within the context of rinderpest eradication from South Asia, Sri Lanka remained largely free from the disease until contaminated in 1987 and then became free from the disease again in 1994. Following the submission of serosurveillance data, Sri Lanka was declared rinderpest free in 2011.**

KEYWORDS **Eradication – Rinderpest – Sri Lanka.**

INTRODUCTION

Sri Lanka, which was known as Ceylon until 1972, is an island lying off the south-east coast of India. It has a land area of 62,705 km^2 and a human population of approximately 21 million. The livestock population at present in Sri Lanka includes 1,000,880 cattle, 280,550 buffaloes, 287,190 goats, 10,389 sheep, 95,120 pigs and 21.28 million poultry. The first recorded occurrence of rinderpest in Sri Lanka was in 1888 and the disease persisted until its eradication in 1934 (1). In 1942, rinderpest was observed in goats imported from India that were in quarantine and the disease was suppressed in the quarantine station itself (2). However, it was reintroduced during the Second World War in 1943 via goats imported from India; 14,578 cases and 10,157 deaths among local cattle were recorded (3, 4, 5). Eventually, the country gained rinderpest-free status in September 1946. Sri Lanka remained rinderpest-free for the following 41 years.

EPIDEMIC RINDERPEST: 1987 TO 1994

The livestock population in the country during the year 1987 was 1,807,000 cattle, 1,007,000 buffaloes, 502,000 goats, 27,000 sheep, 96,000 pigs and 8.59 million poultry. The Sri Lankan Government made a 'peace accord' with the Government of India in June 1987 to control ongoing civil unrest in parts of the country. Subsequently, an Indian peace keeping force (IPKF) arrived in northern and eastern parts of the island. Goats were shipped from India without any quarantine procedure under the emergency status, in order to feed the Indian troops. Pregnant goats were kept in the IPKF camps that were located in Northern and Eastern provinces until kidding. There they were allowed to mingle with indigenous cattle, bartered for local goats and exchanged for chicken and fish (6). Rinderpest in sheep and goats in India has been recorded on several occasions (7) and reached epidemic proportions (8). Sheep, and particularly goats, in South India have reportedly acted as asymptomatic carriers, and the disease in small ruminants always preceded the outbreak in cattle when the outbreak involved both species (9). The first clinical case of rinderpest in the 1987 episode in Sri Lanka was observed in a cattle herd in Sinna Urani, a village in the peninsular area of Batticalo district in Eastern province in October 1987 (Fig. 1). Within a few days, 509 cattle were affected in ten contiguous villages in this area.

Sick animals experienced fever followed by nasal and ocular discharges that were at first serous and slight but became mucopurulent and profuse later. Visible mucous membranes were congested, being particularly prominent in conjunctivae. Shallow erosions developed on the muzzle and

FIG. 1
LOCATION OF INDEX CASE IN THE 1987 EPISODE
Source: Jereon, 2005 (11), modified to indicate location

buccal mucosa and opening the mouth released a foetid odour. The animals craved water. Afterwards, projectile diarrhoea led to dehydration and rapid emaciation. Sick animals collapsed and died 10–15 days after the onset of sickness. Some, however, lingered on for as long as three weeks. In post-mortem examinations, erosions and ulcers were observed on congested and oedematous abomasal folds. Haemorrhagic and necrotic lesions were found in the small intestines, markedly in Peyer's patches. Prominent stripes that were similar to 'zebra marking' or 'tiger stripes' extended from the blind end of the caecum to the caeco-colic junction and continued to the rectum. Diagnostic samples were dispatched to the Pirbright Institute, which confirmed the disease as rinderpest by the agar-gel immune diffusion technique.

By 1988, rinderpest cases were seen in the vicinity of many IPKF camps in the Northern and Eastern provinces and later in the North Central and Western provinces. Transport of cattle for various reasons contributed largely to the spread of the disease and by 1989 all provinces had reported rinderpest. By 1991, in the face of heavy vaccination, the pattern of disease shifted from epidemic (1987–1990) to endemic (1991–1993). Two cases were observed in 1994 in the eastern part of the country at Trincomalee (Figs 2–6). A total number of 45,023 cases were recorded during this epidemic, which lasted from October 1987 until February 1994. Apart from a few cases in goats seen during the early outbreaks in areas surrounding the IPKF camps, cases were confined to cattle and buffaloes.

Under an initial eradication campaign aimed at zoo-sanitary control, 3,403 cattle and buffaloes and 113 goats were slaughtered; this slaughter policy

FIG. 2
DISTRIBUTION OF RINDERPEST OUTBREAKS IN 1988
Source: Jereon, 2005 (11), modified to indicate outbreaks

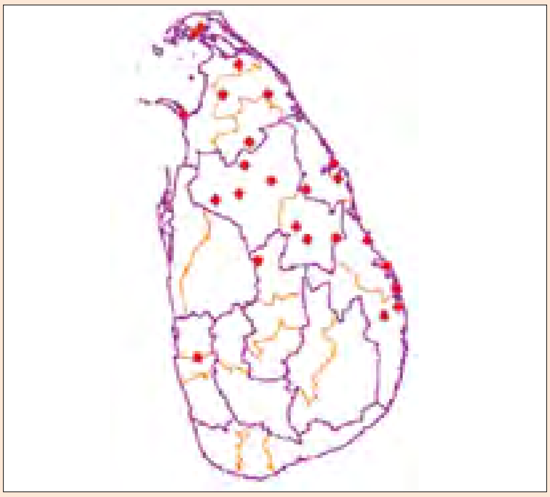

FIG. 3
DISTRIBUTION OF RINDERPEST OUTBREAKS IN 1989
Source: Jereon, 2005 (11), modified to indicate outbreaks

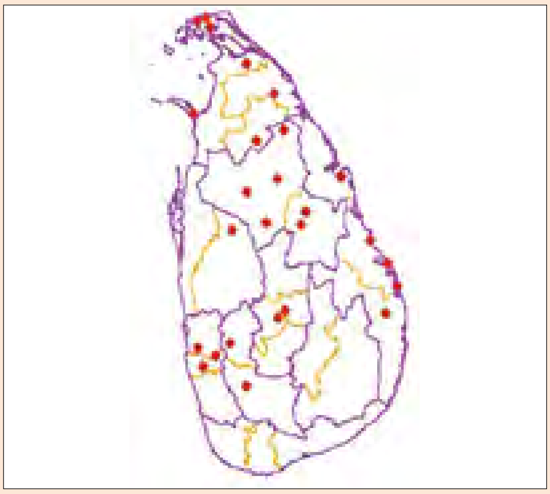

FIG. 4
DISTRIBUTION OF RINDERPEST OUTBREAKS IN 1990
Source: Jereon, 2005 (11), modified to indicate outbreaks

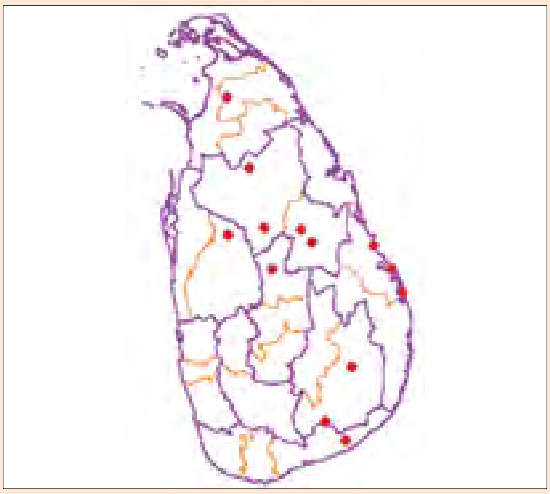

FIG. 5
DISTRIBUTION OF RINDERPEST OUTBREAKS IN 1991–1994
Source: Jereon, 2005 (11), modified to indicate outbreaks

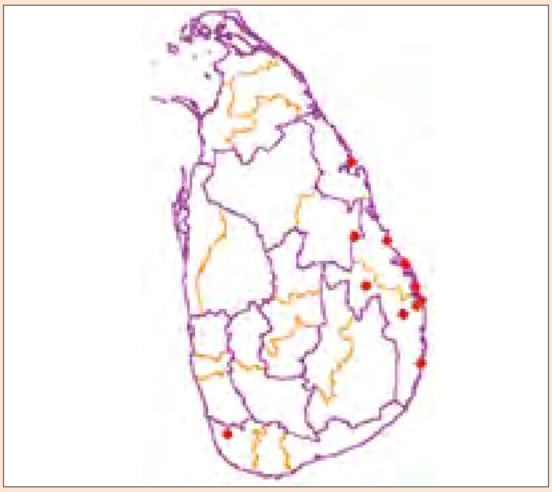

FIG. 6
LOCATION OF THE LAST CASE IN SRI LANKA
Source: Jereon, 2005 (11), modified to indicate location

was modified in 1989 and abandoned in 1991. Using tissue culture rinderpest vaccine, rinderpest vaccination was introduced in 1987 and mass-scale vaccination campaigns were launched in 1988–1989 in which 1.1 million vaccinations were carried out. Vaccine was imported from Pakistan and India as well as from a vaccine bank held by the Animal Production and Health Commission for Asia and the Pacific. Coverage levels were at their highest (60%) in 1988. Widespread vaccination was discontinued in 1992, but a programme was maintained in Northern and Eastern provinces until 1997. In total, 1.45 million vaccinations were carried out in the country. The outbreak was curtailed through a mixture of vaccinations in and around villages where cases were reported and the slaughter, with compensation, of affected animals. Sri Lanka, being an island, would seem to enjoy the advantage of protection from exotic diseases. Nevertheless, the fact that military operations had introduced rinderpest on several occasions showed that disease control measures, such as quarantining incoming livestock, had been hindered by political instability and civic strife. However, it became impossible to continue with this approach in subsequent outbreaks that cropped up in different parts of the country. As Sri Lanka is a Buddhist country, the slaughter campaign was hindered not only by the religious leaders but also by the public, and therefore it became incomplete and was abandoned later. Thereafter, strict control of animal movement and compulsory vaccination played major roles in suppressing diseases. This approach led to the ultimate eradication of rinderpest.

SURVEILLANCE

After 1998, a syndromic disease reporting system was introduced in which fever accompanied by stomatitis and enteritis were to arouse suspicion of rinderpest. This programme was promulgated among stock owners, livestock technicians and veterinary field officers. The latter were required to submit monthly reports, even if negative. In addition, a rumour registry was introduced into veterinary investigation centres. The counter-immunoelectrophoresis test was introduced to support the investigations. A total of 78 field investigations were carried out, giving negative results. A serosurveillance programme was undertaken in 1998 that permitted a declaration of provisional freedom from rinderpest. A further programme involving 4,500 samples was undertaken in 2010. These samples were evaluated for rinderpest antibodies using the standard competitive enzyme-linked immunosorbent assay test, and the ensuing negative results facilitated a declaration of freedom from rinderpest in 2011 after analysis of the dossier by the World Organisation for Animal Health (OIE) Scientific Commission (10).

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CHAPTER 4.14

TIMELINE FOR SOUTH ASIA

Countries in South Asia on the Global List of Countries officially recognised as free from rinderpest infection as at May 2011

Source: United Nations (2011). – Map of South Asia. Available at: www.un.org/geospatial/content/south-asia (accessed on 9 June 2021). Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

YEAR	COUNTRY / CROSS REFERENCE								
	AFGHANISTAN/CHAPTER 4.13.2			BANGLADESH			BHUTAN/CHAPTER 4.13.3		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
Background notes	First recorded 1942. Sporadic nature of outbreaks suggests disease never endemic.						First outbreak recorded 1949		
1951	Hazarajat province	+			+	...*etc		+	
1952					+	...		+	
1953					+	...		+	
1954					+	...		+	
1955					+	...		+	
1956					+	...			
1957				3 million cattle and buffalo deaths	+	...			
1958	1958-1962 Kapsala Province; probably of Pakistani origin 1959 high morbidity and mortality			Sylhet district	+	2,000***			
1959		+				2,100			
1960		+				2,200			
1961		+		FAO assistance in improving vaccine production		3,200			
1962						7,150			
1963						6,700			
1964						5,720			
1965						6,420			
1966						6,560			

LEGEND

–* etc.	*Routine vaccination by Veterinary Services, number of vaccinations not known*	FAO	*Food and Agriculture Organization of the United Nations*
150,000**etc.	*Emergency vaccination by Veterinary Services funded by FAO or donor, number × 1,000*	FDGTV	*Freeze-dried goat tissue vaccine*
2,000***etc.	*Routine vaccination by Veterinary Services, number × 1,000*	GTV	*Goat tissue vaccine*
(yellow)	*Unreported*	NWFP	*North-west Frontier province*
+	*Virus endemic: number of outbreaks in the year not recorded*	TCRV	*Tissue culture rinderpest vaccine*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*	(pink)	*Virus epidemic: + or number indicate outbreaks recorded in the year*

YEAR	AFGHANISTAN/CHAPTER 4.13.2 Narrative	AFGHANISTAN/CHAPTER 4.13.2 Number of outbreaks	AFGHANISTAN/CHAPTER 4.13.2 Vaccinations	BANGLADESH Narrative	BANGLADESH Number of outbreaks	BANGLADESH Vaccinations	BHUTAN/CHAPTER 4.13.3 Narrative	BHUTAN/CHAPTER 4.13.3 Number of outbreaks	BHUTAN/CHAPTER 4.13.3 Vaccinations
Background notes	First recorded 1942. Sporadic nature of outbreaks suggests disease never endemic.						First outbreak recorded 1949.		
1967						7,320			
1968						6,350	Starting in Paro in 1968 and lasting until 1971		Controlled by ring vaccination at critical points
1969						10,350		4,000 deaths	
1970	Farah province	+				9,550			
1971				Indian imported cattle seen as risk so policy was to vaccinate border districts to depth of 20K plus villages alongside national highways		6,460			
1972						1,064			
1973	Logar province	+				8,250			...
1974						7,580			...
1975						6,600			...
1976	Hirat province	+				5,220			...
1977						6,010			
1978						9,770			
1979						11,720			
1980	1980-1984 low morbidity, low mortality					12,700			
1981		+				11,100			
1982	1981 Hirat province; probably originating in the Islamic Republic of Iran	+				111,160			
1983		+				10,520			
1984				Both FDGTV and TCRV in production		9,680			Contingency immune belt along Indian border
1985						9,230			
1986						10,310			
1987	Hilmand province; probably originating in Pakistan	+				7,070			
1988		+				12,660			
1989		+				14,290			
1990						8,150			
1991						14,010			
1992						7,200			
1993			150,000** doses FAO emergency vaccination			11,720			
1994	Khost province; Pakistani origin			Vaccination ended after cross-border meeting with India		12,340			
1995		+				3,900			
1996						2,250			
1997						1,850			

LEGEND

–* etc.	*Routine vaccination by Veterinary Services, number of vaccinations not known*	FAO	*Food and Agriculture Organization of the United Nations*
150,000**etc.	*Emergency vaccination by Veterinary Services funded by FAO or donor, number × 1,000*	FDGTV	*Freeze-dried goat tissue vaccine*
2,000***etc.	*Routine vaccination by Veterinary Services, number × 1,000*	GTV	*Goat tissue vaccine*
(yellow)	*Unreported*	NWFP	*North-west Frontier province*
+	*Virus endemic: number of outbreaks in the year not recorded*	TCRV	*Tissue culture rinderpest vaccine*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*	(pink)	*Virus epidemic: + or number indicate outbreaks recorded in the year*

YEAR	COUNTRY / CROSS REFERENCE								
	INDIA/CHAPTERS 4.13.4 AND 4.13.5			MYANMAR/CHAPTER 4.13.6			NEPAL/CHAPTER 4.13.7		
	Narrative	Number of outbreaks	Vaccinations	Number of outbreaks	Vaccinations: desiccated goat vaccine	Vaccinations: lapinised and lapinised-avianised	Narrative	Number of outbreaks	Vaccinations
Background notes	1871, Cattle Plague Commission confirms presence of rinderpest. 1897, Robert Koch arrives after seeing rinderpest in Africa and notes presence of identical disease in India.						First reported 1939; 1957 FAO call for creation of Veterinary Service. Achieved through Colombo Plan assistance from Government of India.		
1951		+	...	73	350			No information	
1952		+	...	18					
1953		+	...	16					
1954		+	...	7					
1955		+	3,105	0					
1956	1956-1977 1956, Government of India launches national rinderpest eradication programme; initially successful, after 25 years this programme could not eliminate rinderpest from southern India 1956-1984 Mass vaccination and follow-up programmes at level of individual states in accordance with availability of vaccine, supplementary central finance and perception of presence of disease	3,429	10,176	2	642	17			
1957		6,043	14,576		960	32			
1958		4,787	25,622		1,100	35			
1959		1,774	27,267		824	16			
1960		1,081	22,054		877	10			
1961		1,130	15,750		833				
1962		747	21,955		381				
1963		715	26,266		407		From 1963 to 1969, ring vaccination of outbreaks plus creation of immune belt with assistance from FAO, Government of India and Oxfam	Some 40 outbreaks discovered in west and centre of country	150
1964		545	26,032		326				609
1965		810	29,496		271				777
1966		771	28,787		282				852
1967		1,106	25,725		258				457
1968		436	31,129		730				126
1969		325	31,448		1,487				Immune belt abandoned
1970		344	33,534		1,224				
1971		143	42,064		967				
1972		88	44,145		743			1	
1973		64	41,344		419			7	
1974		173	41,360		1,369		1974 -1979, border vaccination reinstated		4,491
1975		68	48,631		749				
1976		108	56,590		211				
1977		150	550,700		199				
1978		75	53,918		210				
1979		95	51,877		153				
1980		170	57,807		194				
1981		155	52,617		139				
1982		105	55,922						
1983	1983-1988 Regional variation recognised; call for fresh approach	44	53,450						
1984		80	52,786			164		1	
1985		47	17,433						
1986	1986-1988 epidemic in Gujarat State	68	18,498					6	707,000 emergency vaccinations
1987		112	21,361			148			
1988		184	19,506			48		2	
1989	1989, India begins second national eradication programme; last case in Tamil Nadu 1995	139	16,445			45		1	

LEGEND

–* etc.	*Routine vaccination by Veterinary Services, number of vaccinations not known*	FAO	*Food and Agriculture Organization of the United Nations*
150,000**etc.	*Emergency vaccination by Veterinary Services funded by FAO or donor, number × 1,000*	FDGTV	*Freeze-dried goat tissue vaccine*
2,000***etc.	*Routine vaccination by Veterinary Services, number × 1,000*	GTV	*Goat tissue vaccine*
	Unreported	NWFP	*North-west Frontier province*
+	*Virus endemic: number of outbreaks in the year not recorded*	TCRV	*Tissue culture rinderpest vaccine*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*		*Virus epidemic: + or number indicate outbreaks recorded in the year*

YEAR	COUNTRY / CROSS REFERENCE								
	INDIA/CHAPTERS 4.13.4 AND 4.13.5			MYANMAR/CHAPTER 4.13.6			NEPAL/CHAPTER 4.13.7		
	Narrative	Number of outbreaks	Vaccinations	Number of outbreaks	Vaccinations: desiccated goat vaccine	Vaccinations: lapinised and lapinised-avianised	Narrative	Number of outbreaks	Vaccinations
Background notes	1871, Cattle Plague Commission confirms presence of rinderpest. 1897, Robert Koch arrives after seeing rinderpest in Africa and notes presence of identical disease in India.						First reported 1939; 1957 FAO call for creation of Veterinary Service. Achieved through Colombo Plan assistance from Government of India.		
1990		114	19,518			40		1	
1991		94	21,062			24			
1992		96	20,631			30			
1993		103	16,026			7			
1994	1994, vaccination ended in all but states of southern India	29	13,261			6			
1995		10	9,905						
1996			14,424						
1997									
1998									
1999									

LEGEND

–* etc.	Routine vaccination by Veterinary Services, number of vaccinations not known	FAO	Food and Agriculture Organization of the United Nations
150,000**etc.	Emergency vaccination by Veterinary Services funded by FAO or donor, number × 1,000	FDGTV	Freeze-dried goat tissue vaccine
2,000***etc.	Routine vaccination by Veterinary Services, number × 1,000	GTV	Goat tissue vaccine
	Unreported	NWFP	North-west Frontier province
+	Virus endemic: number of outbreaks in the year not recorded	TCRV	Tissue culture rinderpest vaccine
25 etc.	Virus endemic: number denotes total outbreaks recorded in the year		Virus epidemic: + or number indicate outbreaks recorded in the year

YEAR	COUNTRY / CROSS REFERENCE						
	PAKISTAN/CHAPTER 4.13.8				SRI LANKA/CHAPTER 4.13.9		
	Number of outbreaks	Number of outbreaks other than Sindh and Karachi	Number of outbreaks in Sindh and Karachi	Vaccinations	Narrative	Number of outbreaks	Vaccinations
Background notes					Very severe outbreak in 1888–90 killed 40% cattle and buffaloes.		
1951			+				
1952			+				
1953			+				
1954			+				
1955			+				
1956		+	+				
1957		+	+				
1958		+	+				
1959	Major epidemic involving Punjab and NWFP	+	+				
1960		79	+				
1961		23	+				
1962		17	+				
1963			+				
1964			+				
1965			+				
1966			+				
1967			+	Nationwide vaccination implemented with GTV and lapinised vaccines			
1968			+				
1969							
1970	Outbreak in NWFP confirmed but with mild signs	1					
1971							
1972							
1973							
1974							
1975				Earlier vaccines with TCRV after 1975			
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984							
1985							
1986							
1987		1				114	103
1988	Outbreak in Quetta, Balochistan					203	638
1989						132	519
1990						65	145
1991	Present in Quetta	1		Sindh vaccination programme eliminated endemic situation	Outbreak initiated by Indian goats in Batticaloa; TCRV used for ring vaccinations and later for mass vaccinations of rinderpest-free areas	8	20
1992						4	10
1993						18	10
1994		Northern Areas epidemic killed 40K bovines in 1994/95				last case	3
1995							1
1996	Outbreaks recorded in Quettta, Punjab province and Northern Areas 1994–1997						2
1997							2
1998							
1999							
2000							

LEGEND

–* etc.	*Routine vaccination by Veterinary Services, number of vaccinations not known*	FAO	*Food and Agriculture Organization of the United Nations*
150,000**etc.	*Emergency vaccination by Veterinary Services funded by FAO or donor, number × 1,000*	FDGTV	*Freeze-dried goat tissue vaccine*
2,000***etc.	*Routine vaccination by Veterinary Services, number × 1,000*	GTV	*Goat tissue vaccine*
	Unreported	NWFP	*North-west Frontier province*
+	*Virus endemic: number of outbreaks in the year not recorded*	TCRV	*Tissue culture rinderpest vaccine*
25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*		*Virus epidemic: + or number indicate outbreaks recorded in the year*

CHAPTER 4.15

INTRODUCTION TO THE POST-SECOND WORLD WAR RINDERPEST HISTORY IN SOUTHEAST ASIA AND EVIDENCE FOR THE ERADICATION OF RINDERPEST FROM CHINA AND THAILAND

Several Southeast Asian countries were able to rid themselves of rinderpest at a relatively early date without external support – Indonesia (1907), Singapore (1930), Malaysia (1935) and the Philippines (1955). It is assumed that during the Second World War rinderpest was endemic in Indochina (now Cambodia, Lao People's Democratic Republic, Malaysia, Myanmar, Thailand and Viet Nam) and would have been difficult to control; Myanmar, for instance, acquired the disease after an absence of a number of years. As the conflict ended, outbreaks were reported in Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam. In the following decade the region benefited from assistance in vaccine production technology through the agency of the Food and Agriculture Organization of the United Nations (FAO) and the Japanese International Cooperation Agency (JICA) and the virus was quickly eradicated (see Chapter 4.16). The years in which rinderpest made its final appearance across the region were as follows: Thailand – 1959; Cambodia – 1964; Lao People's Democratic Republic – 1966; and Viet Nam – 1977. In Cambodia, Lao People's Democratic Republic and Viet Nam vaccination ended more or less coincidently with the final cases of the disease, ultimately permitting these countries to be accepted onto the World Organisation for Animal Health (OIE) list of historically free countries. Thailand maintained the use of rinderpest vaccination until 1995, which precluded entry to the OIE's historical list and required the completion of surveillance routines and the submission of a dossier (see Chapter 4.15.2).

China, which is also dealt with in this section, eradicated rinderpest in1956, although it briefly resurfaced in Tibet in 1969. China would have qualified for historical freedom but for the use of rinderpest vaccine in the border region with Pakistan in 1994/1995 against a perceived threat of spread from that country. Data from across China were compiled into a dossier proving that it was free from rinderpest (Chapter 4.15.1).

Summarised regional data are shown in Chapter 4.16.

CHAPTER 4.15.1

CHINA

J. YOULING

Former Chief Veterinary Officer, Veterinary Bureau, Ministry of Agriculture, Beijing, China

SUMMARY **Rinderpest had a long historical presence in China, but, subsequent to the founding of the People's Republic, a five-year plan eliminated the disease in 1956. This was accomplished through the use of a variety of substrains of the Nakamura III lapinised rinderpest vaccine, together with a strong zoosanitary approach. To exclude the possibility of rinderpest entering China from an epidemic in neighbouring Pakistan, vaccination was reintroduced after an interval of 25 years. Serosurveillance work undertaken between 2001 and 2002 demonstrated that no such incursion had happened.**

KEYWORDS **China – Rinderpest history – Serosurveillance – Vaccination history.**

INTRODUCTION

China is situated in the eastern part of Asia and on the west coast of the Pacific Ocean. It has a territory of 9.6 million km^2. China is bordered by 15 countries: Democratic People's Republic of Korea to the north-east, Russian Federation and Mongolia to the north; Kazakhstan, Kyrgystan and Tajikistan to the north-west; Afghanistan, Pakistan, India, Nepal, Sikkim, Bhutan and Burma to the west and south-west; and the Lao People's Democratic Republic and Viet Nam to the south.

In 2005, China had more than 141 million cattle and more than 500 million pigs. The Ministry of Agriculture is responsible for the unified administration of animal health.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN CHINA

The earliest documented record of rinderpest in China can be traced back to AD 75 (East Han Dynasty). Before the founding of the People's Republic of China, rinderpest was endemic throughout the country and occurred at intervals of three, five or ten years. Rinderpest was regarded as a seasonal disease, occurring mostly in winter and spring when feedstuff was in short supply and disease resistance low. During the period 1938–1941, rinderpest struck Sichuan, Tibet and Qinghai, and caused more than one million cattle deaths.

After the founding of the People's Republic, rinderpest vaccination campaigns started in 1949. In December 1952, a new five-year plan for rinderpest eradication was prepared, with a view to eradicating rinderpest in China by 1957. Several types of rinderpest vaccine were developed, and vaccine was used on a large scale across the country. Vaccination was practised by delineating zones, producing vaccine on the spot and vaccinating animals zone by zone. Immune zones were built between safe and unsafe areas. Campaigns began in north-east China and the Inner Mongolia autonomous region (where an immune zone 1,000 km long by 50 km wide was created along the border), after which the programme was implemented across the entire country. Cattle in immune zones were vaccinated annually for three successive years. Quarantine stations were set up on every road leading into an infected zone to prevent the spread of the disease. Finally, a task force organised by the Ministry of Agriculture took the programme to 'old infected zones' such as Qinghai, Sichuan and Tibet, enduring considerable hardship in the process.

In addition to vaccination, in the face of infection, infected premises were isolated and strict movement controls were imposed. Infected animals were slaughtered and buried and the premises disinfected. As a result, both morbidity and mortality caused by rinderpest decreased significantly during the period 1950–1954. The disease was under control by 1955, and by 1956 rinderpest was considered eradicated, a year earlier than proposed. The last outbreak was recorded in Tongren, Qinghai province. However, in 1969 the disease appeared again in Tibet due to the introduction of infected animals. The new rinderpest foci were wiped out quickly, and since then no new outbreak of rinderpest has occurred in China.

Immediately after the revolution in 1949, lapinised (Nakamura III) vaccine at the 799 passage level was made available at the Veterinary Research Institute in Harbin (see also Chapter 3.4). Between 1949 and 1956, the following four strains of this virus were used in China for rinderpest vaccination campaigns.

1. Lapinised vaccine strain: blood, lymph nodes and spleens taken from rabbits inoculated with lapinised Nakamura III strain. This vaccine was used in northern and eastern China, central southern China, south-west China, north-east China and Inner Mongolia during the early years of the rinderpest eradication campaign. This vaccine was unsafe for Korean cattle and yaks.
2. Blood taken from a calf inoculated with Nakamura III vaccine strain: this blood was used as a vaccine in north-east China and Inner Mongolia.
3. Caprinised vaccine: blood taken from goats inoculated with the virus (Nakamura III vaccine virus adapted to goats by serial passages). This vaccine was used in north-east China and Inner Mongolia.
4. Ovinised vaccine: blood taken from sheep inoculated with lapinised (Nakamura III) vaccine virus adapted to sheep by serial passages at the Harbin Institute. This vaccine was safe in all types of cattle and yaks; it was used in Qinghai province and Guangxi autonomous region.

The ovinised vaccine became a powerful tool in the prevention and eradication of rinderpest. In the absence of a cold chain, seed virus and basic equipment could be carried by hand into the field to make the vaccine at the grass roots level.

The uptake of vaccine between 1949 and 1956 is shown in Table I. Vaccination was compulsory and combined with rigorous stamping-out measures. When a region did not report

TABLE I
NUMBER (ROUNDED TO THE NEAREST THOUSAND) AND DISTRIBUTION OF ANIMALS (CATTLE/BUFFALOES) VACCINATED IN CHINA FROM 1949 TO 1956

Province	Year							
	1949	1950	1951	1952	1953	1954	1955	1956
Beijing	–	–	44	68	75	–	–	–
Hebei	143	15	44	53	32	40	–	–
Shanxi	–	46	303	52	21	–	–	–
Inner Mongolia	584	1,172	1,262	1,414	202	256	–	30
Liaoning, Jilin	190	473	752	169	52	–	–	–
Heilongjiang	171	454	283	140	27	–	–	–
Zhejiang	–	–	116	21	–	–	–	–
Fujiang	–	–	–	120	–	–		–
Jianxi	–	39	–	426	–	–	–	–
Henan	–	–	–	35	–	–	–	–
Hubei	–	2	214	108	–	–	–	–
Hunan	–	178	494	95	23	–	–	–
Guangdong	–	700	2,550	643	–	–	–	–
Hainan	–	74	281	45	44	30	272	299
Guangxi	–	203	–	–	–	–	–	–
Sichuan	–	68	87	92	350	327	600	600
Guizhou	6	39	177	250	–	–	–	–
Yunnan	1	100	133	10	7	2	2	–
Tibet	–	2	29	38	–	–	–	–
Shanxi	–	175	144	–	–	–	–	–
Gansu	–	232	235	39	14	19	–	–
Qinhai	–	1	23	18	160	334	400	137

rinderpest for three consecutive years, it was considered rinderpest-free and vaccination stopped. Vaccination ceased altogether in 1970 but resumed again in 1994 and 1995, when preventive vaccination was carried out in border areas to prevent the possible introduction of rinderpest from the northern areas of Pakistan – then suffering a severe epidemic (see Chapter 2.6). Accordingly, China was ineligible for recognition as a historically free country and consequently had to register a set of clinical and serological results with the World Organisation for Animal Health (OIE).

The results, in terms of diminishing case incidence levels, are shown in Table II.

TABLE II
YEARLY NUMBER OF RINDERPEST CASES FROM 1949 TO 1956

Year	No. of rinderpest cases	Case fatality rate	Provinces affected
1949	71,012	74.2	Inner Mongolia, Liaoning, Jilin, Heilongjiang, Fujian, Hunan, Sichuan, Guangdong, Hainan, Qinghai, Guizhou, Jiangxi
1950	38,515	89.5	Inner Mongolia, Liaoning, Jilin, Heilongjiang, Fujian, Yunnan, Hunan, Sichuan, Hainan, Qinghai, Gansu, Ningxia, Guizhou, Jiangxi
1951	52,622	93.7	Inner Mongolia, Liaoning, Heilongjiang, Fujian, Yunnan, Hunan, Sichuan, Hainan, Qinghai, Gansu, Ningxia, Guizhou, Jiangxi
1952	23,395	96.3	Inner Mongolia, Liaoning, Zhejiang, Fujian, Yunnan, Hunan, Sichuan, Hainan, Qinghai, Gansu, Ningxia, Guizhou, Jiangxi
1953	34,045	96.6	Hunan, Sichuan, Hainan, Qinghai, Gansu, Ningxia, Tibet
1954	29,505	97.7	Sichuan, Hainan, Tibet
1955	645	86.0	Gansu, Qinghai
1956	120	0	Qinghai

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Between 2001 and 2007, the National Animal Disease and Surveillance System reported 20 different livestock diseases across China; rinderpest was not one of them.

In 2001, 1,212 randomised cattle samples were collected from five provinces in northern China and tested using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3) (Table III). All samples gave negative results.

TABLE III
RESULTS OF C-ELISAS CARRIED OUT IN 2001

Province	No. of provinces sampled	No. of samples	Result
Gansu	7	113	Negative
Hebei	2	220	Negative
Jilin	3	400	Negative
Heilongjiang	1	114	Negative
Inner Mongolia autonomous region	3	365	Negative

In 2002, 11,087 randomised samples were collected from 8,655 cattle, 1,618 sheep and 814 pigs from eight provinces and tested using the rinderpest c-ELISA (Table IV). All samples gave negative results.

TABLE IV
RESULTS OF C-ELISAS CARRIED OUT IN 2002

Province	No. of samples			Result
	Cattle	Sheep	Pigs	
Hebei	1,002	200	100	Negative
Gansu	1,045	225	119	Negative
Sichuan	1,310	199	111	Negative
Heilongjiang	998	196	100	Negative
Inner Mongolia	1,000	200	100	Negative
Xingjiang	1,300	200	100	Negative
Tibet	1,000	198	84	Negative
Jilin	1,000	200	100	Negative

In 2001 and 2002, a further set of 5,721 samples were collected from 4,080 cattle, 766 sheep, 415 pigs and 460 yaks from five provinces and tested using the rinderpest c-ELISA (Table V). All samples gave negative results.

TABLE V
RESULTS OF C-ELISAS CARRIED OUT ON SAMPLES COLLECTED IN 2001 AND 2002

Province	No. of samples			Result
	Cattle	Sheep	Pigs	
Yunan	1,029	239	105	Negative
Guangxi	983	117	81	Negative
Guizhou	1,056	198	115	Negative
Hainan	1,012	212	114	Negative
Tibet	460 yaks	–	–	Negative

In 2003 and 2004, a set of 22,331 cattle samples, 11,431 sheep samples and 4,724 pig samples were collected from 12 provinces and tested using the rinderpest c-ELISA (Table VI). All samples gave negative results.

In 2005, a set of 21,145 cattle samples, 11,861 sheep samples and 2,777 pig samples were collected from 12 provinces and tested using the rinderpest c-ELISA (Table VII). All samples gave negative results.

In 2006, a set of 24,068 cattle samples, 11,962 sheep samples and 3,111 pig samples were collected from 12 provinces and tested using the rinderpest c-ELISA (Table VIII). All samples gave negative results.

In 2007, samples were collected from Qinghai and Jilin provinces. There were no positives among the 3,814 cattle sera, 2,015 sheep sera and 486 pig sera.

In addition, in 2003, 15 samples were collected from Mongolian gazelles in Inner Mongolia with negative results.

TABLE VI
RESULTS OF C-ELISAS CARRIED OUT ON SAMPLES COLLECTED IN 2003 AND 2004

Province	No. of samples			Result
	Cattle	Sheep	Pigs	
Xinjiang	1,892	1,011	367	Negative
Tibet	1,868	1,030	295	Negative
Gansu	2,000	1,000	356	Negative
Inner Mongolia	2,000	1,006	400	Negative
Hebei	2,000	1,029	357	Negative
Jilin	1,510	365	275	Negative
Heilongjiang	1,989	999	401	Negative
Sichuan	2,000	1,000	389	Negative
Yunnan	2,058	989	475	Negative
Guizhou	2,054	1,102	499	Negative
Guangxi	2,010	950	450	Negative
Hainan	1,950	950	460	Negative

TABLE VII
RESULTS OF C-ELISAS CARRIED OUT ON SAMPLES COLLECTED IN 2005

Province	No. of samples			Result
	Cattle	Sheep	Pigs	
Gansu	2,000	1,000	400	Negative
Hebei	2,000	953	400	Negative
Jilin	1,994	988	390	Negative
Heilongjiang	2,000	994	400	Negative
Sichuan	2,000	989	387	Negative
Inner Mongolia	960	1,000	400	Negative
Xinjiang	2,000	1,000	400	Negative
Tibet	1,791	957	–	Negative
Hainan, Guangxi, Yunnan and Guizhou	8,200	3,980		Negative

TABLE VIII
RESULTS OF C-ELISAS CARRIED OUT ON SAMPLES COLLECTED IN 2006

Province	No. of samples			Result
	Cattle	Sheep	Pigs	
Gansu	2,000	1,000	391	Negative
Hebei	2,000	983	400	Negative
Jilin	1,990	998	397	Negative
Heilongjiang	2,000	998	393	Negative
Sichuan	1,980	983	387	Negative
Inner Mongolia	1,960	1,000	400	Negative
Xinjiang	1,900	980	361	Negative
Tibet	1,818	1,000	382	Negative
Hainan, Guangxi, Yunnan and Guizhou	8,420	4,020	–	Negative

DOCUMENTARY EVIDENCE

Based on the results of more than 90,000 negative serological tests, the OIE Scientific Commission recommended recognition of China as a rinderpest-free country in 2008 (1).

Reference

1. World Organisation for Animal Health (OIE) (2008). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 19–21 February 2008. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_feb2008.pdf (accessed on 27 May 2019).

CHAPTER 4.15.2

THAILAND

Y. LIMLAMTHONG

Former Director-General of the Department of Livestock Development, Ministry of Agriculture and Cooperatives, Thailand

SUMMARY **Thailand experienced rinderpest between 1926 and 1956. During this time various vaccines were used, including an inactivated vaccine, a goat-attenuated vaccine, a lapinised vaccine and a lapinised–avianised vaccine for use in pigs. The final series of outbreaks was eliminated using mass vaccination in conjunction with zoosanitary controls. Mass vaccination continued until 1995. To qualify as a rinderpest-free country the Veterinary Services undertook simultaneous village search and serosurveillance programmes between 2000 and 2002. Thailand was accepted as a rinderpest-free country in 2004.**

KEYWORDS **Rinderpest history – Serosurveillance – Thailand – Vaccination history – Village searches.**

INTRODUCTION

The Kingdom of Thailand is situated in the heart of Southeast Asia. It shares borders with Myanmar to the north and west, Lao People's Democratic Republic and Cambodia to the north-east and Malaysia to the south (Fig. 1). In 2001 Thailand's livestock population contained some 5 million beef cattle, 340,000 dairy cattle, 1.7 million buffaloes and 8 million pigs.

Veterinary Services are provided by the Department of Livestock Services of the Ministry of Agriculture. For administrative purposes the Department divides the country into nine livestock administrative regions (Fig. 2).

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN THAILAND

Rinderpest was first recognised in Thailand in 1926 when it caused many deaths and severe economic hardship. The Ministry of Agriculture imported antiserum from Natrang (Indochina, modern-day Viet Nam) while simultaneously establishing rinderpest antiserum and vaccine manufacturing facilities at Pak-Chong railway station at Nong-Sarai, Nakhonratchasima province (also known as Nakhon Ratchasima). The first lot of buffalo antiserum was produced and distributed in 1930. Contemporary vaccines consisted of either a glycerol inactivated product made from the spleen and lymph nodes of infected buffaloes or a live attenuated vaccine developed by serially passaging the virus through goats until a reduction in virulence was obtained. This vaccine was considered to be very effective, conferring lifelong immunity and being cheap to produce (one goat provided 2,000 cattle doses). It was, however, unsuitable for buffaloes. Regional production units overcame the thermolability problem associated with the distribution of this product.

Rinderpest reappeared in Thailand in 1945 in the aftermath of the Second World War. At this time, with the exception of southern Thailand, the disease spread throughout the kingdom. The mortality levels among cattle and buffaloes were 20,526 in 1945 and 84,000 in 1946 and resulted in a severe lack of draught power. This in turn led to the launching of a control and eradication campaign

FIG. 1

MAP OF THAILAND SHOWING MAJOR POLITICAL SUBDIVISIONS AND NEIGHBOURING COUNTRIES

Source: United Nations, 2009 (1)

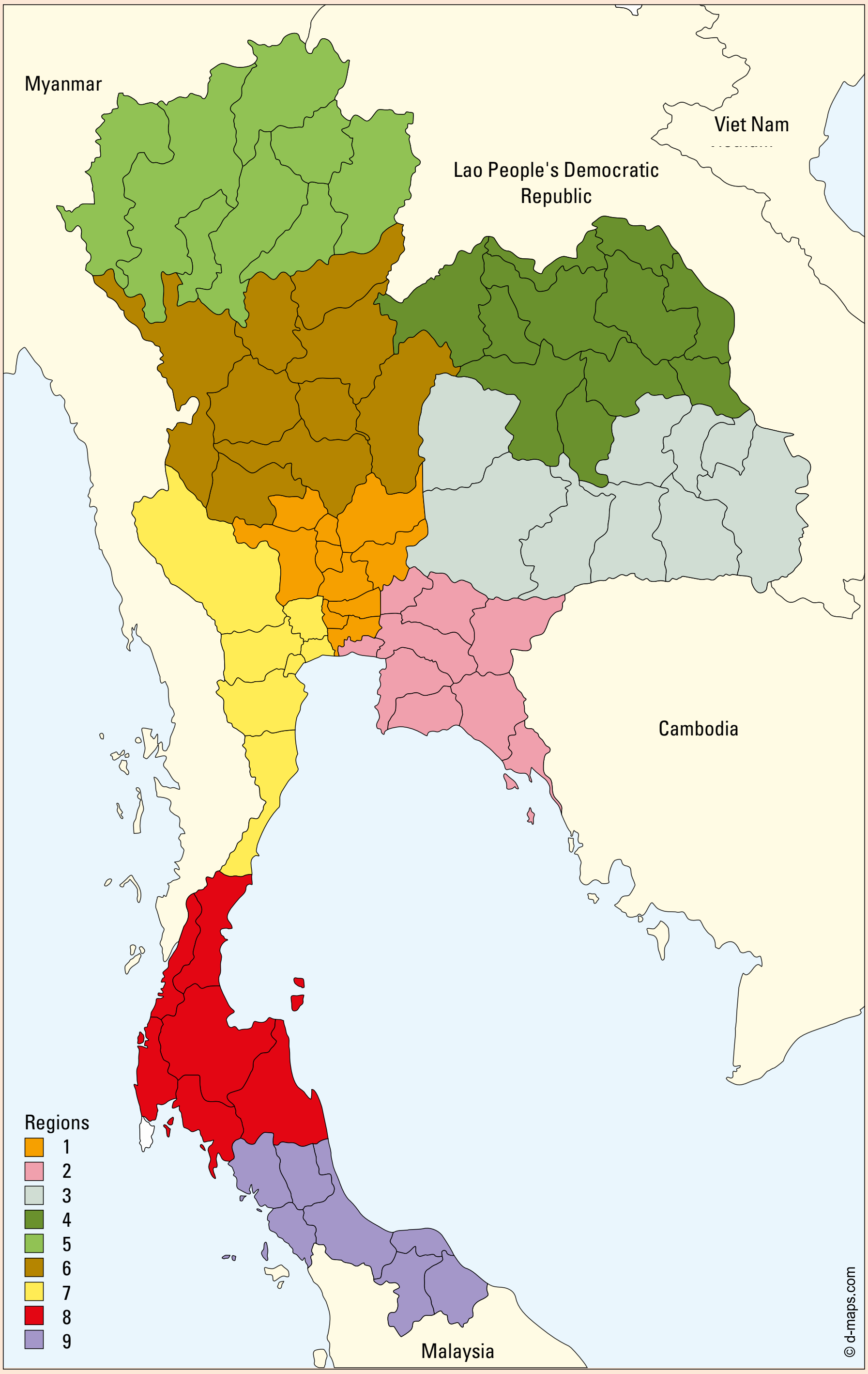
using goat vaccine. Aided by the importation of 200,000 doses of antiserum, this campaign was immediately effective with rinderpest being finally eliminated from the western provinces of Ratchaburi, Kanchanaburi and Suphanburi. Thereafter, the disease only ever recurred twice, once in 1946 and once in 1948, both outbreaks being attributed to transhumance bringing the disease from the north-eastern to the central parts of the kingdom. Further spread of the disease was prevented by movement controls and three years of mass vaccination.

Rinderpest recurred in the north-eastern provinces of Buriram, Surin and Nakhonratchasima in 1951 and 1956 due to livestock smuggling from Cambodia. In these instances, mass vaccination was combined with the slaughter of sick animals.

From 1978 until 1995 Thailand continued with mass vaccination against rinderpest using either lapinised vaccine (Nakamura III strain) for cattle and water buffaloes or lapinised–avianised vaccine for pigs. Annual returns, indicate the administration of

FIG. 2
MAP OF THAILAND SHOWING DEMARCATION OF LIVESTOCK ADMINISTRATIVE REGIONS

Source: D-maps, 2020 (3), modified to indicate administrative regions



totals of around 2.5 million doses of lapinised virus vaccine and 340,000 doses of lapinised–avianised vaccine.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

The national passive surveillance system failed to detect rinderpest after 1956.

For the purpose of qualifying as free from rinderpest infection, a series of village searches were undertaken in each of 2000, 2001 and 2002 (Table I) involving all livestock operation centres and provincial livestock offices throughout the country; 129,572 searches among 70,014 villages failed to disclose any sign of rinderpest.

Over the same period rinderpest competitive enzyme-linked immunosorbent assays

TABLE I
VILLAGE SEARCHING SCHEDULE FOR RINDERPEST

Livestock administrative region	Number of villages	Number of villages searched			
		2000	2001	2002	Total number of searches
1	5,519	3,447	3,699	2,585	9,651
2	4,980	2,871	2,787	2,498	8,156
3	15,511	11,591	10,846	9,958	32,395
4	15,018	10,631	10,222	8,514	29,367
5	7,422	4,471	4,730	4,121	13,322
6	7,644	4,950	4,985	4,323	14,258
7	5,396	3,575	3,473	2,977	10,025
8	4,129	2,289	2,375	2,001	6,665
9	4,095	1,949	1,970	1,814	5,733
Total	**70,014**	**45,774**	**45,087**	**38,711**	**129,572**

(c-ELISAs; see Chapter 3.3) were carried out on samples collected across the nine livestock administrative regions shown in Table II. None of these 14,997 samples tested positive for rinderpest.

TABLE II
SAMPLING DISTRIBUTION FOR RINDERPEST C-ELISAS, 2000–2002

Region	Number of tests		
	2000	2001	2002
1	596	618	292
2	700	698	375
3	665	632	320
4	720	619	320
5	682	712	477
6	720	720	580
7	701	716	411
8	587	690	0
9	711	495	0

DOCUMENTARY EVIDENCE

Based on the above results the World Organisation for Animal Health (OIE) Scientific Commission recommended recognition of Thailand as a rinderpest-free country in 2004 (2).

References

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3. D-maps.com (2020). – Map of Thailand. Available at: https://www.d-maps.com (accessed on 9 June 2021).

CHAPTER 4.16

TIMELINE FOR CHINA AND SOUTHEAST ASIA

Countries in China and Southeast Asia on the Global List of Countries officially recognised as free from rinderpest infection as at May 2011

Source: United Nations (2020). – Map of the world. Available at: www.un.org/geospatial/content/map-world (accessed on 2 October 2021).
Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

YEAR	COUNTRY / CROSS REFERENCE								
	CAMBODIA			CHINA/CHAPTER 4.15.1			LAO PEOPLE'S DEMOCRATIC REPUBLIC		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
Background notes	Endemic in cattle and buffaloes throughout early 20th century			Winter epidemics in early 20th century but pandemic 1938–1941			Endemic in cattle and buffaloes throughout early 20th century		
1897									
1898									
1899									
1945		+			+				
1946		+			+			+	
1947		+			+			+	
1948		+			+			+	
1949		+			71.021	1,100***		+	
1950		+			38.515	3.985		+	
1951		+			52.622	8.985		+	
1952	Vaccination with expensive inactivated vaccine	+		Five-year eradication plan successfully implemented	23.395	4.205		+	
1953		230			35.045	1.430		+	
1954		164			29.505	1.013		+	
1955		171			645	1.275		+	
1956		102			120	1.067		+	
1957	In 1957, FAO introduced lapinised rinderpest vaccine; in 1962 Japanese Government introduced lapinised-avianised vaccine	106				...		+	
1958		41				...		+	
1959		32				...	Sporadic outbreaks along border with Cambodia and Thailand	+	
1960		11				...		+	
1961		53				...		+	
1962		13				...		+	
1963		11				...		+	
1964		2				...		+	
1965	In addition, FAO experts Fukosho and Furanti joined Colombo Plan experts Ito and Sonoda					...		+	
1966						...	Mild outbreaks in south	28	
1967						...			
1968						...			
1969					Tibet	...			
1970									
1971									
1972									
1973									
1974									
1975									
1976									
1977									
1978									
2002									
2003									
2004									

LEGEND

...* etc.	*Routine vaccination by Veterinary Services, number of vaccinations not known*	+	*Virus endemic: number of outbreaks in the year not recorded*
120**etc.	*Routine vaccination by Veterinary Services, number × 1,000*	25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
117***etc.	*Emergency vaccination by Veterinary Services funded by FAO or donor, number × 1,000*		*Unreported*
FAO	*Food and Agriculture Organization of the United Nations*	OIE	*World Organisation for Animal Health*
TCRV	*tissue culture rinderpest vaccine*		

YEAR	COUNTRY / CROSS REFERENCE								
	PHILIPPINES			THAILAND/CHAPTER 4.15.2			VIET NAM		
	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations	Narrative	Number of outbreaks	Vaccinations
Background notes	First recorded 1882, massive outbreak 1886, eliminated 1936, reintroduced 1940s and eliminated 1955			Contingency vaccination continued from 1978 to 1995 – data not shown			1897, presence of rinderpest recognised by Carré and Fraimbault		
1897									
1898									
1899									
1945		+	...		104,526 deaths	...		+	...
1946		+	...	Phased national eradication scheme 1946–1950		...		+	...
1947		+	...		+	...		293	...
1948		+	...		+	...		120	...
1949	Brought under control with lapinised virus grown in pigs	+	...		+	...		115	...
1950		+	...		+	...		74	...
1951		+	...		+	...		21	...
1952		+	...		0	...		17	...
1953		+	...	Rinderpest-free	0	257		8	...
1954		+	...			506		0	...
1955		+	...		0	665		1	...
1956			...	Re-entry from Cambodia eliminated with FAO help	+	445		5	...
1957			...			340		4	...
1958			...			735		1	...
1959			...			727		3	...
1960			...			271		1	...
1961						266		1	...
1962						390		2	...
1963						555		3	...
1964						387		0	...
1965						401		15	...
1966						443		10	...
1967							TCRV introduced	18	...
1968								6	...
1969								0	...
1970								1	...
1971								10	...
1972								+	...
1973								+	105
1974								+	119
1975								+	137
1976								+	182
1977								+	202
1978									225

LEGEND

...* etc.	*Routine vaccination by Veterinary Services, number of vaccinations not known*	+	*Virus endemic: number of outbreaks in the year not recorded*
120**etc.	*Routine vaccination by Veterinary Services, number × 1,000*	25 etc.	*Virus endemic: number denotes total outbreaks recorded in the year*
117***etc.	*Emergency vaccination by Veterinary Services funded by FAO or donor, number × 1,000*		*Unreported*
FAO	*Food and Agriculture Organization of the United Nations*	OIE	*World Organisation for Animal Health*
TCRV	*tissue culture rinderpest vaccine*		

CHAPTER 4.17

INTRODUCTION TO THE RECENT HISTORY OF AND EVIDENCE FOR ERADICATION OF RINDERPEST FROM THE RUSSIAN FEDERATION AND CENTRAL ASIA

When the Russian Federation eradicated rinderpest in 1928 the country was fearful that the virus could re-enter from the republics to the south. To limit this danger, a vaccinated belt was maintained along Russia's southern border. Latterly, the vaccine used in this belt was the K37/70 live attenuated strain. Albeit without categorical proof, it appears that this strain could occasionally revert to a virulent and transmissible form (see Chapter 2.7). Thus rinderpest occurred on the border with Mongolia twice, once in 1991 and again in 1992. It did so again in 1998 on the border with China. Although these outbreaks were limited in extent, in consequence the Russian Federation was placed in the position of having to undertake large-scale surveillance in order to gain recognition as a rinderpest-free country.

At the time the outbreaks occurred on the border with the Russian Federation, Mongolia had not reported rinderpest since 1947 and had not used rinderpest vaccine since 1948. Vaccination was reintroduced in 1991 and continued until 1997. Subsequent surveillance routines were required to gain recognition as a rinderpest-free country.

Kazakhstan was free of rinderpest in 1927 but employed vaccination along the border with China in a programme ending in 1991. In 2006, K37/70 vaccine was used on the border with Kyrgyzstan in the east and Turkmenistan in the west, compromising recognition of freedom on a historical basis.

In addition, each of the following countries needed to provide surveillance results to be considered rinderpest-free:

- Uzbekistan, which had remained rinderpest free after 1928, but vaccinated from 1970 to 1998;
- Tajikistan, which had reported an outbreak in 1949 and had vaccinated along the borders with Afghanistan and China between 1949 and 2002;
- Turkmenistan, which reported rinderpest in 1954 and had vaccinated young cattle on the border with Afghanistan from 1954 to 2001.

The evidence provided by the Russian Federation and the Central Asian republics is provided in the following chapters. Kyrgyzstan never reported rinderpest and stopped vaccinating against it in 1972, thus qualifying the country for consideration as historically rinderpest free.

CHAPTER 4.17.1

KAZAKHSTAN

Z. NIGMAT KHAMITOVICH

Former Deputy Chairperson of State Inspection, Ministry of Agriculture, Kazakhstan

SUMMARY **Rinderpest was endemic across Kazakhstan throughout the 19th century but was eradicated in 1927 by a combination of vaccination using the serum–virus method and zoosanitary controls. Vaccination was briefly reintroduced in 2006, compromising the country's ability to claim historical freedom from rinderpest. Serosurveillance work undertaken in 2009 demonstrated freedom from rinderpest.**

KEYWORDS **Kazakhstan – Rinderpest history – Serosurveillance.**

INTRODUCTION

The Republic of Kazakhstan is a land-locked Central Asian country occupying approximately 2.7 million km^2, making it the ninth largest country in the world. It has borders with the Russian Federation to the north and the China to the east; Mongolia is also to the immediate east but there is no common border. To the south lie Kyrgyzstan, Uzbekistan and Turkmenistan (Fig. 1).

While located primarily in Asia, a small portion of Kazakhstan is also located west of the Urals in eastern Europe.

The terrain extends west to east from the Caspian Sea to the Altay Mountains and north to south from the plains of Western Siberia to the oases and deserts of Central Asia. The Kazakh steppe (plain), with an area of around 804,500 km^2 occupies one-third of the country and is the world's largest dry steppe region. The steppe is characterised by large areas of grasslands, grassland and forest, and sandy regions, primarily occurring in the north or in the basin of the Ural river in the west. Otherwise the country, including the entire west and most of the south, is either semi-desert or desert.

The main political divisions are oblasts (Fig. 2) and rayons.

Cattle are mainly located in the southern oblasts (Almaty, Zhambyl, Kyzylorda, South Kazakhstan) and in the northern oblasts (Akmola, Kostanay, Pavlodar, North Kazakhstan).

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN KAZAKHSTAN

According to historical reports, rinderpest was introduced to Kazakhstan from China through trade caravans and through the livestock of farmers that were migrating from Ukraine and European Russia.

The first descriptions of rinderpest in Kazakhstan date from the early 18th century from the Semirech'ye grasslands in the south-west of Kazakhstan (present-day Almaty oblast).

In the 19th century, rinderpest was widespread and particularly prevalent in regions with a settled livestock industry. Between 1843 and 1848, 21,000 animals died of rinderpest in Akmola, Kokshetau, Bayanaul and Ayaguz counties (Akmola, Pavlodar and East Kazakhstan oblasts), representing a 70% mortality rate. Veterinary reports for 1869–1889 show that the disease was occurring in Akmola oblast, where approximately 3,000 animals died annually. In 1885–1887, 12,500 animals died of rinderpest in Semirech'ye. In oblasts along the borders with China, rinderpest was constantly present. According to reports, in 1905–1909 in Semirech'ye alone, 35,176 animals were killed by

FIG. 1

MAP OF KAZAKHSTAN IN RELATION TO NEIGHBOURING COUNTRIES

Source: United Nations, 2020 (1)

FIG. 2

OBLASTS OF KAZAKHSTAN

Source: OIE-WAHIS

rinderpest. Serious damage was caused to the Kazakh livestock industry in 1908–1909 when the disease spread from Afghanistan to the Akmola region.

Good progress in combating the disease was achieved when people started to follow the regulations of Tsarist Russia, but only in that part of Kazakhstan that was a part of the Russian Empire and then only 10–20 years after their legal adoption. In places where the Russian requirements were met (meaning that rinderpest cases and suspect cases were slaughtered and all necessary veterinary and quarantine measures were taken), the disease was generally eradicated. In places where such measures were omitted and quarantine was not imposed, rinderpest could still spread.

In the late 19th century, vaccination, using the serum–virus method, alongside the slaughter of clinical and suspect cases, was initiated and, by

1903, was in practice throughout Kazakhstan. Annually, tens of thousands of cattle were vaccinated. The best results were reported where vaccination was supported by zoosanitary measures. Thereafter a slaughter policy was included in the list of mandatory rinderpest eradication measures.

In spite of obstacles and failures, the Veterinary Services achieved eradication of rinderpest epidemics throughout the whole territory of Kazakhstan by 1910. However, during the First World War the disease returned to the western part of contemporary Kazakhstan.

During the Soviet era, rinderpest was eradicated by the Soviet government as part of a nationwide programme through enforcement of strict zoosanitary measures together with the use of the serum–virus immunisation method, as perfected by Russian scientists. The last registered case was in the Akmola oblast in 1927 (the last within the Soviet Union as a whole was in 1928). Since that time, no case of rinderpest has ever been registered in Kazakhstan. Nevertheless, during the Soviet era, protective vaccination zones were established along the border with China, but after the dissolution of the Soviet Union in 1991, this programme was ended.

In 2004, following the adoption of a new law in 2002 relating to the creation of a 30 km-wide buffer zone of vaccinated animals along the international border for the prevention and eradication of contagious diseases, Kazakhstan purchased a supply of live attenuated rinderpest vaccine strain Kazakh 37/70 manufactured by the Institute for Biological Safety of the Ministry of Education and Science. The vaccine was not initially deployed and was stored as a contingency supply. Close to its expiry date in 2006, however, it was used to vaccinate 169,500 animals in Almaty oblast and 7,100 in Mangistau oblast. In 2007, because of a reduction of funds allocated to state programmes, vaccination of cattle against rinderpest was terminated and was never reintroduced. Nonetheless, its deployment compromised Kazakhstan's status as a country historically free from rinderpest, necessitating the collection of evidence to demonstrate freedom from infection.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Passive disease monitoring was performed in the course of scheduled diagnostic surveys and through monitoring information regularly submitted by state veterinary inspectors of rural areas, rayons, cities and oblasts.

Given that rinderpest has not been detected in Kazakhstan since 1928, no rinderpest-specific disease surveillance programme was mounted in support of the country's rinderpest-free status. However, the sensitivity of the existing passive reporting system would have been sufficient to have recognised the disease had it occurred.

It was a matter of historical record that a diagnosis of rinderpest was confirmed from Bogdanovsky and Akhalkalasky krais in Georgia in 1989, from Chitinskaya and Tuva oblasts in the Russian Federation in 1991 and in the village of Simonova in the Amurskaya oblast in 1998 (see Chapter 2.7). These outbreaks did not represent any real threat of disease entry to Kazakhstan, as the locations were many kilometres away from Kazakhstan and during the period of economic reforms Kazakhstan did not import any animals or animal products from any of these areas.

As mentioned earlier, rinderpest vaccination was undertaken in 2006 to prevent the entry of the virus into Kazakhstan. It remained technically possible, though highly unlikely, that a modified strain of rinderpest could have crossed the vaccine belt and remained present within the country beyond the cessation of vaccination. Thus, in order to support a claim to be rinderpest-free, it was decided that serosurveillance should be undertaken in 2009 in the area where vaccination was undertaken in 2006, taking samples from rayons in six oblasts. From these, a total of 144 rural counties were randomly selected and from each county an average of 15 samples were collected from one- to three-year-old animals. Results obtained using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3) are presented in Table I. All 2,254 samples were negative.

DOSSIER

Based on an absence of clinical rinderpest since 1928, no rinderpest vaccination since 2007, and a lack of serological evidence of its presence, in 2010 Kazakhstan claimed recognition as a rinderpest-free country. This claim was accepted by the World Organisation for Animal Health (OIE) Scientific Commission (2), and Kazakhstan was officially declared free from rinderpest in May 2011 during the General Session of the World Assembly of the OIE Delegates.

TABLE I
RESULTS OF TESTS ON OBLAST CATTLE SAMPLES COLLECTED IN 2009

Name of rayon	Number of rural districts	Number of samples	Age of animals (years)	Test results
Almaty oblast				
Eskeldy	10	150	1–3	Negative
Karatal	10	150	1–3	Negative
Koksu	10	150	1–6	Negative
Sarkand	10	150	1.5–13	Negative
Mangistau oblast				
Mangistau	14	280	1–5	Negative
Tupkaragan	4	80	1–2	Negative
Karakiya	6	120	1–3	Negative
Munaily	6	120	1–3	Negative
Karaganda oblast				
Buharzhyrau	5	65	1–11	Negative
Nura	5	65	1–10	Negative
Osakarovsky	5	60	1–16	Negative
Shet	5	60	1–3	Negative
West Kazakhstan oblast				
Akzhaik	2	30	1–8	Negative
Burli	2	30	1–4	Negative
Zelenovsky	5	90	1–12	Negative
Terekty	5	100	1–4	Negative
Kyzylorda oblast				
Zhalagash	5	65	1–9	Negative
Syr Darya	5	78	1–3	Negative
Shieli	5	60	1–3	Negative
Zhanakorgan	5	100	1–3	Negative
East Kazakhstan oblast				
Glubokovsky	5	65	1–12	Negative
Ulan	5	65	1–12	Negative
Katon Karagai	5	60	1–12	Negative
Zyryanovskiy	5	60	0.5–10	Negative
Total for Kazakhstan	**144**	**2,254**		**Negative**

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CHAPTER 4.17.2

MONGOLIA

R. SANJAATOGTOKH

Former Director, State Veterinary Service, Ministry of Food and Agriculture, Mongolia

SUMMARY Rinderpest occurred in Mongolia between 1910 and 1947, after which it went unreported until 1991, when an outbreak was recorded in Russian cattle grazing on Mongolian territory; these animals had recently been vaccinated with the K37/70 strain of live attenuated rinderpest vaccine. A further outbreak occurred in 1992 in yaks moving from the Russian Federation to Mongolia. Vaccinations in the areas around the outbreaks continued from 1991 up until 1997, during which time no further outbreaks were reported. Clinical and serological surveillance between 2000 and 2004 failed to disclose evidence of endemic rinderpest.
The World Organisation for Animal Health (OIE) accepted that Mongolia was free of rinderpest in 2005.

KEYWORDS Mongolia – Rinderpest – Serosurveillance – Vaccination

INTRODUCTION

Mongolia covers an area of 1,566,500 km^2 and has borders with the Russian Federation in the north and China in the south. The livestock population in 2004 comprised 1.8 million cattle, 0.5 million yaks, 21 million small ruminants and 0.25 million camels. In addition, there are a number of wildlife species, susceptible to rinderpest, within the order Artiodactyla.

The country is divided into provinces (also known as aimags) and districts (also known as soums) (Fig. 1).

The State Veterinary and Animal Breeding Department is located within the Ministry of Food and Agriculture.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN MONGOLIA

Rinderpest was first officially recognised in 1910, at a time when the disease was also endemic in both China and Russia and when annual losses in Mongolia averaged 120,000 head of cattle. After 1910, Russia operated a rinderpest control programme in Chita province – bordering Mongolia's Dornod (Eastern) province – based on the use of immune serum. From 1918 to 1932, similar control was practised in Mongolia with immune serum produced in Ulaanbaatar. From 1932 to 1947, an inactivated suspension vaccine was introduced. Rinderpest was reported in 1936, 1938, 1945 and 1947, but after 1947 Mongolia remained rinderpest-free until 1991.

In July 1991, rinderpest occurred in Russian cattle grazing in Bayan Uul district, Dornod province (Fig. 1). The outbreak area legally belonged to Mongolia but was separated from the land mass of Mongolia by rivers. The area was only accessible from the Russian Federation, which used it for grazing by bilateral agreement. Three Russian herds totalling 902 cattle were involved; the K37/70 vaccine had just been used in these herds. In total, 167 animals died. Rinderpest was diagnosed by Russian scientists from the All-Russian Animal Health Institute, Vladimir, and the Virology Institute, Pokrov. Intensive searching failed to reveal any clinical suspicion of rinderpest in Mongolian cattle on the Mongolian

FIG. 1

MAP SHOWING THE PROVINCES OF MONGOLIA AND THE LOCATION OF THE 1991 RINDERPEST OUTBREAKS (RED DOTS)

Source: United Nations, 2004 (1), modified to show rinderpest outbreaks

side of the rivers and no antibodies to rinderpest could be found in local cattle.

As a consequence of this outbreak, 1,000 local Mongolian cattle were immediately vaccinated. The following year (1992), vaccinations were undertaken in Bayan Uul and Ereentsav districts (Dornod province) and in Norovlin, Binder, Dadal, Umnudelger districts (Henty province). On these occasions, the tissue culture rinderpest vaccine (TCRV) produced in Ulaanbaatar was used. At a cross-border meeting between Mongolian and Russian specialists, it was agreed that quarantine restrictions would be imposed and that a stamping-out policy would be applied to clinically suspected cases. The outbreak promptly ended.

In December 1991, a separate rinderpest outbreak occurred in a yak herd, which had entered Sagil and Bukhmurun districts – Uvs province – an area 1,600 km west of the earlier Bayan Uul outbreak (Fig. 1). The yaks came from Tuva in the Russian Federation. The disease was diagnosed by the Mongolian Veterinary Services. At the same time, Russian veterinarians diagnosed rinderpest in yaks in Russia's Malchin district and in cattle on 60 state farms. The outbreak continued until May 1992 and resulted in the death of 267 yaks. Yaks and cattle in the affected and surrounding districts were vaccinated with rinderpest bovine old Kabete (RBOK), or Kabete 'O', TCRV.

Vaccination continued up until 1997 in the districts involved in the two rinderpest occurrences (Table I); after this time, all vaccine was withdrawn.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS – 2000, 2002 AND 2004

Clinical surveillance for rinderpest

Routine clinical and laboratory investigations, following reports of erosive diseases, identified bovine virus diarrhoea (BVD), infectious bovine rhinotracheitis (IBR), and foot-and-mouth disease (FMD) in the country during the period 2000–2001. An erosive disease in cattle, which occurred in July 2002 and February 2004, was also rapidly identified as FMD (and eradicated using stamping-out and ring vaccinations).

Specific rinderpest clinical surveillance was carried out in connection with the three serological surveys in 2000, 2002 and 2004. No evidence for clinical signs suggestive of rinderpest was found during these surveys.

Serosurveillance for rinderpest – 2000 and 2002

In 2000, three years after vaccination ended, a total of 12,463 sera samples were collected from cattle (9,790), sheep (1,167), goats (1,021), and camel and horses (485) in 71 districts within 14 provinces, which bordered the Russian Federation and China (and where vaccination had been undertaken). The herds in which the sera were collected were also inspected for any clinical signs of rinderpest; none were found. The target sampling age was two to six years, but in some areas animals up to ten years of age were included in the sample.

All sera were tested using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3) with a cut-off of 50% percentage inhibition (PI). After initial testing 745 sera were identified for retesting from which 40 cattle sera had PI values > 50% and were deemed positive. All sera were traced back to animals more than eight years old and no animals under eight years old were positive. Of the 40 cattle that were positive in the 2000 survey only 5 could be retraced during follow-up investigations in 2002. From the sera collected in 2000 in Bayan Uul district in one herd, one ten-year-old cow tested positive. Follow-up investigation in the same herd in 2002 again showed 3 positive results out of 101 cattle: ten-year old and 12-year-old cattle and the cow that had been previously tested and was now 12 years old. As no animals born after vaccination were positive, it was concluded that the positive sera were due to vaccination.

Otherwise, in 2002, a total of 4,230 sera from cattle (2,210), sheep (965), goats (565) and camels and horses (490) were collected in 45 districts within four central heavily stocked provinces. No vaccinations had been carried out in the provinces sampled. The herds in which the sera were collected were also inspected for clinical signs of rinderpest but none were found. The sampling age group was two to six years. No animals testing positive were found.

SEROLOGICAL SURVEY IN 2004

The sampling frame was a randomised, multi-stage, cross-sectional sampling frame. Complete lists of the *bags* (villages) are available at the Veterinary Department, and in each of the two strata

TABLE I

MONGOLIAN VACCINATION RETURNS FOR THE PERIOD 1991–1997

Province and district	Year	No. of cattle vaccinated	Vaccine used
Dornod: Bayan Uul, Ereentsav	1991	1,000	K37/70
Henty: Norovlin, Binder, Dadal, Umnudelger	1991	89,000	TCRV
Dornod: Bayan Uul, Ereentsav Henty: Norovlin, Binder, Dadal, Umnudelger Uvs: Buh Murun Bayanulgii: Nogoon Nuur	1992	290,500	TCRV
	1993	246,700	TCRV
	1994	128,200	TCRV
	1995	129,500	TCRV
	1996	126,900	TCRV
	1997	129,400	TCRV

314 *bags* were randomly selected from a total of 1701 *bags*. There is a total of 1,012 *bags* in the northern stratum and 689 in the southern stratum. Within each *bag,* one herd was randomly selected, and sera were collected from 18 cattle, which were also randomly selected.

Since it had been more than 13 years since the last outbreak of rinderpest in the northern stratum, it was assumed that any circulating rinderpest virus would have infected a sizeable proportion of animals in an infected herd and also within the *bag*. Any outbreak of clinical erosive disease within the herd would have been reported and detected.

A total of 11,052 sera were collected, of which 9,210 were from cattle and 1,842 were from sheep/goats. At the Veterinary Research Institute, the sera were tested. No animals testing positive were found.

RINDERPEST SURVEILLANCE IN SPECIES OTHER THAN CATTLE

Serum samples from sheep and goats were collected in locations where insufficient cattle were available during the 2000, 2002 and 2004 serological surveys. Only two species of the order Artiodactyla occur in substantial numbers in Mongolia. These are the white-tailed gazelle, (Mongolian name is zeer; estimates in 2003 were greater than 1.5 million animals) and the black tailed gazelle (in 2000 there were approximately 150,000 animals). Sixty-six sera were collected from white-tailed gazelle and tested using the c-ELISA for antibodies to rinderpest virus. No indication of infection of this species was found.

In the northern part of Mongolia, a group of people keep around 240 domestic reindeer. A number of sera were collected from the domestic reindeer and tested; all were negative.

DOSSIER

Based on the fact that the last outbreak of rinderpest in Mongolia occurred in 1992, the last vaccination against rinderpest was carried out in 1997, and, as a result of the random clinical and serological surveys undertaken in 2000, 2002 and 2004, Mongolia applied to the OIE for recognition of freedom from rinderpest infection. The application was upheld by the OIE General Session in May 2005 (1).

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CHAPTER 4.17.3

RUSSIAN FEDERATION

N. VLASOV

Former Deputy Director-General, Veterinary Department, Ministry of Agriculture and Food, Russian Federation

SUMMARY **Following an absence since 1928, two isolated rinderpest outbreaks occurred on Russia's border with Mongolia, approximately 1,300 km from each other – one in July 1991 in Chitinskaya oblast and one in October 1991 in Tuva republic. Prior to these incidents, rinderpest vaccinations were regularly undertaken in the regions bordering China and Mongolia.**

A further outbreak occurred in Amurskaya oblast in 1998, in a village where vaccines had been used. All vaccination was stopped in 2001. Active and passive surveillance of rinderpest was undertaken in 2003.

The World Organisation for Animal Health (OIE) accepted that the Russian Federation was free of rinderpest in March 2010.

KEYWORDS **K37/70 vaccine – Rinderpest occurrences – Russian Federation – Serosurveillance data.**

INTRODUCTION

The territory of the Russian Federation spans some 17 million km² (17,075,400 km²). The country has land borders with Azerbaijan, Belarus, Estonia, Finland, Georgia, Kazakhstan, Latvia, Lithuania, Mongolia, the Democratic People's Republic of Korea, Norway, China, Poland and Ukraine. It is divided into seven federal okrugs, which are subdivided into 89 republics, krais, oblasts and autonomous okrugs (Fig. 1).

As a result of its large territory, the Russian Federation experiences seven climatic zones, which are not all equally suitable for livestock farming. Regions of the Southern federal okrug and adjoining Belgorodskaya, Voronnezhskaya Kurskaya and Bryanskaya oblasts as well as Bashkiria, Tartarstan, Udmurtia, Chuvashia and the Republic of Mordovia of the Privolzhsky federal okrug have the greatest livestock density.

Transhumance and migratory systems are prevalent in the northern part of the country, while commercial production occurs elsewhere in the Russian Federation; stabling and grazing are otherwise the norms.

Control of animal diseases falls under Russian federal law and is undertaken by the State Veterinary Service of the Russian Federation. In the rinderpest incidents discussed below, the diagnosis and coordination of anti-rinderpest activities were implemented by the Federal Centre for Animal Health (FGI 'ARRIAH', Vladimir) – the OIE Collaborating Centre for Diagnosis and Control of Animal Diseases for Eastern Europe, Central Asia and Transcaucasia.

HISTORY OF RINDERPEST IN THE RUSSIAN FEDERATION

After a lapse of 63 years (1928 to 1991), a single rinderpest outbreak occurred in Chitinskaya oblast in July 1991 while a large outbreak began in the Republic of Tuva in October 1991 (Fig. 2). In both outbreaks, the disease occurred in animals that grazed on pastures that were jointly used with Mongolia or leased from Mongolia. In the Chitinskaya incident, a group of recently vaccinated cattle from a Russian farm was moved to Mongolia for grazing with transhumant Mongolian cattle, which then demonstrated the disease (see Chapter 2.7).

FIG. 1
ADMINISTRATIVE DIVISIONS OF THE RUSSIAN FEDERATION
Source: D-maps, 2020 (2), modified to indicate administrative regions

In the Tuva outbreak, in October and December 1991, the disease selectively affected Russian yaks and unvaccinated cattle, mainly young animals. The yaks had been grazing in Mongolia but had been vaccinated as a result of the earlier Chitinskaya incident. In the Russian Federation, the disease primarily occurred in cattle that grazed with the returning yaks, but, because of its subclinical nature in the yaks, the disease was only recognised when these animals came into contact with cattle in the second half of 1992. The cattle showed signs of pyrexia, ocular and nasal discharges, and excessive salivation; deaths also occurred. The disease spread widely. In Chapter 2.7, it is indicated that mortality in Tuva and Chitinskaya amounted to some 2,500 yaks and 10,000 cattle.

The final occurrence of rinderpest in the Russian Federation took place in June 1998 in the Siminovo settlement, Shimanovsky rayon, Amurskaya oblast; the rayon had previously been free from rinderpest since 1946. The rayon is situated 18 km from the River Amur, which constitutes the border with China. In 1998, scheduled vaccinations took place in ten of the border rayons of the Amurskaya oblast, including in Siminovo settlement in Shimanovsky rayon. The settlement held 213 cattle, 200 pigs and 6 goats, but only 58 cattle, amounting to 27% of the population, were vaccinated. There were no communal livestock in the settlement, as all were under backyard ownership and grazed on pastures adjacent to the village. The settlement was surrounded by taiga and without public transport. The vaccine used had been made at the Pokrov biological plant with the K37/70 live attenuated strain of rinderpest virus.

At the end of June, a disease of unknown aetiology occurred shortly after putting the settlement livestock out to graze. The first case involved an 18-month-old bull, which died within two days of being found ill; poisoning was diagnosed. Shortly after, another case occurred, but the animal recovered. About a week later, a number of animals became ill with signs that included pyrexia, anorexia, depression, mucopurulent nasal discharges and a slight cough. Although pasteurellosis and leptospirosis were considered, the animals continued to become ill and antibiotic therapy was ineffectual. During July and August, 70 animals were involved, of which 42 died and 5 underwent emergency slaughter for a case fatality rate of 67%. It was noticed that almost all the cases occurred in animals that had not been vaccinated against rinderpest. At post-mortem examination, changes characteristic of rinderpest were found. In August,

FIG. 2

RINDERPEST OUTBREAKS IN THE RUSSIAN FEDERATION SINCE 1990

Source: D-maps, 2020 (2), modified to indicate outbreaks

① The Kyrinsky rayon of the Chitinkskayan oblast (on summer pastures in Mongolia), July 1991

② The Mongun-Tayginsky and other rayons of the Republic of Tuva – yaks, cattle (joint pastures with Mongolia), October/December 1991, July 1992

③ Village Simonovo of the Simanosvsky rayon of the Amurskaya oblast (18 km from the Chinese border), June/July 1998

samples were submitted to the FGI 'ARRIAH' Vladimir, where rinderpest was diagnosed using the complement fixation test and the agar gel precipitation test and through polymerase chain reaction.

Wild animals crossing the border from neighbouring countries might have introduced the infection, but confirming this would have involved selective shooting in the border areas and the sampling of pathological material; this was not attempted.

The state Veterinary Service revaccinated all cattle, sheep, goats and pigs across the infected rayon, which was also placed under quarantine. No further spread occurred.

Two experimental animals inoculated with material collected from animals affected during the outbreak exhibited nasal and ocular discharges and a brief pyrexia, and the rinderpest virus was isolated in calf kidney cell cultures. This virus was neutralised by sera from animals that had recovered, confirming the diagnosis.

The batch of vaccine originally used was subjected to intensive experimental testing. The batch of vaccine used in Siminovo continued to meet normal production standards. On serial passage, the vaccine virus neither regained virulence nor was transmitted by contact. Yet, when the *F* and *H* genes of K37/70 (and the vaccine parent Kabul virus) and the virus isolated from Siminovo were compared, the primary structure of the *H* gene fragments sequenced were identical, while the *F* gene fragments differed by one substitution (two in the case of the Kabul virus).

HISTORY OF RINDERPEST VACCINES AND VACCINATION IN THE RUSSIAN FEDERATION

An inactivated vaccine was developed between 1948 and 1949 and described as P.M. Bazylev's formol-toluene vaccine against rinderpest. It was produced in biofactories in Chita, Georgia and Azerbaijan. In 1965, a live vaccine was made at the Chita biofactory with the LT strain of rinderpest (a derivative of the Nakamura III lapinised vaccine grown in calf kidney cells), and between 1984 and 1987 the same vaccine was produced at the Pokrov plant. Between 1978 and 1980, the live attenuated vaccine K37/70 was developed by the Kazakhstan Research Institute for Agriculture, and from 1987 it went into production on a commercial scale at the Pokrov plant.

In 1992, the manufacturing of the LT vaccine was recommenced at the All-Russian Research Institute of Veterinary Virology and Microbiology (Pokrov) and the manufacturing of K37/70 was recommenced at the All-Russian Foot and Mouth Disease Research Institute (Vladimir).

Although vaccine production in the Russian Federation ended in 2001, its deployment – subsequent to the events of 1998 – is described as part of a rinderpest control and prevention programme, whereby zonal vaccination was carried out in the regions of Siberia and the far east bordering China and Mongolia between 1998 and 2000 (Table I and Figs 3 and 4). No vaccination was undertaken in 2001. Vaccination was with either the LT vaccine or K37/70.

TABLE I
RINDERPEST VACCINATIONS IN 1998, 1999 AND 2000

Region	No. of cattle vaccinated (thousands)		
	1998	1999	2000
Republic of Gorny Altai	4.4	1.6	
Chitinskaya oblast	40.2	34.2	
Republic of Buryatia	96.5	35.1	
Primorski krai	103.5	327.5	
Khabarovski krai	53.5	14.1	
Amurskaya oblast	155.9	60.9	100
The Jewish autonomous oblast	18.8	7.7	
Republic of Tuva	39.9	38.8	80

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Clinical surveillance

During the period 1998–2004, investigations aimed at detecting possible rinderpest infection in animals were carried out. This surveillance of diseased animals with clinical signs similar to those of rinderpest was carried out in the Central, Southern and North-western federal okrugs. No such clinical signs were found.

FIG. 3
ZONES OF PREVENTIVE VACCINATION OF CATTLE AGAINST RINDERPEST (IN COLOUR) IN THE RUSSIAN FEDERATION IN 1998–1999

Source: D-maps, 2020 (2), modified to indicate zones

FIG. 4

ZONES OF PREVENTIVE VACCINATION OF CATTLE AGAINST RINDERPEST (IN COLOUR) IN THE RUSSIAN FEDERATION IN 2000

Source: D-maps, 2020 (2), modified to indicate zones

FIG. 5

REGIONS OF SERUM SAMPLING FOR RINDERPEST SEROSURVEILLANCE (IN COLOUR) IN THE RUSSIAN FEDERATION IN 2005

Source: D-maps, 2020 (2), modified to indicate sampling regions

Serological surveillance

Serological examinations of animals were carried out to detect antibodies to rinderpest virus in the cattle population of the east and south-east regions of the country. Blood samples were taken only from cattle aged 18 months to 3.5 years. Sampling was performed by the local Veterinary Services, and serology was carried out at the FGI 'ARRIAH'.

During the period 1998–2004, in the FGI 'ARRIAH', Vladimir, 782 blood sera samples were tested for rinderpest-specific antibodies using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; Chapter 3.3). These blood sera samples were collected from cattle and small ruminants, from swine in the Primorski krai (11 rayons), the Republic of Bashkortostan (one rayon), the Orenburgskaya oblast (one rayon) and the Amurskaya oblast (four rayons). No specific antibodies were detected in the tested blood sera samples.

In 2005, 8,076 samples were tested, which were collected in 393 locations (approximately 20 sera samples from each location) in 90 districts of 14 regions of eastern Siberia and Primorski krai (the Amurskaya, Novosibirskaya, Kurganskaya, Omskaya, Chitinskaya, Irkutskaya, Chelyabinskaya, Tyumenskaya oblasts; the Primorsky, Khabarovsky, Altaisky krais; the Jewish autonomous oblast, the Republics of Buryatia and Altai) (Fig. 5).

This sampling volume complied with OIE requirements and corresponded to the 95% confidence level; 88 of them were positive (Table II), and these were additionally tested using the neutralisation test. The additional tests detected no positive samples. Furthermore, each holding where at least one animal was ELISA positive was subjected to additional examination by representatives of the local Veterinary Services, including clinical inspection of the majority of susceptible animals, without detecting signs of rinderpest.

TABLE II
RESULTS OF C-ELISA FOR ANTIBODIES TO RINDERPEST VIRUS ON SERUM SAMPLES COLLECTED IN 2005

Region	No. of district samples	No. of samples collected	No. of positive samples
Amurskaya oblast	10	877	24
Novosibirskaya oblast	5	526	0
Kurganskaya oblast	4	436	1
Primorsky krai	11	453	7
Omskaya oblast	5	529	5
Khabarovsky krai	2	440	0
Ikutskaya oblast	8	660	6
Chelyabinskaya oblast	8	525	1
Tyumenskaya oblast	4	440	3
Altaisky	7	726	0
The Jewish autonomous oblast	4	438	0
Republic of Buryatia	7	664	24
Republic of Altai	5	455	8
Chitinskaya oblast	8	907	9

TABLE III
ORIGIN OF SAMPLES COLLECTED AND TESTED IN 2006

Republic, krai or oblast	Rayon	No. of samples collected
Chitinskaya	Ononsky	100
	Borzinsky	79
	Priargunsky	90
	Kalgansky	34
Khabarovsky	Komsomolsky	25
	Bikinsky	60
	Khabarovsky	60
	Lazo	153
	Najansky	29
	Vyazemsky	120
	Amursky	33
Amurskaya	Arkharinsky	45
	Blagovecshensky	45
	Konstantinovsky	43
	Ivanovsky	45
	Tambovsky	38
	Svobodnensky	45
	Mikailovsky	45
Primorsky	Mikailovsky	89
	Pogranichny	43
	Oktyabrsky	39
	Khasansky	48
	Kirovsky	80
	Spassky	80
	Khorolsky	105
	Lesozavodsky	60
	Dalnerechensky	39
	Ussuriisky	40
	Pozharsky	79
	Khankaisky	80

No samples were taken from wild animals

In 2006, 1,871 cattle sera samples from four regions of the Russian Federation (Table III) were tested by the c-ELISA. All samples were found to be negative. During the course of the clinical inspections, no suspected cases of rinderpest were detected in susceptible animals.

DOSSIER

The above results were submitted to the OIE, requesting recognition of freedom from rinderpest infection. This was accepted (1).

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CHAPTER 4.17.4

TAJIKISTAN

A. NAIMOVISH MAHMADSHOEV

Former First Deputy, Main Board of Veterinary Service, Ministry of Agriculture, Tajikistan

SUMMARY **The last outbreak of rinderpest was reported in Moscowsky district of Khatlon province in 1949. Rinderpest vaccination of animals in the 12 districts bordering Afghanistan and China were conducted between 1949 and 2002, when the vaccine was officially prohibited. Between 2005 and 2006, active disease searches through randomised participatory disease serosurveillance and field investigations were carried out, but they did not confirm the presence of rinderpest.**
The World Organisation for Animal Health (OIE) recognised Tajikistan as free of rinderpest in 2008.

KEYWORDS **Border vaccination – Clinical surveillance – Rinderpest – Serosurveillance – Tajikistan.**

INTRODUCTION

The Republic of Tajikistan is a mountainous, central Asian republic that borders Afghanistan to the south, Uzbekistan to the west, Kyrgyzstan to the north and China to the east (Fig. 1).

The country has four major administrative divisions – Gorniy Badakhshan autonomous oblast (GBAO), Sughd oblast (formerly Leninabad), Khatlon oblast and a group of districts termed Direct Rule districts. The capital is Dushanbe.

In 2008, the livestock population consisted of 1.4 million cattle, 3 million small ruminants and 15,000 yaks. Transhumance does not occur and livestock from neighbouring countries do not enter the country for grazing.

HISTORY OF RINDERPEST AND RINDERPEST VACCINATIONS IN TAJIKISTAN

The last rinderpest outbreak in Tajikistan occurred in 1949 and was detected in the private sector herd within Moskovsky district, Khatlon province (former Kulyab province) in the border area that Tajikistan shares with Afghanistan.

From 1949 to 2002, rinderpest vaccinations were carried out in 12 districts along the borders with China and Afghanistan under the Soviet Union's policy of protecting these borders from an ingress of infection. Prophylactic vaccination was undertaken from 1963 to 1991 using the LT strain of rinderpest, which was made in the Russian Federation. Its further use was banned in January 2002.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Clinical surveillance

During 2005, 21 training courses were conducted for 600 field veterinarians throughout the country on the detection and clinical differentiation of rinderpest, peste des petits ruminants, foot-and-mouth disease, pasteurellosis, vesicular stomatitis, bovine contagious pleuropneumonia, contagious caprine pleuropneumonia, bluetongue, etc. The veterinarians and livestock farmers were aware of clinical signs of the aforementioned diseases and were further educated through posters and brochures.

A randomised participatory disease (PDS) surveillance programme was undertaken in 300 villages

FIG. 1
MAP OF TAJIKISTAN

Source: United Nations, 2009 (1)

across Tajikistan between 2005 and 2007. The results showed that PDS respondents had never observed clinical signs of any disease similar to rinderpest.

Serological surveillance in 2006 and 2007

In 2006, the first random serosurveillance was conducted. This involved 300 randomly selected villages and 6,000 serum samples collected from cattle less than three years old and tested using a competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3). Only seven test samples proved positive. Backtracing indicated that these were non-specific results, and there was no evidence of rinderpest in the areas of investigation.

The second round of serosurveillance was conducted precisely one year later, following the same principle. A total of 6,050 serum samples were collected. All tests proved negative. After two rounds of serosurveillance, 12,050 blood sera had been collected from cattle less than three years old (Table I), tested and proved negative.

TABLE I
DISTRIBUTION OF SAMPLES FOR RINDERPEST C-ELISA TESTING, 2006–2007

Province	No. of samples tested	
	2006	2007
Direct Rule districts	1,600	1,630
Sughd	1,420	1,400
Khatlon	2,180	2,200
Gorniy Badakhshan autonomous oblast	800	820

CONCLUSION

In 2008, the above information was compiled in a dossier of information requesting freedom from rinderpest disease and infection. The dossier was submitted to the OIE, and the request was accepted (2).

References

1. United Nations (2009). - Map of Tajikistan. Available at: www.un.org/geospatial/content/tajikistan (accessed on 9 June 2021).
2. World Organisation for Animal Health (OIE) (2008). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 19–21 February 2008. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_feb2008.pdf (accessed on 2 August 2019).

CHAPTER 4.17.5

TURKMENISTAN

M. GAZAKOVITCH GOTCHMURADOV

Former Director of Veterinary Services, Ministry of Agriculture, Turkmenistan

SUMMARY **No rinderpest was seen in Turkmenistan after 1954, but vaccination continued along its borders with Afghanistan and the Islamic Republic of Iran until 2001. Clinical and serological surveillance after 2005 demonstrated that Turkmenistan was free from rinderpest. In 2009, this information was compiled in a dossier to the World Organisation for Animal Health (OIE), which granted freedom from rinderpest.**

KEYWORDS **Border vaccination – Clinical surveillance – Rinderpest – Serosurveillance – Turkmenistan.**

INTRODUCTION

Turkmenistan is a central Asian country bordered to the north by Kazakhstan and Uzbekistan and to the south by Afghanistan and the Islamic Republic of Iran. The Caspian Sea – across which lies the Russian Federation and Azerbaijan – is situated to the west of the country. Of the country's approximately 492,000 km^2 area, 80% is made up of the Karakum desert. The country has five administrative velayets: Balkan, Dashhowuz, Lebap, Ahal and Mary (Fig. 1).

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN TURKMENISTAN

The last recorded outbreak of rinderpest was in the Kalinin collective farm, Tagatbazar district, Mary velayat in 1954. The 500 animals that were involved were slaughtered and burned. Unaffected stock were vaccinated with a Russian vaccine.

Since 1954, there have been no confirmed cases of rinderpest in Turkmenistan. From 1954 to 2001, young stock in the districts bordering Afghanistan and the Islamic Republic of Iran were vaccinated on an annual basis; vaccination ceased in 2001.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Clinical surveillance and active disease searching

When Turkmenistan was part of the Soviet Union, clinical surveillance of exotic diseases, including rinderpest, was routine along its borders with Afghanistan and the Islamic Republic of Iran. Rinderpest was never suspected, and up until 1999 there was no call for a laboratory diagnosis.

In 2005, under the Food and Agriculture Organization of the United Nations (FAO) regional project 'Controlling Transboundary Animal Diseases in Central Asian Countries' (see also Chapter 5.3), 273 veterinarians attended training courses on the detection and differential diagnosis of rinderpest. In their subsequent routine surveillance work, these officers did not detect rinderpest in Turkmenistan.

FIG. 1
POLITICAL DIVISIONS OF TURKMENISTAN

Source: United Nations, 2004 (1)

In addition, participatory disease surveillance (PDS) was conducted in 2006 without detecting any indications of rinderpest.

Serosurveillance

Beginning in 2006, two rounds of rinderpest serosurveillance were carried out in 300 villages that were randomly selected from across the entire country. Twenty animals from each village were bled and tested for the presence of antibodies using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3). During the first round, 6,000 samples were collected. In the second round, 6,060 samples (from different villages) were collected and tested. Samples were tested by the newly established ELISA laboratory at the premises of the Veterinary Unit, Ashgabat. The distribution and results by velayat are shown in Table I. The results did not show the presence of antibodies to rinderpest in the 12,060 samples examined.

CONCLUSION

In 2007, based on the absence of clinical evidence of rinderpest since 1954 and an absence of rinderpest antibodies in the unvaccinated cattle population, Turkmenistan demonstrated that it was free from rinderpest infection.

In 2009, the above information was compiled in a dossier of information requesting for freedom from rinderpest disease and infection, which was submitted to the OIE. The request was accepted by the OIE Specialist Commissions (2), and Turkmenistan was officially declared free from rinderpest in May 2011 during the General Session of the World Assembly of the OIE Delegates.

TABLE I
VELAYAT SERUM SAMPLING PATTERN, 2006–2007, AND RESULTS

Velayat	No. of samples collected		No. of samples c-ELISA +ve/ no. samples tested
	2006	2007	
Lebap	1,500	1,500	0/3,000
Ahal	1,500	1,520	0/3,020
Mary	1,420	1,400	0/2,820
Dashhowuz	1,080	600	0/1,680
Balkan	500	1,040	0/1,540

References

1. United Nations (2004). - Map of Turkmenistan. Available at: www.un.org/geospatial/content/turkmenistan (accessed on 9 June 2021).
2. World Organisation for Animal Health (OIE) (2011). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 1–4 February 2011. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_feb2011.pdf (accessed on 8 August 2019).

CHAPTER 4.17.6

UZBEKISTAN

M. VAHABJON MAKHMUDOVICH

Former Chief Veterinary Officer, Ministry of Agriculture and Water Resources, Uzbekistan

SUMMARY **Uzbekistan last experienced rinderpest in 1928, but it maintained a vaccination programme on its border with Afghanistan from 1970 to 1998. To qualify as a rinderpest-free country, Uzbekistan undertook a participatory disease surveillance (PDS) programme across the country between 2005 and 2007. This failed to disclose evidence of recent rinderpest. Similarly, serosurveillance carried out in 2006 and 2007 failed to find evidence of rinderpest. A dossier was successfully submitted to the World Organisation for Animal Health (OIE) in 2007.**

KEYWORDS **Border vaccination – Clinical surveillance – Rinderpest – Serosurveillance – Uzbekistan**

INTRODUCTION

The Republic of Uzbekistan is a central Asian country bordered by Kazakhstan to the north and west, Tajikistan and Kyrgyzstan to the east, and Afghanistan to the south. The country is divided into the 12 provinces of Andijan, Bukhara, Ferghana, Djizakh, Namangan, Navoi, Kashkadarya, Samarqand, Syrdarya, Surkhandarya, Tashkent, Xorazm and the Karakalpakstan Republic (Fig. 1).

HISTORY OF RINDERPEST AND RINDERPEST VACCINATION IN UZBEKISTAN

The last outbreak of rinderpest in Uzbekistan was registered in 1928, in the Surkhandarya (also known as Surkondaryo) province. At this time, the country was a republic within the Soviet Union. Information provided by veterinarians who witnessed the outbreak indicates that all animals with clinical signs and a high fever were slaughtered and burnt. The remaining susceptible livestock population was vaccinated using vaccine produced by the Soviet Union.

From 1970 to 1998, annual vaccination of between 90,000 and 100,000 young livestock was conducted by the Main State Veterinary Department in the Angor, Murzabad, Termez and Jarkurgan districts of Surkhandarya province on the border with Afghanistan. The vaccine was manufactured in the Russian Federation. This programme was terminated in 1998.

CLINICAL AND SEROLOGICAL SURVEILLANCE RESULTS

Clinical surveillance and active disease searching

There are about 7,695 villages and sub-villages in Uzbekistan; most are served by state veterinarians and the rest by private veterinarians. By law, each veterinarian – whether a state or private veterinary officer – submits a monthly report on the work done for the state Veterinary Service. All clinical cases of any disease are described in these reports. Rinderpest has never been identified.

Within the Food and Agriculture Organization of the United Nations (FAO) regional project 'Controlling Transboundary Animal Diseases in Central Asian countries', 2004–2012 (see also Chapter 5.3), one of the activities was to conduct training workshops throughout the country for the clinical

FIG. 1
TERRITORIAL DIVISIONS WITHIN UZBEKISTAN
Source: United Nations, 2004 (1)

recognition of the main transboundary animal diseases, including rinderpest. Field veterinarians and progressive farmers were invited to attend these training workshops. Written information provided by the 750 participating veterinarians indicated that rinderpest no longer existed in Uzbekistan.

In addition, participatory disease surveillance (PDS) activities were carried out in 300 randomly selected villages between 2005 and 2007. The extent of the three-year, village-based active disease search programme throughout Uzbekistan is given in Table I. PDS respondents had never observed clinical signs of rinderpest.

Serosurveillance

Two rounds of serosurveillance were carried out across the whole country in 2005 and 2007 (Table II). In the first round, 6,600 serum samples from cattle aged between two and six years were collected and tested. These samples were collected from 300 randomly selected villages and tested using the rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3). Only 13 samples tested proved positive. Nevertheless, backtracing proved that these animals had never showed any signs of rinderpest, and there had been no report of rinderpest in the area; most probably, these samples were non-specifically positive.

One year later, the second round was conducted following the same principle, but different villages were selected. During this round, 6,000 serum samples were collected and tested using the c-ELISA. Only six samples tested proved positive, which, on investigation, were determined false positives. In summary, after two rounds of serosurveillance, 12,600 blood sera had been examined from cattle aged between two and six years, with 19 animals having non-specific antibodies to the rinderpest virus.

CONCLUSION

An analysis of the results of the serosurveillance and the passive disease reporting system clearly demonstrated that, in 2007, Uzbekistan was free from rinderpest.

In 2007, the above information was compiled in a dossier of information requesting freedom from

TABLE I
SUMMARY OF THE EXTENT OF THE THREE-YEAR, VILLAGE-BASED ACTIVE DISEASE SEARCH PROGRAMME IN UZBEKISTAN

Provinces	Total villages and sub-villages in province	No. of villages randomly selected in given year			Total searched
		2005	2006	2007	
Karakalpakstan Republic	775	0	0	20	**20**
Andijan	475	0	20	0	**20**
Bukhara	600	32	0	0	**32**
Ferghana	835	0	0	22	**22**
Djizakh	525	0	24	0	**24**
Namangan	565	0	20	0	**20**
Navoi	270	32	0	0	**32**
Kashkadarya	805	0	28	0	**28**
Samarqand	625	0	34	0	**34**
Syrdarya	360	0	0	14	**14**
Surkhandarya	570	0	0	20	**20**
Tashkent	730	0	0	18	**18**
Xorazm	560	0	0	16	**16**
Total	**7,695**	**64**	**126**	**110**	**300**

TABLE II
PROVINCIAL VILLAGE SAMPLING PATTERN AND SAMPLING NUMBERS, 2006–2007

Province	No. of villages randomly selected		No. of serum samples collected	
	2006	2007	2006	2007
Karakalpakstan Republic	24	24	528	480
Andijan	22	22	484	440
Bukhara	22	22	484	440
Ferghana	24	24	480	480
Djizakh	22	22	484	440
Namangan	22	22	484	440
Navoi	20	20	440	400
Kashkadarya	28	28	616	560
Samarqand	28	28	616	560
Surkhadarya	24	24	528	480
Syrdarya	16	16	352	320
Tashkent	24	24	528	480
Xorazm	24	24	528	480

rinderpest disease and infection, which was submitted to the OIE. The request was accepted by the OIE Scientific Commission (2), and Uzbekistan was officially declared free from rinderpest in May 2008 during the General Session of the World Assembly of the OIE Delegates.

References

1. United Nations (2004). - Map of Uzbekistan. Available at: www.un.org/geospatial/content/uzbekistan (accessed on 9 June 2021).
2. World Organisation for Animal Health (OIE) (2008). – Report of the meeting of the OIE Scientific Commission for Animal Diseases, 19–21 February 2008. Available at: www.oie.int/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/SCAD/A_SCAD_feb2008.pdf (accessed on 2 August 2019).

PART 5
STAKEHOLDERS

CHAPTERS

CHAPTER 5.1

ROLE OF VETERINARY SERVICES AS THE MAJOR STAKEHOLDER IN THE CONTROL AND ERADICATION OF RINDERPEST AND OTHER HIGHLY CONTAGIOUS DISEASES

J. DOMENECH

La Fabrèguerie, 12170 Lédergues, France (Formerly at the World Organisation for Animal Health [OIE], 12 rue de Prony, 75017, Paris, France)

SUMMARY **This article outlines the roles of national Veterinary Services as a major stakeholder in the implementation of veterinary strategies, legislation and programmes, including measures to control and eradicate rinderpest and other highly contagious diseases. Satisfactory enforcement of animal health policies relies not only on legislation but also on political commitment. Epidemiological surveillance and reporting are presented as key components, since they are at the basis of detection, early warning and response to animal disease events. Other roles in various domains are described, and the importance of good governance, including compliance with international standards, quality of Veterinary Services, effective chain of command and private and public stakeholder partnership, are underlined as is legislative backing. National, regional and international levels are addressed and support from the World Organisation for Animal Health (OIE) and other international or regional organisations are mentioned.**

KEYWORDS **Epidemiosurveillance – Eradication programmes – Implementation of control measures – Rinderpest – Veterinary legislation – Veterinary Services.**

INTRODUCTION

The overall role of Veterinary Services is ensuring food security through the provision of sufficient animal protein and economic security for people whose livelihood depends on livestock production or trade, protecting the public against dangerous zoonotic diseases, ensuring the safety of animal food products (1) and securing trade.

Rinderpest was at the origin of the establishment of the veterinary profession and subsequently the Veterinary Services. Such services have the authority to devise national health laws, policies and regulations, which have to be in compliance with the OIE standards, as set out in the OIE *Terrestrial* and *Aquatic Animal Health Codes* (2, 3). They play a leading part in legislation enforcement (4, 5, 6).

Veterinary Services have played a major role since early times in controlling and then eradicating rinderpest, but if they were first directed towards the prevention and control of diseases, the extension of their mandates resulted in stronger cooperation with all interested parties, particularly those in charge of public health and protection of the environment, as well as intergovernmental organisations, in particular the OIE, the Codex Alimentarius Commission, the World Trade Organization (WTO) Sanitary and Phytosanitary (SPS) Committee or United Nations (UN) technical agencies, such as the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO).

DEFINITIONS

The definitions and some key elements of the organisation and missions of national Veterinary Services and related bodies are described in the OIE *Codes* (2, 3) (Box 1).

Governance

Effective Veterinary Services are based on international standards and principles of good governance.

Good veterinary governance implies that Veterinary Services follow fundamental principles of quality, including independence, impartiality and integrity. Good governance also means that it has to be participatory, consensus-oriented, accountable, transparent, responsive, effective and efficient, equitable and inclusive, without duplication of other parts of public or private services/bodies, and follow the rule of law (1, 7, 8).

Therefore, good veterinary governance addresses many questions, in particular the legal and institutional aspects of veterinary policies, effective chain of command or public–private partnerships among all the private and public stakeholders.

Chain of command

The appropriate structure and chain of command are crucial elements with regard to the effectiveness of Veterinary Services activities.

The stability of the Veterinary Services structure has to be ensured, and policies have to be sustained over time through national strategic plans.

Veterinary Services can have varied structures, from centralised to completely decentralised. Those with a strong central Veterinary Authority have a top-down chain of command, and those with a federal system have a decentralisation of powers and resources. But to be successful, the decentralised systems have to be well coordinated

BOX 1
DEFINITIONS FROM THE OIE *TERRESTRIAL* AND *AQUATIC ANIMAL HEALTH CODES*

Veterinary Services means the governmental and non-governmental organisations that implement animal health and welfare measures and other standards and recommendations in the OIE *Terrestrial* and *Aquatic Animal Health Codes* in the territory.
National Veterinary Services include (i) public service veterinarians (and other categories of public personnel, e.g. administrative staff, communication officers, legal experts) responsible for preparing and enforcing the laws related to disease control, food safety and animal welfare, for implementing the measures (or monitoring and evaluating the implementation of measures delegated to the private stakeholders) in these fields and for contributing to the safeguard of biodiversity, and (ii) private veterinarians and other professionals working in these fields.
The Veterinary Services are under the overall control and direction of the Veterinary Authority, which is a governmental authority (typically a national government service of the ministry in charge of animal health and welfare) responsible for drafting and implementing (or supervising the delegated implementation) of national laws and regulations, policies, programmes and measures, international veterinary certification and other standards and recommendations related to animal health and welfare. The Chief Veterinary Officer (CVO) is the head of the Veterinary Authority and private sector organisations, veterinarians, veterinary paraprofessionals or aquatic animal health professionals have to be accredited by the Veterinary Authority to deliver the delegated functions.
The Veterinary statutory body is an autonomous regulatory body for veterinarians and veterinary paraprofessionals. It is not part of the national [Veterinary Services]. Its role is to oversee the quality and competence of veterinarians in a country and in so doing it can ensure the excellence of the veterinary profession (e.g. through appropriately licensing or registering veterinary professionals, providing minimum standards for education...).

and carefully structured to maintain appropriate national response capacity and information flow, in order to ensure notification of outbreaks of animal disease and responses to them. Concerning highly contagious diseases, a proper direct chain of command has been shown to be very effective with regard to sanitary information and allowing more dynamic action in response to disease events.

Legislative backing

Laws and regulations support the realisation of policy objectives, and they give Veterinary Services the authority to implement measures related to the management of animal disease. It is important that all relevant stakeholders be involved from the public sector and from economic and civil society, e.g. associations dealing with the protection of consumers or animals or the environment (1).

To support harmonisation of rules in the veterinary field, the OIE provides *Guidelines on Veterinary Legislation* (9), and FAO also assists countries in this field.

'Public good' concept

Rinderpest was typically a highly contagious disease of a transboundary nature and the concept of 'public good', which was rather new and not theorised as such at the time, affirming the need for public action, applies here. The benefits of controlling animal diseases and preventing the risks posed to humans are international and intergenerational in scope. Moreover, at regional and international levels, the failure of one country may have dramatic negative consequences for animal health in neighbouring or more distant countries. Therefore, prevention and control of animal diseases carried out by an animal health system operated by national Veterinary Services are considered to be in the global public interest, and this animal health system qualifies as 'public good' (1, 4, 5).

KEY ROLES OF VETERINARY SERVICES IN RINDERPEST ERADICATION

Background

Many documents have described and regularly updated the list of Veterinary Services roles and activities, and among the most comprehensive sources are the OIE *Codes* and other OIE publications. The principal roles can be classified into relevant headings (Box 2).

Effective Veterinary Services need good governance and the proper application of international standards, which depend on the quality of these services (2, 10, 11).

The OIE is in charge of setting international standards and guidelines for animal health and welfare within the framework of the WTO and its SPS Agreement (see Part 5, Chapter 5.2, on the role of the OIE in rinderpest eradication).

BOX 2
ROLES OF VETERINARY SERVICES

Transversal cross-cutting roles such as the preparation of legislation, regulations and policies, evaluation and monitoring of the results of programmes on animal health, food safety, animal welfare and their contribution to the environment (wildlife domains), controls for veterinary medicines and laboratory biologicals, audits of the control systems, and continuing education and training.

Roles in animal health such as surveillance and reporting, definition and implementation of programmes and activities to prevent, control or eradicate diseases, and emergency preparedness (see the text for more details).

Roles in food safety such as assessment of compliance with food safety requirements when the primary responsibility is given by the Competent Authority to private operators, identification, registration and inspection of establishments involved, traceability of products and certification for international trade, inspection of animals and meat at slaughter (or control delegated) processing and distribution stages, verification of process controls when they are delegated, surveillance of and response to foodborne disease outbreaks, and direction given to farmers on practices regarding prudent use of veterinary medicinal products.

Roles in animal welfare, such as provisions for direct intervention in the event of neglect by animal keepers, prohibition of the abandonment of animals and management of abandoned animals.

Roles in the environment, such as protection of wildlife health to conserve biodiversity and to avoid the transmission of diseases to domestic animals and humans.

These standards are adopted at the OIE annual General Assembly by all OIE delegates who are representing their national governments (12). Actually, the OIE is both at the service of its Members and a master proposing standards and other guidelines prepared by a combination of nominated chiefs of Veterinary Services and scientific experts.

The need for evaluation of the quality of Veterinary Services is addressed in a chapter of the OIE *Terrestrial Animal Health Code* (*Terrestrial Code*, Chapter 3.2. Evaluation of Veterinary Services [2]), and a specific tool has been developed, the OIE PVS (Performance of Veterinary Services) Tool (10), which is part of a full OIE PVS Pathway (a global programme to support the improvement of a country's Veterinary Services).

Other international organisations have supported Veterinary Services in their fight against rinderpest, particularly the FAO, as well as regional organisations (e.g. Interafrican Bureau for Animal Resources, IBAR, in Africa, and the Association of Southeast Asian Nations, ASEAN, in Asia).

Rinderpest control and eradication at national level

Three major activities related to rinderpest control and eradication can be emphasised:

a) implementation of sanitary measures to prevent and control diseases;
b) delivery and implementation of other disease prevention and control measures, particularly through vaccination;
c) surveillance and disease reporting.

Implementation of sanitary measures

Sanitary measures were first defined and then introduced successfully to control rinderpest centuries ago (13, 14, 15) (see also Part 3, Chapter 3.2), long before the aetiology of the disease was known. Despite the availability of effective vaccines, sanitary measures are often a valuable means of eliminating a pathogen in an infected country or in preventing the introduction and spread of pathogens in countries or regions free of the disease.

In 1995, rinderpest became the second disease to be included in the OIE official recognition of countries' disease status procedures (just after foot-and-mouth disease – FMD), and this was a major step in the eradication programme.

Sanitary measures are based on the best updated scientific knowledge, and they are in official documents published by international organisations, such as the OIE *Codes* and *Manuals*, FAO guidelines, European Commission regulations and other legal acts, and non-binding documents or national standards and regulations.

Official Veterinary Services are responsible for devising laws and regulations that are informed by ethical principles, values and policy objectives. Laws and regulations support the realisation of policy objectives, and they give Veterinary Services the authority to implement measures related to effective management of any animal disease, provided that strong political will and appropriate financing are guaranteed.

But if it seems to be relatively easy for stock owners and other operators to accept the cost and various constraints of sanitary measures (as well as vaccination) during epidemics, it will be much more difficult during endemic periods, between upsurges in outbreaks or when the disease has been eliminated (16). The role of local political powers and administrations is very important to persuade herders and other operators and owners that these measures are necessary. Police and the army may also be called when needed.

When veterinary tasks are delegated to individuals or enterprises outside the Veterinary Authority, information on regulatory requirements and a system of evaluation should be established to monitor and verify the performance of the delegated activities.

Vaccination

During the 20th and 21st centuries, while sanitary measures remained the principal means of achieving final eradication in previously endemically infected countries and preventing rinderpest introduction in disease-free countries, and considering that the problem in endemic countries with low economic capacity lies in their difficulties in implementing sanitary measures, vaccination became the major control and eradication tool in infected developing countries.

Given that the beginning of national rinderpest control coincided with the advent of the introduction of live attenuated vaccines, it was the role of the national Veterinary Services to administer these. This was first essentially undertaken with a view to reducing losses from the disease at national level (or provincial level, in the case of the National Rinderpest Eradication Programme – NPRE – in India).

Later on, the international community supported regional programmes with an objective of rinderpest eradication (Joint Programme 15 – JP15 – in Africa), and in some countries, such as India, a programme, clearly conceived as an eradication programme to be implemented by state Veterinary Services, attracted additional finance from the national government. Here again, the staff of the state Services were to act as stakeholders undertaking large-scale vaccination, according to centrally agreed targets. This programme, as well as JP15, demonstrated the high degree of control that could be obtained through mass vaccination but failed to eradicate rinderpest.

International and national funding were then mobilised to launch regional (e.g. the Pan-African Rinderpest Campaign – PARC – and the Programme for Control of Epizootic diseases – PACE – in Africa) or national programmes that were still based on vaccination but followed the OIE Pathway rules. In India, a second NPRE was launched, which was also based on the OIE Pathway and integrated the zoning concept (see Part 4, Chapters 4.13.4 and 4.13.5).

If Asia and Africa demonstrated that vaccination and international cooperation can eradicate rinderpest from many countries, sanitary measures remained indispensable to protect against the reintroduction of the virus from countries or zones that were still contaminated (17). Both zoosanitary controls and vaccination campaigns definitely played a role in the eradication of rinderpest (18, 19, 20).

Official Veterinary Services were at the core of designing and implementing vaccination programmes, either carrying out the campaigns themselves or subcontracting these activities to private veterinary officers. The vaccination strategies defined by official Veterinary Services were increasingly based on targeted epidemiologically based approaches. In difficult regions, participatory approaches and alternative delivery systems using community-based animal health workers (CAHWs) could be used. Their role was crucial, for example in Afar region in Ethiopia, Karamoja in Uganda, South Sudan and Somalia.

Regarding the production of the vaccines and when a producing laboratory existed in the country, the national Veterinary Services were responsible for controlling, with the assistance of the African Union Pan-African Veterinary Vaccine Centre (AU-PANVAC), the quality of the vaccines. Veterinary Services were responsible for licensing the vaccines in the country and for delivery and storage at various levels. Whether or not the vaccine was produced in the country, Veterinary Services had the responsibility of guaranteeing an effective cold chain all along the chain of vaccine delivery and the good quality of the vaccination, either implemented directly or subcontracted to private veterinary professionals.

Surveillance and disease reporting

Disease reporting and alerts

In the early days, Veterinary Services informed their neighbours and the international community of the extent of their rinderpest problem through their annual reports. There was no mechanism for the distribution of outbreak data, for instance in compiling their epidemiological study, prior to the inauguration of JP15 in eastern Africa.

Today, all OIE Members have an obligation to report to the OIE their disease situation and in doing so make this information available internationally. The OIE's internationally recognised official reporting system is called the World Animal Health Information System (WAHIS) (21). WAHIS consists of two components: an early warning system to inform stakeholders, through 'alert messages', of relevant epidemiological events that occurred in OIE Members' territories, and a monitoring system for OIE listed diseases (presence or absence). A reporting and alert system has also been developed by FAO, called EMPRES-i (22), and several regional organisations and many countries have their own systems.

With regard to eradication and recognition of the disease-free status of a country, Veterinary Services reporting had to follow the procedure, known as the 'OIE Pathway', adopted in May 1998 (23), which describes how to verify how far countries are from a status of 'provisional freedom from disease' (two years after clinical cases have disappeared) and 'freedom from infection with the rinderpest virus', which includes cessation of vaccination and intense surveillance.

Epidemio-surveillance and disease intelligence

Surveillance objectives are basically to demonstrate the presence or absence of a disease or infection and provide data to understand the epidemiological trends, to define control strategies, to monitor the implementation of control programmes and to communicate the disease situation and therefore safeguard trade. Wildlife may be included when relevant.

A surveillance network is based on a 'tripod', composed of official veterinarians, private veterinarians and animal producers, allowing, in particular, early detection of outbreaks to enable a rapid response.

Surveillance tools and methods are described in many specialised books and guidelines or scientific articles (e.g. 24, 25) and in the OIE *Terrestrial Code* (2). They are summarised in Box 3.

BOX 3
EPIDEMIO-SURVEILLANCE

The classification of surveillance activities includes 'active surveillance' and 'passive surveillance'. Passive surveillance, which remains the basis of surveillance systems, is the most likely way to detect new or emerging diseases (including bioterrorists' intentional introduction of disease).
Active and passive surveillance can be general or targeted (focus on one or more specified diseases, pathogens or syndromes) or risk-based (focus on groups within the population that are at a higher risk of having the disease than the rest of the population).
'Participatory disease surveillance' (or participatory disease searching, PDS) describes an approach to surveillance involving engaging trained farmers to conduct interviews with farmers.
Participatory approaches, and particularly PDS (26, 27), were used during the last stages of the rinderpest eradication programmes, especially in Africa in remote areas or in difficult areas facing civil wars or civil unrest. Today, the community-based programmes and participatory epidemiology tools occupy significant positions in epidemiological studies.
Media-based surveillance initiatives, such as ProMED (Program for Monitoring Emerging Diseases), GPHIN (Global Public Health Intelligence Network – Canada and WHO) and Healthmap, are based on screening information and data captured by the communications media.

At national level, many countries have developed networks of laboratories and epidemiology teams that carry out surveillance and disease intelligence, and an evaluation of their quality is increasingly being undertaken (28). To support national Veterinary Authorities in developing countries, FAO has developed a model information system – Transboundary Animal Disease Information (TADInfo).

The roles of Veterinary Services in carrying out surveillance and disease reporting were particularly key with regard to rinderpest eradication, especially by the closing stages of the disease's existence. By the same token, national veterinary laboratories' skills had to be improved to put them in a position to confirm the field staff reports, particularly after the cessation of vaccination and absence of clinical cases, when the bovine population had to be actively examined to demonstrate the virus infection's disappearance.

The basic results of the reporting by countries engaged in rinderpest control and eradication to the OIE system are shown in the various regional timelines accompanying the chapters in Part 4.

Finally, at the end of the OIE Pathway, the results of the surveillance, together with a full account of the Veterinary Services' activities, had to be incorporated into a dossier of evidence submitted to the OIE, in order to be officially recognised as rinderpest-free. This needed new specific Veterinary Authority administrative skills.

Emergency preparedness

Preparing emergency programmes, particularly in countries free from high-threat diseases, is one of the more important core functions of national animal health services, to be better prepared to respond to a disease emergency.

Good emergency management practice (GEMP) was developed by FAO in 1998 to prepare the rinderpest-free countries in the event of any recurrence of the disease. This overall approach to increase preparedness for and response to animal health emergencies provided basic rules to define organised procedures, structures and resource management tools that help emergency managers detect diseases at an early stage in an animal population, predict and limit the spread, target control measures and eliminate the disease with subsequent re-establishment of verifiable freedom from infection. GEMP later guided national services in preparing four kinds of disease-specific documents that are usually required in particular in the emergency preparedness plan (what needs to be done before an outbreak occurs in order to be prepared) and the response or 'contingency plan' (what has to be done when an outbreak arises). This is what happened, for example, during the avian influenza crisis.

Animal movements, identification, registration and traceability

Basic sanitary measures have addressed animal movements from ancient times to today and especially in Europe during the eradication of rinderpest. Implemented under the control of Veterinary Services, these measures are actually very difficult to enforce, particularly in developing countries, because of the costs of imposing trade movement restrictions, or in nomadic pastoral production systems in arid and semi-arid regions, where traditional movements cannot be stopped (29).

Similar constraints apply to the establishment and management of systems for the identification and registration of animals in developing countries, where their cost is a limiting factor.

Knowledge and monitoring of wildlife movements is also an important role of the Veterinary Services and, for example, applying specific sanitary measures for wildlife taken abroad for zoos or as pets (30). Natural migrations at country or regional level, such as wild ruminants in eastern Africa or long-distance migration of wild bird species which can spread diseases, cannot be stopped without posing biodiversity preservation problems. But best knowledge of migration routes, specific surveillance and risk analysis allow better forecasting of the potential introduction of pathogens. Besides, preventing contact between wild and domestic animals will be an effective measure.

Communication, training and capacity building

These are indispensable tools for the implementation of sanitary measures, and Veterinary Services play a leading role in these domains.

Rinderpest control and eradication at the regional level

In 1962, the regional JP15 was launched, lasting until 1976 (see Part 4, Chapter 4.1). This programme introduced substantial amounts of donor money to rinderpest control in Africa, channelled into vaccination programmes undertaken by the national Veterinary Services but in accordance with plans drawn up by international coordinators.

JP15 demonstrated that a high degree of control could be obtained through mass vaccination. But due to the inability of Veterinary Services to hold on to the advanced control obtained under JP15 and the dangers of reverting to an endemic and epidemic situation with Veterinary Services balancing rinderpest control against other diseases and diminishing budgets, the only option was to reintroduce additional finance and attack the disease again.

In a second round of mass vaccination by national or state Veterinary Services rinderpest was actually eradicated. In Africa, the international community and country donor funding became available under PARC and PACE, in the Middle East it became available through FAO-WAREC and in India it was made available under the NPRE.

Integral to these achievements were epidemiological studies at regional and national levels, incorporating the Veterinary Services, assisted by FAO, the European Union and non-governmental organisations to elucidate the sources of persistent foci of infection and thus allow these to become the targets of intensified vaccination, particularly in Africa. Regional networks of national epidemio-surveillance teams and laboratories were also set up through collaboration between research institutes and reference laboratories, such as the Institute for Animal Health (IAH, Pirbright, United Kingdom of Great Britain and Northern Ireland) and CIRAD (Montpellier), and with the Joint FAO/International Atomic Energy Agency (IAEA, Vienna, Austria).

Rinderpest eradication at international level

In 1994, the FAO Council established the Global Rinderpest Eradication Programme (GREP) in the Emergency Prevention System (EMPRES) programme as a time-bound programme aimed at supporting global eradication of rinderpest virus by 2010. The GREP Secretariat contributed in many ways to making this achievement possible, such as assisting the Veterinary Services to eliminate the infection or assessing the evidence for such virus eradication, and assisting countries with preparing the dossiers for OIE recognition of disease-free status. The GREP Secretariat was also very active at regional and international levels through its support to various networks and organisation of many technical expert meetings and coordination events.

GREP was the basic strategy of rinderpest global eradication, and in this context the OIE developed relevant standards, which were included in specific chapters on rinderpest in the OIE *Terrestrial Code* and in the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (*Terrestrial Manual*), as well as in the surveillance guidelines for rinderpest. The already mentioned OIE Pathway for rinderpest eradication, a step-by-step process that leads a country to the official recognition of freedom from rinderpest infection (see 'Rinderpest control and eradication at national level' above), was adopted at the 66th General Session of the OIE in May 1998 (23). Rinderpest became the second disease to be considered after FMD for 'official recognition of countries' disease status'.

The first list of officially recognised rinderpest-free countries was adopted by the OIE in 2000, followed by annual new lists, until all countries of the world were officially recognised as free in 2011.

International quality standards for laboratory diagnosis of rinderpest and manufacture of rinderpest vaccines were also adopted by the OIE and included in the *Terrestrial Manual*.

In 2009, the OIE and FAO established the joint FAO/OIE Committee on Global Rinderpest Eradication, which reported to the two Directors-General, who decided that the world could be declared free from rinderpest. The Joint Committee also prepared guidelines for the global sequestration of rinderpest virus and virus-containing material in biosecure laboratories (April 2010). The procedure for the designation of facilities holding rinderpest virus containing material was adopted by the OIE World Assembly in May 2014 (Resolution No. 23).

EVOLVING PRINCIPLES, CONCEPTS AND TOOLS TO ERADICATE HIGHLY CONTAGIOUS DISEASES

The increasing importance of good governance of Veterinary Services and the rather new concept of 'public good' have already been explained under 'Good governance' and 'Definitions' above. However, other concepts regarding Veterinary Services, roles and activities have evolved in recent years, whose basic principles and practices were first implemented during the rinderpest eradication period in eastern Africa, such as the herder communities' roles and, more generally, organising delivery systems with strong partnerships between all stakeholders.

Stakeholders' partnership and delivery systems

As stated above, the role of the herder communities was key when eradicating rinderpest in remote or unsafe areas, such as in Afar region in Ethiopia or in Somalia. Effective animal health systems have progressively and increasingly depended on close public–private partnerships among all stakeholders along the animal-product value chains, including public sector veterinarians, private veterinarians, producers, processors and distributors.

When private sector organisations are involved in Veterinary Services, activities (e.g. the associations of private veterinarians for sanitary defence or unions and associations of producers, including those among the nomadic pastoral communities), they are accredited or approved by the Veterinary Authority to deliver the delegated functions. And whatever share of the responsibility is devolved, the final responsibility with regard to the consumer and international trade (certification) lies with the administration (public Veterinary Services) (11).

Historically, the funding of the control and eradication of animal diseases has been the responsibility of governments. However, this paradigm has been changing in recent years, since, as a clear beneficiary of the policies and programmes, the private sector agreed to assume a greater responsibility for their execution and share the costs of these activities. The implementation of compartmentalisation and industry-led control programmes in some countries is a good example of this approach (31). Obviously, stakeholders are involved when preparing the policies, related laws and regulations, and the sanitary measures must be proportionate to the disease risks and their economic and sociological impacts. Cost–benefit analysis of sanitary measures will demonstrate if the operators can take advantage of their application.

Public funds are used predominantly when animal diseases have the potential to cause major national socio-economic issues or when they may have significant public health and/or environmental consequences, and in contrast private funds predominantly finance control activities when diseases are not so economically important for production and loss of trade and when the main beneficiaries of control programmes are the affected livestock industries.

Access to animal health services should not be taken for granted, in certain contexts, such as in remote regions, when the livestock density is low or/and when the livestock owners cannot pay for the services provided by veterinarians, and in the case of civil unrest or other gaps in governance, public veterinarians or private practitioners may not be present. These services may be rendered by non-veterinarians, such as veterinary para-professionals. The role of CAHWs, who are livestock owners who have received a small amount of training in basic animal health principles and who live within their communities, has been mentioned, and they work under the supervision of a veterinarian or an animal health technician, who is in turn supervised by a veterinarian. Accreditation schemes for veterinary para-professionals or CAHWs could be useful for developing profitable private practices in rural areas (26, 32). All this fits with the OIE's guidance on what constitutes a quality Veterinary Service, as described in the OIE *Terrestrial Code* (2).

The collaboration between the public side of Veterinary Services and private veterinarians, veterinary para-professionals and livestock owners can take the form of legal contracts, which establish the rules for delivering certain services, such as disease prevention and control, disease surveillance, vaccination and food inspection. The 'Sanitary Mandate' with private veterinarians in France is an example of such partnership. Contracts for vaccination with private veterinarians have been put in place in several Sahelian African countries, including in remote areas of Chad during the rinderpest eradication campaigns, which assisted with the establishment of a private veterinary practice in these extensive animal husbandry systems (33).

Disease reporting and alerts, epidemio-surveillance and disease intelligence

New communication technologies enable real-time notifications to the OIE and accelerate the capacity to relay information through WAHIS (21). While the WAHIS relies on official information provided by the OIE delegates, the OIE may also report unofficial (but reliable) information of global health concern. The information gathered from Members is collated in the World Animal Health Information Database (WAHID), which generates reports on disease and world maps.

A new platform, OIE-WAHIS, is being prepared that will allow improved use of data collected (including genomic data linked to epidemiological data in WAHIS) and interconnection with other international or regional information systems (34).

OIE disease tracking uses unofficial animal health information and rumours disseminated by the media, networks such as GPHIN and ProMED, scientific journals and publications, etc. Following the launch of this active search activity for rumours and unofficial information, the number of immediate notifications published increased, thereby helping to improve the OIE Early Warning System. The OIE Reference Laboratories have a mandate that includes informing both the country OIE delegates and OIE headquarters of any positive findings relating to an OIE listed disease.

The FAO disease tracking system, EMPRES-i (22), uses official OIE health information but also many other sources. Warning information is disseminated through the FAO/Animal Health Service/EMPRES website and electronic distribution lists. The *EMPRES Bulletin* is also distributed in hard-copy, complemented by some specific bulletins when appropriate (e.g. *FAO AIDENews* on highly pathogenic avian influenza).

Disease intelligence is being increasingly carried out in several epidemiology centres and organisations such as FAO, the OIE and WHO, which jointly manage the platform Global Early Warning System (GLEWS) (35). GLEWS' objective is to share health information, especially that derived from active search mechanisms and verification networks of the three organisations, and in doing so it allows better risk assessments and provision of recommendations for surveillance, prevention and control.

Regional and international epidemio-surveillance networks are constantly developing, and there are a number of examples in many regions and continents, such as the FMD networks LabNet (laboratories) and EpiNet (epidemiology centres or teams) in Southeast Asia under the auspices of the Southeast Asia and China FMD campaign (SEACFMD), and the four thematic subnetworks of the North African REMESA (Mediterranean Animal Health Network – Réseau Méditerranéen de Santé Animale). At the international level, the OIE and FAO have established several networks of reference centres, sometimes but not always jointly (e.g. FMD Reference Laboratory Network or OFFLU – the network of expertise on animal influenza).

Important and rather recent developments regarding standards for surveillance, reporting and trade were the introduction of progressive changes to the previous standard paradigms, such as the obligation to use an established set of epidemiological criteria for disease reporting or the recognition of the concepts of zoning and compartmentalisation, which led to the recognition of production system biosecurity practices. The improved availability and efficacy of vaccines have also had an impact on veterinary health policies.

Other changes include introducing commodity-based risk, which allows safe trade of specific commodities under precise conditions, including when the disease is present in a country or zone, or when official freedom cannot be declared but the mitigating measures certified by the Veterinary Services render the commodity safe (32, 36, 37). This makes it possible for disease prevention and control policies to be more proportionate and not exclusively focused on only the traditionally unique option, which was to obtain disease-free status for a country or zone (37).

Other evolving domains

If the importance of wildlife was addressed extensively by Veterinary Services during the rinderpest eradication period, the roles of Veterinary Services were further expanded under the 'One Health' concept at the human/animal/environment interface. This approach emerged strongly during the highly pathogenic avian influenza epidemic, and consequently Veterinary Services broadened the focus of their traditional activities and collaborations with agencies responsible for public health and the environment.

Lastly, Veterinary Services' role has been strengthened to ensure an adequate supply of good-quality and safe food from the farm to the slaughterhouse and finally to subsequent stages of the food chain. This rather recent concept, which is of course more applicable to foodborne diseases than specific animal diseases such as rinderpest, is commonly referred to as a 'farm to fork' approach (38).

Bioterrorism might appear not to be directly related to a chapter devoted to the measures being implemented to control and eradicate infectious diseases, with particular reference to rinderpest. But the intentional introduction of pathogens to countries free from infection, including rinderpest (or the threat of new disease entities through, for example, the possibility of using genetically engineered organisms), can be approached in the same ways that accidental or natural introductions are, and the same general principles of prevention and control policies and programmes, and specifically sanitary measures can be considered when addressing bioterrorism.

Evaluation and monitoring have become strict requirements for many decision-makers and specialised agencies when supporting official control programmes and for all when financing development projects. Evaluation and monitoring exercises carried out by Veterinary Services allow good management of the programmes and activities and appropriate adjustments. Specialised tools and scientific skills exist (using, for example, a number of verifiable indicators accompanied by a relevant means of verification to assess the results of ongoing projects).

As stated above, surveillance networks are being evaluated more and more often (28), and the quality of the Veterinary Services themselves is evaluated using the OIE PVS tool.

CONCLUSIONS

The fight against rinderpest and other highly contagious diseases needs intense and long-term efforts, particularly when the objective is to eradicate the virus from a country or a region or from the entire world. The case of rinderpest global eradication, which was officially declared in 2011, is very representative of what has to be undertaken. There is a focus on the role of Veterinary Services in implementing all the appropriate measures that are to be backed and enforced through the relevant institutional settings, laws and regulations. The preservation of animal health and the prevention of the risk of transmissible diseases to humans are considered to be of global public interest, and this public good dimension was particularly considered when eradicating rinderpest.

One of the required conditions for controlling and eradicating rinderpest and other major diseases is to have strong Veterinary Services compliant with international standards and good governance. They have to be politically and financially supported by government authorities and operate in full partnership with all public and private stakeholders.

Several elements of the Veterinary Services' mandates and roles are key, particularly epidemiological surveillance and reporting as well as the implementation of sanitary measures.

Finally, the extraordinary saga of rinderpest eradication, which took several decades, was a unique experience that has left Veterinary Services stronger than they were before, and the credo 'surveillance–detection–warning–early reporting–early response' that applied during the rinderpest eradication period remains fundamental for all other highly contagious diseases.

It was also shown that, under the OIE systems' leadership and with strong collaboration with many regional and international organisations and agencies, the OIE internationally recognised standard-setting procedures have been able to integrate all relevant research results and contexts to make standards more effective and efficient and finally more acceptable to all stakeholders involved.

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CHAPTER 5.2

ROLE OF THE WORLD ORGANISATION FOR ANIMAL HEALTH (OIE) IN RINDERPEST ERADICATION

M. THIBIER [(1)*] & D. CHAISEMARTIN [(1)]

(1) World Organisation for Animal Health (OIE), 12 rue de Prony, 75017 Paris, France

*Corresponding author

SUMMARY The World Organisation for Animal Health (OIE) and rinderpest have been intimately linked since the establishment of the OIE in Paris in 1924 until the eradication of the disease in 2011 – a close and successful interaction for almost a century. The aim of this chapter is to report the critical role of the OIE in the eradication programme and its close connection to all its stakeholders: farmers, veterinarians, Veterinary Services, financing institutions, governments and other international and intergovernmental bodies. Three major periods can be identified during this process. The first period for fighting rinderpest around the world, both before and after the Second World War and referred to as the 'early days' in this chapter, established the rationale and standards for future efficient global eradication plans. The second period, referred to as the 'maturation period', included: (1) waves of massive regional vaccination programmes; and (2) the development of the OIE Pathway and the evaluation of disease status applications. The third period, referred to as the 'ultimate period', led to the global eradication of rinderpest and the provisions for a safe global sequestration of rinderpest virus and virus-containing materials. Lessons may be learnt from the unique achievement of eradicating a viral animal disease that may help eradicate other viral animal diseases such as peste des petits ruminants and foot-and-mouth disease.

KEYWORDS Animal diseases – Governance –OIE – Resolutions – Rinderpest – Standards – Veterinary Services – World intergovernmental organisation – World Organisation for Animal Health.

INTRODUCTION

The Office International des Epizooties (OIE), known since 2003 as the World Organisation for Animal Health, and the history of one of the worst infectious animal diseases, namely rinderpest, have been intimately linked from the time of the establishment of the OIE to the eradication of the disease, which was declared by the OIE and the Food and Agriculture Organization of the United Nations (FAO) in 2011. This is a unique example of a continuous link, over almost a century, between an intergovernmental body and the evolution of a worldwide disease to its extinction. The reasons for such an extraordinary achievement are related to the close association of the OIE with all of its stakeholders over many decades in the 20th and 21st centuries. The stated goals of the OIE were a particularly efficient foundation from which to lead such an endeavour. As stated in its statutes, the OIE's objectives were to:

– ensure transparency in the global animal disease situation;

- collect, analyse and disseminate veterinary scientific information;
- encourage international solidarity in the control of animal diseases;
- safeguard world trade by publishing health standards for international trade in animals and animal products;
- improve the legal framework and resources of national Veterinary Services.

These objectives were particularly relevant for the problem of rinderpest in the livestock population across the world and were implemented consistently by all the stakeholders involved: farmers, field operators, veterinarians and technicians, Veterinary Services, veterinary research institutes, reference laboratories, financing bodies, governments, intergovernmental and international organisations, etc. Vigilance against transboundary animal diseases (TADs) is of paramount importance in preventing the spread of diseases with a potentially catastrophic impact on animal health, public health, the economy, the environment and food security. The success of such vigilance depends on effective collaboration between all participants in the chain of stakeholders and good governance by the national Veterinary Services. Farmers, field operators, veterinarians and technicians should play a key role in applying and complying with animal health regulations and standards at national and international levels. Vigilance against TADs is based on permanent sanitary surveillance and the early detection of any disease incident. This early detection is ensured by a network of veterinary service agents in each country and the support of diagnostic laboratories, and through the cooperation of veterinary practitioners, field agents, technicians and farmers. The OIE considers the early detection of and rapid response to animal diseases or zoonoses to be dependent on all the above-mentioned actors at national and local levels and that appropriate legislation must be put in place within each country to promote good veterinary and sanitary governance in order to best respond to the emergence of local and national risks. Every year, groups of experts are invited by the OIE to develop or improve chapters on diseases in the OIE codes and manuals, which are examined by relevant OIE Specialist Commissions, composed of elected members, and Performance of Veterinary Services (PVS) expert missions can be requested by Members. Each year, the World Assembly of Delegates of the OIE adopts new resolutions on the update of OIE Reference Laboratories and OIE Collaborating Centres to maintain expertise on diseases, regulations and standards on animal health, including good governance, and the official recognition of disease status. The new regulations and standards must be taken into account by all OIE Members.

The aim of this chapter is to describe how, over a number of decades, the OIE has successfully managed rinderpest, in cooperation with the various stakeholders.

THE EARLY DAYS

Rinderpest and the veterinary community have a very long history in common. 'Rinder Pest', 'the Plague', '*La Peste, la Terrible*' had become one of the most dreaded livestock diseases in the world, including in Europe. In the middle of the 18th century, a dramatic epidemic of rinderpest hit Western Europe and particularly France. It was at that time that Giovanni Maria Lancisi, physician to Pope Clement XI, made very sound recommendations regarding measures to deal with this disease, and ultimately infectious diseases as a whole, such as the establishment of quarantine and the destruction of sick animals. However, there was a need to increase capacity and to improve some of the measures and implementation methods. A 'genius' by the name of Claude Bourgelat went to see Louis XV, King of France and convinced him to establish a science-based veterinary college in Lyon in 1761, the first ever veterinary college, in order to try to control this terrifying animal disease that had led to periods of starvation in some communities. The recurrence of rinderpest on mainland Europe stimulated the organisation of the first international conference on the disease, in Vienna in 1871. The measures adopted during this conference were implemented by the attending countries and reduced the presence of rinderpest in Europe. However, during the years that followed, the measures proposed by the members of international veterinary congresses were not pursued. In August 1920, rinderpest recurred unexpectedly in Belgium, as a result of infected zebu cattle (*Bos indicus*), that had come from India and were destined for Brazil, stopping in transit at the port of Antwerp. Ten zebus died on the premises during quarantine in Antwerp and the area was not subsequently disinfected. Cattle imported from the Americas and destined for slaughter in Belgium were held on the same premises during quarantine and became infected without showing any clinical signs. They were then transported to various centres in Belgium, and in these centres the animals came into contact with other cattle destined for farms in Belgium. The surviving zebus were shipped to Brazil where, in March 1921, the presence of rinderpest was reported. The reports suggest that rinderpest had most likely been imported through the zebus that came originally from India and had transited the port of Antwerp. Concern over the resulting international spread of the disease, with the virus propagating in Belgium, Italy and other parts of Europe, in particular Poland, led to an international conference of chief veterinary officers from around the world being held in Paris in May 1921 (1). The conference participants agreed on the following recommendations to support a concerted international effort in the fight against rinderpest:

- immediate notification of neighbouring countries by telegram when new outbreaks of the disease occur in regions hitherto free;
- in principle, compulsory slaughter of sick and clinically suspect bovids and also, as far as possible, any contaminated animals even if apparently healthy, with substantial and immediate compensation;
- a ban on the use of any product that is virulent or likely to revert to virulence to immunise animals in rinderpest-free regions, such as a vaccine prepared from virus-containing blood;
- a ban on the industrial production of sera and vaccines against rinderpest in rinderpest-free regions, except in scientific establishments supervised by the state.

Although these recommendations were written around 100 years ago, we can see how up to date and accurate this advice was. Based on previous recommendations (from Giovanni Maria Lancisi and international veterinary congresses), the following key themes were also mentioned: transparency of information, the concept of 'stamping out', the search for non-harmful vaccines and the care taken to prevent infection from the vaccines or vaccine production. Everything that was needed to achieve the goal of the OIE was there. So in 1924, as a result of the determined efforts of Professor Emmanuel Leclainche (first Director-General of the OIE) and his group of visionary veterinarians, the decision was taken to found an international organisation that could provide its Members with the scientific information they needed to improve their animal disease control measures. So the organisation started its work in the middle of Paris, where the headquarters of the OIE are still located.

BOX 1
THE FIRST MEMBERS OF THE OIE

The International Arrangement for the Establishment of the International Office of Epizooties (OIE) was signed on 25 January 1924 in Paris by 28 countries: Argentina, Belgium, Brazil, Bulgaria, Denmark, Egypt, Finland, Germany, France, Great Britain, Greece, Guatemala, Hungary, Italy, Luxembourg, Morocco, Mexico, the Principality of Monaco, the Netherlands, Peru, Poland, Portugal, Romania, Siam, Sweden, Switzerland, the then Czechoslovak Republic and Tunisia.

When the OIE was established in 1924, rinderpest was one of the nine notifiable diseases, the others being foot-and-mouth disease (FMD), contagious bovine pleuropneumonia (CBPP), anthrax, sheep pox, rabies, glanders, dourine and swine fever.

Emmanuel Leclainche, being a scientist and professor at the Veterinary College of Alfort (located in Maisons Alfort, near Paris), had rightly identified the scientific community as the first place to ask for help in finding the most efficient methods of fighting the spread of rinderpest. The initial steps were, first, to encourage the research institutions to produce safe and effective vaccines and, second, to try to achieve a strategic consensus on how to control and prevent the spread of the diseases in the Member countries.

After the Second World War, in 1947, during its 15th General Session, the International Committee of the OIE (now representing 38 countries), taking into account the very serious losses of livestock around the world in countries where rinderpest was endemic and the great risk of it spreading more widely, and the studies on protective measures against rinderpest virus performed by the USA–Canada Joint Scientific Commission (2), adopted the following firm resolutions for countries free of rinderpest (3):

- There will be an absolute ban on importing susceptible animals and dangerous animal products from infected countries.
- In cases of the first occurrence of the disease in a new country, the disease must be stamped out. This may be supplemented by the vaccination of animals in uninfected areas with a harmless vaccine, excluding any vaccine containing a virulent agent.
- Countries with laboratories that prepare rinderpest vaccines will provide regular reports to the OIE on their ability to provide vaccines;
- The introduction of animals, meat and animal products can only be done through ports or border posts that are subject to veterinary inspection and only after import authorisation has been issued by the importing country.

The International Committee of the OIE considered that developing a centre for international research on rinderpest would provide significant opportunities to train technicians to prepare the immunising agents against rinderpest and to train veterinarians employed in those countries without specialised staff.

In 1947, the OIE was already promoting international solidarity by mediating between donors, vaccine producers and countries in need, thereby supporting large-scale campaigns based on the most up-to-date scientific information available.

BOX 2
NORTH AMERICAN INVOLVEMENT DURING THE SECOND WORLD WAR (4)

- In 1941, the Joint Scientific Commission (United States of America [USA] and Canada) and the US Chemical Warfare Service requested, in the utmost secrecy, that the group of scientists working at the laboratory of Grosse Ile (on the Saint Lawrence River, between Canada and the USA) do the following:
  1) prepare rinderpest vaccine according to known methods and surround possible outbreaks with an area of immunised animals;
  2) study the possibility of obtaining another, more economical vaccine that would not require the sacrifice of a large number of cattle.
- The results of this request were not published until April 1946 (2). These results referred not only to the methods of vaccination but also to the research that had to precede and accompany the development of new immunisation processes.

During its 16th General Session in 1948, the International Committee of the OIE strengthened its major role in policy setting for rinderpest (5). The adopted resolution on rinderpest stated that:

- The eradication of rinderpest is vital for the economy and for maintaining the food supply.
- Coordination of the veterinary institutes and Veterinary Services must be implemented globally to efficiently fight rinderpest.
- Control of the efficacy and innocuity of the immunisation methods is critical in the eradication of rinderpest. These processes must meet the requirements of safety, efficiency, simplicity of application, low cost and sustainable immunity.
- Worldwide technical cooperation is necessary to reach such a goal.
- Practical conditions in the field and the sensitivity of the animals are so variable that at least two research centres have to be established: one in Africa and one in the Far East. The choice of certain laboratories had already been considered. This appeared to be particularly urgent with the emergency in Asia at that time.
- The OIE strongly urges its Members, in particular from Africa and Asia, to join in these efforts and to nominate permanent delegates.
- The OIE will organise extraordinary meetings with permanent delegates and veterinary experts, in agreement with relevant governments, whenever a new threat of extensive spread occurs.

In the resolutions of the 18th General Session in 1950 (6), after being informed by the Director-General, Gaston Ramon, that rinderpest had recently been introduced into the zoological gardens in Rome through wild animals that had come from East Africa, the International Committee urged delegates once again to take all the necessary measures to ban the import of animals from infected countries.

During the 19th General Session in 1951 (7), emphasis was placed on the two following OIE recommendations:

1. Members wishing to import wild animals that are susceptible to rinderpest should request advice from the OIE before taking any decision on importation.
2. Members should consider establishing a detailed classification of the various strains of the rinderpest virus to be used for the production of vaccines as a first step in the standardisation of the vaccines, and the OIE recommends that such a classification be established without delay. This classification, overseen by a member of the Commission of Standardisation of Biological Products, will be published in the *OIE Bulletin*.

Some years later, at its 25th General Session in 1957 (8), another step forward in the standard-setting role of the OIE in international trade was approved with the following recommendations:

- The OIE recommends that no country free from rinderpest should import meat or offal from an infected country or region.
- A country in which vaccination is practised to eliminate rinderpest should be considered infected for as long as vaccination is necessary.
- A region or a country, where the disease has been endemic, should be considered rinderpest free if no case of rinderpest has occurred for two years and no vaccination has been done during the same period.
- Recognising the need for some countries to find new sources of meat supply, the OIE recommends that meat-producing countries take

intensive measures to eradicate rinderpest, in order to allow importing countries to accept their products safely.

- The OIE recommends that research be undertaken on the conditions that affect the persistence of the virus in meat and offal, and particularly the risks of infection of susceptible animals posed by infected meat and offal.

During the 28th General Session in 1960, the International Committee of the OIE adopted the following recommendations on the rapid detection of a contagious disease in a country where it has not yet been recognised:

- It is assumed that, by law, any country will endeavour to take precautions against the introduction of disease by imports, and in order to do so satisfactorily it must study the disease position in those countries with which it has trade or other contacts. Full use should be made of the *FAO/OIE Animal Health Yearbook*, the monthly *OIE Bulletin* on epizootics and the OIE emergency notifications of outbreaks, but consultation with the authorities in the exporting countries is necessary before arrangements for importation are made.
- So that an exotic or hitherto unidentified disease may be detected as early as possible, veterinarians should be located so that all parts of the country, as far as possible, are covered. Veterinarians should be made aware of the importance of consulting the official Veterinary Service or a laboratory for assistance in diagnosis when they encounter a disease condition outside their previous experience. They should be kept informed by all available means of any symptoms that would lead to a suspicion of the existence of one of the more important exotic diseases.
- A laboratory within the country or region should be designated as the diagnostic centre when an exotic disease is suspected. If necessary, this laboratory should send material to a laboratory abroad where it has been agreed that facilities for diagnosis will be provided: every opportunity should be given to the laboratory workers to become familiar with the up-to-date diagnostic methods. This may be done using the scientific literature and through discussions with experts at home and abroad.
- Pending the diagnosis of a suspected case of an exotic or hitherto unidentified infectious or contagious disease, precautions to prevent the spread of infection should be imposed.

These recommendations adopted by the International Committee of the OIE clearly illustrate the concerns of the OIE Members at this stage: the need to ensure that international trade in meat products would be safely implemented and the need to develop standards based on sound science carried out in research institutions.

So this period of the OIE's history regarding rinderpest, both before and after the Second World War, resulted in the organisation having strategically commissioned national research institutes throughout the world to conduct work tailored to the needs of the international community of Veterinary Services. The OIE encouraged and facilitated research on appropriate methods to prevent the spread of rinderpest through international trade in bovine meat from infected countries, including appropriate virus inactivation procedures and experimental work on the standardisation of the safety of rinderpest vaccines.

Rinderpest thus significantly contributed to the birth of the concept of OIE Reference Laboratories and OIE Collaborating Centres – an essential global network of specialists. This approach will also be followed when addressing other diseases or topics.

In the late 1950s, stable, safe and affordable rinderpest vaccines became available that could give lifelong immunity to susceptible livestock.

BOX 3
THE OIE NETWORK OF REFERENCE LABORATORIES AND COLLABORATING CENTRES

The network of OIE Reference Laboratories and Collaborating Centres constitutes the core of OIE scientific expertise and excellence. The ongoing contribution of these institutes to the work of the OIE ensures that the standards, guidelines and recommendations developed by the OIE specialist commissions and published by the OIE are scientifically sound and up to date.
In 2019, the OIE had a global network of 254 Reference Laboratories covering 106 diseases or topics in 37 countries, and 58 Collaborating Centres covering 50 topics in 28 countries. Lists can be found at the following URLs: www.oie.int/en/scientific-expertise/reference-laboratories/list-of-laboratories/; www.oie.int/en/scientific-expertise/collaborating-centres/list-of-centres/

MATURATION PERIOD

Plans for a massive vaccination programme

From the 1960s onwards, the regional organisations, under the umbrella of the Organisation of African Unity (OAU) and with the support of the OIE and FAO, launched and coordinated several large-scale campaigns, using coordinated vaccination, to strengthen the capacity of countries to eradicate rinderpest and control other major transboundary diseases (Fig. 1). The first was the multinational Joint Programme 15 (JP15; see Chapter 4.1), which was at first a real success, considerably diminishing the number of outbreaks.

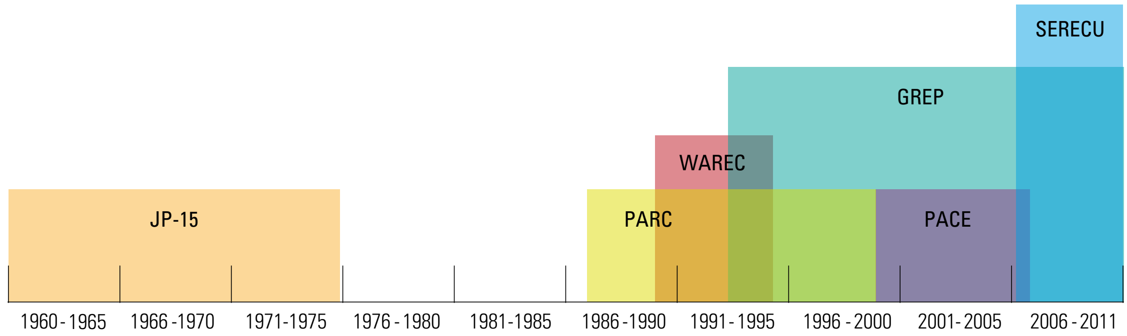
During the 36th General Session in 1968, the International Committee examined and approved the first edition of the *International Zoo-sanitary Code* (the project was proposed during the 33rd General Session in 1965) and recommended that Members put into practice the rules of the code (10). The *International Zoo-sanitary Code* (11) is composed of eight sections (section 1, definitions; section 2, notifications and epizootiological information; section 3, zoo-sanitary organisation; section 4, zoo-sanitary measures and formalities; section 5, arrangements for each of the mandatory notifiable diseases; section 6, arrangements applicable to the diseases in Lists B and C of the OIE; section 7, transitory arrangements; and section 8, patterns of international certificates approved by the OIE) and a specific chapter on rinderpest (Chapter 2.9) is included in section 5.

The OIE together with FAO and the World Health Organization (WHO) organised a meeting of experts on rinderpest to discuss international requirements for rinderpest vaccines, held from 20 to 21 May 1968 in Paris. Draft standards were drawn up for the production of rinderpest vaccines made in birds, goats and rabbits and for cultured rinderpest vaccine (12). The meeting was followed by further exchanges with additional scientific experts and the draft standards were examined and adopted by the WHO Expert Committee on Biological Standardization, with the participation of the OIE and FAO, in October 1969 (13). The standards on vaccines were approved by the International Committee during its General Session in May 1969 and they were inserted into the second edition of the *Zoo-sanitary International Code,* which was approved by the International Committee of the OIE and published in 1971 (14).

During the 37th General Session in May 1969, a detailed report on rinderpest (15, 16, 17) was presented and the International Committee indicated serious concern regarding the recurrence of rinderpest in Indonesia, the Lao People's Democratic Republic and Afghanistan, which may have gone on to compromise the good results that had been achieved in the previous decade by the elimination of the disease in several countries. The report also stated that vigilance against rinderpest should continue in Africa, even although several vaccination campaigns (in Egypt, Sudan, Ethiopia and the countries of Central and West Africa covered by the JP15 campaign until 1968) had been successful, because of the possibility of the disease recurring in

FIG. 1
TIMELINE OF MAJOR GLOBAL AND REGIONAL VACCINATION AND RINDERPEST ERADICATION CAMPAIGNS IN AFRICA AND THE GREATER MIDDLE EAST REGION

Courtesy of the authors using data from the World Organisation for Animal Health, 2011 (9), p. 7



GREP Global Rinderpest Eradication Programme (1993 and continuing), worldwide activities
JP-15 Joint Programme 15 (1960–1976), parts of sub-Saharan Africa
PACE Pan-African Programme for the Control of Epizootics (1999–2007), parts of sub-Saharan Africa
PARC Pan-African Rinderpest Campaign (1987–1998), parts of sub-Saharan Africa
SERECU Somali Ecosystem Rinderpest Eradication Coordination Unit (2006–2010), Kenya and Somalia
WAREC West Asia Rinderpest Eradication Campaign (1989–1994), greater Middle East region

areas not easily accessed by vaccination teams and as long as the entire area of an outbreak cannot be included in regional and sub-regional programmes of rinderpest eradication.

The report noted that the quality of the vaccines had been satisfactory, which explained the initial success in nearly eradicating the disease globally, e.g. from China and Southeast Asia.

But the JP15 programme ultimately failed in the late 1970s and early 1980s when a devastating re-emergence and spread of the virus took place on the African continent in the 1980s (see Chapter 2.4).

The continuous development of improved diagnostic tools, vaccines and surveillance methods was necessary to support a second round of control programmes, to survey and eradicate the disease, region by region, once and for all.

During its 50th General Session in 1982, the International Committee of the OIE adopted resolution XVII (18) recommending that *all rinderpest-infected countries* implement an eradication programme with the aim of achieving the global eradication of the disease; asking governments of the countries to support the eradication programme financially; and giving the mandate to the OIE Director-General, Louis Blajan, to find, in cooperation with the OAU and FAO, funding to eradicate the disease across the African continent.

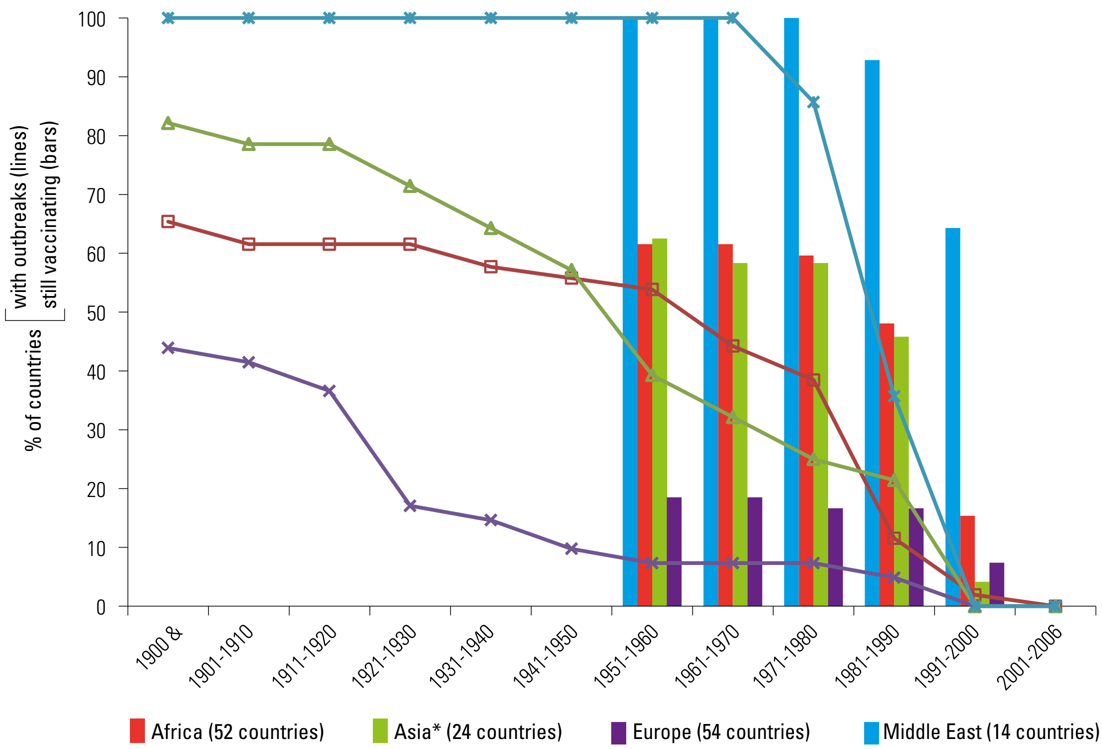
The OIE–FAO–OAU joint meeting on the financing of the campaign to eradicate rinderpest in Africa was held on 23 and 24 February 1982 at the OIE's headquarters in Paris, with the participation of several countries (Canada, France, Germany, Italy and the USA) and international organisations (African Development Bank, Centre International pour l'Élevage en Afrique, Commission of the European Communities, Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux, World Bank) (19). The results encouraged the launch of several programmes to eradicate rinderpest in Africa.

Following this re-emergence, the second wave of widespread eradication programmes, including several regional programmes, was initiated, as shown in Figure 1. The Pan-African Rinderpest Campaign (PARC) followed by the Pan-African Programme for the Control of Epizootics (PACE) in Africa and the West Asia Rinderpest Eradication Campaign (WAREC) were implemented in the 1980s (see Chapters 4.2, 4.3 and 4.10) (Fig. 2).

FIG. 2

HISTORICAL DECLINE OF OUTBREAKS OF RINDERPEST IN HISTORICALLY INFECTED REGIONS (EXCLUDING PACIFIC-OCEANIA AND THE AMERICAS) OVER ONE CENTURY (LINE GRAPH) AND THE DECLINE IN VACCINATING COUNTRIES (BAR GRAPH; RELIABLE DATA ONLY ~1955 ONWARDS)

Courtesy of the authors using data from the World Organisation for Animal Health, 2011 (9), p. 8



The development of the OIE Pathway and evaluation of the disease status applications

Along with these large-scale rinderpest eradication campaigns, OIE Members expressed the need for more guidance on how to conduct and standardise rinderpest surveillance, so that they could avoid the outcome of JP15 and substantiate their claims of freedom from rinderpest to their trading partners or assess whether a neighbouring or exporting country's surveillance was trustworthy and transparent.

The OIE Expert Consultation on Rinderpest Surveillance Systems (Paris, August 1989) led to the development of the widely known 'OIE Rinderpest Pathway', a step-by-step process that, if followed properly, would lead to certified freedom from rinderpest infection within five years of ceasing vaccination.

During its 59th General Session in 1991 (Fig. 3), the International Committee of the OIE adopted the *Recommended Standards for Epidemiological Surveillance for Rinderpest*, developed by experts and amended by the OIE Foot and Mouth Disease and Other Epizootics Commission (now the Scientific Commission for Animal Diseases). The guidelines for surveillance of rinderpest paved the way for the certification process for rinderpest-free status for countries and zones. The guidelines helped Members to demonstrate their freedom from rinderpest, after which they had the right to cease vaccination and proceed to the next steps of the pathway leading to disease freedom.

In 1991, the OIE Standards Commission (now the Biological Standards Commission since the adoption of Resolution XVII by the International Committee of the OIE on 22 May 2003) initiated a programme for the development of international standards for the laboratory diagnosis of rinderpest and for the manufacture of rinderpest vaccines. This activity resulted in the harmonisation of test protocols and the designation of reference reagents to be used in these tests, facilitating surveillance and greatly contributing to the successful outcome of the campaign for rinderpest eradication. These standards are published in the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (*Terrestrial Manual*).

During the 63rd General Session in 1995, by the resolution adopted by the International Committee of the OIE (20), rinderpest became the second disease to be included in the OIE procedure for official recognition of disease status (the first being foot-and-mouth disease): this was a major step in the eradication programme, as it obliged countries to submit a detailed dossier on the sanitary measures undertaken in order to receive official recognition of rinderpest status; field missions could be authorised to check the information given in the detailed dossier.

The Global Rinderpest Eradication Programme (GREP) started in 1994 at FAO as a single-target disease programme, and the OIE fully played a significant part in preparing standards in collaboration with the GREP secretariat and other stakeholders in *ad hoc* working groups. The work done by the *ad hoc* working groups was amended by the OIE Foot and Mouth Disease and Other Epizootics

FIG. 3

MEMBERSHIP OF THE OIE GENERAL SESSION OF 1991, WHICH ENDORSED STANDARDS FOR RINDERPEST SURVEILLANCE AND STANDARDS FOR RINDERPEST DIAGNOSIS AND VACCINE PRODUCTION

Source: World Organisation for Animal Health Documentation Centre

Commission, and revised versions of the chapters on rinderpest in the OIE codes and manuals and the critical surveillance guidelines were proposed and adopted by the International Committee of the OIE during its 66th General Session in 1998.

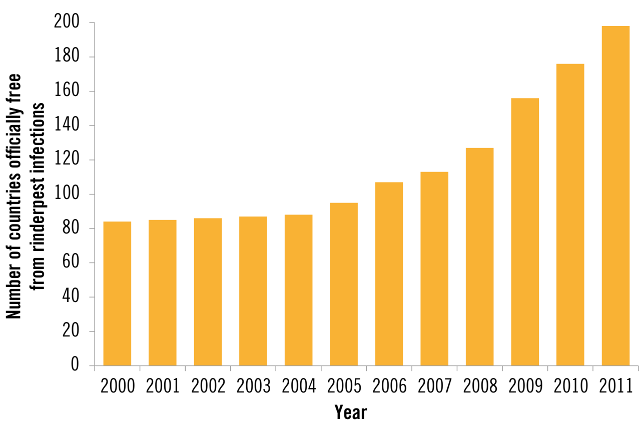
During its 68th General Session in 2000, the International Committee of the OIE adopted the first list of officially recognised Members free from rinderpest infection (21). In accordance with the *Terrestrial Code*, each Member has to reconfirm annually its status and that the criteria by which its status was recognised remain the same. Each year, a new list of officially recognised Members free from rinderpest infection was adopted by the International Committee of the OIE.

Members that were not historically free were then invited to submit detailed evidence to support claims of freedom from rinderpest. These steps were fundamental in preparing for the global eradication programme. Indeed, the OIE Scientific Commission (Scientific Commission for Animal Diseases) took into account the progress of global rinderpest eradication and the knowledge of the distribution of historical rinderpest risks among different regions of the world. A list of countries located in the regions of the world that had never faced rinderpest outbreaks or had managed to eradicate rinderpest several decades earlier (the Americas, the western part of Europe and Oceania, except Australia) was drawn up by the OIE *Ad hoc* Expert group on rinderpest. The OIE Members included in this very first list had previously documented that they met the requirements for freedom from rinderpest based on historical grounds, in full accordance with the corresponding provisions of the *Terrestrial Code*.

FIG. 4
CUMULATIVE PROGRESS IN THE EVALUATION AND OFFICIAL RECOGNITION OF COUNTRIES FREE FROM RINDERPEST INFECTION

(200 countries in total, comprising both OIE Members and non-Members)

Courtesy of the authors using data from the World Organisation for Animal Health, 2011 (9), p. 9



During the 75th General Session, in May 2007, the International Committee adopted the proposed update in the 'OIE Rinderpest Pathway' of the *Terrestrial Code*. In view of the progress in global rinderpest eradication, the provisions of Chapter 2.2.12 of the *Terrestrial Code* 2007 were restricted solely to recognise rinderpest-free status representing countrywide infection-free status. Therefore. new applications from Members for zones free from rinderpest or 'rinderpest disease free' status were no longer applicable or listed (see Chapter 7.1 on the OIE Rinderpest Pathway).

During its 76th General Session in 2008, the International Committee adopted Resolution XXII (22), which specified and updated the procedure Members should follow to achieve official recognition and maintenance of status for certain animal diseases.

From 2002 to 2009, the list of official recognition of rinderpest status adopted by the International Committee of the OIE (now the World Assembly of Delegates of the World Organisation for Animal Health since the adoption of Resolution 13 by the International Committee of the OIE on 29 May 2009) also included countries that fulfilled the criteria for being free from clinical rinderpest or that had applied zoning to parts of their territories.

The cumulative progress in the evaluation and official recognition of countries free from rinderpest infection is illustrated in Figure 4.

This key period, before the final global eradication period, was also instrumental in initiating a programme for the development of international quality standards for the laboratory diagnosis of rinderpest and for the manufacture of rinderpest vaccines. This fruitful interaction with the OIE Biological Standards Commission was also a good example of the critical role of stakeholders, such as the research institutions and the diagnosis laboratories, in harmonising test protocols and designating the reference reagents to be used in the tests, in facilitating surveillance and in greatly contributing to the successful outcome of the campaign for rinderpest eradication (23). These standards were published in the *Terrestrial Manual*.

THE ULTIMATE STEP: THE GLOBAL ERADICATION OF RINDERPEST

Almost 15 years after declaring the official goal of eradicating rinderpest globally, it was agreed in June 2009 that the OIE and FAO would establish a joint FAO/OIE Committee on Global Rinderpest Eradication (the Joint Committee). Its main function was to report to the two Directors-General whether it was confident that the world could be declared free from rinderpest and to recommend the actions to be taken to achieve this. In January 2011, the OIE *Ad hoc* Expert group on rinderpest evaluated the last remaining countries, and the process of reviewing freedom from rinderpest of all 200 countries and territories with susceptible animal populations was completed. The Committee commended this endeavour. And so the Joint Committee acknowledged the success of eradicating the rinderpest virus by the 2010 deadline (the last outbreak was in 2001 and last use of vaccination was in 2006).

The first official eradication of an animal disease agent, namely rinderpest virus, was announced to the world in Paris on 25 May 2011: **'The world is free from Rinderpest: OIE completed global free status recognition'** as stated by Resolution 18 adopted by the World Assembly of Delegates of the OIE during its 79th General Session (24). It was recognised that all 198 countries with rinderpest-susceptible animal populations in the world were free of the disease.

However, the job was not over, and a very important problem remained to be controlled, this being virus sequestration. Again on this critical point the OIE played a significant part as the standard-setting body. The *Guidelines for Rinderpest Virus Sequestration* were endorsed with amendments on 28 January 2010 by the Biological Standards Commission of the OIE, endorsed by the Joint OIE/FAO Committee on Global Rinderpest Eradication on 14 April 2010 and adopted by the World Assembly of Delegates of the OIE during its 79th General Session in May 2011 (see the Appendix of Resolution 18 and Chapter 7.2 on sequestration).

During its 80th General Session, the World Assembly of Delegates of the OIE adopted Resolution 33 on 25 May 2012 (25) in which it is recommended that the OIE Reference Laboratory network provides services to OIE Members to assist with the destruction and/or sequestration of remaining stocks of rinderpest virus and that this network ensures global preparedness for, surveillance and investigation of and response to suspect cases. This resolution also requested the OIE Director-General, Bernard Vallat, to accelerate the process of virus sequestration and destruction, under the guidance of the new Rinderpest Joint Advisory Committee, and the implementation of all activities specified in Resolution 18, which was adopted in May 2011.

Following the declaration of global freedom from rinderpest infection, resolutions adopted at the World Assembly of OIE Delegates in May 2011 and the FAO Conference in June 2011 entrusted a set of oversight functions to FAO and the OIE. This included the establishment of the Rinderpest Joint Advisory Committee.

Taking into account the work done by the Rinderpest Joint Advisory Committee and the OIE experts, the World Assembly of Delegates of the OIE adopted Resolution 23 on the procedure for the designation of facilities holding rinderpest virus containing material in order to maintain global freedom from rinderpest during its 82nd General Session on 27 May 2014 (26).

Finally, Resolution 25, designating facilities as approved for holding rinderpest virus-containing material, was approved by the World Assembly of Delegates of the OIE during its 83rd General Session, on 26 May 2015 (27).

CONCLUSION

The global eradication of rinderpest is a major achievement for humanity and in particular for veterinary professionals. There have been many success stories, some bitter lessons have also been learnt. The eradication of rinderpest would not have been possible without international solidarity across continents, such as the support from the OIE in chairing the advisory committee of PACE, as well as the firm commitment of many international and regional organisations, including FAO and the African Union. Equally, it could not have been achieved without continually encouraging all countries to be transparent about their disease situations and the OIE's efforts to disseminate new scientific information, or without the continued support from generous donors, such as the European Union and the United States Agency for International Development (USAID). That said, the main contribution to the global eradication of rinderpest came from the countries themselves and countless numbers of highly dedicated individuals, whether farmers, veterinarians, scientists or local community workers.

So as noted by Unger *et al.* (28), 250 years after the establishment of the first veterinary college in Lyon to educate veterinarians on the control of rinderpest, the veterinary profession was set to declare the global eradication of this major animal viral disease.

The strategies employed and the actions taken by the OIE and its partners in the fight against rinderpest should not be forgotten. May the lessons learnt from its eradication remain alive, particularly in view of the other animal diseases, such as peste des petits ruminants and, maybe later, foot-and-mouth disease, which could eventually be eradicated in the future.

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CHAPTER 5.3

ROLE OF THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS IN THE ERADICATION OF RINDERPEST

B.G. TEKOLA [(1)*], F. NJEUMI [(1)], M. RWEYEMAMU [(2)], Y. OZAWA [(3)†] & J. LUBROTH [(1)]

(1) Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00153 Rome, Italy
(2) 6 Robins Dale, Knaphill, Woking, Surrey, United Kingdom
(3) 1-15-2-3404 Tamagawa, Setagayo-Ku, Tokyo 158-0094, Japan
†Deceased

*Corresponding author: Berhe.Tekola@fao.org

SUMMARY **The goal of first controlling and then eradicating rinderpest was a priority of the Food and Agriculture Organization of the United Nations (FAO) from its founding as an agency of the United Nations in 1945. To achieve this goal, FAO through its various activities, particularly in affected and at-risk countries, helped build capacity in Veterinary Services, assisted governments in establishing laboratories and laboratory/epidemiology networks, created regional institutions, supported vaccine production and quality assurance, initiated fundraising to complement its internal resources, and organised, in conjunction with the World Organisation for Animal Health (OIE), a systematic global eradication programme for rinderpest. This coordinated approach led to the declaration that the world was free of rinderpest at the 37th FAO conference in Rome in June 2011, following a similar declaration at the General Session of the World Assembly of the OIE in May 2011.**

KEYWORDS **Control – Coordination – FAO – Food and Agriculture Organization of the United Nations – Mandate – Rinderpest – Surveillance.**

CONTROL OF RINDERPEST AND EPIDEMICS AS PART OF THE ORIGINAL MANDATE OF FAO

Before the end of the Second World War, there was little international collaboration on rinderpest control and research. Following the establishment of FAO as an agency of the United Nations in 1945, it convened a series of meetings to guide countries in developing disease control/eradication programmes and specifically to find ways to produce suitable vaccines for the control of rinderpest. Such activity fell within the mandate of FAO to promote the global objectives of improving food security, nutrition, livelihoods and economic development of rural peoples (1). The first recorded activity by FAO involving rinderpest was an *ad hoc* committee meeting on animal health in London on 15 August 1946, which emphasised the need for action on the widest international lines to eradicate the major plagues. As the outcome of that meeting, in December 1946, the Animal Industry Branch and later the Animal Production Branch were established in FAO, with Dr R.W. Phillips (animal husbandry specialist) appointed as the first chief. The meeting considered the problem of rinderpest and came to the conclusion that this disease still represented a major threat to the world's supply of food and felt that every effort should be made to eradicate it. The Subcommittee on Animal Health of the FAO Standing Advisory Committee on Agriculture, which met in Washington, DC, United States of America (USA), in April 1947, recommended that FAO should assist in the establishment and distribution of avianised virus for production of rinderpest vaccine. (This vaccine had been developed during the Second World War at Grosse Isle, Canada, by the Canadian and US Governments, who feared that rinderpest virus might be used as a bioweapon.) The committee also recommended that a meeting of scientists should be convened to discuss ways in which the activities of veterinary organisations all over the world could be coordinated. In 1947, FAO assumed responsibility for the agriculture advisory project of the United Nations Relief and Rehabilitation Administration (UNRRA) in nine countries, namely Australia, China, Czechoslovakia, Ethiopia, Greece, Hungary, Italy, Poland and Yugoslavia. Rinderpest control was the most important part of the programme in China and Ethiopia (2). UNRRA was responsible for the relief of victims of war in any area under the control of any of the United Nations agencies. In Ethiopia, one of the first things that FAO undertook after inheriting the UNRAA work was to develop a programme for rinderpest control. This programme, which began in 1947, set up laboratory and other services and vaccinated about 3 million cattle between 1950 and 1953 (see Box 1).

BOX 1

In March 1953, FAO had sent a mission to Ethiopia to help modernise the country's agriculture and forestry, including experts in crop production, animal production, animal disease control, rural welfare, forest development and nutrition. This mission included a team of FAO veterinarians (Fig. 1).

FIG. 1
TWO ETHIOPIAN VETERINARIANS RECONSTITUTING RINDERPEST VACCINE
THE ONE ON THE RIGHT IS FILLING A SYRINGE WITH DILUTED VACCINE
Source: FAO/G. Gregoire

Rinderpest control was the most important part of the UNRRA programme in China. Towards the end of 1947, two veterinarians were assigned to the FAO special advisory group in China to assist the Chinese on animal disease control problems, and in particular to assist in the further development of the avianised and lapinised rinderpest vaccines. By 1957, rinderpest was fully controlled and since that time no outbreak has ever been reported in China. At the end of April 1948, a veterinarian (K.V.L. Kesteven) was appointed to the FAO staff in Washington, DC. He was assigned primarily to work on the rinderpest problem. An overview of FAO's subsequent capacity-building activities in all aspects of the Veterinary Services and its assistance to governments in organising a systematic control programme may be found in issue 38 of the *EMPRES Bulletin* (3).

EARLY PROGRAMMES FOR RALLYING INTERNATIONAL COLLABORATION FOR RINDERPEST CONTROL AS PART OF THE ORIGINAL MANDATE OF FAO

In October 1948, FAO in collaboration with the British Colonial Office organised the first international rinderpest conference for Africa. The subject of the conference was 'rinderpest vaccines, their production and use in the field' and it was held in Nairobi. Participants unanimously concluded that the eradication of rinderpest was a practical possibility and should be carried out without delay. This conference examined the question of rinderpest elimination from Africa and drew attention to the fact that in some countries, namely Eritrea (then a part of Ethiopia), Ethiopia, Somalia and Sudan, assistance might be required in the spheres of finance and the provision of personnel and vaccines. Furthermore, attention was directed to the existing overstocking of certain areas in the territories. This overstocking could become accentuated as the control of rinderpest progressed. In view of these dangers, the marketing and utilisation of surplus stock was imperative. The African rinderpest conference considered that, globally, FAO would be the most suitable organisation to consider the solution to the problems as well as to disseminate information. This was in line with the Brazzaville conference (February 1948), which created a permanent bureau and an international scientific committee to hold regular meetings to discuss developments in the research and control of African trypanosomiasis. The outcome of both the Brazzaville and Nairobi conferences was the formation of the intergovernmental Commission de Co-operation Technical en Africa (CCTA). One of the first actions of the CCTA was to constitute a working group to consider the functions of a proposed bureau to deal with the scourge of rinderpest. CCTA and FAO provided assistance in the creation of an African office to coordinate the rinderpest activities in Africa (4, 5, 6). It was established in November 1951 at Muguga, Kenya, as the Inter-African Bureau of Epizootic Diseases (IBED; a precursor of the present-day African Union Interafrican Bureau for Animal Resources [AU-IBAR]), which subsequently played a key role in supporting eradication of rinderpest from Africa (5, 6). In Asia, FAO convened a similar rinderpest conference in Bangkok in 1949, at which several governments agreed to coordinate their programmes to control and eliminate rinderpest.

EARLY RECOGNITION OF THE IMPORTANCE OF GOOD-QUALITY VACCINES AS ESSENTIAL FOR EFFECTIVE RINDERPEST CONTROL

At the April 1947 meeting in Nassau county (New York), FAO recognised the importance of the proper manufacturing of good-quality vaccines. The first international training workshop for the manufacture of live virus vaccines, particularly rinderpest vaccine, was held at Izatnagar, India, as early as in 1953. Using these vaccines, India implemented a mass rinderpest vaccination campaign during the 1950s (see Chapter 4.13.4). A similar international training workshop was held in Egypt in 1955, followed by another in Pakistan in 1959. During the 1950s, FAO supported the use of attenuated vaccines (lapinised vaccine or lapinised avianised vaccine, developed by J. Nakamura [7]) in rinderpest control campaigns in Southeast Asia (8) (Fig. 2).

In 1968, FAO, the OIE and the World Health Organization (WHO) jointly organised a meeting in Paris to draw up standards for the production of avianised, caprinised and lapinised rinderpest vaccines. FAO joined the Colombo Plan in 1961 and this helped rinderpest control in Cambodia. Between 1961 and 1965, FAO experts established a production plant for the lapinised avianised rinderpest vaccine in Cambodia and used the vaccine to control the disease (9) (Box 2). Similarly, FAO experts supported and advised on the design, construction and/or operation of facilities for lyophilised vaccine production in Thailand, Bangladesh, India and Pakistan, as well as in Egypt, Nigeria and Sudan.

In the early 1960s, attenuated tissue culture vaccine was developed by Walter Plowright (10) at the then East African Veterinary Research Organisation (EAVRO), Muguga, Kenya. This new vaccine was first evaluated in the field in Nigeria, (11, 12) by Robert Johnson, who obtained an earlier passage

FIG. 2
THAILAND – DRAWING BLOOD FROM THE HEART OF A RABBIT TO MAKE LAPINISED VACCINE
Source: FAO photo

of the Kabete 'O' attenuated strain from Plowright, further attenuated it, and used it in Nigeria, while Plowright himself was still persuading the authorities in Kenya and East Africa to accept the vaccine, which was safer and yet as effective as the then established caprinised vaccine (details provided in Chapter 3.5). The results in Nigeria contributed to reducing resistance to the introduction of new vaccine in East Africa, which then paved the way to what turned out to be the Plowright tissue culture vaccine that was so pivotal to the eventual global eradication of rinderpest.

THE THIRTY-YEAR STIMULUS FOR REGIONALLY COORDINATED RINDERPEST CONTROL (1960–1980)

Learning from the Chinese and Ethiopian projects, and with the availability of a tissue culture vaccine that could be produced in relatively large quantities in a controlled system, FAO embarked upon stimulating regional and international organisations (Fig. 4) towards coordinated rinderpest control, as a cost-effective programme. FAO implemented the Near East Animal Health Institute's (NEAHI's) regional project (see Chapter 4.7) from 1962 to 1971 in five Near East countries, namely Iran, Iraq, Lebanon, Sudan and the United Arab Republic, funded by the United Nations Special Fund. From 1969, a Near East rinderpest pandemic engulfed the region, rolling through Afghanistan and Iran from 1969 to 1973, reaching Turkey in 1970, and then the Syrian Arab Republic, Lebanon and Jordan (Chapter 2.3). FAO recommended the use of the tissue culture vaccine for Middle East countries in 1970. The NEAHI project established a rinderpest unit in the Near East Animal Health Institute in Cairo, Egypt, for rinderpest diagnosis and tissue culture vaccine production for the region. NEAHI was followed by the Near East Animal Production and Health Centre (NEADEC) from 1972 to 1975 (Chapter 4.8). There was again an upsurge of rinderpest outbreaks in various non-endemic Gulf States in the period 1981–1985 (13). FAO continued its support through a successor project, the Middle and Near East Regional Animal Production and Health Project (MINEADEP), which was implemented from 1975–1991 (Chapter 4.9).

In Africa, an ambitious and internationally funded rinderpest control programme was set up with the objective of 'eradication' from the African continent (Joint Programme 15 or JP15). This operated between 1962 and 1976 in 22 African countries, supported by the Scientific and Technical Committee of the Organisation of African Unity (OAU) with funding from the European Development Fund and the United States Agency for International Development (see Chapter 4.1.). This programme aimed to deliver herd immunity levels in excess of 90% (with the high delivery level to be achieved by vaccinating at country level annually for three

BOX 2

The anti-rinderpest campaign in Cambodia was coordinated by J.R. Hudson (FAO vaccine specialist). In 1958, 25,732 cattle, 37,782 buffaloes and 13,481 pigs were protected against rinderpest. FAO's role was to address:

- The shortage of personnel - addressed through training.
- The vaccine used in 1959, which was expensive to produce and gave a relatively short period of immunity, so lyophilised lapinised vaccine was adopted.
- The attitude of the farmers; many of them were little worried at the losses caused by the disease and therefore did not report the disease or failed to bring all their animals for vaccination.

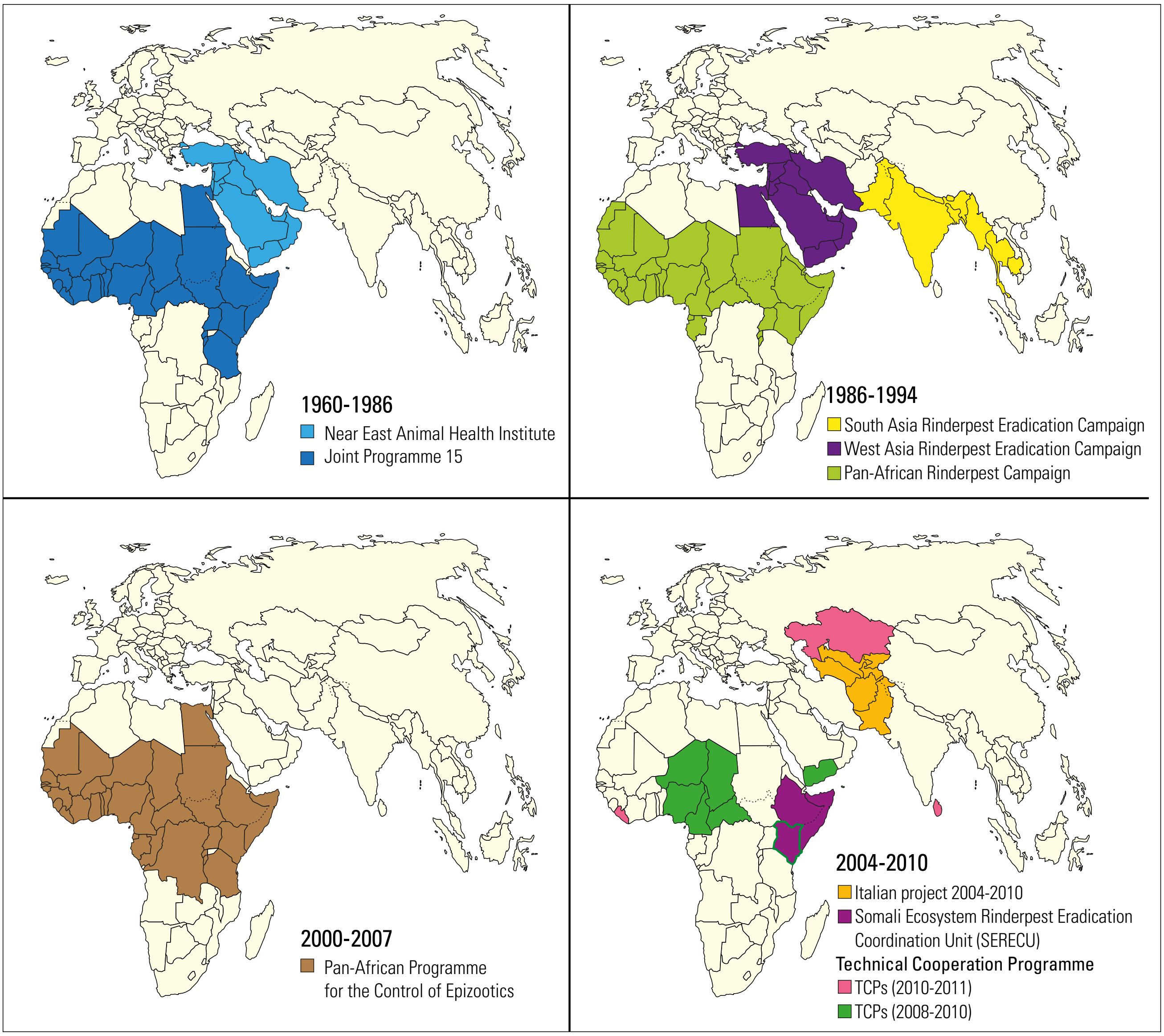
In the Thailand–Cambodian border, following the eradication of rinderpest, a belt of vaccinated animals 5 km deep along the Cambodian frontier was created: in 1959 a total of 107,892 cattle, 141,223 buffaloes and 7,531 pigs were vaccinated in this area.
From 1960 to 1965, FAO assisted the Government of Cambodia to conduct a large-scale campaign aimed at the eradication of rinderpest (Fig. 3). This involved the vaccination of some 2.5 million cattle and buffaloes, many of them in remote jungle and mountain areas.
The operation was a truly international one, with FAO coordinating the generous help given by Japan, Australia, France and the USA, while Cambodia supplied the services of the Pasteur Institute at Phnom Penh, research and laboratory workers, and the trained teams of vaccinators. The campaign continued for at least another three years and eliminated the danger of rinderpest to the livestock industry in Cambodia and its neighbouring countries. The last outbreak in Cambodia occurred in July 1964 in Kompong Thom province.

FIG. 3
FAO RINDERPEST CAMPAIGN CAMBODIA, SIEM REAP PROVINCE, 1960–1965
Source: FAO/J.G. Rumeau

successive years) through a phased approach (covering different countries at different times), starting from West and Central Africa. When JP15 was extended to eastern Africa, FAO ran training schemes in Ethiopia and Somalia, funded by the United Nations Development Programme (UNDP). By the end of JP15 in 1976, surveillance and reporting at the national level made it clear that the virus had survived in a number of African countries that had participated in JP15 (see Chapters 4.1

FIG. 4
REGIONAL PROGRAMMES/PROJECTS

Adapted from Njeumi *et al.*, 2012 (8), modified to comply with United Nations, 2020. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.



and 4.6), which was the reason for the last African pandemic (Chapter 2.4).

Distressingly, towards the end of the 1970s and early 1980s, clinical rinderpest resurged in several sub-Saharan countries. In response to an earlier drought in the Sahel, FAO had established, in 1976, a mechanism for responding to food security emergencies, namely the FAO Technical Cooperation Programme (TCP). Such emergency assistance provided by the FAO TCP amounted to US$6.534 million from 1980 to 1983, and with it FAO was able to help the affected countries with a series of technical collaboration projects aimed at arresting the spread of new rinderpest outbreaks, pending international support for eradication. Based on the careful implementation of 35 technical collaboration projects (Table I), no outbreak was reported in Central and West Africa after their completion (except in Benin and Burkina Faso, which reported their last outbreaks in 1987 and 1988, respectively). Based on this success, the OAU-IBAR, encouraged by FAO and other international organisations, called for another vaccination campaign. A major Pan-African Rinderpest Campaign (PARC; 1986–1998) was set up with a series of OAU-IBAR-coordinated projects funded by the European Union, France, Japan, Sweden, the United Kingdom of Great Britain and Northern Ireland and the FAO TCP. A common understanding of the international community that participated in the PARC programme was that rinderpest control should be built on the positive and negative lessons of JP15 and combined with aspects that could contribute to institutional reforms/modernisation and the long-term sustainability of animal health services.

TABLE I

FAO ASSISTANCE FOR RINDERPEST CONTROL IN AFRICA FROM 1980 UP TO 31 JANUARY 1984 (US$)

Country	1980	1981	1982	1983	Total
Mauritania		80,000		200,000	**280,000**
Senegal		90,000		195, 000	**285,000**
Gambia		50,000		60,000	**111,000**
Guinea-Bissau				115,000	**115, 000**
Guinea [a]				322,000	**322,000**
Sierra Leone				90,000	**90,000**
Liberia				50,000	**50,000**
Côte d'Ivoire			97,000		**97,000**
Mali [b]	232,000	30,000		100,000 125,000	**487,000**
Upper Volta (Burkina Faso)	90,000			186,000	**276,000**
Niger	190,000			185,000	**375,000**
Ghana	58,000				**58,000**
Togo	50,000			64,000	**114,000**
Benin	50,000			125,000	**175,000**
Nigeria				380,000	**380,000**
Cameroon				190,000	**190,000**
Chad				133,000	**133,000**
Central African Republic				105,000	**105,000**
Zaire				50,000	**50,000**
Burundi				25,000	**25,000**
Sudan			20,000	215,000 230,000	**465,000**
Egypt			20,000		**20,000**
Ethiopia				245,000	**245,000**
Somalia				250,000	**250,000**
Kenya				223,000	**223,000**
Uganda	110,000			250,000	**360,000**
United Republic of Tanzania			105,000	243,000	**348,000**
Malawi				45,000	**45,000**
Zambia				20,000	**20,000**
Regional projects		50,000	67,000	314,000	**431,000**
Nigeria (laboratory)				250,000	**250,000**
Nigeria (field)				130,000	**130,000**
Zaire				50,000	**50,000**
Total	**780,000**	**300,000**	**212,000**	**5,242,000**	**6,534,000**

TCP, Technical Cooperation Programme

[a] Guinea had two TCP projects in 1983: TCP/2309 (E) campaign and TCP/4401 (Lab)

[b] Mali had two TCP projects in 1983

In 1987, FAO convened the Expert Consultation on the Global Strategy for Control and Eradication of Rinderpest (14). Essentially this consultation took the positive lessons from Africa and recommended that FAO should work with regional organisations in West Asia and South Asia to formulate regional rinderpest campaigns similar to PARC.

In West Asia, FAO encouraged the countries of the region to set up an FAO-facilitated West Asia Rinderpest Eradication Campaign (WAREC) in 1989, a campaign that involved Egypt, Jordan, Lebanon, Iraq, the Islamic Republic of Iran, Saudi Arabia, the Syrian Arab Republic, Turkey, the United Arab Emirates and Yemen (at that time comprising the Yemen Arab Republic and the People's Democratic Republic of Yemen). Despite the Gulf War (1990–1991), clinical rinderpest cases were eliminated in the project areas by the end of WAREC (1993) and countries were ready to enter the surveillance phase. Soon after the termination of WAREC, focal rinderpest was detected in the region and addressed. After

1993, assistance was provided through national technical collaboration projects (i.e. TCP/IRQ/2253, TCP/RAB/4452, TCP/LEB/2254, TCP/TUR/0154, TCP/TUR/0155) or other funding. Although the last reported outbreak in the area was in 1996 (see Chapter 4.12), vaccination was implemented in several countries until 2003, the last use of vaccine in the region being in Saudi Arabia. Surveillance was carried out until the last countries were recognised as free from rinderpest.

In South Asia, the FAO Regional Office for Asia and the Pacific and its Animal Production and Health Commission for Asia and the Pacific (APHCA) promoted the philosophy of a South Asia Rinderpest Eradication Campaign (SAREC). Although the concept of SAREC was generally accepted, it was not easy to form a single regional project for many reasons. In India, Bhutan and Nepal, European Economic Community-funded national projects were implemented, while in Nepal TCP/NEP/2902, 'Protection against rinderpest and other major diseases of farm livestock through emergency preparedness planning and new vaccine technology', assisted in preparing data for dossier formulation.

Much later, in Pakistan, FAO supported its risk-based rinderpest control campaign as well as epidemiological surveillance through a combination of various projects. In Central Asia, through Italian support (joint programme GTFS/INT/907/ITA, 'Controlling transboundary animal diseases in Central Asian countries' 1 August 2004 to 31 July 2012), FAO implemented surveillance towards freedom from rinderpest in Afghanistan, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkmenistan and Uzbekistan.

TOWARDS FILLING TECHNICAL GAPS FOR SUCCESSFUL PROGRESSIVE REGIONALLY COORDINATED RINDERPEST CONTROL

During the execution of the new regional rinderpest control programmes, FAO learnt from previous experience and from internationally coordinated disease control programmes of WHO, especially the smallpox and poliomyelitis campaigns. Accordingly, FAO with its international and regional partners identified four key areas of attention between the mid-1980s and 1992. These were:

(i) the quality assurance of coordinated rinderpest control programmes through the use of quality controlled vaccines, seromonitoring to ensure effective immunisation, and later serosurveillance of unimmunised animals to assure the absence of silent virus circulation;
(ii) epidemiological analysis to guide various aspects of the assessment of disease occurrence, strategic targeting of interventions, the effectiveness of control and the risk of recurrence;
(iii) the support of the OIE in establishing and monitoring standards for rinderpest virus freedom at various geographical levels;
(iv) the definition of steps for progressive control towards a time-bound, global rinderpest eradication objective.

Vaccine quality control

The programme for the organised control of vaccine quality was focused primarily in Africa and was initially designed to support PARC. Through its TCP support, FAO conducted a series of random quality checks on vaccines produced and used in Africa, especially with respect to vaccine virus titre and sterility. This was undertaken between 1983 and 1986. This testing demonstrated that the vaccines produced in Africa were of variable quality. The findings led FAO to recommend to PARC that only vaccines that had been quality checked by FAO be used in its campaign. To assist African vaccine producers, FAO, with support from its TCP budget and the UNDP, supported the purchase of new vaccine production equipment. As a preparatory step to setting up a five-year training project to improve vaccine production and quality control to be funded by the UNDP (see Chapter 5.6), it commissioned a consultancy in 1988 by an expert with industrial experience to advise on the technical aspects of vaccine production and quality control as well as on long-term sustainability. One of the recommendations was to identify a good name that would link the units being set up in Ethiopia and Senegal, from which the concept of a Pan-African Veterinary Vaccine Centre (PANVAC) emerged (15). This name was accepted by the OAU-IBAR, FAO and the UNDP. After several cycles of projects (TCP/RAF/2266, TCP/RAF/2267, TCP/RAF/4565, GCP/RAF/305/EEC, TEMP/RAF/996/EC, GCP/RAF/318/EC and GCP/RAF/337/JPN) and support from the UNDP, FAO, the European Union and Japan, PANVAC was eventually mainstreamed into the AU core system in 2004.

Seromonitoring and serosurveillance

This was organised in Africa, West Asia and South Asia through the Joint FAO/International Atomic Energy Agency (IAEA) Division of Nuclear Techniques in Food and Agriculture. This was supplemented by training in diagnostic methods either at its training laboratory in Seibersdorf, Austria, (see Chapter 5.4) or *in situ* in the laboratory network of experienced scientists (16).

The collaboration with the OIE on standards led to the launch of the three-stage 'OIE Rinderpest Pathway' by the OIE in 1989, for countries to be officially recognised as free from rinderpest (see Chapter 7.1). An officer was tasked to attend and support the OIE *Ad hoc* Group for rinderpest until 2011.

THE TIME-BOUND PROGRAMME FOR GLOBAL RINDERPEST ERADICATION

By the beginning of the 1990s, rinderpest control programmes in Africa and West and South Asia were showing success in terms of a substantial reduction in the number of outbreaks recorded. In 1992, FAO commissioned an independent study by Gordon Scott and Alain Provost, the leading experts on rinderpest at that time, to review the progress in rinderpest control and advise on the feasibility of a time-bound objective for global rinderpest eradication. This study recommended that a concerted global campaign could result in verified rinderpest eradication within 20 years, i.e. by 2010 (17). FAO then convened, in Rome in October 1992, the Expert Consultation on the Strategy for Global Rinderpest Eradication (18). Although the expert consultation accepted the conclusion by Scott and Provost of the goal of verified global rinderpest eradication by 2010, it recommended an FAO-coordinated Global Rinderpest Eradication Programme (GREP) rather than the global rinderpest eradication campaign (GREC) run by FAO. Through the GREP proposal, the primary responsibility for rinderpest eradication operations would fall within nation states and regional organisations (see Chapter 6.1). It was envisaged that such an experience would help to develop sustainable systems that would result in effective rinderpest eradication and that, furthermore, would be relevant to the control of other epidemic diseases. In working towards a world free of rinderpest, the role for FAO was (i) to provide global coordination and technical guidance to national and regional operations, (ii) to help with the epidemiological analyses that would become increasingly important as the incidence of clinical disease subsided, and (iii) to assist the OIE with respect to international standards.

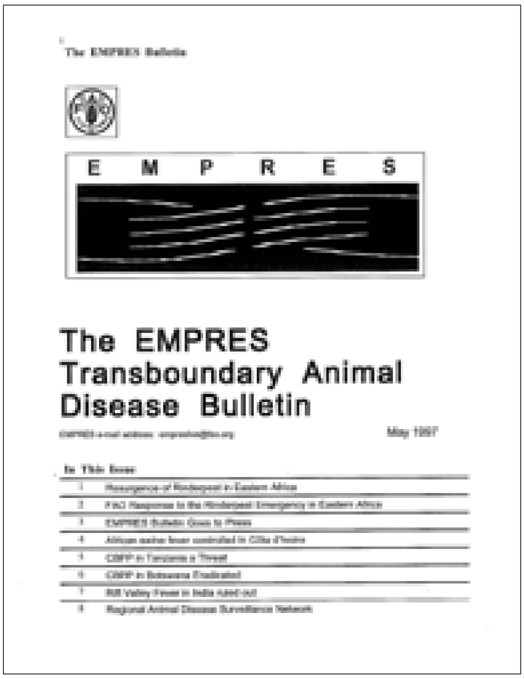
ESTABLISHING DEDICATED STRUCTURES FOR GLOBAL RINDERPEST ERADICATION AND RISK MANAGEMENT OF EPIDEMICS

Between 1993 and 1996, the FAO Animal Health Programme underwent a series of changes, in support of its coordination of GREP. This coordination role in addition to GREP was to strengthen Veterinary Services and improve animal production. First, the incoming Director-General (Dr Jacques Diouf) introduced two linked FAO special programmes, one focused on food security and the other that established the Emergency Prevention System (EMPRES) against transboundary animal and plant pests and diseases. The animal disease component of EMPRES was to focus primarily on rinderpest eradication but also to develop systems for the risk management of other epidemics. Accordingly, the Animal Production and Health Division set up within its Animal Health Service a dedicated Infectious Diseases EMPRES Group, which included the Secretariat for GREP. (Incidentally, EMPRES is what introduced the term transboundary animal disease into the veterinary vocabulary.) Figure 5 illustrates the first edition of the *EMPRES Bulletin* in May 1997.

FIG. 5

FIRST EDITION OF THE EMPRES BULLETIN IN MAY 1997

Source: FAO (1997). – The Empress Transboundary Animal Disease Bulletin. May 1997.



E M P R E S

The EMPRES Transboundary Animal Disease Bulletin

May 1997

As an FAO special programme, the work of EMPRES and thereby the coordination of global rinderpest eradication had to report regularly to the Director-General of FAO, who had set up a high-level steering committee that he chaired.

In 1996, the World Food Summit of Heads of States and Governments committed the world to global rinderpest eradication and the progressive control of other transboundary animal diseases. Its Rome Declaration and Plan of Action (19), commitment 3, objective 3.1(i) stated:

'Seek to ensure effective prevention and progressive control of plant and animal pests and diseases, including especially those which are of transboundary nature, such as rinderpest, cattle tick, foot and mouth disease and desert locust, where outbreaks can cause major food shortages, destabilise markets and trigger trade measures; and promote concurrently, regional collaboration in plant pests and animal disease control and the widespread development and use of integrated pest management practices.'

At the operational level, FAO set up an EMPRES Expert Consultation mechanism, which replaced the Epizootic Panel that had previously advised the FAO Director-General on matters of epidemics. The work of the new EMPRES Expert Consultation was better focused and it was appointed in 1996 to provide advice (initially) on an annual basis with respect to three objectives:

(i) strategies and actions necessary to achieve and verify global rinderpest eradication by 2010;
(ii) goals, strategies and actions for the EMPRES high-priority diseases that would allow these diseases to be brought under substantial control;
(iii) goals, strategies and actions for the implementation of the EMPRES global early warning and early reaction systems.

In addition, FAO set up a specific GREP Technical Consultation mechanism that convened rinderpest specialists from regions of the world with recent experience of the disease and those from rinderpest-free regions of the world. Along with this, FAO reinforced the work of its GREP Secretariat by nominating a network of rinderpest reference laboratories, with the FAO World Reference Laboratory for Rinderpest and Other Morbilliviruses at the Pirbright Institute at its apex.

The first EMPRES Expert Consultation, in 1996, drew up a global roadmap for progressive elimination of rinderpest on a country-by-country basis. This was later modified by the EMPRES Expert Consultation in 1998 to include a special focus on intensive and ecosystems-based surveillance of disease and infection. This strategy helped to focus intensified control and surveillance action in those few ecosystems where infection was suspected after 1998.

Several GREP expert and technical consultation meetings were organised in 1995, 1996, 1997, 1999, 2000, 2002, 2007, 2009 and 2010 (20, 21, 22, 23, 24, 25, 26, 27, 28, 29). The recommendations of these consultations provided guidance for GREP's way forward (see Chapter 6.1).

Overall, FAO promoted many of the tools and techniques that were successfully used for rinderpest eradication. These included:

- the science-based 'pathway' approach, developed with the OIE for countries to follow towards eradication;
- quality assurance of vaccine and serological tests;
- provision of diagnostic kits;
- risk-based surveillance supported by molecular analyses;
- the use of the thermostable version of the cell culture vaccine that facilitated vaccine delivery into inaccessible areas beyond cold chains;
- participatory disease searching techniques
- community-based vaccination programmes using community-based animal health workers;
- mathematical modelling.

FAO supported almost all of the countries that were infected by rinderpest, by training epidemiologists and laboratory staff and by procuring laboratory equipment. Training workshops were also held on surveillance, diagnosis, vaccine production and disease management. These skills and materials developed for the eradication of rinderpest remain available for the control of other diseases (see Box 3).

TOWARDS THE END GAME FOR RINDERPEST

Based on the cessation of vaccination and the accumulation of favourable surveillance results, in October 2010, the FAO Director-General (Dr Jacques Diouf) was in a position to declare the cessation of all field activities for the control of rinderpest (Fig. 7), nine years after the last reported case of rinderpest.

From December 2009 until June 2011, FAO and the OIE formed the Joint FAO/OIE Committee on Global Rinderpest Eradication (see Chapter 7.2). The Joint Committee was asked to review all reports from the OIE indicating the freedom from rinderpest of all countries and territories worldwide, supplemented by information provided by FAO indicating the technical soundness of the surveillance and diagnostic methodologies underpinning these reports. FAO also played a secretariat role for the Joint Committee. The report of this committee led to, in June 2011, the FAO and OIE making a joint declaration of 'a world without rinderpest'. Both the OIE and FAO celebrated the eradication of rinderpest in

BOX 3
CONCERNING GIOVANNI MARIA LANCISI

FAO and its partners brought to an end the important work started by Lancisi (Fig. 6). Giovanni Maria Lancisi (1654–1720) was a physician and archiater of Pope Clement XI, well known as an anatomist and epidemiologist, who made an important contribution to veterinary medicine when rinderpest (cattle plague) affected Europe in the 18th century. His book, De bovilla peste, published in 1715, illustrates the characteristics of cattle plague and, above all, 11 control measures. Of the control measures, the most relevant were the introduction of stamping out, with special instructions for the killing and burial of affected animals, the prohibition of animal movements, and the adoption of special hygienic and political measures. Lancisi points out the relationship between politics and history on the one hand and cattle plague on the other. He may be considered the modern co-inventor (along with Thomas Bates) of sanitary control measures - these are still applicable today (see Chapter 3.2).

FIG. 6
GIOVANNI MARIA LANCISI

Source: Giovanni Maria Lancisi. Line engraving by G. Marcucci after G. Cleter. Wellcome Collection. Public Domain Mark

FIG. 7
FAO PRESS CONFERENCE, OCTOBER 2010, AT WHICH DR JACQUES DIOUF (DIRECTOR-GENERAL) ANNOUNCED THE CESSATION OF FAO ACTIVITIES AGAINST RINDERPEST

Source: Source: FAO/Giulio Napolitano

2011, at the 79th OIE General Session and 37th FAO Conference, respectively (29). A plaque commemorating the eradication of rinderpest was installed at the FAO entrance hall on 28 June 2011 (Fig. 8). FAO also recognised outstanding contributors to this major achievement in our history. A monument commemorating the success was erected in Rome by FAO and the Government of Italy. To achieve the completion of global rinderpest eradication, sequestration of rinderpest virus has been started,

FIG. 8
PLAQUE AT FAO HEADQUARTERS COMMEMORATING THE ERADICATION OF RINDERPEST
Source: FAO/Alessandra Benedetti

to prevent the accidental release of the virus. The FAO–OIE Rinderpest Joint Advisory Committee has been actively working on the sequestration of the virus (see Chapter 8.2).

ACKNOWLEDGEMENTS

FAO thanks all stakeholders, including Member Nations, donors, collaborating organisations, the joint FAO/IAEA division, farmers, traders, non-governmental organisations, civil society organisations and others who played a role in the first eradication of an animal disease in our history. This would have not been possible without the leadership of the directors (Table II) of the Animal Production and Health Division since 1946, the chiefs of the Animal Health Service, the head of EMPRES, the GREP secretaries, as well as all the technical offices in Rome and the decentralised offices.

TABLE II
NAMES OF THE DIRECTORS OF THE ANIMAL PRODUCTION AND HEALTH DIVISION (AGA) FROM FAO'S FOUNDATION

Serial	Name	Nationality	Dates	Position title
1	R.W. Phillips	USA	December 1946 to May 1949	Chief, Animal Industry Branch and Animal Production Branch
2	R.W. Phillips	USA	May to December 1949	Continued to supervise the Branch from his new post as Deputy Director of Agriculture Division
3	K.V.L. Kesteven	Australia	January 1950 to December 1958	Chief, Animal Industry Branch 1950–1951; Animal Production Branch 1951–1958
3	K.V.L. Kesteven	Australia	January 1950 to December 1968	Director, Animal Production and Health Division (AGA)
(3)	E.A. Eichhorn	USA	December 1968 to March 1969	Acting Director, AGA
4	H.A. Jasiolorowaki	Poland	April 1969 to November 1975	Director, AGA
(4)	R.B. Griffiths	United Kingdom	December 1975 to August 1977	Acting Director, AGA
5	H.C. Mussman	USA	September 1977 to July 1980	Director, AGA
(5)	R.B. Griffiths	United Kingdom	July 1980 to September 1980	Acting Director, AGA
6	R.B. Griffiths	United Kingdom	October 1980 to 1983	Director, AGA
7	H.A. Jasiolorowaki	Poland	1984–1990	Director, AGA
8	E.P. Cunningham	Ireland	September 1990 to 1991	Director, AGA
(8)	A.W. Qureshi	Pakistan	1992–1994	Officer in Charge/Acting Director, AGA
9	T. Fujita	Japan	December 1994 to 1997	Director, AGA
10	S. Jutzi	Switzerland	1998–2011	Director, AGA
11	B. Tekola	Ethiopia	2011–2020	Director, AGA

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CHAPTER 5.4

ROLE OF THE INTERNATIONAL ATOMIC ENERGY AGENCY IN RINDERPEST ERADICATION

M.H. JEGGO [(1)*] **& J.D. DARGIE** [(2)]

(1) Former IAEA Technical Cooperation Regional Expert in Animal Health, and Head, Animal Production and Health Section, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria

(2) Former Head, Animal Production and Health Section, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and Director, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria

*Corresponding author

SUMMARY

This chapter describes how the International Atomic Energy Agency (IAEA), through its Joint Programme with the Food and Agriculture Organization of the United Nations (FAO), assisted individual countries and the international community to develop and implement enzyme-linked immunosorbent assay (ELISA) and molecular tests, sampling protocols and quality assurance procedures for the seromonitoring and surveillance of rinderpest to support its eradication. Descriptions are provided of the test procedures themselves and of the various mechanisms used to provide strategic direction and to coordinate activities within countries, between regions and at the global level to establish or strengthen infrastructural and human resource capacities for conducting testing and reporting results to national and international authorities. Major achievements included the development of validated ELISA-based systems for detecting antibodies to rinderpest virus induced by vaccination or field infection, validated ELISAs for detecting rinderpest and peste des petits ruminants (PPR) virus antigens in support of surveillance and a universally accepted sampling frame for cattle, and the establishment of an operational quality assurance programme for rinderpest testing laboratories in Africa and elsewhere. Partnerships had an indispensable role in ensuring that seromonitoring and surveillance contributed effectively to rinderpest eradication. Of particular importance were partnerships between the IAEA and national veterinary laboratories and services, partnerships with officials of the Pan-African Rinderpest Campaign (PARC; see Chapter 4.2) and other regional entities, partnerships with FAO itself and with the World Organisation for Animal Health (OIE), and partnerships with the international donor community.

KEYWORDS

Coordinated research – ELISA – International recognition – Quality assurance – Rinderpest – Seromonitoring and surveillance – Technical cooperation – Test kits.

INTRODUCTION

This chapter provides historical context and describes the specific role played by one organisation – the International Atomic Energy Agency (IAEA) – in supporting the global efforts to fight rinderpest. It begins by answering two fundamental and related questions: why the IAEA, and why rinderpest? Without going into technical details, it then goes on to describe the unique contributions that the IAEA – through its Joint Programme with the Food and Agriculture Organization of the United Nations (FAO) – 'brought to the table' in terms of strategies, technologies, and management and financial support, and how it went about broadening and intensifying its partnership base to introduce and embed seromonitoring and surveillance tests and reporting procedures in national rinderpest control and eradication programmes, which proved so critical a contribution to the positive outcomes achieved by affected countries.

WHY THE IAEA AND THE JOINT FAO/IAEA PROGRAMME?

The IAEA was set up in 1957 as the world's 'Atoms for Peace' organisation within the United Nations (UN). It worked with its Member Countries and multiple partners worldwide to foster, through research, the development and practical applications of safe, secure and peaceful nuclear technologies. In 1964, it joined forces with FAO, establishing a Joint FAO/IAEA Division to promote and coordinate efforts to tackle hunger and food insecurity through the application of nuclear science and technologies. This Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture therefore truly – and in many respects uniquely – embodied the spirit of the strategy of system-wide coherence, which was much later adopted by the UN General Assembly as part of its 'Delivering as One' approach (1).

The formation of the Joint Division and both the conceptual and operational aspects of its work through a wider partnership base within the IAEA itself and with FAO as the Joint FAO/IAEA Programme provided a strong mandate to pursue nuclear applications in animal production and health. However, somewhat controversially, decisions were made in the early 1980s by the secretariats of both organisations to change both the focus of its livestock activities and the nature of the technologies it intended to support. Before this point, it had not been supporting work on animal reproduction, and its activities in animal health were restricted to using isotopes and radiation to explore the pathogenesis of helminth and protozoal diseases, and to develop radiation-attenuated vaccines against these. Moreover, its partnership base with Member Countries was confined largely to working with scientists in university departments and in institutes run by atomic energy authorities, and 'success' was measured by 'outputs' such as publications and number of training courses held. Generating 'outcomes' that could meaningfully improve the livelihoods of farmers and rural communities was 'on the radar' but had yet to be strategised and implemented.

Scientific and technological driving forces for change

Five scientific and technical developments – none of which had an impact on livestock issues at the time but each of which subsequently had enormous practical and lasting global impacts – drove the dramatic changes in the technical direction and emphasis of the Joint FAO/IAEA Programme in animal production and health. The first was the development of radioimmunoassay (RIA) – a radioisotope tracing technique that enables the measurement of tiny quantities of various biological substances in blood and other fluids. For this, the American medical physicist Rosalyn Yalow received the Nobel Prize in Physiology or Medicine in 1977. The second development, invented by Frederick Sanger, a British biochemist, was the dideoxy chain-termination method, which uses radiolabelled nucleotides to determine the exact sequence of nucleotides in a gene and which was later employed to sequence the entire human genome. It was for this work that Sanger received his second Nobel Prize in Chemistry in 1980. The third development was the polymerase chain reaction (PCR) technique, which enables millions of copies of a specific deoxyribonucleic acid (DNA) sequence to be produced quickly and accurately and for which Kary Mullis of the USA was awarded the Nobel Prize in Chemistry in 1993. The fourth development – again requiring radioisotopes – came from the work of British geneticist Alec Jeffries who, in 1984, invented and developed techniques for DNA fingerprinting and DNA profiling. The fifth development, recognised by the award of the Nobel Prize for Physiology or Medicine in 1984, was the discovery by César Millstein and Georges Köhler, working in Cambridge, United Kingdom of Great Britain and Northern Ireland, of the principle of producing monoclonal antibodies to enhance the power of immune-based diagnostic techniques.

Collectively, these scientific and technological breakthroughs were instrumental in revolutionising many aspects of agricultural research and development, including the detection, diagnosis and control of reproductive and infectious diseases in farm animals. However, the wide variety of problems confronted by small-scale livestock producers, and the inevitable budgetary restrictions within the IAEA and FAO, left the FAO/IAEA Programme, in addressing its twin mandates of supporting research and development through nuclear applications, with three inter-related challenges:

- How should it respond to the rapid and constant innovations in these basic immunological and molecular methods, which were leading to variants that no longer relied on radioactive labels and tracers?
- Specifically, for what problems should such world-class scientific and technical breakthroughs be used in the laboratories and farms of developing countries?
- How should any such developments be used in the most effective and cost-efficient manner?

An expanded mandate from IAEA and FAO Member countries: from 'nuclear' to 'nuclear and related' techniques

Getting around the first issue was not easy. In the early days of immunoassay development, radio-isotopes were the labels of choice and even today they are still used extensively in RIAs to measure reproductive hormones and, to a lesser extent, as labels in other diagnostic procedures involving molecular methods. However, since the 1980s, enzymes have been recognised as more appropriate labels for diagnostic tests based on immunoassays where the need has been more for high throughput and simple 'yes or no' answers rather than for measuring something down to picogram, or lower, concentrations. Nevertheless, in the process of developing and purifying reagents for enzyme-linked immunoassays (ELISA) and for validating their specificity and sensitivity, isotopes remain important. Although a final immunoassay – the one appearing in the 'shop window' so to speak – does not contain a radioisotope, ELISA would be difficult to develop without isotopes; indeed, some of the very first immunoassay-based serological tests for rinderpest used antibodies labelled with iodine-125. Similar developments have been seen in molecular methods, with radioisotopes being largely replaced by fluorescent labelling or tagging. Enzyme immunoassays and many of the molecular methods mentioned earlier can therefore rightly and variously be described as 'nuclear-based', 'nuclear-derived' or 'nuclear-related' techniques. Generally, they are as sensitive and specific as their radioisotope-based counterparts, but they avoid the hazards associated with the use of radioisotopes and therefore are simply more suitable for the purposes envisaged.

It was against this background that much discussion and debate took place within both IAEA and FAO circles about the appropriateness of the Joint Division supporting technologies such as ELISA that did not directly involve radioisotopes. One argument in favour was that, for some years before embarking on support for the eradication of rinderpest, the FAO/IAEA Programme had established in many countries an effective and much-appreciated track record in transferring RIAs to improve the reproductive efficiency of cattle and other domestic livestock. In so doing, it had become well acquainted with the challenges, principles and skills needed both to carry out testing and to manage and interpret immunoassay data. In effect, the support provided to, and the capabilities already being transferred for, RIA would also be relevant for ELISA. Other – probably decisive – factors in obtaining the 'green light' were the repeated articulation of the cornerstone philosophy of the Joint Division, namely that the programme be problem rather than technique oriented, and – possibly most importantly – the fact that rinderpest was *the* global threat to livestock health at the time. Given the well-recognised technical and logistical problems of using existing techniques to treat rinderpest, it was obvious that these new techniques should be tried. In effect, it was rinderpest that exemplified the potential opportunities for incorporating ELISA, and later molecular technologies, into the FAO/IAEA support package to meet the monitoring, surveillance and diagnostic needs of Veterinary Services and livestock keepers in Africa and elsewhere (see Chapter 6.3 for details).

While this debate continued for a number of years, thanks to the pragmatism and farsightedness shown by higher management within the IAEA and FAO and the approval by representatives of Member States themselves during debates on successive programmes of work and budgets, ELISAs and molecular methods became core animal health technologies supported by the IAEA. Such approval provided the mandate and basis for its involvement in global efforts to eradicate rinderpest through seromonitoring and providing support for wider surveillance (2).

Unique supportive mechanisms for technological innovations and transfer

The IAEA and Joint FAO/IAEA Programmes have a unique blend of funding mechanisms and organisational and coordination structures for tackling significant animal health constraints to food security. These were progressively brought to bear in helping affected countries to establish and maintain effective and quality assured testing in support of rinderpest eradication.

Coordinated research programmes

To the authors' knowledge and at the time of writing, the IAEA is the only UN organisation operating a mechanism to support research institutions in developing countries financially and technically. It does this by offering research contracts with modest financial support (US$5,000–10,000 per year), which, subject to satisfactory progress, can be renewed for up to five years and even extended under a follow-on programme. These contracts can be grouped to form a coordinated research programme (CRP), which, in essence, is a network within which a number of cost-free research agreements are awarded to institutions that have internationally recognised expertise and experience in the particular problem being tackled. Such CRPs are funded from the IAEA's regular budget or by external donors and they also involve bringing everyone together at regular research coordination meetings (RCMs) to both plan and review the work undertaken. IAEA or FAO technical officers coordinate, manage and report on the progress of CRPs to the IAEA's Board of Governors. Details of how this mechanism was used to support efforts to tackle rinderpest are given below (see 'FAO/IAEA networks: establishment and strengthening of infrastructures and human resources').

Technical cooperation projects

The IAEA's Department of Technical Cooperation manages national and regional projects along with staff from various technical divisions. These technical cooperation projects (TCPs) help countries to develop their human resources and infrastructures so that they are better able to address the problem in question. Like CRPs, they involve partnerships between the IAEA and one or a number of national institutions that provide basic infrastructural resources, but, unlike research contracts, they must be endorsed officially by a Member Country itself and be of high priority in terms of meeting its development goals. The IAEA allocates funds substantially in excess of what would normally be available through a research contract to purchase equipment (such as ELISA readers, pH meters, computers and water deionisers), consumables and kits for carrying out blood testing in the case of rinderpest (see below). TCPs also cover training (e.g. in using ELISA as well as in necessary related aspects such as epidemiology, statistics and computer software packages) through courses, fellowships and on-site visits by outside experts and FAO/IAEA technical staff. Such projects were an indispensable part of the FAO/IAEA rinderpest support package – particularly because of the 'joined up' approach taken by the Agency with respect to rinderpest in planning and implementing CRPs and TCPs from both technical and managerial perspectives (see the sections on the tests and their quality assurance and FAO/IAEA networks below).

The FAO/IAEA Agriculture and Biotechnology Laboratories at Seibersdorf, Austria

Unlike other organisations within the UN system, the IAEA has its own laboratories. These were opened in 1961, but it was not until 1984 that an Animal Production Unit became part of the set-up, focusing initially on developing, testing and transferring RIA 'kits' for measuring the reproductive hormone progesterone in blood and milk to CRP and TCP recipients. In 1986 – after hiring technical experts and obtaining funding for equipment and other running costs – the time was ripe for establishing a disease diagnostic laboratory. Rinderpest was the obvious target disease. Technical details about what the Joint FAO/IAEA Division and its laboratory contributed to rinderpest eradication are outlined below and described in detail in Chapter 3.3. It should be noted that this laboratory is not permitted to work with live rinderpest virus and thus the production of that component of the rinderpest ELISA and other related kits was undertaken at the high-containment laboratory in Pirbright, United Kingdom. Reagents sent to the Seibersdorf laboratory for these kits were certified free of rinderpest virus.

WHY RINDERPEST? FEEDBACK FROM NATIONAL VETERINARY AUTHORITIES AND DIAGNOSTIC LABORATORIES

In 1986, the Animal Production and Health Section of the Joint Division established an international consultative group to advise on the future focus of its animal health activities in Africa. After visiting many countries, it recommended support for incorporating ELISA into its programme for the diagnosis and control of livestock diseases. The rationale for doing so was that it was abundantly clear from consultations with veterinary officials, visits to national veterinary laboratories and discussions with their staff that many laboratories were simply unable to provide either the quality or the level of services required to support field programmes aiming to control livestock diseases. This was due to a combination of factors: little functional equipment, lack of diagnostic capability, little in the way of operating resources and constraints inherent in the methodologies employed to support diagnostic and epidemiological investigations. At the same time, national rinderpest control and eradication authorities and Pan-African Rinderpest Campaign (PARC) officials were increasingly recognising the limitations of existing methods for testing large numbers of sera for rinderpest antibodies to monitor the effectiveness of vaccination programmes, to conduct surveillance and to diagnose the disease from clinical samples. It became obvious – indeed logical in the light of the critical food security situation in Africa – that the IAEA's efforts should first be targeted towards developing and transferring cheap and reliable tests to affected countries to support rinderpest eradication.

DEVELOPING AND IMPLEMENTING THE STRATEGY

The tests and their quality assurance

From the outset, the global strategy for controlling and eradicating rinderpest involved mass vaccination followed by targeted surveillance. Its success required national, regional and global authorities to introduce sampling frameworks and diagnostic tools for conducting seromonitoring to assess the effectiveness of vaccination programmes and to support disease surveillance in order to complete the OIE Pathway and ensure final eradication. Procedures were also required to ensure both the reliability of the diagnostic tests themselves and the quality of the results obtained. Standardisation and quality assurance of the tests and testing procedures were therefore key elements of the overall approach.

ELISAs appeared to be ideally suited to meet the laboratory support needs of PARC, the West Asia Rinderpest Eradication Campaign (WAREC; see Chapter 4.10) and, ultimately, the Global Rinderpest Eradication Campaign (GREP; see Chapter 6.1) subject to:

- their availability;
- there being an organisation with the technical knowledge to identify potentially useful tests and work with their developer(s) to adapt them to standardised 'kit' formats while ensuring their 'fitness for purpose' within recipient developing country contexts by incorporating quality assurance techniques, which, moreover, were both capable of identifying and assessing new technological innovations and sufficiently flexible to support their transfer when justified technically;
- an organisation being willing to finance and manage their transfer and effective use within national and regional campaigns;
- crucially, political and technical commitments being made within the countries themselves to engage in what would amount to a paradigm shift in the monitoring and surveillance of rinderpest.

In this context, the vast majority of GREP countries utilised such kits. India, however, produced its own kits, which were similar to the FAO/IAEA kits and were validated against these initially.

Given the IAEA's institutional support mechanisms (CRPs and TCPs) and its laboratory, some key decisions had to be made about how to implement these tasks. Foremost among these was whether the IAEA should provide veterinary centres with the capability to produce their own testing kits, supply kits from a commercial source or produce kits itself. Having weighed the pros and cons of each option, the IAEA and FAO decided to use the facilities and expertise available at the FAO/IAEA laboratory, not, it should be emphasised, to conduct the upstream research to develop diagnostic reagents and protocols for use in ELISA but to adapt existing reagents and techniques to 'kit formats' suitable for use in developing countries. To achieve this, it worked closely with the Institute for Animal Health based at Pirbright in the United Kingdom (now known as the Pirbright Institute) to develop and transfer both indirect and competitive ELISA (known as ic-ELISA and c-ELISA, respectively) kits for rinderpest (3, 4, 5). It also worked with L'Institut d'Élevage et de Médecines Vétérinaires des Pays Tropicaux (IEMVT) at Maisons-Alfort, France (now part of the Centre International de Recherche Agronomique pour le Dévelopement [CIRAD]) to develop and transfer a solid-phase immunocapture ELISA kit (ICE) (6) and, later, a molecular method based on PCR to support surveillance for detecting rinderpest and peste des petits ruminants (PPR) virus antigens from animal tissues.

To ensure uniform diagnostic performance within and between laboratories, standardisation and quality control were two aspects that received particular attention in the course of developing the rinderpest kits and the subsequent monitoring of their performance in counterpart laboratories. Detailed protocols therefore had to be written describing equipment requirements, the preparation and storage of reagents, assay procedures, quality control activities, data acceptance criteria, the interpretation of results and trouble-shooting. Critical to the success of these diagnostic tools were a number of ancillary support activities. These included the development and supply – with training – of standardised computer software for data storage and management, defined epidemiological approaches, the operation of an FAO/IAEA laboratory accreditation system and the publication of annual reports from the regions. Again, the Pirbright laboratory and IEMVT proved to be highly committed cooperative partners in these endeavours.

One outcome of this collaborative work on the international standardisation of rinderpest ELISA techniques and reagents was the inclusion of the c- and ic-ELISA tests as the internationally agreed diagnostic tests for rinderpest and PPR in the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (*Terrestrial Manual*), thereby contributing to the health of animals in international trade. Another outcome was the designation in 1992 of the laboratory at Seibersdorf as the FAO/IAEA Centre for ELISA and Molecular Techniques in Animal Disease Diagnosis and as the OIE Collaborating Centre for Immunoenzymatic and Molecular Diagnostic Methods. The FAO/IAEA Programme played a prominent role in working with the OIE and the GREP Secretariat to develop both the OIE Pathway for rinderpest eradication (see Chapter 5.2), including the use of performance indicators in surveillance programmes, and in having ELISAs approved as prescribed or recommended tests within the framework of rinderpest control and eradication programmes.

Sampling strategies

Initially, an FAO/IAEA consultant group was convened to provide guidelines on the sampling protocol to be adopted. These guidelines took into account both the objectives of seromonitoring and the constraints that restrict the use of ideal sampling approaches in Africa. These were then published (7), and, during subsequent RCMs and training courses, they formed the basis for developing sampling strategies in each country participating in the networks. However, in all cases account had to be taken of local constraints, and in no two countries was the sampling approach identical. Descriptions of the sampling strategies adopted were contained in annual reports prepared by the research contract holders.

The Epidemiological Unit of the University of Reading (United Kingdom) and its associated commercial organisation, PAN Livestock Ltd provided most of the epidemiological expertise for the approach adopted. To some extent, this was a learning process for all concerned and it evolved continually during the early stages of GREP.

It was usual for the basic objectives of national surveys to be redefined each year before detailed planning was undertaken. Needs changed as PARC and GREP progressed and resources had to be used in the most cost-effective way. In particular, the requirements of different parts of a country had to be examined in relation to progress within both the country and neighbouring countries. This process included defining the population and subpopulations to be monitored.

Selecting individual animals for sampling often proved to be the most difficult part of the process. It was recommended that ten animals in each of the age groups zero to one year, one to two years, two to three years and over three years should be sampled; however, this sometimes caused a number of difficulties, most obviously what should be done if the herd was too small to generate the required numbers?

When an animal was selected for sampling, it was important to ensure that its selection was free from bias. The danger, for example, of sampling those animals that were easy to catch is obvious. Similarly, it would be very dangerous to let a farmer or farm staff choose the animals. Because of the wide variation in working conditions, it was not possible to recommend a method that was optimal everywhere. However, once collected, it was crucial that samples be submitted to the testing laboratory as soon as possible, along with all associated data.

FAO/IAEA networks: establishment and strengthening of infrastructures and human resources

Networking and infrastructural and human capacity building constituted the 'nuts and bolts' of the FAO/IAEA support for rinderpest seromonitoring and surveillance. This chapter does not go into details about the numbers of projects, equipment and expert services provided, people trained, technical and coordination meetings held, funds expended, etc., through the FAO and IAEA regular and IAEA technical coordination programmes over the 20 years of sustained support provided. It is nevertheless important to stress the following general points concerning the country and institutional partnerships that formed the foundations of the activities conducted, some of which are expanded on later and in Chapter 6.3.

– Three FAO/IAEA CRPs, two of which were funded by the Swedish International Development Cooperation Agency (SIDA) and one of which was funded through the IAEA and FAO Regular Programmes as well as through PARC, and some 26 national IAEA TCPs and regional TCPs involving 44 countries formed the backbone of the FAO/IAEA and IAEA TCP partnership package, with around 50 laboratories in Member Countries involved in rinderpest eradication.

- Irrespective of whether they were supported through an FAO/IAEA CRP, an IAEA TCP or both, all activities in Africa were channelled into national veterinary institutes that were officially mandated to support PARC and thereby contributed to GREP.
- Collectively, these institutes, together with the Pirbright Institute and CIRAD-EMVT, constituted an FAO/IAEA/PARC Rinderpest Laboratory Network in Africa, which over time evolved with regard to size and representation, but generally involved 20–25 countries (Fig. 1).
- Through a regional IAEA TCP 'Support to Rinderpest Surveillance in West Asia', the following countries constituted a similar regional network under WAREC and were also an integral part of GREP: Afghanistan, Jordan, the Islamic Republic of Iran, Iraq, Kazakhstan, Kuwait, Lebanon, Qatar, Saudi Arabia, the Syrian Arab Republic, Turkey, United Arab Emirates, Uzbekistan and Yemen.
- Asia, Malaysia, Mongolia, Myanmar, Pakistan, the Philippines, Sri Lanka, Thailand and Viet Nam were assisted through national IAEA TCPs.
- Within the framework of these mechanisms, 21 training courses were held, involving 325 participants from affected countries, and 102 expert missions were undertaken, many by African diagnosticians and epidemiologists.
- Over its some 20 years of operation, the type of test transferred evolved considerably. It involved ic-ELISA during the mid- to late-1980s, which was replaced by c-ELISA throughout the 1990s and beyond and, in some cases, by the later introduction of the ICE (from the mid-1990s onwards) for the detection of rinderpest and PPR virus antigens and PCR diagnostic and characterisation methods (Chapter 3.3).
- The roles of the Seibersdorf laboratory also evolved from supplying kits to developing and supporting software for ELISA readers and related quality assurance programmes and activities. Biological Diagnostic Supplies Ltd (United Kingdom), working in collaboration with the Pirbright laboratory, eventually took over the supply of c-ELISA.

Coordination

Overall coordination of these activities was carried out by the FAO/IAEA animal health regional technical cooperation experts who, at all times, maintained a close dialogue between the IAEA, FAO (as the GREP Secretariat) and PARC – and in particular with the FAO epidemiological team based in PARC headquarters in Nairobi, as well as with those involved in the later Pan-African Programme for the Control of Epizootics (PACE; see Chapter 4.3). Regional meetings were conducted in both French and English, and major publications were made available in both languages. Particularly notable here were the contributions made by Dr J. Anderson of the Pirbright Institute and Dr G. Libeau of CIRAD–EMVT who were research agreement holders throughout the operation of the African Network (Fig. 1). These scientists not only developed the FAO/IAEA rinderpest c-ELISA to improve its sensitivity and specificity, they also contributed greatly to the training undertaken.

Once it became clear that network participants could test samples reliably using the ELISA-based systems, the emphasis on training moved towards basic and applied epidemiology to ensure that the samples collected would provide the information required. Towards the completion of the CRPs (i.e. in the early 1990s), training was provided on the use of computers and specialised computer software to store and analyse the data. One gratifying outcome of these training activities was that, as the FAO/IAEA activities progressed, it became possible to call on the expertise of the more experienced contract holders from the African region to act as IAEA experts to other laboratories within and outside Africa.

Implementing these institutional capacity building activities was not without challenges. For example, some institutes entered the networks later than others as the need for a seromonitoring capability arose in individual countries. In addition, in a number of cases, individuals identified initially as partner institute representatives changed, owing for example to a national decision to change the institute responsible for testing. In other cases, the national representative left the country and it therefore became necessary to identify a new contract holder. This happened more than once in some countries. Finally, the political instability of some countries considerably affected the ability of contract holders to carry out their work. In Somalia, for instance, the institute awarded a research contract was never in a position to test sera. On the other hand, a number of participants managed to collect sera at considerable personal expense and at a high degree of individual risk: one outstanding example is the representative in Uganda who collected and analysed 4,000 sera during a period of intense civil unrest in that country.

International recognition of tests

When the Joint FAO/IAEA Programme initiated its activities in 1986, there was no internationally agreed process for verifying freedom from

FIG. 1

THE RINDERPEST SURVEILLANCE NETWORK IN AFRICA

Final boundary between the Sudan and South Sudan has not yet been determined

Source: Andreas 06 (2006). – Political map of Africa. Available at: https://en.wikipedia.org/wiki/File:Blank_Map-Africa.svg (accessed on 9 June 2021); modified to indicate the surveillance network

rinderpest, nor was ELISA included as a prescribed test. In addition, little guidance was available to countries concerning the principles and methods for validating diagnostic methods for infectious diseases; a particular gap was identified in relation to the new molecular methods that were beginning to become available. Equally crucial to the eradication programme as it gained momentum was the need for an internationally agreed process that provided assurance that the results emanating from testing laboratories could be relied on as correct. To meet this need, quality assurance processes were developed in a staged fashion, starting with the use of internal quality controls in all kits and culminating in a viable internal process for laboratory accreditation to an International Organization for Standardization (ISO) standard (8, 9). Although created to meet the needs of the rinderpest testing laboratories, many of these processes are now incorporated into OIE quality standards, and the laboratory accreditation process now forms the basis of the ISO 10750 accreditation standard for veterinary laboratories worldwide.

As described in Chapter 5.2, the OIE incorporated a set of Recommended Standards for Epidemiological Surveillance for Rinderpest (the 'OIE Pathway') within its *Terrestrial Animal Health Code* (*Terrestrial Code*), which govern the actions of Members wishing to demonstrate that they are free from infection. These include details of how to use and interpret serological tests for the surveillance of rinderpest. In addition, the *Terrestrial Manual* describes the use of c-ELISA to determine the presence of rinderpest antibodies in animals that have been infected with field virus or that have received rinderpest vaccine, and this has become the prescribed test for international trade. The indirect ELISA is also described, as is the ICE for differentiating between rinderpest and PPR virus, and there are now detailed chapters on test validation procedures and conducting PCR-based tests. In large part, these achievements were made possible as a result of information relating to test procedures and results from the Pirbright Institute, CIRAD-EMVT, FAO/IAEA, and African Network laboratories, as well as from FAO/IAEA expert group meetings dealing with particular tests, test validation and quality control procedures and laboratory accreditation.

OVERALL ACHIEVEMENTS

The FAO/IAEA rinderpest laboratory networks were first established in 1987 with a focus on seromonitoring national rinderpest vaccination programmes, initially in Africa but subsequently across all countries infected with rinderpest. The approaches and technologies established under PARC were transferred to SAREC and WAREC and eventually embedded in GREP. The following were the main achievements in relation to supporting serological activities at national and regional levels:

- the establishment of laboratory networks in PARC, SAREC, WAREC, PACE and eventually GREP to undertake activities relating to rinderpest seromonitoring and surveillance;
- the development of validated ELISA-based systems for detecting antibodies to rinderpest virus induced by vaccination or field infection;
- the development of validated ELISAs for detecting rinderpest and PPR virus antigens in support of surveillance;
- the full standardisation of the above assays *across all laboratories* participating in GREP;
- the development of standardised lists of laboratory equipment and data management software to support rinderpest seromonitoring and surveillance;
- the development of a universally accepted sampling frame for cattle for undertaking rinderpest seromonitoring;
- the development of a quality assurance programme for rinderpest testing laboratories;
- the development of processes and meetings that ensure the delivery of annual reports in a standard format from all participating laboratories undertaking rinderpest seromonitoring;
- the routine operation of an FAO/IAEA external quality assurance programme to ensure the quality of national reports on seromonitoring, and to facilitate the accreditation of a number of laboratories using an internationally agreed set of guidelines;
- the development and maintenance of a cadre of scientists from rinderpest endemic countries to support rinderpest laboratory activities.

PARTNERSHIPS

Although staff of the Joint FAO/IAEA and IAEA TCPs took technical and managerial leadership roles in coordinating the development, transfer and related quality assurance of standardised serological tests, any success achieved was, in reality, the result of the concerted political, institutional and technical efforts made by very many dedicated people over a period of more than 20 years. In particular, the financial, technical and political support provided by veterinary and other authorities within the countries themselves, and especially the outstanding commitment shown over the years by regional coordinators and staff within the national diagnostic laboratories who worked so diligently in the service of their national partnerships with the Pirbright Institute and CIRAD-EMVT (both of which are world-leading centres of excellence in research and surveillance of viral diseases in farm animals) cannot be overemphasised. To these institutes, and particularly to Dr John Anderson and Dr Genevieve Libeau, the FAO/IAEA and its partners in developing countries owe an enormous debt of gratitude for their unfailing commitment to the laboratory testing networks in terms of the development of strategies and kit development and transfer.

In addition, and as noted earlier, the work of the Joint FAO/IAEA Programme is planned and funded by both FAO and the IAEA. Indeed, one of the principles established at the time of its founding was that it would bring together the technical, managerial and political strengths of *both organisations* when planning and conducting its operations. Consequently, FAO's Animal Health Service – under whose auspices GREP and the GREP Secretariat was set up to provide coordination and technical guidance to regional organisations (e.g. to the African Union for PARC and PACE) – was the Joint Programme's 'partner of first choice', contributing in particular to strategic decision-making. At all stages, FAO's Animal Health Service, the GREP Secretariat and PARC/PACE staff were active partners in the processes of incorporating diagnostic technologies into national and regional seromonitoring and surveillance campaigns, contributing to technical consultations organised by the Joint FAO/IAEA Programme and to the formulation of technical guidelines. Likewise, staff of the Joint FAO/IAEA Programme were involved with FAO in PARC and PACE as members of steering committees and contributed actively to decision-making.

Worth mentioning too, were the critical roles played by FAO in securing funding through its own TCP and donor trust funds and in incorporating rinderpest control and surveillance programmes into humanitarian aid programmes. The GREP Secretariat, partnered in many cases by Joint FAO/IAEA Programme staff, provided technical support to these programmes, the progress achieved illustrating the benefits of the partnership.

Another partnership of unquestionable importance was that between the OIE and the Joint FAO/IAEA Programme (which included the GREP Secretariat). This was critical in paving the way for the adoption of the international standards, described in the section on the international recognition of tests, by delegates at the OIE General Assembly. It was also integral for facilitating global harmonisation of approaches for both implementing specific procedures and measuring progress towards rinderpest eradication. One indication of the continuing importance of this partnership is that the Joint FAO/IAEA Programme represents FAO on the OIE Biological Standards Commission.

Finally, the funding partnerships between the programme and SIDA, which so generously supported two CRPs in Africa, should be acknowledged, as should the government of Germany, through its Ministry of Agriculture, which generously provided funding to both FAO and IAEA for a series of junior professional officers to work in the Joint Division. The expertise and commitment of these young veterinarians proved invaluable for planning and implementing the FAO/IAEA Programme. Indeed, one of these veterinarians went on to become an FAO/IAEA regional animal health expert based in the GREP Epidemiology Unit to support the African seromonitoring and surveillance network.

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CHAPTER 5.5

ROLE OF THE AFRICAN UNION INTERAFRICAN BUREAU FOR ANIMAL RESOURCES (AU-IBAR) IN RINDERPEST ERADICATION

A. ELSAWALHY [(1)], H. WAMWAYI [(1)*], H. BOUSSINI [(1)] & B. JAW [(1)]

(1) African Union Interafrican Bureau for Animal Resources, P.O. Box 30786-00100, Nairobi, Kenya

*Corresponding author: henry.wamwayi@au-ibar.org

SUMMARY

The present-day African Union Interafrican Bureau for Animal Resources (AU-IBAR) was initially established in 1951 as the Inter-African Bureau of Epizootic Diseases (IBED) to coordinate the study and control of rinderpest in Africa. In 1960, the functions of IBED were expanded to include other causes of ill health, and the institution's name was changed to the Interafrican Bureau for Animal Health (IBAH). Following the formation of the Organisation of African Unity (OAU) on 25 May 1963, the IBAH was integrated as a regional technical office of the OAU, with its activities covering all the independent African countries. A further extension of its functions to include animal production activities resulted in a name change to the OAU Interafrican Bureau for Animal Resources (OAU-IBAR). In 2003, it became AU-IBAR, following its incorporation as a specialised technical office of the AU Commission. It is presently mandated to support and coordinate the development and utilisation of animal resources (livestock, fisheries and wildlife) for human well-being and economic development in the Member States of the AU.

Between 1962 and 2011, AU-IBAR coordinated three major continent-wide programmes, namely Joint Programme 15 (JP15), the Pan-African Rinderpest Campaign (PARC) and the Pan-African Programme for the Control of Epizootics (PACE), and one regional programme, the Somali Ecosystem Rinderpest Eradication Coordination Unit (SERECU), aimed at the eradication of rinderpest. PARC led to the establishment of the Pan-African Veterinary Vaccine Centre (PANVAC), which became a specialised technical office of the AU Commission (AU-PANVAC) in 2004, providing independent quality testing of veterinary vaccines used in Africa.

The rinderpest eradication process also enhanced the capacity of the national Veterinary Services in Africa, particularly in epidemiology and laboratory diagnosis, including the creation and operationalisation of effective epidemio-surveillance and laboratory networks and the continental Animal Resources Information System (ARIS).

The greatest strength of the rinderpest eradication process in Africa was the coordination and harmonisation of interventions and approaches among the participating and affected countries. AU-IBAR played a pivotal role in this process by mobilising and sustaining

essential political support and human, financial and material resources to support implementation of successive programmes until the final eradication of the disease. The combined efforts and commitment of the African governments, the AU Commission, financial partners – the European Union, the United States Agency for International Development (USAID), the UK Department for International Development (DFID), and the governments of Canada, France, Italy, Nigeria and Switzerland – and technical partners underpinned the success. The European Union was the most consistent long-term funding partner not only for the eradication of rinderpest but also for the strengthening of AU-IBAR's institutional and operational capacities.

The cooperation and participation of livestock owners, national Veterinary Services, the Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (OIE), world reference, regional and national laboratories, the wildlife services and some non-governmental organisations (NGOs) in the eradication programmes were essential for success.

Following the eradication of rinderpest, AU-IBAR and AU-PANVAC jointly mobilised political support that resulted in the adoption of a policy by the AU Member States of non-retention of rinderpest virus-containing materials, except under safe storage at the AU-PANVAC laboratory. AU-IBAR also spearheaded the formulation of a Post Rinderpest Eradication Strategy for Africa that aims to ensure continued vigilance of African Veterinary Services for rinderpest in susceptible livestock and wildlife populations. AU-IBAR is collaborating with the FAO-OIE Rinderpest Joint Advisory Committee towards attaining the objectives of the Global Rinderpest Action Plan (GRAP).

Key lessons learnt in the eradication of rinderpest will inform the formulation and implementation of interventions for similar challenges faced in animal resources and other sectors in Africa.

KEYWORDS **African Union – Animal resources – Capacity building– Coordination – Eradication – Interafrican Bureau – Partnerships – Rinderpest.**

INTRODUCTION

The InterAfrican Bureau of Epizootic Diseases (IBED), the forerunner of the African Union Interafrican Bureau for Animal Resources (AU-IBAR), was established in 1951. IBED had its origin in a conference to discuss rinderpest that was held in October 1948 in Nairobi, Kenya. At that time, many African countries were experiencing outbreaks of rinderpest, the most feared disease of cattle and some species of wildlife, with many deaths in both cattle and wildlife. The conference recognised the need to tackle the disease at continental level and recommended that an Interafrican Bureau to coordinate the study and control of rinderpest should be established. This replicated a similar call, by an earlier meeting held in February 1948 in Brazzaville, Congo, which created a permanent bureau and an international scientific committee to hold regular meetings to discuss developments in the research and control of African trypanosomiasis. The outcome of the recommendations from the two meetings was the formation of an intergovernmental Commission for Technical Co-operation (CCTA) in Africa. The Commission, whose acronym derives from its French title, Commission de Coopération Technique en Afrique au Sud du Sahara, was officially created on 18 January 1950, with its headquarters initially in London and later transferred to Lagos, Nigeria, in 1959 (1, 2).

One of the first actions of the CCTA was to constitute a working group to consider the functions of a proposed bureau to deal with rinderpest. The Commission recommended that the scope of the bureau's activities should extend beyond the containment of rinderpest to cover all epidemic diseases. Hence IBED was established on 1 November 1951 at Muguga, on the outskirts of Nairobi, Kenya.

In 1960, the functions of IBED were expanded to include other causes of ill health, and the institution's name was changed to Interafrican Bureau for Animal Health (IBAH). The bureau assumed responsibility for activities covering all countries in Africa, south of the Sahara. Following the formation of the OAU on 25 May 1963, proposals for the integration of the CCTA within the Organisation of African Unity (OAU) were presented at the first Ordinary Summit of the OAU Heads of State and Government held in Cairo in July 1964. The delegates of the summit decided that a Scientific Technical and Research Commission (STRC) based in Lagos, Nigeria, should be created to replace the CCTA. The STRC, started its operations in January 1965 and immediately took over all the activities of CCTA, including IBAH. This marked the integration of IBAH as a regional technical office of the OAU. Following this development, the activities of IBAH were extended to cover all the independent African countries.

In 1971, the 14th Ordinary Session of the OAU Council of Ministers, held in Addis Ababa, endorsed a recommendation from the directors of Veterinary Services that the functions of IBAH should be expanded further to address animal production activities and that it should be renamed OAU-IBAR.

To expedite the process of economic and political integration in the African continent, the African Union (AU) was launched in 2002 in Durban, South Africa, at a summit that convened the first Assembly of the Heads of State and Government of the AU. In 2003, AU-IBAR was incorporated as a specialised technical office of the AU Commission under the Department of Rural Economy and Agriculture (DREA), leading to a further name change to AU-IBAR. The name changes of the bureau, from IBED to IBAH, OAU-IBAR and AU-IBAR, reflected its progressively increasing roles up until its present day mandate of supporting and coordinating the development and utilisation of animal resources (livestock, fisheries and wildlife) for human well-being and economic development in the Member States of the AU.

FIG. 1
AU-IBAR OFFICES IN NAIROBI, KENYA, 2007
Courtesy of the authors

This is the institution that played a proven and pivotal role in coordinating activities, building institutions and partnerships, and mobilising resources for the eradication of rinderpest from Africa and thus significantly contributed to its global eradication by 2011. Its offices are shown in Figure 1.

INSTITUTIONAL CAPACITY BUILDING AT NATIONAL, REGIONAL AND CONTINENTAL LEVELS

Institutional capacity building at all levels was key to the success in the control and eradication of rinderpest from the African continent. This was done under the leadership of AU-IBAR, in close collaboration and partnership with national, regional and international organisations, including research institutions. The key achievements in this regard were:

- Building capacity in national and regional laboratories (e.g. AU-PANVAC in Debre Zeit, Ethiopia; the Veterinary Research Centre in Muguga, Kenya; the Laboratoire Central de Pathologie Animale – LANADA – in Bingerville, Côte d'Ivoire; the National Veterinary Laboratory of Cameroon – LANAVET; the Institute Senegalais de Recherches Agricoles – ISRA; and all the national veterinary laboratories in other AU Member States) to conduct the diagnosis of rinderpest and serological testing for the surveillance of rinderpest and the seromonitoring of mass vaccination campaigns.
- The national and regional animal disease surveillance systems were strengthened through the establishment and operationalisation of epidemio-surveillance networks and the continental ARIS.
- African experts were trained on and deployed in laboratory techniques, epidemiology and surveillance, among other areas.
- Institutional collaboration was established and strengthened between national, regional and international organisations and laboratories across the continent and the globe.
- The ecosystem approach with enhanced coordination and harmonisation between the Veterinary Services of neighbouring countries proved critical for the eradication of the disease.
- The reinforcement of intersectoral collaboration and cooperation among livestock and wildlife value chain stakeholders for a common course proved invaluable and has since been replicated in other initiatives for disease control and eradication at national and international levels.
- Innovative approaches including the use of community animal health workers (CAHWs) and participatory epidemiology techniques for

animal health services delivery facilitated access and elimination of the disease from remote areas affected by poor physical infrastructure, political instability, civil strife and insecurity. This was coupled with an immense communication campaign with awareness-raising materials.
– The privatisation of Veterinary Services and public–private sector partnerships was promoted in animal health services delivery.

In summary, the rinderpest eradication process played a critical role in building capacity of the national Veterinary Services in Africa, particularly in epidemiology and laboratory diagnosis, including the effective creation and operationalisation of epidemiological and laboratory networks.

COORDINATION, PARTNERSHIPS AND RESOURCE MOBILISATION

Over a period of five decades, AU-IBAR coordinated a series of three major continent-wide programmes and one regional programme aimed at the eradication of rinderpest. These commenced with Joint Programme 15 on rinderpest (JP15) from 1962 to 1975 (1, 2, 3, 4; see also Chapter 4.1), followed by PARC from 1986 to1998 (5, 6; see also Chapter 4.2) and PACE from 1999 to 2007 (7; see also Chapter 4.3). Ancillary projects that complemented these flagship programmes included PANVAC from 1986 to 2004 (see also Chapter 5.6), the Thermostable Rinderpest Vaccine Transfer of Technology (TRVTT) Project from 1990 to 1995, the Participatory and Community-Based Vaccination (PARC-VAC) Project from 1996-1999, the African Wildlife Veterinary Project (AWVP) from 1998 to 2000, the Community Animal Health and Participatory Epidemiology (CAPE) project from 2000 to 2004, and SERECU I and II from 2006 to 2010 (4, 7, 8; see also Chapter 4.4). Each programme provided experiences and vital lessons that were built on to improve the implementation of subsequent programmes until eradication was achieved. PARC informed the establishment of PANVAC, which became a specialised technical office of AU-PANVAC in 2004 and continues to provide the important service of independent quality testing of veterinary vaccines used in Africa.

In addition to the rinderpest programmes, AU-IBAR has, since 1960, provided coordination for trypanosomiasis activities in Africa and hosts the International Scientific Council for Trypanosomiasis Research and Control (ISCTRC), a platform that promotes international cooperation in the fight against trypanosomiasis. The ISCTRC was instrumental in the establishment of an important trypanosomiasis control initiative, the Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC), which is coordinated by a technical office of the AU (AU-PATTEC).

AU-IBAR has also implemented numerous projects that have aimed to control other epidemic diseases, providing capacity building, production and marketing support to the animal resources sector in line with its broadened mandate. However, the eradication of rinderpest was AU-IBAR's main focus until the global eradication of rinderpest was confirmed in June 2011, following the joint official declaration by the OIE and FAO during celebrations to mark the end of the fight against rinderpest. AU-IBAR played a leadership role by coordinating efforts and mobilising resources in the process of eradicating rinderpest globally by ensuring the eradication of the disease from Africa. This important milestone was marked by celebrations organised by Veterinary Services in many Member States of the AU.

AU-IBAR's mandate and the successful implementation of its programmes and projects required that AU-IBAR partnered with a large number and diversity of stakeholders at national, regional, continental and international levels. In this regard, AU-IBAR established robust relationships with FAO and the OIE as key international technical partners in the eradication of rinderpest. The Pirbright Institute in the United Kingdom of Great Britain and Northern Ireland, the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) in France, the International Atomic Energy Agency (IAEA) and Tufts University in the United States were key technical partners for enabling research and technology transfer for improved laboratory diagnostics, epidemiological surveillance and seromonitoring tools, rinderpest virus molecular characterisation and thermostable rinderpest vaccine development and application. Other international partners included the Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) GmbH, which was previously Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), which provided technical support through the engagement of various experts, to support the implementation of the PACE project.

The financial support provided by the European Union, USAID, DFID and the governments of Canada, France, Italy, Japan, Nigeria and Switzerland was catalytic and critical in providing and sustaining the momentum of the different eradication programmes. The funding provided by the European Union was the most consistent long-term financial investment not only for the eradication of rinderpest but also for the strengthening of AU-IBAR's institutional and operational capacities.

Within Africa, AU-IBAR partnered with the national line ministries responsible for Veterinary

Services, with the public national Veterinary Services Departments acting as the entry points for the collaborative partnerships. AU-IBAR also mobilised the support of regional reference laboratories in Muguga, Kenya, and Bingerville, Côte d'Ivoire, and the Institut Sénégalais de Recherches Agricoles (ISRA) in Dakar, Senegal. These laboratories played key roles in providing relevant research and diagnostic support to the rinderpest eradication programmes. In addition, rinderpest vaccine production laboratories and institutes across Africa were engaged to ensure the availability of the necessary quantities and quality of vaccines, particularly for the JP15 and PARC programmes. Under the PACE programme, collaboration was established with the Botswana Vaccine Institute, which served as a vaccine bank for easy access to quality-assured vaccine in the event of disease emergencies. This was also the only institution that commercially produced thermostable rinderpest vaccine that was used in interventions in the final stages of the eradication process.

To better understand the role of wildlife in the epidemiology of rinderpest, AU-IBAR entered into a contract with CIRAD, which in turn sub-contracted the Zoological Society of London to support research on wildlife. Under the PACE programme, national wildlife institutions in Chad, the Central African Republic, Sudan, Ethiopia, Kenya, Uganda and the United Republic of Tanzania were engaged to support the generation of data, to verify the absence of rinderpest virus circulation in selected high-risk areas. The Kenya Wildlife Service also provided technical support by training personnel from Ethiopia and Somalia on wildlife capture and sampling techniques at the field level.

ROLES PLAYED BY AU-IBAR

AU-IBAR played a number of roles that guaranteed the success of the rinderpest eradication process. The key roles among these were:

- mobilising and sustaining the political support and interest of the Member States of the AU, which ensured that rinderpest remained among the national development priorities, thus guaranteeing the allocation of national resources towards its eradication;
- engaging donor organisations to mobilise and sustain the long-term financial support that was essential to achieving eradication;
- identifying and engaging various technical partner organisations at the international, continental, regional, national and local levels to undertake agreed activities based on their institutional mandates and comparative advantage;
- identifying and championing innovations to enable the completion of eradication, including surveillance and epidemiological methods, risk-based strategies and approaches to delivery of community-based vaccination in challenging environments;
- establishing high-level advisory committees comprising representatives of the key stakeholder institutions involved in the global eradication programme to provide overall strategic guidance and support to the rinderpest eradication programmes in Africa (PARC and PACE);
- formulating the rinderpest control and eradication programmes and outlining the policies and strategies to guide their implementation at national, regional and continental levels as well as for components implemented by technical partners;
- channelling donor funds to partner organisations and NGOs implementing components of the eradication programmes;
- providing technical support and backstopping to Member States for the implementation of national components, including the contracting of some NGOs as partners to support implementation in some countries (Somalia and South Sudan) in conflict situations that prevented the effective delivery of interventions by the government Veterinary Services;
- monitoring the implementation of the national programmes and components implemented by other partners to assess progress and undertake corrective measures as necessary to achieve programme objectives;
- establishing rinderpest vaccine banks and outlining criteria for countries to access the vaccine;
- coordinating interventions and harmonising activities and approaches (including annual continental coordination meetings, cross-border harmonisation meetings, communication and awareness raising, engagement of livestock owners and other stakeholders, and vaccination campaigns and disease surveillance activities through the establishment of national epidemiological surveillance and diagnostic laboratory systems linked across the continent through continental epidemiological surveillance and laboratory networks, respectively);
- introducing an electronic information system, the PACE Integrated Database (PID), which evolved into the Animal Resources Information System (ARIS);
- identifying and commissioning relevant enabling research to improve the implementation of rinderpest eradication programmes;

- organising regional training in key areas, such as rinderpest diagnostic and surveillance testing; rinderpest vaccine production and quality assurance; and wildlife capture and sampling for rinderpest surveillance;
- assisting countries to adopt international standards for rinderpest surveillance and protocols to obtain recognition of freedom from rinderpest;
- encouraging and providing technical support to countries so that they could progress along the OIE Pathway for rinderpest eradication, and compile and submit dossiers to the OIE for recognition of rinderpest-free status.

POST RINDERPEST ERADICATION STRATEGY FOR AFRICA

In May 2010, AU-IBAR convened a meeting of the ministers responsible for animal resources in Africa in Entebbe, Uganda. By this time, rinderpest had been eradicated, but the world awaited the declaration of global freedom by the OIE and FAO. The ministerial meeting recommended that the Member States of the AU should destroy all rinderpest virus strains held in Africa and hand over whatever was deemed necessary to AU-PANVAC for safe storage. Africa thus collectively adopted a policy of not retaining rinderpest virus-containing materials, except under safe storage at the AU-PANVAC laboratory in Debre Zeit, Ethiopia. AU-IBAR subsequently collaborated with AU-PANVAC, FAO and the OIE in the preparation of an inventory of establishments holding rinderpest virus-containing materials in Africa and in catalysing the destruction or sequestration of the materials at AU-PANVAC.

In 2012, AU-IBAR also spearheaded the formulation of a Post Rinderpest Eradication Strategy for Africa that aims to ensure continued vigilance of African Veterinary Services for rinderpest. The strategy addresses the risk of the re-emergence of rinderpest and aims to reduce the probability of re-emergence by reinforcing the continent-wide policy of non-retention and safe sequestration of rinderpest virus-containing materials by institutions in the Member States while advocating new generation diagnostic kits that pose no risk of re-introducing rinderpest. It also aims to enhance detection of re-emergence by strengthening syndromic disease surveillance and disease information gathering, analysis and dissemination, as well as ensuring the rapid containment and eradication of any re-emergence. To support this, the African Association of Veterinary Education Establishments (2A2E-V), comprising representatives from 51 veterinary faculties, colleges and schools across Africa, met in Cairo, Egypt, in July 2018 and agreed to retain rinderpest as one of the important transboundary animal diseases in the veterinary curricula (9). Similarly, at the Tenth Annual Meeting of Directors of Veterinary Services and Chief Veterinary Officers of the AU Member States, convened by AU-IBAR, from 23 to 27 April 2018 in Nairobi, Kenya, it was resolved that awareness of rinderpest would be maintained among staff and stakeholders to enable early detection and reporting in the event of its re-emergence. In both meetings, the participants were provided with links to enable access to rinderpest awareness-raising materials, prepared and made available by the FAO-OIE Rinderpest Secretariat.

Between 2013 and 2017, AU-IBAR implemented the Standard Methods and Procedures in Animal Health (SMP-AH) project in the Greater Horn of Africa Region. This project involved the development of standard methods and procedures (SMPs) for harmonisation of surveillance, diagnostic and control actions against ten priority transboundary animal diseases and zoonoses in the region. The SMPs are based on the relevant OIE standards for each disease. The project supported regional veterinary experts to formulate SMPs for the containment of rinderpest in the Greater Horn of Africa in the event of any re-emergence of the disease. The objective of the rinderpest SMPs is to ensure continued vigilance for rinderpest by enhancing and maintaining veterinary expertise in the Greater Horn of Africa for effective surveillance in susceptible livestock and wildlife. The SMPs approach will be replicated in northern, central, western and southern Africa.

AU-IBAR is collaborating with the FAO-OIE Rinderpest Joint Advisory Committee to attain the objectives of the Global Rinderpest Action Plan (GRAP). AU-IBAR is actively enhancing awareness and advocacy of the need to prevent the re-emergence of rinderpest in Africa, as well as ensuring vigilance and preparedness to rapidly deal with any re-emergence or threat of the disease. AU-IBAR is also undertaking a review of the Post Rinderpest Eradication Strategy to incorporate a status recovery phase that was not included when the strategy was initially formulated in 2012. A continental contingency plan for rinderpest will be prepared to guide the preparedness and rapid response to any re-emergence of rinderpest in Africa.

CONCLUSION

The greatest strength of the rinderpest eradication process in Africa was coordination that ensured innovation and the harmonisation of interventions and approaches among the participating and affected countries. AU-IBAR played a pivotal role in this process over a period of five decades by mobilising and sustaining essential political support and human, financial and material resources to support the implementation of successive programmes until the final eradication of the disease. The combined efforts and commitment of the African governments, the AU Commission, financial partners and technical partners underpinned its success. The sustained funding of interventions by the African governments and the donor community, particularly the European Union, was both catalytic and critical to achieving the objective of eradication.

The cooperation and participation of the livestock owners, national Veterinary Services, FAO, the OIE, the world reference, regional and national laboratories, the wildlife services and some NGOs in the eradication programmes were essential for success.

The eradication of rinderpest provided AU-IBAR, Member States and international partners with experience and vital lessons in forging partnerships for cooperation, collaboration and coordination to address transboundary animal diseases. These lessons will serve to inform the formulation and implementation of interventions to address the many other similar challenges that continue to be faced in animal resources and other sectors in Africa.

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CHAPTER 5.6

ROLE OF THE AFRICAN UNION PAN-AFRICAN VETERINARY VACCINE CENTRE (AU-PANVAC) IN RINDERPEST ERADICATION

N. NWANKPA [(1)], K. TOUNKARA [(2)*], S. HAILE MARIAM [(3)], M. RWEYEMAMU [(4)] & D. SYLLA [(5)]

(1) The African Union, Pan-African Veterinary Vaccine Centre (AU-PANVAC), PO Box 1746, Debre Zeit, Ethiopia
(2) World Organisation for Animal Health (OIE) Regional Representation for Africa, Parc de Sotuba, PO Box 2954, Bamako, Mali
(3) Supporting Evidence-Based Interventions (SEBI) Consultant, Addis Ababa, Ethiopia
(4) Executive Director, Southern African Centre for Infectious Diseases and Surveillance (SACIDS), Sokoine University of Agriculture, Chuo Kikuu, Morogoro 67104, United Republic of Tanzania
(5) C/O Central Veterinary Laboratory PO Box 2295, Bamako, Mali

*Corresponding author: k.tounkara@oie.int

SUMMARY

The failure of Joint Programme 15 for the control of rinderpest in Africa by the mid-1980s raised concerns that some vaccines used in the campaign did not meet the required international standard of quality, and this subsequently led to the establishment of the Pan-African Veterinary Vaccine Centre of the African Union (AU-PANVAC) – the centre responsible for the provision of international, independent vaccine quality control of rinderpest vaccines in Africa. By the end of 1991, the directors of Veterinary Services in Africa noted with satisfaction the continuing impact of PANVAC and the progress made, particularly in the improvement of the quality of the rinderpest vaccine for the Pan-African Rinderpest Campaign (PARC), the training of laboratory personnel in vaccine production technology, the dissemination of technical information to national laboratories and the strengthening of the cooperation between vaccine production laboratories in Africa. The contributions of PANVAC were well appreciated and recognised by various evaluation and review teams, consultants, beneficiary laboratories and governments, which reported that the strict, standardised quality control of rinderpest vaccines initiated by PANVAC had resulted in significant improvements in the quality of the vaccines applied in the field and had thereby contributed to the success of PARC. In February 1998, recognising the significant role played by PANVAC in the control of rinderpest and other economic diseases, the 67th ordinary session of the Organization of African Unity (OAU) Council of Ministers, held in Addis Ababa, decided to elevate PANVAC to a centre of excellence for vaccine production and quality control, with the status of an OAU specialised agency. Subsequently, PANVAC became assimilated into the structures of the AU and was officially launched as an AU Regional Centre on 12 March 2004. The mandates of AU-PANVAC were subsequently expanded to include quality control of all vaccines and collaboration with international

partners. Today, AU-PANVAC continues to play a major role in maintaining Africa free from rinderpest.

KEYWORDS **AU-PANVAC – Global Rinderpest Eradication Campaign – GREP – Pan-African Veterinary Vaccine Centre of the African Union – Pan-African Rinderpest Campaign – PARC –Rinderpest – Quality control – Vaccines.**

INTRODUCTION

By the end of Joint Programme 15 (see Chapter 4.1), most of the participating countries were largely free from rinderpest, but it was a short-lived success, as sporadic rinderpest outbreaks occurred shortly after in several of the countries that had been involved in JP15. This prompted the African Heads of State, through a meeting organised by the Food and Agriculture Organization of the United Nations (FAO) in Nairobi, Kenya, in 1981, to recommend a new programme which ultimately led to PARC (1; Chapter 4.2). The failure of JP15 raised concerns that some vaccines used in the campaign did not meet the required international standard of quality. In support of the concept of PARC, FAO established two expert consultations. The first, in 1984, established a system of international vaccine quality control for rinderpest vaccine in Africa, and the second, in 1986, focused on the global eradication of rinderpest. During the implementation of the first, FAO commissioned Dr Daouda Sylla, a consultant, to collect vaccine samples from 11 vaccine-producing laboratories and carry such samples by hand to Pirbright, United Kingdom of Great Britain and Northern Ireland, and Maisons Alfort, near Paris, France for testing by the two FAO International Reference Laboratories. The majority of these samples failed to attain the prescribed level of potency, and many also failed in sterility. These findings provided FAO with an impetus in the second expert consultation to develop two independent African vaccine quality control centres to assist PARC. These two centres collectively represented what was to become the Pan-African Veterinary Vaccine Centre of the African Union (AU-PANVAC).

The control of rinderpest through PARC began in 1986 and involved mass vaccination and surveillance. However, it must be noted that PARC was also aimed at revitalising the Veterinary Services of all AU Member States on a long-term sustainable basis.

FAO's support of PARC was implemented in three areas:

1. a study of the epidemiology of rinderpest under the responsibility of William Taylor from the PARC team in Nairobi;
2. seromonitoring of vaccinated cattle through the Joint FAO–IAEA (International Atomic Energy Agency) Division, under the responsibilities of Martyn Jeggo and Jim Dargie; and
3. independent vaccine quality control testing within Africa, under the responsibilities of Daouda Sylla, who was posted to Dakar, Senegal, and Kris Wojciechowski, who was posted to Debre Zeit, Ethiopia.

The three activities were initially funded by FAO through its internal Technical Cooperation Programme (TCP). As the two units for quality control were being set up in Dakar and Debre Zeit, FAO recruited Mark Rweyemamu in 1986 from the vaccine industry as a short-term consultant to provide advice on measures for the long-term sustainability of vaccine quality control. One of his recommendations was that FAO should give the units a name that reflected a long-term vision. That same year, he was invited to join FAO as a vaccine specialist and directed to implement his recommendations. The initial focus on quality control was for the two units to test for vacuum, potency (by titration) and sterility of the vaccines held by PARC in the five designated rinderpest vaccine banks – namely Botswana Vaccine Institute (BVI), Botswana; Kenya Veterinary Vaccine Production Institute (KEVEVAPI), Kenya; Laboratoire National Vétérinaire (LANAVET), Cameroon; Laboratoire Central d'Élevage (LABOCEL), Niger; and the National Veterinary Institute (NVI), Ethiopia – which, by definition, would be used at short notice in any part of Africa (1).

It soon became obvious that more resources were needed in this area to support PARC's activities and to stimulate vaccine production in Africa. In response, a new project titled 'Production and Quality Control of Veterinary Vaccines in Africa', with the financial assistance of the United Nations Development Programme (UNDP), was set up in 1988 to take over the work initiated by FAO and the OAU under the TCP. The aim of this new project was 'to make Africa self-sufficient in priority Veterinary Vaccines by the year 2000'.

Drs Mark Rweyemamu and Douda Sylla, during a visit to Dakar, agreed on the name PANVAC, as it reflected the pan-African mandate of the two units. The suggestion was strongly supported by Dr Fikre, Director of the Ethiopian National Veterinary Institute, Dr Walter Masiga, Director of the Inter-African Bureau for Animal Resources (IBAR), and the Project Steering Committee meeting, which included FAO and UNDP personnel at Debre Zeit. Thus, in 1991, the two units became jointly named as PANVAC (2).

SUPPORT FOR PANVAC ACTIVITIES

In recognition of PANVAC's certification of rinderpest vaccine quality, the Meeting of Directors of National Veterinary Vaccine Laboratories in Africa, held in Nairobi, Kenya, on 27 and 28 September 1990, recommended that 'PANVAC should be the appropriate agency for international quality control of vaccines in Africa' (3). Consequently, all laboratories were encouraged to submit all vaccines to PANVAC for quality control, and at the end of 1991 the directors of Veterinary Services in Africa and PARC coordinators committed themselves to buying vaccine tested by PANVAC, a move that increased the use of good-quality vaccines (4). To further strengthen this, the FAO Expert Consultation on vaccine quality control in developing countries, held in Rome in December 1991, recognised the value of the activities of PANVAC and recommended that FAO and OAU/IBAR should solicit appropriate regional and international support for the conversion of PANVAC to the status of a long-term programme institute with appropriate facilities and support (2). As a follow-up, the Directors of the National Veterinary Vaccine Laboratories of 23 Member States of the OAU met in Dakar, Senegal, from 6 to 8 July 1992, to review the activities of the two regional vaccine quality control and training centres.

Noting the financial problems faced by PANVAC, the directors urged all ministries to allocate part of their UNDP national Indicative Programme Fund (IPF) to the secondment of their national scientists and/or technicians to PANVAC for training for up to two years. It also directed PANVAC to include in its mandate the training of national personnel in good manufacturing practice (GMP), in addition to scientific principles.

Concerned with the sustainability of PANVAC, Drs Mark Rweyemamu and Daouda Sylla worked closely with Dr Yves Cheneau, Chief of FAO's Animal Health Service, to identify proposals towards this goal. This led to a major restructuring of PANVAC, namely:

- splitting the functions of PANVAC into two components, i.e. component A, dealing with vaccine quality control (which could be subject to cost recovery), and component B for vaccine and process development, which could be regarded as the research wing of PANVAC not subject to any cost recovery;
- closing PANVAC Dakar, transferring the equipment to Institut Sénégalais De Recherches Agricoles/Laboratoire National de l'Élevage et de Recherches Vétérinaires (ISRA/LNERV) and concentrating all PANVAC activities in Debre Zeit, with Dr Daouda Sylla as the sole PANVAC Director assisted by Dr Vilmos Palya, who had previously been in Debre Zeit with Dr Rweyemamu.

This coincided with the end of Dr Jan Prandota's contract as an FAO specialist in Dakar. The two centres were merged in 1993 to perform the functions of PANVAC at one site in Debre Zeit. Dr Mark Rweyemamu then moved to FAO, Rome, initially as the vaccine specialist and later as Head of the Infectious Diseases Group at EMPRES, the Emergency Prevention System for Animal Health. PANVAC, at that time, was mandated to primarily perform quality control of rinderpest and contagious bovine pleuropneumonia (CBPP) vaccines (which were then considered as priority), in accordance with international standards; promote the concepts of biological standardisation and control in Africa, through the establishment of a repository of characterised reference vaccine materials; transfer the appropriate vaccine technologies to Africa, including adapting or developing them to suit African conditions; develop internationally recognisable quality control criteria; and promote the principles of good manufacturing practice (GMP).

Encouraged by the performance of PANVAC, the Fourth Conference of African Ministers Responsible for Animal Resources in Africa recommended the institutionalisation of PANVAC as a technical centre of the OAU during its meeting from 11 to 15 April 1994 in Addis Ababa, Ethiopia. Following the retirement of Dr Daouda Sylla from PANVAC, the late Dr Boubacar Seck took over the leadership of the centre, as an FAO specialist, with Dr Joseph Litamoi, another FAO specialist responsible for component B of PANVAC. Thus, these people became pioneers of what was then known as PANVAC.

INSTITUTIONALISATION OF PANVAC

In 1998, recognising the importance of livestock production to the African economy and the significant role played by PANVAC in the control and eradication of economic diseases in Africa, the 67th ordinary OAU Council of Ministers held in Addis Ababa, Ethiopia, from 23 to 27 February 1998, decided to elevate PANVAC to a centre of excellence for vaccine production and quality control in Africa with the status of an OAU specialised agency. Appreciating the encouraging decisions of the 67th Council of Ministers, the European

Union granted about ECU1 million (the European currency unit was the predecessor of the euro) in September 1999 through OAU/IBAR to support PANVAC component A for a period of five years and also to give the OAU enough time to achieve the institutionalisation of PANVAC. However, it was not until 12 March 2004 that PANVAC was officially launched as an AU regional centre (5) (Fig. 1). The structure of PANVAC as a Regional Technical Centre of the AU Commission was approved by the Sixth Extraordinary Session of the AU Executive Council on 6 December 2004 in Addis Ababa, Ethiopia. PANVAC under the AU became AU-PANVAC, and the first substantive Director, Dr Karim Tounkara, was appointed on 10 March 2006 (Fig. 2).

CONTRIBUTION OF PANVAC TO RINDERPEST ERADICATION

PANVAC played a major role in improving the quality of vaccines used under PARC, as all vaccines used in the PARC programme were required to be quality certified by PANVAC. It contributed to the success of PARC, which recorded a drastic reduction in the number of infected countries from 18 in 1983 to 3 in 1991, and, in turn, created confidence in the international community, including the European Economic Community (EEC), FAO and the World Organisation for Animal Health (OIE). The quality of rinderpest vaccine was raised to levels comparable with the standards of the European Pharmacopoeia and was far above the OIE requirement of $10^{2.5}\log_{10}$ $TCID_{50}$/ml (6). When African laboratories adopted the production of thermostable rinderpest vaccine, PANVAC implemented a quality standard for thermostability that required rinderpest vaccines labelled thermostable to retain their minimum dose for at least 2 weeks at 45°C. The proportion of African vaccine lots that achieved international quality standards rose from about 33% in 1985 to more than 90% in 1997. Between 1988 and 1993, PANVAC tested a total of 694 rinderpest vaccine batches, representing over 180 million doses.

FIG. 1
DR BERHE TEKOLA WELCOMING PARTICIPANTS TO THE PANVAC
Courtesy of the authors

FIG. 2
MRS HADERA GEBRU CUTTING THE RIBBON AT THE OFFICIAL LAUNCH OF AU-PANVAC
Courtesy of the authors

Unfortunately, the interruption of PANVAC activities in 1995 negatively affected this progress, so much so that the quality of vaccines fell from 91.91% in 1994 to 62.68% in 1996 (6). Likewise, the average titre of rinderpest vaccine produced fell from $10^{3.1}\log_{10}$ $TCID_{50}$/ml in 1994 to $10^{3.04}\log_{10}$ $TCID_{50}$/ml in 1996 (Fig. 3). However, following the resumption of operations in 1996, the quality of rinderpest vaccines produced in Africa quickly rose from 62.68% to 85% in 1998, during which period 212 rinderpest vaccine batches, representing 55 million doses, were certified by PANVAC (see Fig. 4 for an example of PANVAC-certified ampouled rinderpest vaccine). At that time, rinderpest vaccines were received from Cameroon, Chad, Mali, Nigeria, Senegal, Botswana, Ethiopia, Kenya, Somalia, Sudan and Uganda. However, among these countries, only Botswana, Kenya, Chad and Ethiopia submitted vaccines on a regular basis to PANVAC (6). Similarly, between 1994 and 1998, apart from low titre, the main causes of rejection of rinderpest vaccines were contamination with bacteria, fungi and particularly the genus Mycoplasma. The problem of contamination reached alarming proportions following the resumption of PANVAC activities in 1996. PANVAC responded to the mycoplasma problem in 1994 by preparing guidelines for the elimination of mycoplasma and by supplying cells and virus seeds that were certified free from mycoplasma to vaccine-producing laboratories. The impact of this was so significant that, by 1998, contamination was almost completely eliminated from vaccines produced by laboratories.

The contributions of PANVAC to PARC, and specifically to the eradication of rinderpest was recognised by the Government of Ethiopia (Fig. 5) and further

FIG. 3
THE EVOLUTION OF RINDERPEST VACCINE POTENCY FROM 1985 TO 1996 IN TERMS OF LOG$_{10}$ TCID$_{50}$ PER ML (MEDIAN TISSUE CULTURE INFECTIOUS DOSES)

Courtesy of the authors

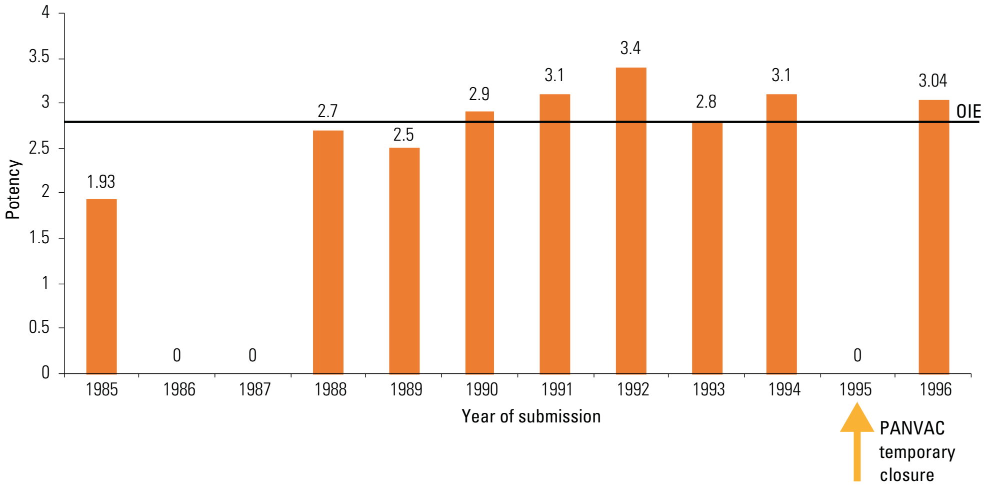

FIG. 4
RINDERPEST VACCINE BATCHES SUBMITTED TO PANVAC FOR QUALITY CONTROL

Courtesy of the authors

can be appreciated by the following comment from the expert review team commissioned by the European Commission in 1997 (7):

'The success of the Pan-African Rinderpest Campaign (PARC) and the Pan-African Programme for the Control of Epizootics (PACE) clearly demonstrated that no amount of vehicles, syringes, trained personnel, communication materials, would have eliminated rinderpest if the vaccine batches used were of poor quality. The secondary and independent level of quality control assessment assured by PANVAC played a major role for this success and led, at the same time to a sustained improvement in the quality of vaccines against rinderpest and contagious bovine pleuropneumonia produced in Africa.'

Vaccine production and quality assurance technologies based on PANVAC quality assurance procedures were transferred to countries in other regions, such as India, Iraq and Pakistan. It was noted that one of these transfers, carried out by PANVAC staff in 1995, may have been decisive in eliminating rinderpest in the countries concerned.

ROLE OF PANVAC IN NETWORKING AND CAPACITY DEVELOPMENT

PANVAC's activities throughout PARC were not restricted to laboratory processes to ensure that vaccines released for the campaign were of good quality. PANVAC was also active at producer level, promoting the concept of GMP, and in training laboratory personnel. It is outside the scope of this chapter to review these in detail, but a few examples will illustrate the activities of PANVAC:

- Standardisation of biologics and standard operating procedures: a repository of well-characterised reference materials was established, comprising cell lines and virus vaccine seed stocks, which were made available to vaccine production laboratories in Africa. Standard operating procedures for the production and quality control of rinderpest vaccine were developed and distributed to vaccine production laboratories by PANVAC.
- Training and technology transfer: PANVAC organised several training programmes from which personnel of vaccine-producing laboratories benefited greatly. PANVAC trained more than 400 veterinarians and technicians from national vaccine-producing laboratories in Africa and provided technical expertise to

FIG. 5
CERTIFICATE AWARDED TO PANVAC IN RECOGNITION OF ITS ACHIEVEMENT IN ERADICATING RINDERPEST FROM THE CONTINENT

Courtesy of the authors

FIG. 6
TRAINEES FROM DIFFERENT PARTS OF THE AFRICAN CONTINENT BEING TRAINED ON VACCINE QUALITY CONTROL

Courtesy of the authors

FIG. 7
ALIMATA BERTHE CISSE UNDERGOING QUALITY CONTROL TRAINING

Courtesy of the authors

improve their productivity. The training sessions were organised as workshop fellowships or in-house arrangements (Figs 6 and 7).

- Countries that did not produce vaccines, such as Burundi, Uganda and the United Republic of Tanzania, benefited from PANVAC assistance in revalidating the potency of their priority vaccine stocks and emergency vaccine banks. Within the framework of the Global Rinderpest Eradication Programme (GREP) collaboration, batches of rinderpest and peste des petits ruminants vaccine from production units in India, Jordan and the Syrian Arab Republic were tested by PANVAC. Senior staff of these laboratories benefited from PANVAC training programmes in quality control and production.
- Information collection and dissemination: although UNDP funding continued, PANVAC published the PANVAC Vaccine Bulletin to support vaccine production activities. This was a quarterly bulletin on vaccine technology and science, which was distributed to network laboratories, providing information on vaccine production and related matters.
- A network of vaccine production laboratories: PANVAC's quality control services and supply of biological materials led to the creation of a network of vaccine-producing laboratories throughout Africa and the Near East. This network brought benefits to member laboratories. It also provided a platform through which recommendations were made to the authorities and donors on policy issues and activities. The 23 laboratories that participated in the PANVAC network in Africa included Angola, Botswana, Cameroon, Chad, Côte d'Ivoire, Ethiopia, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mali, Mozambique, the Niger, Nigeria, Rwanda, Senegal, Somalia, Sudan, the United Republic of Tanzania, Uganda and Zaire.
- Collaboration with other reference centres and institutions: PANVAC built collaborative partnerships with leading global institutions in vaccine science, including the Pirbright Institute, Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Centre for Tropical Veterinary Science (CTVM), Edinburgh, the National Veterinary Services Laboratory/Animal and Plant Health Information Service/Veterinary Services/United States Department of Agriculture, the IAEA Animal Production and Health Laboratory, Seibersdorf, and International Laboratory for Molecular Biology, University of California, Davis, and participated in international working groups, such as the OIE working group on veterinary drug registration and the FAO/AU-IBAR/OIE/IAEA consultative group on contagious bovine pleuropneumonia.

Several young African scientists who underwent apprenticeship-type training and consultancies with PANVAC went on to become scientific leaders in their own countries, some at regional and international levels – examples include Dr Berhe Tekola (Director, Animal Production and Health Division – AGA), Dr Karim Tounkara (OIE), Dr Martha Yami (Director of the National Veterinary Institute, Ethiopia) and Dr Alimata Berthe Cisse (Director of the Laboratoire Central de l'Élevage – LABOCEL, Mali).

THE ROLE OF PANVAC AFTER THE DECLARATION OF GLOBAL FREEDOM FROM RINDERPEST

In recognition of the various roles played by AU-PANVAC and in support of its activities, the OIE in May 2013 designated AU-PANVAC as an OIE Collaborating Centre for Quality Control of Veterinary Vaccines, while FAO, in a similar manner, designated AU-PANVAC as an FAO Reference Centre for Training in Vaccine Quality Control. In addition to its mandates, AU-PANVAC was given the responsibility for safekeeping all rinderpest virus held in Africa and destroying all materials deemed unnecessary (8). This was based on the recommendations of the Eighth Conference of Ministers Responsible for Animal Resources in Africa, which was held in Entebbe, Uganda, in 2010, and this recommendation was endorsed by the Heads of State of the AU (9). During the implementation of this recommendation, the AU Commission provided AU-PANVAC with biosafety level 3 facilities, required by the international veterinary community, for the following: safekeeping rinderpest vaccine seed stocks; safekeeping the emergency preparedness of the rinderpest vaccine stock (1.5 million doses); and keeping laboratory diagnostic capacity for rinderpest. In support of the move by the AU, the OIE designated AU-PANVAC as a rinderpest holding facility for holding rinderpest virus and rinderpest vaccine seed stock. Presently, AU-PANVAC has started to receive rinderpest virus-containing materials from AU Member States (see Chapter 8.2). AU-PANVAC is also collaborating with various international partners in the implementation of projects and activities, especially in relation to vaccine improvement and development and to the harmonisation of vaccine registration and animal disease prevention and control in Africa.

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CHAPTER 5.7

ROLE OF REFERENCE LABORATORIES AND COLLABORATING CENTRES IN RINDERPEST ERADICATION

M. JEGGO [(1)]*, **J. ANDERSON** [(2)] **& G. LIBEAU** [(3, 4)]

(1) Geelong Centre for Emerging Infectious Diseases, Waurn Ponds Campus, Deakin University, Geelong, Victoria 3220, Australia
(2) Pirbright Institute, Pirbright, Woking, Surrey GU24 ONF, United Kingdom
(3) Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Département d'Élevage et de Médecine Vétérinaire (CIRAD), UMR Contrôle des Maladies Animales Exotiques et Émergentes (CMAEE), 34398 Montpellier, France
(4) Institut National de la Recherche Agronomique (INRA), UMR CMAEE 1309, 34398 Montpellier, France

*Corresponding author

SUMMARY **Rinderpest Reference and Collaborating Centres played a crucial role throughout the eradication of rinderpest. The principal reference centres were in the United Kingdom of Great Britain and Northern Ireland (the Pirbright Institute) and France (Institute d'Élevage et de Médecine Vétérinaire), but laboratories in infected countries also played important roles, in terms of both diagnosis and technical support. From the outset, the key centres in the United Kingdom and France were involved in test development, validation, standardisation, quality assurance and reagent supply. As the eradication programme evolved, so did the need for different laboratory tests and for a test that could be used in the field. Thus, there was a continual process of underpinning research undertaken to ensure that the programme had the necessary laboratory-based tools throughout the eradication process. Over and above this, staff of the centres provided continual technical support and attended numerous meetings to ensure that the best possible technical advice was available. They also provided a sustained programme of training for scientists and technical staff in rinderpest-infected countries that evolved and matured as the process rolled out from Africa into Asia. As the programme reached the stage of verification of rinderpest freedom, the centres assisted in the analysis of national surveillance data on which certification of freedom was based.**

KEYWORDS **Assay validation – Collaborating Centre – Laboratory tests – Laboratory training – Penside tests – Quality assurance – Reference Centre – Research – Virus characterisation.**

INTRODUCTION

Both the World Organisation for Animal Health (OIE) and the Food and Agriculture Organization of the United Nations (FAO) (1945) have, from the outset, provided support to developing countries for laboratory diagnosis through designated Reference and Collaborating Centres. Initially the focus was on the provision of a laboratory to which samples could be sent for initial or confirmatory diagnosis of an animal disease. These Reference Laboratories or institutes were ones with specialised expertise in a particular disease, and thus, beyond diagnosis, they were also able to help in test development, in reagent supply, in providing advice and in training. The very first Reference Laboratory was for foot-and-mouth disease and was based in the United Kingdom of Great Britain and Northern Ireland.

The current world of OIE and FAO Reference and Collaborating Centres is a complicated array of laboratories and laboratory activities that have considerable overlap and duplication but provide a powerful tool to manage the risks from the diseases that affect both livestock and wildlife. Reference Laboratories are designated for most of the diseases affecting livestock, while Collaborating Centres handle animal health issues including epidemiology, risk analysis, methodologies such as enzyme-linked immunosorbent assay (ELISA)-based technologies, or disease management concepts such as molecular epidemiology (1).

In the 1980s, as rinderpest eradication activities recommenced in the wake of the failure of post-Joint Programme 15 follow-up measures, the situation was somewhat different. The Pirbright Institute in the United Kingdom (at that time the Institute for Animal Health Pirbright Laboratory) was the recognised global Reference Centre for rinderpest, although it was not recognised officially as the OIE and FAO World Reference Laboratory (WRL) for rinderpest until 1994. However, the Pirbright Institute had a long history of rinderpest research, and long before being designated as the WRL, it had established a repository of rinderpest virus strains that became essential for the subsequent development of the molecular epidemiology around this disease. In France, the Institut d'Élevage et de Médecine Vétérinaire (IEMVT), at this time based in Maisons-Alfort, near Paris, was recognised by the OIE as an OIE Reference and Collaborating Centre. Together these two institutes provided much of the early work on rinderpest second-generation diagnostic tests, on reagent supply and on training (2, 3, 4, 5). As is the case mostly today, these two centres relied on the expertise of a few individuals, on the research they were undertaking, on the goodwill and benevolence of their institutes, and on national government funding in contributing to rinderpest control and eradication.

For both the Pirbright Institute and the IEMVT, there was a strong historical connection with diseases of livestock in Africa and in particular with rinderpest. In both cases much support had been provided to the region over many years. Through institute staff and specific development aid projects, many activities had been undertaken in laboratories and related field activities in individual African countries that were undertaking rinderpest control. In particular at the Pirbright Institute prior to the commencement of the Pan-African Rinderpest Campaign (PARC), a range of rinderpest research and field projects had been undertaken. At both centres diagnostic tests had been developed and validated for both rinderpest antibody and antigen detection, work had been undertaken on vaccine improvement and on the study of combination vaccines, and much basic research had been undertaken on the pathology of rinderpest and on the immune response to virus infection in a number of species (6, 7, 8).

Thus, as the planning and implementation of rinderpest eradication commenced, these two centres were in an excellent position to provide advice and support for the programme.

CENTRES, PEOPLE AND RESOURCES

The FAO and OIE WRL, located at the Pirbright Institute, had a long history of research and support for rinderpest in both Africa and Asia. The key expert was John Anderson, with much of the underpinning research being undertaken by Tom Barrett and subsequently by Michael Baron. Tom Barrett undertook early work on the sequence of the virus, leading to his development of a diagnostic polymerase chain reaction (PCR) test, and from this the identification of the geographic lineages (based on the sequence of the diagnostic PCR product). He also did a lot of work on alternative vaccines, specifically recombinant vaccinia (with Kazuya Yamanouchi) and recombinant lumpy skin disease (LSDV) (with Donald Black and Carlos Romero), and additionally studied the molecular determinants of virulence. Michael Baron's main contribution was sequencing the whole genome, and developing the system for making rinderpest recombinants that were then used to study virus pathology, including the way the virus controlled the host's innate immune system. William Taylor (succeeded by Euan Anderson) ran the World Reference Laboratory for rinderpest and assembled a collection of isolates from Egypt, Nigeria and the Gulf States. Research by them in experimental cattle demonstrated that average survival times behaved as a potential genetic marker. These observations were borne out by experiences in the field and further research in Kenya, and such work undertaken at the WRL, proved crucial in managing the issue of mild clinical disease in the latter stages of the eradication effort. While many staff were involved in rinderpest research and support activities throughout the Global Rinderpest Eradication Programme (GREP), Jayne Thevasagayam and Amanda Corteyn provided dedicated diagnostic technical support for most of the GREP years. As with all such centres, the vast majority of the costs of the resources provided were not recovered and were considered part of the UK Government's contribution to development aid in general and to rinderpest eradication. John Anderson was an FAO/International Atomic Energy Agency (IAEA) agreement holder within the FAO/IAEA coordinated research programmes (CRP) of support to national laboratories in rinderpest-infected countries (9, 10, 11, 12). John Anderson and other staff undertook numerous FAO and FAO/IAEA expert missions and related consultancies to international meetings, technical workshops, individual GREP countries and training courses (12, 13, 14, 15, 16). For the most part, such missions were funded by FAO and IAEA national and regional technical cooperation programme (TCP) projects, the European Union and the UK Department for International Development (DIFD). While assay development and validation was for the most part funded through the Pirbright Institute, the provision of reagents was cost-recovered and included the costs associated with the supply of rinderpest ELISA kits through Biological Diagnostic Supplies Ltd (BDSL). Research, again for the most part, was undertaken using institute funds, although a number of specific projects were funded through national and EU research funding bodies e.g. the Wellcome Trust. As a WRL, the Pirbright Institute received annual funding to partially cover the cost of taking on this role from FAO.

The IEMVT was an OIE Collaborating and Reference Centre at the commencement of PARC. At that time, Alain Provost, previously Director of the IEMVT Farcha Laboratory in Chad, was its head. The organisation subsequently became the Département d'élevage et de médecine vétérinaire du Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD-EMTV) located in Montpellier, in the South of France. Strongly committed to the need for a new pan-African vaccination campaign and the potential for global eradication, he encouraged this institute to continue research on rinderpest. IEMVT was involved in all aspects of rinderpest research and control activities from the early 1950s and throughout PARC and GREP. It had an impressive record of support to countries in Africa, with a real focus on vaccine development and provision of support in this area to a number of key vaccine producers in Africa and Asia. Initially, in the 1980s Pierre-Charles Lefèvre was the leading laboratory expert, with Adama Diallo and Genevieve Libeau contributing to research on improved diagnostic tools, molecular epidemiology and vaccines (17, 18), and Renaud Lancelot was involved as an epidemiologist in Africa. A number of other IEMVT and CIRAD-EMVT staff provided a range of technical and administrative support. Initially Lefèvre and subsequently Libeau were FAO/IAEA agreement holders (19, 20) and, as with the Pirbright Institute, undertook many missions to infected countries during the GREP period. The IEMVT and subsequently CIRAD-EMVT additionally provided considerable support to rinderpest vaccine producers in infected countries.

Similar to the Pirbright Institute, resources for the support to rinderpest were provided directly by IEMVT, but this too was augmented by support for missions to GREP meetings and GREP countries from the specialised United Nations (UN) agencies, by the European Union and, to a lesser extent, by specific vaccine producers. Research was supported through grants nationally and through the European Union.

At the commencement of PARC and GREP, specific expertise and capabilities were somewhat limited in infected countries. Two laboratories in Africa were designated as OIE Rinderpest Reference Laboratories: The Laboratoire National de l'Élevage et de Recherches Vétérinaires (LNERV), Dakar, Senegal, with Joseph Sarr as the expert, and the Kenya Agricultural Research Institute (KARI) Muguga Laboratory, Kikuyu, Kenya, with Henry Wamwayi as the expert. They provided an initial reference diagnostic service and undertook a number of specific research projects on rinderpest.

It should be recognised that, for the most part, national veterinary diagnostic laboratories were officially recognised as national Reference Laboratories, and as with LNERV and KARI, the rinderpest 'expert' in the laboratory was awarded with an FAO/IAEA research contract within the framework of the FAO/IAEA CRP to support their diagnostic role (including seromonitoring and serosurveillance). Support was further augmented through equipment, training and fellowships and expert services by means of FAO and IAEA TCPs, through the EU programme of support and through bilateral country support programmes e.g. the Danish International Development Agency (DANIDA), DFID and the Swedish International Development Cooperation Agency (SIDA).

As with Sarr and Wamwayi, many of these individual FAO/IAEA research contract holders became recognised experts in rinderpest and provided bilateral support to other infected countries, to GREP, to OIE and to FAO.

A similar network of national laboratories undertaking rinderpest seromonitoring and serosurveillance was established in the Middle East, initially under the auspices of the West Asian Rinderpest Eradication Campaign (WAREC). Again the role of individuals in each laboratory was profound in creating a regional competence in serological testing and a routine regional reporting ethos. In Southeast Asia most countries adopted the ELISA test developed by the WRL and distributed by BDSL. This BDSL kit was also extensively used in India for serosurveillance. The serosurveillance programme in India was coordinated at the ELISA Training and Data Management Centre (ETDMC), Bangalore, under the Indian Council of Agricultural Research, with over 500 scientists from some 33 laboratories across India having obtained training in ELISA technology. Only towards the end of the serosurveillance programme in India, and later for follow-up screenings, was a monoclonal antibody-based rinderpest competitive ELISA kit (c-ELISA; see Chapter 3.3), developed at the Indian Veterinary Research Institute, Mukteswar (21), and validated by the WRL, Pirbright, used in India (see Chapter 4.13.4). In other Asian countries and including the Russian Federation, the BDSL ELISA kit was primarily used with continual support from the two OIE Collaborating Centres (the Pirbright Institute and IEMVT).

In a general sense, national veterinary laboratories were responsible for providing a diagnostic service, for undertaking activities such as testing in serosurveillance and seromonitoring and for reporting a positive rinderpest diagnosis to the OIE through their chief veterinary officers. In many cases, such laboratories at the commencement of GREP were not suitably equipped or had staff sufficiently trained, and thus many countries submitted samples either in parallel or directly to the regional Reference Laboratory and the WRL for confirmation or primary diagnosis and further molecular characterisation. In critical regions such as southern Sudan, with no laboratory capability, the samples were all tested at the WRL. The final Somalia samples were tested in Kenya, but then the results were confirmed at the WRL, because this was the critical last focus of infection. The role that the Reference and Collaborating Centres played in creating regional networks of experts and capabilities was crucial to GREP's success, and was, in reality, the precursor to the extensive programme of laboratory twinning now operated by the OIE (22, 23, 24, 25, 26).

TEST DEVELOPMENT, VALIDATION, STANDARDISATION AND SUPPLY

In implementing any disease control or eradication programme it is imperative to have available appropriate tests to meet the various needs of the programme. It is customary for Reference Laboratories and Collaborating Centres to have key roles in developing such tests, in providing reagents and training for their use, in operating a programme of test troubleshooting and quality assurance, and in undertaking specific areas of programme research.

While ideally all these needs should be identified at the planning stage of an eradication programme, be adequately resourced and meet clear programme timelines, the reality for GREP was anything but this. Prior to the commencement of PARC, many rinderpest diagnostic tests had been developed and were in use in various forms in rinderpest-infected countries and utilised within the framework of the two main Reference Laboratories, the Pirbright Institute and IEMVT. However, it was anticipated that most of these would be inadequate for GREP and that GREP would have some specific requirements that could not be met with current tests and that would change as the programme evolved. Seromonitoring of the vaccination programme was initially seen as a crucial early-stage activity, along with an ability to detect infection in the field or, at a minimum, at the national level in participating countries. It was also recognised that most of the testing would be done at the national level, often in poorly equipped laboratories, but with requirements for high throughput in terms of antibody detection tests. It also became clear that test validation, standardisation, test data collection and use, and quality assurance would be crucial issues for GREP. Furthermore, it was clear that most of the development work and subsequent support for this laboratory work would need to be underpinned by the Pirbright Institute and IEMVT.

Fortunately in 1986 and during the planning stages of PARC and GREP, the Animal Production and Health Section (APH) of the Joint FAO/IAEA Division had decided to embark on a programme of support to veterinary laboratories in developing countries, based on the use of the ELISA (see Chapter 3.3). The rinderpest eradication programme provided an ideal opportunity to focus this support programme (27, 28). Much work had already been carried out at the Pirbright Institute on the use of an indirect ELISA for the detection of antibodies to rinderpest, and a field validation programme had been undertaken in the United Republic of Tanzania (29). Over the next few years, through a strong partnership between the Pirbright Institute and the APH, the

ELISA was specifically developed for use as the major diagnostic tool for GREP. It went through a number of development processes, moving from an indirect to a c-ELISA; it was developed into a kit format that could withstand the rigours of travel and use in difficult conditions; it was fully validated and standardised, and software was developed to manage data collection, storage and use. Throughout these processes, the network of laboratories under the FAO/IAEA CRPs was not only supplied with these kits, but it was used to identify and resolve problems with the kits' use. An extensive quality assurance programme was developed to underpin these activities and involved over 34 national rinderpest-testing laboratories. All of these activities were technically underpinned and supported by the Pirbright Institute and IEMVT (30, 31, 32).

As GREP evolved so the needs changed. A move away from mass vaccination and seromonitoring towards epidemiological surveillance, targeted vaccination and the inclusion of wildlife in disease surveillance demanded tests with a different level of sensitivity and specificity, tests for antigen detection in the field and tests for separating immune responses from rinderpest virus (RPV) to those of peste des petites ruminants virus (PPRV). Both the Pirbright Institute and IEMVT carried out work continually on the ELISA to ensure that it was suitable for these tasks. And as the programme moved towards surveillance to demonstrate freedom from disease and subsequently circulating virus, so these tests were further developed to meet these needs through initial work at the Pirbright Institute and IEMVT and then in the field, under the direction of these laboratories (33, 34).

It became essential to delineate clearly the role wildlife played in terms of rinderpest virus persistence. CIRAD-EMVT and the main national and regional Reference Laboratories in Africa were involved in targeted surveillance of wildlife under the African Wildlife Veterinary Project, as a component of PARC. To ensure the maximum benefit from the relatively high-cost samples that were collected from wildlife, both the 'gold standard' test (virus neutralisation test [VNT]) and the newly validated c-ELISA for both PPRV and RPV were utilised at KARI and CIRAD. This work confirmed the value of buffaloes as sentinel animals but also demonstrated that, without infection in livestock, the virus would not persist in wildlife (35, 36, 37).

One specific need was the availability of a test that could confirm a suspected clinical case in the field. Such a penside test was seen as being crucial as the programme evolved, countries became free of disease and the identification of a clinical case had serious repercussions. In such situations, speed and accuracy of the confirmation were vital. Fortunately Pirbright Institute had been working on such a rinderpest penside test for some years and, as the vital need arose in GREP, the WRL was able to provide such a test for use in the field as a robust and relatively inexpensive, but critical, tool. The very last case of rinderpest in the world was diagnosed with such a test in 2001 (38, 39).

As the GREP programme evolved so the role of PPRV infection in small ruminants, cattle and wildlife grew in importance. At CIRAD-EMVT, an immune-capture ELISA test for differentiating RPV from PPRV was developed for routine use in African laboratories. This allowed the possible detection of both RPV and PPRV antigen from the same clinical specimen. This test was applicable to a wide variety of sample types (e.g. blood, tissue, saliva) and species from sheep to dromedary, with high specificity and sensitivity (40).

Central to the support of national rinderpest-testing laboratories is the routine availability of test reagents in good condition and in a form that can be utilised in whatever conditions exist in the laboratory. The APH and the Pirbright Institute decided early on that a kit format, with all the crucial reagents supplied and in a form that would be able to withstand the rigours of travel anywhere in the world, was the way forward. Initially the WRL took on the role of supplying reagents to individual laboratories; subsequently, as the concept of a kit evolved, so the APH section in Vienna supplied kits directly from its own laboratory in Austria. It was at this stage that the section became recognised as an OIE Collaborating Centre for the use of ELISA and molecular techniques in animal disease diagnosis. It soon became clear, however, that the supply of these kits would best be commercialised. Given that, for most countries, the cost of the kits would be met through the FAO/IAEA contract to members of the CRP, the commercialisation would not create a financial burden to GREP and would have many advantages in terms of production, standardisation and supply (10, 41). The WRL and the APH then worked with BDSL to agree a suitable format and process for this approach and, from then on, these ELISA kits were supplied to all GREP countries through BDSL. The WRL still continued to have a crucial role in supplying reagents to BDSL and in quality assurance activities. Similarly, CIRAD-EMVT and BDSL developed a joint arrangement for the distribution of the immune-capture ELISA.

Once the penside test had been developed and validated at the WRL, the supply was taken over by SVANOVA, the commercial arm of the Swedish National Veterinary Research Institute.

As the programme moved from vaccination and containment to one of eradication and surveillance, new molecular technologies were evolving for the detection and characterisation of pathogens. PCR technologies began to revolutionise the detection of viruses. Both the Pirbright Institute and CIRAD-EMVT had been utilising these technologies as research tools, and it now became a focus to transfer such approaches to key laboratories in GREP countries (42, 43). Although more difficult than ELISA technologies to transfer, standardise and quality assure, molecular technologies had much to offer in terms of specificity, sensitivity and speed. The technology itself continued to evolve in this latter stage of GREP, and the Pirbright Institute and CIRAD-EMVT had a critical role in keeping pace with these developments and, where appropriate, in transferring these skills to GREP laboratories. As with the ELISA, the APH programme of support took on board molecular approaches and worked with the WRL and CIRAD-EMVT in a programme of technology transfer.

GENERAL DIAGNOSTIC SUPPORT

One key role of both FAO and OIE Reference Laboratories is to provide a diagnostic service for the member states of these organisations (44). As the WRL for rinderpest, the Pirbright Institute provided this service throughout GREP. Of course, as GREP progressed and the laboratory capabilities grew in the regions and at national levels, the role of both the Pirbright Institute and CIRAD-EMVT diminished somewhat, in terms of routine diagnosis, to one involving the detailed characterisation of the viruses that were isolated, including partial and full sequencing. This became fairly critical as mild strains of rinderpest emerged in the Horn of Africa, probably favoured by the misuse of vaccines over decades in cattle. Questions of vaccine virus reversion to virulence surfaced as an issue at that time because, given the limited capability for high-throughput whole virus sequencing, it was not possible to distinguish vaccine from wild virus. Nevertheless, it was possible to identify the remaining pockets of virus infection in cattle, and eradication was achieved.

Throughout, the WRL and CIRAD provided a general diagnostic service for rinderpest free of charge to any OIE or FAO country requesting such support.

Research activities

Both the Pirbright Institute and IEMVT (now CIRAD) have a long history of undertaking research on rinderpest. Indeed their designation as OIE and FAO Reference and Collaborating Centres is based on this research over many years. Furthermore, most of the senior figures involved in GREP had at some time during their careers worked at one or other of these institutes and been engaged in their research activities. As PARC and GREP commenced, previous research had provided the eradication programme with the necessary vaccine and diagnostic assays to succeed. While further research was undertaken, in terms of basic research around the pathology and immune response, on virus characterisation, on vaccine design and use, and on improved diagnostic tests, it was perhaps the research undertaken prior to the commencement of GREP that ensured that eradication could be achieved.

EXPERT SERVICES

By definition, Reference and Collaborating Centres have specialised expertise, and this existed at the Pirbright Institute and IEMVT in abundance. Such expertise was critical during the planning, implementation and freedom verification stages of GREP. This expertise was provided, however, not only at the strategic and global level but equally on the ground with individual laboratories and implementation personnel. Numerous expert missions were undertaken by staff of the Pirbright Institute and IEMVT throughout the eradication campaign, involving a very wide range of activities and including the preparation and delivery of numerous reports and publications. It should be noted that for the most part such activities received no remuneration other than cost recovery for travel and accommodation and demanded strong personal commitment and sacrifice from those involved.

TRAINING

Training of those taking part in a programme of this nature is an essential component, and it is a prerequisite for an OIE and FAO Reference Centre that the provision of training is a key role. For GREP this role takes on many different guises, including visiting fellows working directly at the two Reference Centres, the support of fellows at many other institutes, support for training courses and training activities linked to other GREP meetings and the preparation of a wide range of training materials (45, 46, 47, 48, 49, 50, 51).

As agreement holders, both Libeau and Anderson attended many research coordination meetings associated with the FAO/IAEA CRPs, at which numerous training activities took place. This proved a powerful tool in ensuring that the level of expertise in all participating laboratories was at a similar level, something crucial when comparing data from different laboratories and countries. It also provided an opportunity to bring on board new laboratory personnel and bring them more rapidly up to speed and to introduce new testing protocols and procedures.

A key concept was around 'training the trainers'. Many of the scientists involved in GREP, who were initially trained through the Pirbright Institute and IEMVT, subsequently became trainers themselves and provided this crucial support at both national and regional levels.

VERIFICATION OF FREEDOM FROM RINDERPEST AND VIRUS SEQUESTRATION

As African countries ceased vaccination, they embarked upon a consolidation programme, PACE (Pan-African Programme for the Control of Epizootics), in 1999. This sought to continue with rinderpest eradication, develop surveillance systems and assist countries in the process of official freedom from rinderpest recognition by the OIE. Similar programmes operated across Asia, led by FAO and GREP. It was only after many thousands of samples from susceptible domestic animals and wildlife had tested negative for the presence of rinderpest virus that it was possible to confirm the global eradication of the disease. Both the Pirbright Institute and CIRAD-EMVT played a crucial role in test support, in analysing the nationally reported laboratory data and in helping to resolve anomalies and confusion. Experts from the Pirbright Institute and CIRAD-EMVT served as members of the OIE *Ad hoc* Rinderpest Group, and, along with other experts, they assessed the country dossiers submitted to support their declarations at the three stages of the OIE Pathway. They then made recommendations on acceptance, rejection or the need for further information to other OIE committees. They were an importance resource for technical support and providing credibility to these declarations. However, such dossiers did not go through the Reference Laboratories and were confidentially prepared by the individual countries, albeit sometimes with assistance from FAO or the OIE. The OIE *Ad hoc* Rinderpest Group gave its opinion as independent experts with no affiliation or political bias.

As a somewhat final task, the group members are now assisting in the task of identifying and removing residual virus from the numerous laboratories and institutes that took part in the eradication programme. It is still to be decided where, if anywhere, remaining samples of rinderpest will be held, but a role for the experts in the future around rinderpest is certain.

CONCLUSIONS

Central to any disease control or eradication programme is the availability of a variety of diagnostic tests and an effective diagnostic service at national, regional and global levels. The availability from the outset for GREP of two world-class Reference Laboratories, in the United Kingdom (Pirbright Institute) and in France (CIRAD-EMVT), each with a long history of research in rinderpest, was to prove critical for the successful eradication of rinderpest. The vital ingredient within such laboratories is the expertise of their staff, and again GREP was well served in this area. While the diagnostic tests that were available at the commencement of the eradication programme met the initial requirements, much needed to be done in terms of validation, standardisation, distribution and quality assurance. All of these needs were met through activities undertaken at the Pirbright Institute and CIRAD-EMVT. As new diagnostic needs became apparent and new technologies became available, these two laboratories and the Joint FAO/IAEA Division were central in bringing these into use across GREP. Much can be learnt for future similar programmes from the roles played by the Pirbright Institute and CIRAD-EMVT in the successful eradication of rinderpest.

ACKNOWLEDGEMENTS

The authors wish to sincerely acknowledge all those that worked in veterinary laboratories and in the field diagnosis of rinderpest in infected countries. Without their tireless efforts, partnership and friendship, and their tolerance of imperfections throughout the programme of eradication, success would not have been achieved.

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CHAPTER 5.8

ROLE OF THE EUROPEAN UNION IN RINDERPEST ERADICATION

B. REY [(1)*], L. CASTILLO FERNANDEZ [(1)], M. KLEMM [(2)], A.-E. FÜSSEL [(2)] & J.D. WOODFORD [(3)]

(1) Directorate-General for International Cooperation and Development (DG DEVCO), Directorate C Planet and Prosperity, Unit C.1 Sustainable Agriculture Food and Nutrition Security, Rue de la Loi 41, B-1040 Brussels
(2) Directorate-General for Health and Food Safety (DG SANTE), Directorate G Crisis Management in Food, Animals and Plants, Unit G.2 Animal Health and Welfare, Rue de la Loi 200, B-1049 Brussels
(3) Le Coderc, La Rochebeaucourt et Argentine, 24340, France

*Corresponding author: Bernard.REY@ec.europa.eu

SUMMARY **This chapter summarises the important contribution of the European Union, and its individual Member States to the global eradication of rinderpest. The crucial element in this success story was the role played by the European Union together with other international actors, the Food and Agricultural Organization of the United Nations (Chapter 5.3) and the World Organisation of Animal Health (Chapter 5.2), in building the capacity of national, regional and subregional institutions to bring about the coordinated, sustained and harmonised approach necessary for the eradication of the disease.**

The experience gained in the eradication of rinderpest lays the foundation for overcoming the challenges of combating foot-and-mouth disease, peste des petits ruminants and many other transboundary animal diseases (TADs), all of which still compromise the ability of many countries to gain access to more lucrative markets for animal products.

This chapter describes the evolution of policy frameworks, programmes and projects during the process of rinderpest eradication, highlighting the crucial role played by the European Union in the strengthening of Veterinary Services and, most particularly, in improving disease surveillance capabilities in those countries where rinderpest eradication and the control of other TADs was being attempted.

KEYWORDS **Development policy – European Union – Food and nutrition security – International trade – Livestock products – Poverty reduction – Rinderpest eradication.**

INTRODUCTION

The European Union was a major contributor to the control and eradication of rinderpest, being a consistent and major donor over time. The European Commission, in addition to being a leading force in this challenge, took advantage of the eradication to build a solid policy of long-term capacity building in animal health and livestock services.

With its wide-ranging development cooperation operations, in most regions of the world, the European Union was well placed to take a prominent role in addressing the global challenge that rinderpest represented. The collaborative efforts of the EU programmes in Africa, the Near East, and Central, South and Southeast Asia, along with EU Member States and other donor-funded projects, combined with the Global Rinderpest Eradication Programme (GREP; Chapter 6.1) of the Food and Agriculture Organization of the United Nations (FAO) and the rigorous evaluation of dossiers submitted to the World Organisation for Animal Health (OIE) by Members in the framework of the 'OIE Pathway' for the eradication of rinderpest, were rewarded with the declaration of global freedom from rinderpest, announced at the 79th General Session of the OIE, held in Paris in May 2011 (see Chapter 7.2).

THE EVOLUTION OF POLICY FRAMEWORKS AND THE FORMULATION OF PROGRAMMES AND PROJECTS DURING THE PROCESS OF ERADICATING RINDERPEST

The global eradication of rinderpest provided an entry point to the long and continuing process of strengthening Veterinary Services as a strategic component to support the European Union's wider policy objectives of poverty reduction and fostering sustainable economic, social and environmental development, as well as promoting democracy, the rule of law, good governance and respect for human rights.

EU support to the process of rinderpest eradication was implemented through three geographically distinct European Commission funding mechanisms.

The first was a series of projects and programmes targeting the African continent, mobilising the European Development Fund (EDF) for the African, Caribbean and Pacific countries and forming partnerships with the African Union/Inter-African Bureau for Animal Resources (AU-IBAR; see Chapter 5.5) and the national governments of implementing countries (Table I).

The second was a series of projects and programmes implemented through the Directorate-General responsible for external relations in other countries of the Middle East, South and Southeast Asia, utilising Asia and Pacific funds and implemented in partnership with the South Asia Association for Regional Cooperation (SAARC) (Table II)

The third was a series of programmes implemented through the Directorate-General responsible for health and food safety policies (now known as DG SANTE), with a particular focus on the protection of livestock production in Europe mainly from neighbouring countries and trade partners.

DG SANTE, which has the responsibility for, among other things, protecting Europe from the incursion of transboundary animal diseases (TADs) and other health threats, was responsible for the formulation of Council Directive 92/119/EEC of 17 December 1992, which introduced, inter alia, the general community measures for the control of certain animal diseases, including rinderpest. That Directive remains applicable today, setting the framework for rapid EU action in the event of rinderpest recurrence in the European Union, the aim being to swiftly eradicate the disease through early detection, strict movement controls, regionalisation and a stamping-out policy without using vaccination. Those measures are to be implemented within the framework of animal health contingency plans. Vaccination may be authorised subject to additional conditions. Furthermore, DG SANTE is responsible for a comprehensive set of harmonised EU legislation that ensures safe imports of animals and animal products, including conditions as regards rinderpest. Finally, DG SANTE continues to support the Veterinary Services of neighbouring countries and other trade partners by way of capacity-building activities such as the Better Training for Safer Food (BTSF) programme.

TABLE I
EU-FUNDED PROJECTS AIMED SPECIFICALLY AT RINDERPEST ERADICATION – AFRICA

Name of project	Period of implementation	Value of funding (€ million)
Joint Project 15	1962–1977	5
Pan-African Rinderpest Campaign	1986–1998	115
Pan-African Programme for Control of Epizootics	1999–2006	77
Wildlife veterinary project (Africa)	2000–2003	2
Somali Ecosystem Eradication Coordination Unit	2007–2010	4
Towards global declaration of rinderpest eradication in 2011 and strategies for a post-rinderpest world – FAO	2010–2011	2.8
Total – Africa	**1962–2011**	**205.8**

TABLE II
A SELECTION OF EU-FUNDED RINDERPEST ERADICATION AND 'STRENGTHENING OF VETERINARY SERVICES' PROJECTS IN ASIA

Name of project	Period of implementation	Value of funding (€ million)
Livestock development project – Baluchistan, Pakistan	Late 1970s	7.45
Emergency supply of rinderpest vaccine for Pakistan (short-term operation)	1995	0.4
South Asia Rinderpest Eradication Campaign Support Project (SAREC-SP/Regional)	1996–2006	7.7
Strengthening Veterinary Services projects – Viet Nam, Lao People's Democratic Republic and Bangladesh	1996–2006	16
Strengthening Veterinary Services projects – India, Nepal and Bhutan	1998–2008	53
Strengthening livestock services project – Pakistan	2001–2009	22.9
Animal Health Development programme – Afghanistan – Phase I	2004–2010	4.65
Animal Health Development programme – Afghanistan – Phase II	2010–2016	9.05
Animal Health Support Programme – Afghanistan (support to non-governmental organisations developing private sector animal health services and vaccine production – Afghanistan) – Phase I	2004–2009	2.65
Animal Health Support Programme – Phase II	2009–2013	3.72
Follow-up livestock smallholder support projects – Cambodia and Lao People's Democratic Republic	2007–2010	8.8
Total – Asia	**1976–2016**	**136.32**

Source: Rey *et al.*, 2011 (2)

In 1962, at the time when the then European Economic Community first became involved in allocating resources aimed at rinderpest control and thereafter for the next two decades, grant contributions for the implementation of livestock development projects and programmes were largely made available under the prevailing policies, targeting specifically agricultural development and livestock production and health, in Africa, the Middle East, Asia and South America.

Towards the beginning of the 1990s the policy environment for international aid was changing rapidly, becoming more horizontal in nature to capture wider political and strategic objectives including poverty eradication, political stability and social equity.

In 1994, for instance, following a series of appraisal missions conducted throughout South and Southeast Asia, a 'new generation' of 'strengthening of livestock services' (SVS) projects were developed with a more holistic and horizontal approach. At that time, the European Union's actions related to agriculture and livestock development were being developed as part of the European Community's political and economic relations with Asian countries in line with the European Union's 'New Asia Strategy', which included strengthening political dialogue, contributing to peaceful development and security and promoting economic reform. More specifically, epidemic disease control, and in particular the progressive control and eradication of rinderpest, were seen as being components of sustainable development of Veterinary Services and as a service to the livestock sector of agricultural production. More generally, the programmes being developed at that time aimed to contribute to 'promoting the economic development of the less prosperous countries and regions in Asia, poverty alleviation and sustainable growth', one of the four broader objectives of the new Asia Strategy (3). Programme and project design took cognisance of the close integration of livestock with crop production, as well as the key role played by women working in agriculture and animal husbandry. The increased income derived from facilitating access to cheaper inputs and breeding of animals with short breeding cycles would, among other benefits, lead to less discrimination against girls' access to food, education and health services. The key issues identified during the appraisals included insufficient and inefficient delivery of veterinary and extension services, high prevalence of diseases, including major epidemic and parasitic diseases, poor animal management practices and suboptimal nutrition, low level of awareness of farmers, and marketing constraints. In response to these issues, SVS projects and programmes were developed initially for Pakistan, Bangladesh, India, Nepal and Bhutan and several other Southeast Asian countries falling within the remit of the South Asia Rinderpest Eradication Campaign (SAREC) support projects through a memorandum of understanding signed with SAARC (1). These projects incorporated actions to overcome the issues identified during appraisal, including policy formulation, the formulation and enactment of veterinary legislation, improved border control, upgrading diagnostic and vaccine production capabilities, setting up communication systems and increasing the efficiency of field veterinary health and extension services (1).

To a great extent, and as a result of a process of cross-fertilisation between the two Directorate-Generals responsible for the formulation and implementation of the projects, a similar approach was followed in Africa towards the end of the period of implementation of the Pan-African Rinderpest Campaign (PARC; 1986–1999 – Chapter 4.2) and while the Programme for Control of Epizootics (PACE; 1999–2007 – Chapter 4.3) was being formulated. PACE followed immediately on the heels of PARC and was designed specifically to achieve the final eradication of rinderpest, but it also followed up on some of the successful components of PARC, including the advocacy of political support for investment in public livestock services; policy formulation leading to the reform of veterinary legislation; the prevention and control of other important epidemic diseases, including contagious bovine pleuropneumonia; the development of sustainable Veterinary Service delivery systems; and continuing to strengthen epidemio-surveillance networks, building up laboratory diagnostic capabilities and increasing vaccine quality assurance. The programme was co-financed by three EU Member States, which was an innovation at the time. The lead role given to the OIE (the OIE's Director-General chaired the main programme committee) in the governance of PACE strengthened the OIE Pathway for the eradication of rinderpest and demonstrated the trade-related assistance nature of the programme.

The privileged relations built between the European Union and AU-IBAR through these programmes have proven to be an essential building block in the political relationships between the Commission of the African Union and the European Commission.

The majority of the funds allocated by the Commission for rinderpest eradication and associated SVS projects and programmes have been disbursed through a combination of geographical (regional and national envelopes) and thematic instruments to ensure ownership of the processes intended to bring about change at the national and regional levels (2). Lessons learnt and feedback from the experiences of those closely involved with the execution of the programmes and projects within the recipient countries, as well as from a wide range of European and other international organisations, have fed into the European Union's own internal process of reform and policy development for future actions.

EUROPEAN UNION INVOLVEMENT IN THE PROCESSES OF RINDERPEST ERADICATION AND STRENGTHENING OF VETERINARY SERVICES IN AFRICA AND ASIA

The Joint Project 15 (JP15; Chapter 4.1), implemented by the AU-IBAR, was the first project to receive financial support for rinderpest eradication from the European Union. At this stage the European Commission allocated funds directly through national envelopes to those countries involved in the project to support the purchase of vaccines. At the end of JP15, rinderpest had almost been eradicated, but at that time no science-based benchmarks had been set as a means of verifying that the virus was not still circulating within cattle and wildlife populations. Indeed, it was subsequently discovered that pockets of infection remained along a trade route between Mauritania and Mali, in some remote livestock populations in south-western Sudan and in parts of northern Kenya and southern Somalia, an area which became known as the Somali ecosystem (4). In addition to the European Union, another major donor to JP15 was the USA (see Chapter 5.9), and additional resources were provided by the United Kingdom of Great Britain and Northern Ireland (see Chapter 5.11), Germany and Canada.

The lessons learnt from JP15 and a growing understanding of the epidemiology of the disease, as well as the findings of research on the longevity of immunity and the effectiveness of the tissue culture vaccine, were instrumental in bringing about the development by the OIE in 1989 of a structured approach to determine freedom from rinderpest in any given population through a step-by-step process of active disease surveillance that became known as the 'OIE Pathway' (discussed in Chapter 5.2).

From the beginning of PARC in 1987, it was already apparent that there was an urgent need to establish new or strengthen existing disease surveillance capabilities in all countries where rinderpest eradication and the control of other TADs was being attempted. Improved disease surveillance capability would lead to:

- early detection and thus improved response capability for epidemic disease control;
- in the case of rinderpest eradication, detailed information with regard to the last residual foci of disease in inaccessible or remote areas of East, Central and West Africa;
- improved understanding of the epidemiology of disease transmission, especially at the livestock–wildlife interface: the European Union was, through the African Wildlife Veterinary Project, at the forefront of ensuring that this critical element was undertaken;
- improved accuracy of animal health status reporting, leading to enhanced credibility of OIE notifications, thus opening the door to international trade in animals and animal products;
- a gradual accumulation of animal disease data that could be used to inform risk analysis for the design of future disease prevention and control

and active surveillance activities at national, regional and global levels.

The process of developing these and other essential capabilities involved the coordination of and collaboration between a wide range of international institutions and individuals with specialised expertise in epidemiological investigation, laboratory diagnostics, vaccine quality assurance, information technology and communication. This was no easy task and presented enormous challenges. In retrospect, much of the experience gained through the process of collaboration and coordination of technical assistance has yet to be critically analysed and recorded for posterity (5). The lessons learnt and the experience gained during this process will prove to be invaluable as future actions are directed towards the control and possible eradication of any one of the remaining group of important epidemic diseases affecting livestock.

Nevertheless, in both Africa and Asia the European Union's support of rinderpest eradication programmes has generated strong and lasting collaborative networks among a wide range of continental, regional and national institutions. Of particular importance have been the lasting partnerships made with a number of world class diagnostic and other veterinary laboratories, including in particular the FAO and OIE Reference Laboratories (see Chapter 5.7) for the diagnosis of livestock diseases and the FAO/International Atomic Energy Agency Agriculture and Biotechnology Laboratories, Seibersdorf, Austria (see Chapter 5.4). Twinning with these institutions, many of them in Europe, has allowed the transfer between participating countries of state-of-the-art technologies being developed in the fields of disease diagnostics, quality assurance of vaccines and medicines and residue testing of animal products destined for human consumption. These partnerships will continue to develop and strengthen capabilities for the control and possible eradication of other important livestock diseases as well as enhancing food safety and food and nutritional security.

Over the past five decades, as human and livestock populations have increased exponentially, most state Veterinary Services in developing countries have been unable to attract sufficient budgetary allocations to maintain or provide the full range of core Veterinary Service functions effectively. Increasingly, rigorous standards to meet international trade requirements, for instance, have been seen as a major challenge for developing countries to penetrate high-value markets especially in Europe, North America and the Far East. In many developing countries budgetary allocations are barely sufficient to cover staff emoluments, leaving insufficient funds to cover operational costs and the maintenance or replacement of essential equipment, including, especially, laboratory instruments and vehicles.

The European Commission and the World Bank, as well as several other major donors, have taken this paradigm as one of the several issues to be addressed through the promotion of the reform of state Veterinary Services in developing countries. In this regard, from the outset of the PARC programme the European Union has been instrumental in supporting the AU-IBAR to host or cohost a series of regional conferences and meetings to which ministers of agriculture and finance and other high-level decision-makers have been invited to create better awareness of the significant contribution the livestock sector makes to the national economies of their countries as well as the livelihoods of the vast majority of farmers and other stakeholders directly or indirectly involved in the livestock value chain. These meetings successfully brought together directors of veterinary services, donor representatives and members of all of the respective regional fora for policy and trade development, including the Inter-Governmental Authority on Development (IGAD), the Economic Community of West African States (ECOWAS), the Southern Africa Development Community (SADC) and the East Africa Community (EAC).

Support to strengthen state Veterinary Services in recent years has therefore shifted towards advocacy for policies aiming to improve veterinary service governance, the allocation of increased resources to provide improved regulatory services and related functions, including food safety of animal products, to promote and facilitate access to markets and to widen the scope of extension services to include farmer training to improve livestock health, production and productivity and human health and security. To this end the European Union continues to support the review and reform of veterinary legislation to bring it in line with the standards recommended by the OIE in the Terrestrial Animal Health Code and the World Trade Organization (WTO) Sanitary and Phytosanitary Agreement, in partnership with the OIE through the framework of the Strengthening Veterinary Governance in Africa (VET-GOV) project being implemented through AU-IBAR (6).

Complementary activities have included investment in communication campaigns, programme monitoring and evaluation and technical assistance. Because many of the PARC, PACE and SVS interventions involved engagement with livestock owners, livestock service personnel and private veterinarians, good communication was considered essential to bring about a change in knowledge, attitude and practice among these stakeholder groups.

Alongside the investments made by the European Union for the eradication of rinderpest, and building on the lessons (epidemio-surveillance networks in particular) and relationships developed during this process, has been the lead taken by the European Union in its support for the prevention and control of highly pathogenic avian influenza (HPAI), which began in 2006.

The 'One Health' concept of integrating animal health interventions with human health and the environment (7) has gained momentum following the European Union's lead in investing in the prevention and control of outbreaks of HPAI.

At the time of the joint declaration by the OIE and FAO of the global eradication of rinderpest, it was estimated that there was still rinderpest-containing virus material (RCVM) in at least 25 laboratories throughout the world (8). Deliberate or accidental 'escape' of RCVM due to the inappropriate actions of individuals or negligence is a serious threat. Rinderpest virus is included in the Australia Group Common Control List of Human and Animal Pathogens and Toxins (9) and thus is included in Council Regulation (EC) No 428/2009 of 5 May 2009 – setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items (10). It is also classified as an 'extremely dangerous pathogen' within the United Nations Security Council Resolution 1540 (2004) (11) and listed as a select agent as defined by the United States Health and Human Services and United States Department of Agriculture (USDA) (12). Rinderpest remains one of the OIE-listed diseases and is thus compulsorily notifiable to the OIE, despite having been eradicated (13).

THE IMPACT OF RINDERPEST ERADICATION AND THE CONCOMITANT STRENGTHENING OF VETERINARY SERVICES

The EU development cooperation programmes are results oriented, and they aim to have impacts on development objectives. Programmes related to rinderpest eradication have been generally both monitored and externally evaluated.

The eradication of rinderpest has brought to an end the ravages of an animal disease that has been the cause of devastating losses to livestock-owning communities and widespread famines throughout Africa and Eurasia for centuries. Added to these losses, wildlife populations in Africa have suffered a succession of devastating shocks.

The process of rinderpest eradication has involved contributions to a wide range of inter-related programmes and projects, some of which were entirely focused on rinderpest eradication while others had a broader remit and gave additional benefits. For this reason, it will be challenging to discern the precise costs attributable directly to rinderpest eradication per se. Furthermore, it is even more challenging to synthesise a comprehensive cost–benefit analysis that captures the totality of all of the socio- outcomes of this story.

A variety of methodologies have been developed to evaluate the costs and benefits derived from animal health interventions, but most of these concentrate on the more obvious direct aspects and the interests of the principal stakeholder groups and do not necessarily capture the full extent and diverse range of socio-economic benefits along the entire value chain of livestock production from producer to consumer. In many instances it is difficult to quantify some of the value-added benefits within such analyses. It is important to include an evaluation of all such benefits into an exhaustive ex post evaluation of any disease control or eradication intervention, because many of the indirect effects often far outweigh the more direct benefits that are easier to measure (14).

Disease impacts such as those related specifically to rinderpest take place at six levels of aggregation:

1. household- or farm-level impacts, which can include impacts on non-farm-related livelihoods;
2. cattle sector impacts;
3. general livestock sector impacts, including substitution effects at the production and consumption levels;
4. national-level value chain impacts based on the forward and backward linkages between livestock and other sectors of the economy;
5. indirect impacts at the national level, based on local externalities such as effects on the environment, wildlife and human well-being, including health, educational and employment development and other socio-economic conditions;
6. indirect impacts at the global or subregional level, based on externality effects, such as the savings other countries make because they no longer have to worry about disease incursion.

In all of these, the cost of a disease is the sum of reduced economic activity/returns and expenditure on control measures (14).

Such an inclusive analysis would be useful to inform future actions regarding the possible eradication of other livestock diseases. In a wider context, an analysis of this nature could also be used to inform the development of policies and strategic frameworks for sustainable agriculture, food security and nutrition.

To date, one of the more comprehensive analyses carried out was an impact assessment undertaken by Tambi *et al.* (15), which analysed the cost-effectiveness of rinderpest eradication, looking at a cohort of ten countries that participated in PARC. By examining economic losses that would have accrued without PARC and measuring these against the losses that occurred with PARC, it appeared that 88% of the total losses could be realised as benefits from PARC. This suggested that PARC saved Africa €99 million during its implementation span. A cost–benefit ratio estimated across the ten countries participating in PARC was 1.85:1. Internal rates of return varied from 11% for Côte d'Ivoire to 118% for Burkina Faso. All were well above the opportunity cost of the capital ventured. Total welfare gains from PARC were estimated at €57.5 million, of which 81% was gained by producers and 19% went to consumers (15). While this analysis is necessarily limited in its lack of inclusion of value-added socio-economic benefits, it tells us that rinderpest eradication was cost-effective. The welfare gains accrued by producers and consumers indicate that significant socio-economic benefits were derived by key stakeholders (5).

LESSONS LEARNT

Eradication is a long-term process

Keeping international actors and development partners constantly mobilised against rinderpest has been a challenge over the 40 years from 1976 to 2016. Discouragement was probably avoided thanks to the progressive development of the programme's design, taking lessons learnt into account, encompassing wider development objectives and adjusting to the evolving paradigms of the international agenda. The European Union has been at the forefront of this evolution. For example, reference to the OIE Pathway and the OIE's prominent involvement in the governance structure of PACE has supported the argument for considering that this is a trade-related assistance programme, which goes beyond a technical programme. The flexibility to organise interventions in South Sudan during the years of civil war was also a significant benefit.

Long-term capacity building must remain the goal

Through its continual focus on long-term capacity building, such as broad institutional reinforcement, multisectoral and comprehensive approaches, and the subregional and regional convergence of standards, the European Union has been a driving force towards achieving an internationally shared platform for livestock disease control. Many of the EU-supported actions described previously included rinderpest control, either on its own or as part of a broader integrated package. Another essential feature is that the European Commission has constantly contributed to shaping the veterinary and public health services of tomorrow and beyond. The natural interactions and necessary cooperation between the animal and human health sectors were addressed early in the process, and they became increasingly obvious as animal health projects and programmes became more sophisticated.

It is therefore not surprising that when it decided to co-organise the first International Ministerial Conference on Avian and Pandemic Influenza in Beijing in January 2006, the European Union promoted, and subsequently funded, actions in response to the avian influenza crisis. These focused on planning, long-term capacity building and a multisectoral integrated approach to pandemic and high-impact sanitary hazards.

Aid effectiveness

Aid effectiveness is a challenge for programmes that cover a wide geographical area and have a long timeframe, such as transboundary disease control. This issue figures significantly on the agenda of the international community. The Paris Declaration and the Accra Agenda for Action promote several concepts that are challenging for programmes such as transboundary disease control. Can we retrospectively draw lessons for future programmes from rinderpest control/eradication?

Ownership, measured by the extent to which developing countries set their own strategies for poverty reduction, improve their institutions and address governance, is the first challenge. Although developing countries participate in the definition of an international agenda (GREP for instance), the translation of this agenda into individual countries' development agendas can remain a difficult issue. The extent to which specific policies are financed compounds the difficulties. The AU-IBAR's efforts to convene ministerial meetings was an attempt to ensure such translation. Improvement of institutions was, however, seldom reflected in country poverty reduction strategy papers. The combination of EDF national and regional funds during PARC also aimed to ensure ownership at the country level.

Donor countries should align behind these objectives and use local systems. In the case of rinderpest control, donors aligned with the international agenda, represented by GREP and the OIE Pathway, much more than with explicit national agendas. While project implementation modalities have remained a central feature of cooperation in animal health issues, the option of a sector approach might offer interesting advantages for ensuring the continuous delivery of veterinary public goods.

Harmonisation is assessed by countries' capacity to coordinate, simplify procedures and share information to avoid duplication. Coordination among donors has been an important feature of AU-IBAR-led programmes, with a particular reference to the PARC technical committees and the PACE Policy Committee. This was backed up by effective EU coordination, allowing continuous support and the sharing of burdens. EDF input generated a dynamic that involved Member States alongside the European Commission. This was particularly the case for the United Kingdom of Great Britain and Northern Ireland, France, Italy and Belgium, which used a variety of modalities: parallel funding of jointly approved activities; co-funding of technical assistance; and delegated management of resources from one donor to another.

CONCLUSIONS AND THE WAY FORWARD

The important contribution made by the European Union towards the global eradication of rinderpest marks it as a key player among the donor community involved in bringing about poverty reduction and in improving opportunities for the safe trade in animals and animal products. Furthermore, the role played by the European Union, and the value added through the contributions of its Member States and other partners by improving capabilities for policy reform, together with all of the other components linked to the better governance of Veterinary Services has built closer collaboration between partner institutions at all levels and thus a solid foundation on which future interventions in the livestock and sustainable agriculture sectors can be built.

Rinderpest eradication offered a challenge and an opportunity for the European Union by addressing this global threat through tailor-made responses. The European Union developed the right mix of external action instruments behind the single objective of rinderpest eradication, and the European Union embedded its efforts within a wider multilateral framework.

In summary, over 40 years, the European Commission has contributed worldwide an amount close to €340 million, while the European Union's contribution to rinderpest eradication might well be about €390 million. However, this figure is not intended to dwarf the contributions of non-EU donors (particularly the USA, Canada, Japan and Switzerland) and – of course – the participation of beneficiary countries.

In recent years the European Union has become a leading partner within the donor community in addressing hunger, and currently it is the biggest development actor in food security, providing significant support, both financial and political.

The current EU food security policy helps developing countries to address long-term food security challenges. The policy, which is aligned to the internationally agreed definition of food and nutrition security, focuses on:

- increasing food production;
- helping the poorest to have economic access to food;
- fighting under nutrition;
- preventing and managing food crises.

The EU food security policy has been complemented by recent, more detailed policies on resilience and nutrition. In 2012 the European Union adopted a policy on building resilience and fostering a more effective EU approach in dealing with food security crises and disasters (16). The Communication on this policy recognises that it is essential to build resilience at all levels, from household to national level, by addressing the root causes of vulnerability and by strengthening response capacity.

Food and nutrition security and/or agriculture was the main sector of EU intervention over the period 2014–2020 in around 60 developing countries with an overall envelope of €8 billion. In this context, EU development policy has strengthened its coherence with other EU policies (agriculture, humanitarian aid, health and food safety, fisheries) and EU Member States in order to consolidate the European Union's role in the international scene and to ensure improved policy and strategy developments at all levels.

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CHAPTER 5.9

ROLE OF THE UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT (USAID) IN RINDERPEST ERADICATION

J.M. TURK

3533 Devon Drive, Falls Church, Virginia 22042, United States of America (Former Senior Livestock Adviser, United States Agency for International Development, Washington, DC, United States of America)

SUMMARY **From the early 1950s, the United States Agency for International Development (USAID), and its predecessor organisations, supported the eradication of rinderpest through vaccination in Asia and Africa. USAID also funded research on improved vaccines and diagnostics. In addition to direct assistance to countries combatting the disease, USAID supported the Joint Programme 15 (JP15) campaign and the Pan-African Rinderpest Campaign (PARC).**

KEYWORDS **Community Animal Health Worker – CAHW – Economic Cooperation Administration – ECA – Indirect ELISA diagnostic – International Cooperation Administration – ICA – JP15 – Mali Central Veterinary Laboratory – PARC-VAC – Recombinant rinderpest vaccine – Thermostable vaccine.**

INTRODUCTION

The international aid programmes of the Government of the United States operate subject to the foreign policy guidance of the US President, the Secretary of State and the National Security Council. Over the decades, international aid has been modelled to fit the themes of presidential legacies: 1950s – 'mutual security'; 1960s – the 'decade of development'; 1970s – 'basic human needs (food and nutrition, population planning, health, education, human resources development)'; 1980s – 'broad-based economic growth', emphasising employment and income opportunities through a revitalisation of agriculture and expansion of domestic markets; 1990s – 'sustainability and democracy', when funds for agricultural programmes were drastically reduced; and 2000s – 'rebuilding economies after civil strife', which stimulated more public–private sector partnerships in USAID programming. Decadal changes in programme priorities and geographic regions have impacted funding for agriculture, especially the livestock sector, in the countries where USAID is active.

US INTERNATIONAL DEVELOPMENT IN THE 1950S: 'MUTUAL SECURITY'

Before the United States Agency for International Development (USAID) was formally established, livestock development activities, specifically improving animal production and controlling diseases, were funded through the United States Economic Cooperation Administration (ECA). The ECA programme operated in Thailand from 1951 to 1956 and was designed to assist the Government of Thailand in the country's development.

The USA provided economic aid totalling US$100 million. Of this funding, US$100,000 was directed to a regional rinderpest eradication programme in Thailand, Lao People's Democratic Republic and Viet Nam. This is the earliest record of the US Government's support for efforts to control and eradicate rinderpest (1).

In June 1955, the ECA was replaced by the US Government's International Cooperation Administration (ICA), which continued to finance the programme with spending authority given to the US Operational Mission (USOM) to Thailand. The Thai Government provided substantial additional funds. The US Government's support consisted primarily of technical assistance to Thailand, the training of Thai nationals in the USA, and the provision of equipment and supplies for demonstration and training projects.

During this time (1951 to 1955), the Thai Government, the US Government and the United Nations Food and Agriculture Organization of the United Nations (FAO) cooperated with Lao People's Democratic Republic, Cambodia and Viet Nam in a regional rinderpest eradication programme and a rinderpest epidemic was brought under control (2).

In 1956, to assist Thailand to eradicate rinderpest as part of a regional campaign, search teams, vaccination teams and disease reporters were trained in the seven provinces where the disease was prevalent. With USOM and FAO assistance, rinderpest vaccine was produced in Thailand.

Apart from technical assistance, USOM also provided jeeps, refrigerators, and other supplies and equipment. By December 1958, no rinderpest was reported in Thailand, following which the Thai Government established a 50 km belt along the Cambodian border for universal vaccination of animals to prevent reinfection from cross-border livestock movements (3).

Although rinderpest control had been conducted in Cambodia since the 1920s, the disease continued to appear. In 1958, the US Government started a vaccination campaign in that country using a killed vaccine. The campaign was expanded throughout the Colombo Plan countries using a Nakamura lapinised vaccine produced by the Institut Pasteur in Cambodia. The last reported rinderpest outbreak in Cambodia was in 1964 (4).

US INTERNATIONAL DEVELOPMENT IN THE 1960S: 'SUPPORTING DEVELOPMENT'

The US Government's ICA was abolished in September 1961 and its functions transferred to the newly formed USAID, which was created by an executive order from President John F. Kennedy to implement development assistance programmes in areas authorised by Congress in the Foreign Assistance Act. The purpose was to unite several US Government foreign assistance organisations and programmes into a single agency to maximise expertise.

Support for the JP15 campaign against rinderpest

In 1960, the Organization of African Unity Interafrican Bureau of Animal Health (OAU-IBAH) and the Heads of African Veterinary Services met in Kano, Nigeria, and pledged to implement a multinational project called Joint Programme 15 (JP15) for Central and Western Africa. This proposal was approved in principle by the Commission for Technical Cooperation in Africa South of the Sahara in 1960, which then applied to international organisations and agencies for financial support. The United Nations Office for the Coordination of Humanitarian Affairs, the European Economic Community (EEC) and USAID were very supportive. Donors recognised that rinderpest was an issue in many humanitarian crises.

The campaign was implemented from 1962 to 1976 in 22 countries in West, Central and East Africa at an estimated cost of US$16 million, cofunded by national governments, the European Development Fund (EDF), USAID and the Governments of Canada, France, West Germany, Italy, Taiwan and the United Kingdom of Great Britain and Northern Ireland (5).

The first three phases of the campaign commenced in 1962 and were completed by 1969 and involved more than 79 million vaccinations in 16 West and Central African nations. USAID and the EEC funded the execution of JP15 in Nigeria, the Niger, Chad and Cameroon. Most cattle were vaccinated two or more times. There was a dramatic reduction in the number, size and distribution of rinderpest outbreaks in the region. For example, 8,290 outbreaks of rinderpest were reported in Nigeria, Cameroon, the Niger and Chad in the ten years preceding their participation in the campaign. When a technical evaluation of the JP15 West African phases was completed, it showed that rinderpest was effectively brought under control during the course of the campaign (6). There was good reason to believe that the disease could be eradicated from that part of the continent in time and with the proper follow-up measures.

The expenses of JP15 phases I, II and III in West Africa were met largely by the EDF (US$6.0 million) and the participating African countries (US$12 million). The USA provided US$2 million, and Canada, France, West Germany, Italy, Taiwan and the United Kingdom contributed a total of US$400,000 (5).

In Eastern Africa (phase IV), USAID financed the entire cost of the Scientific, Technical and Research Commission (STRC) International Coordinator's Unit and provided commodity and budgetary support to Somalia and the United Republic of Tanzania and a small amount of budgetary support to Ethiopia. Other donors supported Uganda and Sudan, while West Germany provided most of the support for Somalia. Kenya conducted its in-country programme without foreign assistance. USAID obligations and expenditures for phase IV were US$800,000. It was concluded that the project in the USAID-supported areas had been satisfactorily implemented. In June 1969, a pre-phase V pilot effort commenced in Ethiopia. A project agreement with the Organisation of African Unity/Scientific, Technical and Research Commission (OAU/STRC) and a memorandum of understanding with the Imperial Ethiopian Government were signed in June and October 1970, respectively, initiating phase V covering the nine southern provinces of Ethiopia. USAID agreed to provide up to US$1 million for equipment and other costs. The Ethiopian Government subsequently also agreed to provide, in cash or in kind, a total of US$1 million for the three-year phase V campaign (5).

During phases IV and V, USAID funds supported vaccinations, legislative and regulatory control measures and their enforcement, immunity testing, and strengthening of the Veterinary Services of the participating countries (7). The campaign's International Coordinator's Unit was highly effective in stimulating and maintaining interest, as well as coordinating the participating countries in the campaign, particularly along international borders. Without this effort, the effectiveness of the campaign would have been diminished considerably. The success of the campaign depended on good vaccination coverage by the vaccinating teams under the supervision of the veterinary departments. The veterinary departments performed well with regard to this activity, but, except for the United Republic of Tanzania, the number of serum samples submitted to assess vaccination coverage was very inadequate. The vaccine used throughout the African campaign was developed at the East African Veterinary Research Organization (EAVRO). Many JP15 veterinarians were trained at the Nairobi Veterinary College. USAID provided training funds to the Head of the Virus Section at EAVRO, for graduate training at Cornell University, New York, USA.

Although most attention was focused on rinderpest outbreaks in Africa in this decade, it should be noted that, in 1969, USAID responded to an outbreak of rinderpest in Viet Nam with an intensive three-week vaccination campaign that was credited with preventing a severe epidemic. Expansion of the mobile team concept received primary emphasis (8).

USAID IN THE 1970S: 'A SHIFT TO BASIC HUMAN NEEDS'

In the 1970s, USAID's focus on technical and capital assistance programmes began to shift more to development assistance that stressed a basic human needs approach. The primary programme foci were food and nutrition, population planning, human health, education and human resources development (9).

There were cutbacks in most USAID programmes in Africa including the rinderpest control project in Ethiopia, funding for which was cut significantly from US$1 million, as mentioned earlier, to US$300,000 (10).

The investment in the late 1960s and early 1970s in phases IV and V of JP15 paid off. There were two measures of success for phase IV:

- the decrease in rinderpest outbreaks in the endemic areas of Somalia and Sudan;
- the continuation and improvement of the level of immunity in the non-endemic areas of Kenya, the United Republic of Tanzania and Uganda.

This was particularly important in the Karamoja area of Uganda along the Sudan border and in Kenya along the Ethiopian and Somalia borders, where cattle movements could introduce the disease at any time. The threat of rinderpest to Kenya and Uganda diminished as immunity levels increased in Sudan, Somalia and Ethiopia. At that time, the risk of rinderpest to the United Republic of Tanzania appeared very slight. The general consensus of a review panel was that phase IV was progressing very well in spite of some problems during the first year, such as the usual delay in shipping equipment. EAVRO had done excellent jobs of producing vaccine and of immunity testing (11).

Conclusions at the end of JP15

The main purpose of JP15 was to control and hopefully eradicate rinderpest in Africa. As a result of JP15, rinderpest was brought under control in those countries involved, except possibly Sudan. A secondary purpose was to strengthen the veterinary departments of participating countries. The impact of JP15 on the morale of the various veterinary departments was excellent. It developed a friendly, competitive desire to improve Veterinary Services.

From the inception of JP15 to its completion, activities were conducted in 22 African countries and involved nine donors. Over 81 million vaccinations were carried out, and it was estimated that 83% of the approximately 33 million cattle were vaccinated at least once in the countries covered. To ensure that at least 80% of the cattle in an area were covered, the programme included three annual vaccination rounds to immunise cattle that were missed during any individual round and calves that were born during the three-year cycle.

Estimates by Lepissier show that the JP15 campaign cost an estimated US$16 million with US$7 million (44%) contributed by national governments, US$7 million (40%) by the EDF and US$3 million (16%) by USAID and the Governments of the United Kingdom, West Germany and Canada (12).

USAID provided support to the campaign in three ways:

– a project agreement with the OAU/STRC to finance equipment and other costs;
– a grant to finance the salary and expenses of the Deputy International Coordinator and the operating costs of his office;
– a grant to the Organization of African Unity/Interafrican Bureau for Animal Resources (OAU-IBAR) to finance follow-up activities in African countries where the campaign was completed.

In addition, USAID also provided a regional livestock adviser, who served in East Africa from 1968 until February 1973 (13).

Rinderpest reappearance in West Africa following JP15

In the early 1970s the animal disease situation in Mali was a source of considerable concern. Rinderpest outbreaks had occurred in Mopti, Gao, Sikasso and Bamako in 1972 and 1973 (14). The immunity level of the national herd was estimated to be at a dangerously low level – below 50%. The Malian Veterinary Service was well staffed with experienced and qualified personnel, and it maintained stations throughout the area north and west of Bamako, through which two million cattle passed annually. However, it was critically short of vehicles and all necessary equipment. In addition, its operating budget was inadequate to confront the animal disease and calf mortality problem in the country. Since the end of the JP15 campaign in 1969, the Malian Veterinary Service received almost no new equipment and its operating budget was sharply curtailed. At a time when the cattle industry was contributing large and growing economic and financial benefits, the industry faced a potentially serious disease situation.

At the beginning of the 1970s, Mali required about 3.3 million doses of rinderpest vaccine annually, but the Central Veterinary Laboratory (CVL) had a stock of only one million doses. Through USAID support, as a component of a livestock production project, by 1973 about three million doses were being produced annually. USAID's investment in the CVL in Mali had a significant direct impact on the livestock sector in Africa, as will be described in the next section.

USAID IN THE 1980S: 'A TURN TO FREE MARKETS'

In the 1980s, USAID's foreign assistance sought to stabilise currencies and financial systems and to promote market-based principles in the restructuring of developing countries' policies and institutions. During this decade, USAID reaffirmed its commitment to broad-based economic growth, emphasising employment and income opportunities through a revitalisation of agriculture and expansion of domestic markets. USAID's development activities shifted from individual projects to larger programmes, increasingly channelled through private voluntary organisations.

The Niger Integrated Livestock Production Project (NILP) was designed and approved in 1983. The NILP was conceived as a model for the development of the region's herders that strongly emphasised organising local associations as the vehicle for introducing technology, financial services and education to people for whom extensive livestock production was their principal source of income. The stated purpose of the project was (i) to prepare a comprehensive and feasible range management and livestock extension plan to optimise annual production, and (ii) to develop the Government of Niger's institutional capacity to carry out the recommendations. A contract was signed with Tufts University in the USA in early 1984 to provide technical assistance, training, equipment and other services (15).

By late 1984, Niger's pastoral zone was being affected by one of the worst droughts of the century, thus the project was redirected to provide emergency relief and to undertake a series of pilot actions that could provide a future basis for a pastoral-zone drought strategy.

The project partly financed the rinderpest vaccination campaign, which contributed to the apparent elimination of rinderpest in the Niger after several years of disease recurrences. Pastoral centres were designated and four additional veterinary appointments were made. A project review led to strong recommendations to (i) improve the effectiveness of the rinderpest vaccine and (ii) anticipate animal health problems that might develop over the following dry season, based on forage availability and expected animal concentrations and movements. Such data would allow the livestock services to stockpile animal vaccines (including rinderpest vaccine), therapeutic and preventive drugs and supplementary animal feed in the regions of expected need.

It was noted that the recurrent costs incurred by providing rinderpest vaccinations was one of the major financial problems of operating the Government of Niger's Livestock Service. To address this situation, this project supported the local costs of field operations on a decreasing-rate basis. The project also financed research by Tufts University in conjunction with the United States Department of Agriculture Plum Island Animal Diseases Center to improve the thermostability of the existing Plowright vaccine such that it could survive for 20 weeks at body temperature (37°C), thus allowing the vaccine to be transported and stored at remote locations where the disease persisted. If this effort was successful, eliminating the need for the cold chain required to deliver rinderpest vaccine to the field would reduce the recurrent costs of the annual vaccination campaigns (16).

The resulting vaccine, a modification of the Plowright vaccine, was being commercially produced on a large scale by 1992 and was tested in the Niger with USAID funding. No longer having to maintain the cold chain saved the Niger more than US$3 million annually.

Production of this vaccine, called Thermovax, was successfully transferred to a number of vaccine manufacturers and proved key to rinderpest control in remote pastoral areas, where it was used by community-based animal health workers (CAHWs) (17), as described elsewhere in this book.

As mentioned previously, in the early 1970s, the Central Veterinary Laboratory in Mali was supported by USAID to produce rinderpest vaccine. Subsequently, it was one of three sites selected in Africa to produce thermostable rinderpest vaccine. Collaborating with the Pan-African Rinderpest Campaign (PARC), Mali's livestock service immunised 77% of the country's total cattle population by 1988, and no cases of rinderpest have been reported since 1986.

BIOTECHNOLOGY AT USAID

USAID's support for rinderpest eradication continued into the late 1980s when interest in biotechnology grew stronger. In June 1985, at the request of the USAID Bureau for Science and Technology/Office of Agriculture (S&T/AGR), the National Science Foundation (NSF) convened a formal panel to discuss vaccine development for tropical animal diseases. The panel supported USAID's interest in using biotechnology to address the problems of animal disease, and it recommended that 'USAID should support research directed towards the development of vaccines with first priority given to exploring the potential of vaccinia virus as a vector for vaccines against many important livestock diseases.' (18).

In particular, the panel listed several target diseases based on the following criteria:

1) diseases causing the greatest losses in a large number of developing countries and for which cheap and effective control strategies were not available;
2) diseases that other agencies were not likely to support research on at the level required for success;
3) diseases for which early success could be reasonably predicted.

While arguably the Plowright vaccine negated the second qualifier for criterion 1, rinderpest was included on the list.

Following NSF recommendations, USAID subsequently awarded funding to scientists at two institutions, Tufts University and Washington State University, for separate research projects that sought to improve the Plowright vaccine (19).

The specific research objectives were to:

1) clone the rinderpest genes responsible for the production of immunogenic proteins (haemagglutinin [HA] and fusion [F]);
2) construct an infectious vaccinia virus recombinant that optimally expressed the two immunogenic genes of rinderpest virus;
3) measure immunity and protection against viral challenge in cattle vaccinated with this recombinant vaccinia vaccine up to 12 months after vaccination;
4) develop more effective promoters and improved techniques for enhanced expression of immunogenic genes in vaccinia virus recombinant vectors.

The genetic codes for the HA and F proteins were subsequently inserted into vaccinia virus, the same 'viral vector' used to formulate the smallpox vaccine.

Although this vaccine was never used in the eradication of rinderpest, it was an early and significant proof of principle for the development of recombinant livestock vaccines. USAID funding enabled scientists to demonstrate that the new vaccine protected cattle against rinderpest and was safe even at high doses. Moreover, it did not require sterile syringes and needles because the vaccine could easily be administered through scarification of the skin.

The Improved Animal Vaccines Through Biotechnology project operated from 1986 to 1989, and USAID's total project funding amounted to US$6 million, with research being conducted both in the USA and in cattle held in containment in Kenya.

This project was consistent with the objectives of USAID's Food and Agriculture Policy and Strategy, to enable developing countries to become food secure. Decreasing the incidences of cattle losses due to rinderpest and increasing the efficiencies of animal production systems was seen as a clear way to achieve the objectives.

USAID IN THE 1990S: SUSTAINABILITY AND DEMOCRACY

In the 1990s, sustainable development, by supporting countries to improve citizens' quality of life, became USAID's top priority. During this decade, USAID tailored development assistance programmes to a country's economic condition. Developing countries received an integrated package of assistance, transitional countries received help in times of crisis, and countries with limited USAID presence received support through non-governmental organisations (NGOs). USAID programmes helped establish functioning democracies with open, market-oriented economic systems and responsive social safety nets.

In the mid-1990s, however, USAID's budget was drastically reduced as a result of an economic recession, US Government deficits and the growing isolationist policy of some opposition groups. During this time Congress established the 'Bumpers Amendment', which demanded termination of research and technical assistance to foreign nations that competed with the USA. This amendment was instigated and supported by large US agricultural companies such as the American Soybean Association. The lack of a solid development agenda within USAID also aggravated these fiscal cuts. The appointment of Brian Atwood as the administrator in 1993 resulted in many changes. Agency goals were reduced from a total of 33 to just 4. Building democracy, stimulating environmental protection, encouraging sustainable economic development and advancing population control were at the core of USAID's policy. The restructuring affected some geographic regions more than others. For example, the Southern African region received less support and, as a result of the Camp David Accords, most of the USAID money remained allocated to the Middle East.

By 1995, USAID was the world's second largest governmental donor. That said, the annual budget of almost US$10 billion amounted to only 0.15% of the US gross national product. Diverse interest groups, such as domestic producer organisations, started to influence USAID policy on foreign development assistance, and a significant reduction in funding for agriculture programmes also had negative impacts on livestock production and health projects (20).

Within this framework, USAID's famine mitigation activity was established in August 1991, with the objective of mitigating famine in regions or in populations vulnerable to food insecurity. A grant was made to Tufts University for technical assistance to the OAU-IBAR to support community-based livestock health delivery. Tufts and the OAU-IBAR continued to be successful in using famine mitigation activity and other Office of Foreign Disaster Assistance (OFDA) funds and substantial support from other donors, such as UNICEF, to fund their activities. A livestock health strategy within the Greater Horn of Africa Initiative (GHAI) was developed from discussions held with USAID, World Bank, International Livestock Research Institute (ILRI) and FAO, which aimed to integrate the community-based approach into larger strategies and link livestock research initiatives to the needs of pastoralists.

USAID's funding to Tufts University School of Veterinary Medicine enabled the OAU-IBAR to continue its efforts to eradicate rinderpest in the Greater Horn of Africa. The rinderpest campaign subsequently evolved from vaccine production and delivery to a community-based animal health care programme. The Thermostable Rinderpest Vaccine Technology Transfer Project addressed the elements of food security, conflict mitigation and private sector community development for pastoral areas in the Greater Horn of Africa. This was a significant step towards eradication of the disease in the remaining localities where rinderpest was still endemic. The Thermostable Rinderpest Vaccine Technology Transfer Project concluded its activities with an extension of funding from USAID that permitted project activities to continue until early 1996 before being subsumed into the Participatory Community-based Vaccination Project (PARC-VAC) (21).

USAID's involvement with improvement of the competitive ELISA to detect antibody to rinderpest virus or vaccine

In the 1990s, the accepted test for the detection of serum antibody to rinderpest was the competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3). Because the protocol required collected blood to be centrifuged and refrigerated (or frozen) until laboratory analysis, the test was cold-chain dependent, thus precluding its use in the more remote areas of the Greater Horn of Africa where rinderpest was endemic. A modification of the ELISA protocol to accept filter paper on which drops of whole blood had been dried permitted greater participation of CAHWs and vaccinators in the monitoring of vaccination coverage and sero-surveillance. This greatly facilitated rinderpest identification and permitted a low-cost, effective way of monitoring vaccination coverage in the more remote and insecure areas of the region.

The research that led to this advance was a collaborative effort that linked the Kenya Agricultural Research Institute (KARI) with the PARC-VAC project and the World Rinderpest Reference Laboratory in Pirbright, United Kingdom. This was an important step towards one of the important goals of PARC-VAC, namely to involve national agricultural research services and international research institutions in developing appropriate and practical solutions to pressing constraints and problems facing the pastoral zone of the Greater Horn of Africa. Partial funding for this effort was also obtained from the US National Institutes of Health (NIH), KARI and the World Rinderpest Reference Laboratory at the Pirbright Institute.

Following successful field trials, the test was introduced into the CAHW vaccination programmes in Sudan, Ethiopia, Kenya, Uganda and Chad in late 1997. This permitted extensive serosurveillance, which was of considerable assistance in the final phases of rinderpest eradication. In remote regions, or conflict zones, where more conventional government vaccination campaigns were unsuccessful or unfeasible, engaging CAHWs for rinderpest eradication efforts demonstrated the value of this service delivery model. In the early 1990s, African governments and regional organisations began to accept CAHWs, and this significantly improved the disease situation in politically challenged areas such as South Sudan and Ethiopia (22). Furthermore, there was growing evidence that the CAHW approach acted as an effective point of contact with remote, pastoral communities that led to other potential benefits such as human health service delivery, conflict mitigation and cross-border livestock disease control.

It should be noted that the community-based animal health delivery activity grew out of the successful project carried out with technical assistance from Tufts University, supported by USAID, USDA and other donors, to develop a thermostable rinderpest vaccine in the early 1990s. This vaccine development enabled the effective vaccination of millions of livestock in marginal and frequently insecure pastoral areas of Somaliland, Chad, Ethiopia and southern Sudan (23).

USAID IN THE 2000S: CIVIL STRIFE AND REBUILDING

The decade beginning in 2000 brought more changes for USAID and foreign assistance as US Government officials once again called for reform of how USAID conducted its business. This began an aggressive campaign to reach out to new partner organisations, including the private sector and foundations, to extend the reach of foreign assistance. However, this did not diminish USAID's support for rinderpest eradication, especially in areas of crises such as the Sudan.

For much of the 1990s, the assistance from the US Government to Sudan focused on emergency relief in response to conflict, droughts and flooding. The US Government provided more than US$1 billion in assistance to Sudan. As the largest participant in the international community's response to the Sudan tragedy, the government provided food, health care and medicines, water and sanitation facilities, seeds and tools to re-establish agricultural activities, veterinary services and drugs, and transport for emergencies. The livestock restocking was coupled with vaccination and treatment of cattle against rinderpest and other diseases, thus enhancing food security. Key results included:

- a significant reduction in rinderpest disease (a decrease from 14 rinderpest outbreaks in 1994 to one outbreak in 1998 (24);
- provision of other animal health services through a community-based approach;
- an increase in the number of livestock herds.

Vétérinaire Sans Frontières Belgium was an active partner in training community-based animal health workers in diagnosis and treatment of various types of endemic animal diseases and rinderpest. Other NGOs such as Catholic Relief Services, Norwegian People's Aid, Save the Children Fund and World Vision were also engaged in the restocking of livestock and training of farmers and community-based extension workers in animal husbandry.

CONCLUSION

For 60 years USAID contributed to international efforts to eradicate rinderpest, which for centuries had caused socio-economic distress in Asia, Europe and Africa. USAID funded country-specific projects implemented by multinational and US partners, as well as research by US universities on vaccines and diagnostics, and joined in supporting multinational eradication campaigns. In spite of administrative and policy changes in USAID's direction over the decades, and the inevitable budget reductions for agricultural sector programmes that invariably had impacts on livestock projects, USAID headquarters and field offices continued the effort to control and later eradicate rinderpest. The positive result of this persistent support for livestock health validated the economic, socio-cultural, environmental and nutritional values of livestock in developing countries and USAID's contributions to livestock development.

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CHAPTER 5.10

ROLE OF THE WORLD BANK IN RINDERPEST ERADICATION

C. DE HAAN

Contrescarp 174, 7202AE Zutphen, Netherlands (Former Senior Livestock Development Adviser, World Bank; now independent consultant)

SUMMARY **In particular, over the period 1981–1987, in the early phases of the rinderpest outbreak, the World Bank funded approximately 40 million vaccinations through financial support from on-going livestock development projects in eight sub-Saharan countries. The World Bank's contribution to the budgets of these projects that funded the vaccinations amounted to US$96 million; no data are available on the share of this amount allocated specifically to rinderpest vaccination campaigns. In parallel, a series of policy changes (partial or complete cost recovery, subcontracting private veterinarians under a sanitary mandate, using paraveterinarians, working through herder organisations and village groups) aimed at ensuring the long-term sustainability of the services were tested. These early vaccinations and the institutional innovations made provided a solid basis for the Pan-African Rinderpest Campaign (PARC; Chapter 4.2) when it was established in 1986, as well as saving the livelihood of millions of pastoralists and agro-pastoralists. The World Bank continued to support rinderpest vaccination in a small number of countries until 1997 under the umbrella of PARC.**

KEYWORDS **Economic evaluations – Lessons learnt in animal health provision – Policy changes – Rinderpest control – World Bank.**

INTRODUCTION

The World Bank was mainly involved in the campaign against rinderpest during the first phase of the resurgence of the disease in sub-Saharan Africa, i.e. from about 1981 until 1987, but extending until 1997. It comprised a dual approach of:

a) financial support from on-going World Bank-funded projects for vaccination campaigns;

b) participation in policy discussions on the strengthening of the animal health care delivery systems.

When the Pan-African Rinderpest Campaign (PARC) became operational, the World Bank continued to support vaccination campaigns in a small number of countries within PARC's framework but phased itself out of the campaign in the early nineties.

WORLD BANK-FUNDED RINDERPEST CONTROL OPERATIONS

At the time of re-emerging outbreaks in the early 1980s, World Bank projects, often in co-financing arrangements with other donors, covered, in full or in part, most major livestock-raising countries of West and Central Africa, except Nigeria. While some projects had included vaccination campaigns in their original plans, for others an emergency reallocation of their budgets was required. The following narrative summarises, on a per country basis and mainly based on information from the World Bank project completion reports (WBPCRs), the specific aspects of the operations.

In **Central African Republic** (Chapter 4.5.4) the rinderpest control operation, which was funded by the World Bank/International Fund for Agricultural Development (IFAD)/African Development Fund (ADF), funded the First Livestock Project (FLP), the first and probably the most extensive support for rinderpest control from any of the World Bank-funded livestock projects in West and Central Africa. The project was implemented from 1980 until 1986 with a total funding of US$11.5 million, of which the World Bank funded US$2.5 million. Upon news of the rinderpest outbreak in the region, the World Bank officer responsible for this project immediately reallocated project funds from FLP to control the disease. World Bank staff travelled from Bangui to Cameroon to purchase the required cool boxes and vaccines and helped the Veterinary Service mount the vaccination campaign. This became a joint responsibility between the Association National des Éleveurs Centrafricain (ANEC, which later became a Federation [FNEC]) and the Veterinary Service. The participation of ANEC turned out to be crucial in gaining rapid access to the mobile herds of transhumant and nomadic herders. The total vaccination coverage was about two million head, nearly 100%, in the first year (1983), declining to about 80% and 60% in the following years. The WBPCR (1) estimates that, because of the rapid intervention, only an estimated 6,500 head of cattle (0.3% of the livestock population) succumbed to the disease, compared with an estimated 7% in both Chad and Nigeria. The total FLP contribution to the vaccination campaigns over the three years (1982–1985) amounted to about US$1.2 million, supplemented by a herder contribution of 10 West African francs (US$0.03) per head vaccinated. The WBPCR also estimated that because of the rinderpest intervention the economic rate of return more than doubled from an already high 35%. The main lessons from this project are thus the effectiveness of a rapid intervention and of the full participation of the target population. The follow-up project (National Livestock Development Project, co-financed with IFAD, Fonds d'aide et de coopérations [FAC] and the European Development Fund [EDF; see also Chapter 5.8]) continued along the same line with annual vaccination and serosurveillance campaigns under the umbrella of PARC (2). The serosurveillance was instrumental in assessing the effectiveness of the campaign, in general and in particular where sanitary mandates were used (see, for example, Chad). During the project's implementation no rinderpest outbreaks were registered.

In **Cameroon** (Chapter 4.5.3), the World Bank and Kreditanstalt Für Wiederaufbau funded the Second Livestock Development Project (3). The project was implemented between May 1981 and December 1988, at a total cost of US$35 million, of which US$16 million consisted of World Bank funding. The veterinary component, at a cost of US$2.8 million, focused on the Adamoua plateau, which registered 13 of the total of 83 rinderpest outbreaks declared by Cameroon in 1983. However, the control activities were affected by delays both in reporting the outbreaks of rinderpest and in procuring equipment. The campaign therefore started with considerable delays, and no data are available on the vaccination coverage or costs and benefits of the international support.

In **Chad** (Chapter 4.5.5), the World Bank/ADF/FAC/Dutch Directorate-General for International Cooperation-funded National Livestock Project (NLP, 1989–1997, at a total cost of US$37.2 million, of which US$14.6 million came from the World Bank) (4), was late (1994) in supporting the vaccination campaign. It focused its support on the eastern and south-eastern part of the country, which hitherto had not been covered because of the security situation, despite heavy losses from the disease. This was due to the different phasing used, compared with other West and Central African projects, because of the security situation in Chad at the time of the regional outbreaks. It incorporated, in coordination with PARC, concepts from the policy discussions with private veterinarians, working under a sanitary mandate, carrying out compulsory vaccinations of rinderpest and contagious bovine pleuropneumonia (CBPP). The vaccinations were partly funded by the NLP and partly by the herders (who contributed 10% of the costs in the first year and 20% in following years). The NLP also financed the rinderpest serosurveillance. The contributions of the herders were deposited in the livestock development fund, which, at project completion, was merged into the government/European Community (EC) (PARC) livestock development fund. A total of 27 private veterinarians (including several on leave without pay from the public sector) formed vaccination teams. The payment to the private operators was made depending on the number of animals vaccinated as confirmed by serological tests. The performance of the private operators was reported as being superior to that of the government agents over the two-year period 1994–1995 in all fields (see Box 1).

BOX 1
COMPARISON BETWEEN PRIVATE- AND PUBLIC SECTOR-IMPLEMENTED VACCINATION CAMPAIGNS IN EASTERN CHAD

- Implementation of the campaign: 80% of cattle population in contracted area covered by private operators compared with 30% by public agents.
- Heads vaccinated per team, mostly consisting of a veterinarian and a small number of vaccinators: 100,000 head per team/year by private operators compared with 30,000 head by public agents.
- Duration of the campaigns: four months by private operators compared with six months by public agents.
- Serological results: over 70% of population positive for the private operators compared with 50% for public agents.
- Cost: 34% lower by the private operators compared with that of the public agents.

After these results from subcontracting private veterinarians for public sector tasks, the 'mandate sanitaire', or sanitary mandate for private veterinarians, was adopted in Chad in the follow-up vaccination campaigns started in 1996 under PARC funding.

In the **Niger** (Chapter 4.5.15), the World Bank-funded livestock project (1979–1989, at a cost of US$15 million, including US$12 million from the World Bank), covering the east and central region of the country (Zinder, Diffa and Maradi districts) supported rinderpest control over the period 1979–1989, through the supply of vaccines, equipment and funding for operating costs. A total of 9.8 million vaccinations in cattle and, on request of the Government of the Niger, 2.8 million in small ruminants were carried out. Wherever feasible, the campaigns were organised through the Groupements Mutualiste Pastoraux organisation. Herder participation in the vaccination project was particularly high in 1984 (2 million vaccinations), at the peak of the drought and with the disease threatening to be introduced from neighbouring countries. No outbreaks were reported in the project area during the project implementation period. Similar to the economic assessment of the project in the Central African Republic and because of the inclusion of the rinderpest vaccination, the economic rate of return jumped from an unsatisfactory 3% to a highly satisfactory 54% (5).

In **Mali** (Chapter 4.5.13), the World Bank-funded livestock project (1975–1984), covering a region in Central Mali, consisting of most of the inner delta of the Niger river, integrated vaccination into the project from 1979, with more than 3 million vaccinations per year (approximately 75% of the total cattle population) (6). The follow-up project, the Mopti Area Development Project (1985–1992) (7), continued the support for this vaccination programme, but on average reached only about 40% of the population. According to the WBPCR, this was partly because of the monopoly of the implementing agency, which did not allow any private sector involvement, as was successfully implemented elsewhere in the region.

In **Burkina Faso** (Chapter 4.5.2), the World Bank Livestock Development Project (1975–1984, at a total cost of US$19 million, of which US$13.43 million was provided by the World Bank) covered an organisme régional de développement (or regional development agency) in the south-western part of the country. It included a vaccination component for rinderpest and CBPP, with cost recovery being directed into a livestock development fund. Vaccination coverage was about 50% during the earlier years of the project, peaked in 1981 to about 80% when the threat of rinderpest emerged, but declined again in the following years, in part because of the success of the earlier years. The WBPCR notes that 'long-term programs to control endemic diseases may face lack of support from stock owners once control is achieved and stock owners forget the severity of the disease. If farmers have to pay for the vaccines, they are less likely to give vaccination high priority in the absence of a clear disease threat.' The government changed therefore to a free policy; however, the resources were inadequate, and the coverage fell even more. No outbreaks were recorded in the project area. As the disease emerged in other parts of the country, approximately US$350,000 of the project fund was reallocated for the emergency vaccination of about 700,000 cattle in four other regions (8).

In **Senegal** (Chapter 4.5.17), the World Bank/Caisse centrale de coopération économique/FAC/Saudi Development Fund financed the Eastern Senegal Rural Development Project, which supported vaccination campaigns in the northern region. The total cost of the project was US$14 million, of which US$1 million was specifically for livestock.

The campaign started in 1985 with the training of 100 veterinary assistants, who worked under supervision of the Veterinary Services but within the framework of the farmers' village associations. No data are available on the vaccine coverage (9).

In **Ethiopia** (Chapter 4.5.9), the World Bank-funded Rangeland Development Project (1976–1985, with a total project cost of US$35.8 million, of which US$26.1 million was provided by the World Bank) covered rangeland areas in the south, east and north-east of the country. While it focused on improving rangeland and marketing, it also included a veterinary component that became especially important towards the end of the project when the threat of rinderpest emerged. This was evident in the vaccination figures, as the number of vaccinations in the eastern and southern regions increased from about 400,000 in 1979 to 1.4 million in 1984 (10).

POLICY DIALOGUE

The need for a policy dialogue on the organisation of animal health care delivery systems emerged after the resurgence of rinderpest about ten years after the Joint Programme 15 campaign (Chapter 4.1) had ended. Several analytical papers (11) highlighted the deteriorating quality of animal health care offered by public Veterinary Services in sub-Saharan Africa (see Box 2).

Workshops were organised to discuss the topic with veterinary authorities of the sub-Saharan region: in Bujumbura, Burundi (1984), for the francophone countries and in Blantyre, Malawi (1985), for the anglophone countries, with a subsequent review of progress in Bangui, Central African Republic (1989). These workshops were organised by the European Economic Community (EEC)-sponsored Technical Centre for Agricultural and Rural Cooperation, in cooperation with German Technical Aid (GTZ) and the Institut d'elevage et de médecine vétérinaire pays tropicaux/Centre de coopération internationale en recherche agronomique pour le développment (IEMVT/CIRAD), and attended by all major donors involved in livestock development in the region, such as the United States Agency for International Development, the UK Department for International Cooperation and the EEC. Led by GTZ, the initial focus was on basic animal health care systems, but the discussion widened, recognising the need for more effective delivery of veterinary services. A good overview of these workshops is provided by Leidl *et al*. (12). The World Bank advanced the following proposals:

- The distribution of responsibilities between the public and private sector should be improved, with the public sector mainly focusing on so-called 'public goods' (mainly vaccination for transboundary diseases) and sanitary enforcement of public health standards, whereas the private sector would be better equipped to handle tasks related to 'private goods', such as curative veterinary treatments and drug supply.
- International support should cover both the private and the public service providers. This included, for the public sector, support in adapting the legislation, and funding for equipment and other veterinary infrastructure. For the private sector it included funding (as a gift) of the initial instalment needs (equipment, pharmaceutical and operating costs) and the veterinary mandates, obtained from the Government Veterinary Service.
- The use of privately operating paraveterinarians should be increased, especially in pastoral areas with low densities of livestock and people, where delivery by government officials is costly.
- Cost recovery for services and supplies should be increased. They recommended that (i) full cost recovery for private tasks should be undertaken by the public sector to avoid unfair competition with emerging private veterinary practices, and (ii) operating costs for the public good tasks, such as vaccination for rinderpest, should be recovered. Income from this could be deposited in a livestock development fund (although it was pointed out that such a dedicated flow of funds was not recommended by macroeconomic institutions such as the International Monetary Fund). In later publications (13) the justification for beneficiary contribution

BOX 2
MAIN CONSTRAINTS AFFECTING SUB-SAHARAN AFRICAN VETERINARY SERVICES IN THE EARLY 1980S

- Inefficient staff/operating cost ratios, forcing staff to sit idle in their offices without the means to operate.
- A lack of a clear vision on priorities and responsibilities, causing university-schooled public servants to engage in tasks that belonged, by nature, in the private sector, or could better be carried out by less skilled (and hence less expensive) staff.
- Government monopolies that frequently stifled the supply of drugs.
- Poorly adapted sanitary regulations and a lack of instruments to enforce them.
- A government budget often not in line with the importance of the livestock sector in the economy.

to predominantly public goods, such as rinderpest vaccination, was further challenged.
– Government monopolies on the import and distribution of drugs should be lifted.

SUMMARY AND LESSONS LEARNT

Rapid access to funds through World Bank-funded and co-funded projects facilitated the vaccination for rinderpest of more than 15 million head of cattle in the first year of the 1981–1984 period, during which the disease re-emerged in sub-Saharan Africa. While exact figures on the total number of animals vaccinated were not recorded in the available documentation, one can safely assume that the total number of vaccinations carried out in the first half of the 1980s reached 40 million. This undoubtedly reduced the disease challenge and saved the livelihoods of millions of livestock-dependent families. The 1.6 million cattle that were sick, and the 400,000 that died, in the first half of 1983 in Nigeria might be an indication of the level of losses prevented (14).

The planned overall budgets of the livestock development projects from which the vaccination campaigns were funded amounted to US$182 million, of which US$96.7 million was from the World Bank. Information on the share of these funds used for the vaccination campaigns is not available.

In addition, a number of institutional innovations (partial or complete cost recovery, subcontracting private veterinarians under a sanitary mandate, using paraveterinarians, working through herder organisations and village groups) were introduced and tested. It is thought that these early actions provided a solid basis for PARC when it was established in 1986. However, the approach of the World Bank at that time, which was to fund projects within countries rather than by region, did not allow eradication of a transboundary disease, such as rinderpest. Nowadays regional projects are part of World Bank lending, for example in West and East Africa pastoralism. Global and regional standard-setting institutions, such as the World Organisation for Animal Health (OIE), the Food and Agriculture Organization of the United Nations (FAO) and the Organization of African Unity Inter-african Bureau of Animal Resources, and regional funding agencies such as the European Union are better equipped to address the eradication of a transboundary disease.

The important lessons that emerge are:

– Policy and investment must be linked. An approach based only on investments is unlikely to result in eradication.
– Herder organisations with strong social cohesion enable good access and provide governance.
– Serosurveillance provides validation of the effectiveness of vaccination; for the herders this protects them against malpractice, and for governments this allows them to assess the efficiency of the private sector in executing the eradication programme.
– Flexibility and pragmatism in cost recovery should be adapted to local conditions.
– Technical and global public organisations (OIE, FAO, etc.) define, in dialogue with the countries and funding sources, the eradication strategy for the countries involved. Following this, funding organisations (European Union, World Bank, etc.), through national and regional investment, provide funding for implementation.
– Long-term engagement is critical for successful eradication.

ACKNOWLEDGEMENTS

The valuable inputs and comments of Francois le Gall, now retired but then Lead Livestock Specialist at the World Bank, are gratefully acknowledged.

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CHAPTER 5.11

ROLE OF THE ODA, DFID AND UK AID IN RINDERPEST ERADICATION

G. FREELAND [(1)] & T. LEYLAND [(2)]

(1) Churchside Cottage, 77 Main Street, Palterton, Chesterfield, Derbyshire S44 6UR, United Kingdom
(2) Lifestock Inc. Ltd, 315 Old School Road, RD2, Nelson 7072, New Zealand

SUMMARY **The UK Government's aid programme has provided funding for rinderpest research, control and eradication for over 50 years. Key research outputs included the Plowright rinderpest vaccine, sequence analysis of rinderpest virus lineages, a new recombinant vaccine for rinderpest that is capable of differentiating infected from vaccinated animals, plus an accompanying penside test. The UK Government through its aid instruments was an influential partner in the planning and implementation of all the major rinderpest control and eradication efforts since the 1980s, providing technical and financial assistance directly and through the European Development Funds. The United Kingdom of Great Britain and Northern Ireland continues to fund research on vaccines and penside tests as part of the global effort to eradicate peste des petits ruminants (PPR).**

KEYWORDS **Community-based Animal Health and Participatory Epidemiology – CAPE – Department for International Development – DFID – Edwards – Overseas Development Administration – ODA – Penside – Pirbright – Plowright – Peste des petits ruminants – PPR – Rinderpest – UK AID – Vaccine.**

The UK Government through its Overseas Development Administration (ODA) and other relevant ministries and offices was much involved in rinderpest control, diagnosis and research, both in eradicating the disease from the United Kingdom of Great Britain and Northern Ireland and in combating it in Africa and Asia.

Much of Britain's most productive research was done in its overseas laboratories. For example, in the 1920s, J.T. Edwards, working in the National Veterinary Laboratory of colonial India, developed the goat-adapted rinderpest vaccine, and confirmed that it conferred lifelong immunity to vaccinated cattle (1). Walter Plowright worked at the East African Veterinary Research Organisation in Kenya in the 1950s to develop the tissue culture rinderpest vaccine using, at the time, new *in vitro* techniques for growing viruses (2), for which he received many accolades, including the World Food Prize in 1999 (3).

In October 1948, the Food and Agriculture Organization of the United Nations (FAO) and the British Colonial Office organised a pan-African meeting in Nairobi, Kenya, specifically to discuss methods of controlling rinderpest. This African Rinderpest Conference recommended the creation, by FAO, of an organisation tasked with the coordination of rinderpest control in Africa. The United Kingdom was therefore an active player in the establishment of the Interafrican Bureau of Epizootic Diseases, which became the Organization of African Unity's Interafrican Bureau of Animal Resources (OAU-IBAR;

Chapter 5.5) (latterly known as African Union IBAR), under whose aegis the first pan-African rinderpest control effort, the Joint Programme 15 campaign (JP15), (described in Chapter 4.1) was inaugurated.

JP15 involved the collaborative efforts of 22 countries in an attempt to end rinderpest disease outbreaks in the African continent. It so nearly succeeded that by 1976 Sudan (with its massive and very mobile nomadic and transhumant herds) was the only country left declaring clinical rinderpest.

Sadly, however, after the apparent disappearance of the disease in so many countries, the failure of some countries to maintain the annual vaccination of national cattle herds led to a gradual increase in the non-immunised proportion of herds where hidden foci of the disease apparently remained, and the resurgence of disease became an inevitability. A significant outbreak was recorded in Nigeria in 1980. Initially, this was contained, but subsequent outbreaks soon overran the country and massive losses were sustained by the national herds of Nigeria (see Chapter 2.4) and neighbouring countries. This led the OAU-IBAR to begin the formulation of a new multinational control campaign (the Pan-African Rinderpest Campaign – PARC, see Chapter 4.2), for which it sought both financial and technical assistance from major bilateral and multilateral organisations.

The Animal Virus Research Institute, Pirbright (now the Pirbright Institute), had long been a major player in rinderpest research and diagnosis, and the first ODA contribution to IBAR's new rinderpest campaign was to fund Pirbright, through the efforts of Leslie Rowe, to provide and maintain a bank of 4 million doses of tissue culture rinderpest vaccine that could be called upon by any country that needed an urgent supply to combat and contain a rinderpest emergency.

The European Economic Community (EEC), now known as the European Union, was one of the donors from which assistance was sought by the OAU-IBAR for its new pan-African campaign (see Chapter 5.8). Despite initial scepticism about the huge cost and doubts about the likelihood of its success, the EEC was sufficiently conscious of the enormous damage the epidemic was causing that, in 1983, it called a meeting of livestock technical advisers from each of its 12 Member States to discuss and sound out support for EEC involvement. Also at the meeting were representatives of the OAU-IBAR, FAO, the World Bank, the World Organisation for Animal Health (OIE) and other organisations.

Guy Freeland attended this meeting on behalf of the United Kingdom, and the ODA. Opinion among the Member States was divided, with some opposed for environmental reasons as well as fearing a very costly repeat of the failed JP15 Programme. Strong protagonists for the scheme included the United Kingdom, France and the Netherlands. This enthusiasm, coupled with positive views expressed by FAO and the World Bank, was sufficient to stimulate the EEC to delve deeper into the issues involved.

Further 'EEC Livestock Technical Committee' meetings were held, with Jan Mulder as their co-ordinator, in Brussels and Nairobi. Gradually, the EEC became convinced of the need to strongly support the initiative, but quite how still remained a question.

France and the United Kingdom both funded technical advisers to IBAR in Nairobi, to help with promotion and formulation of the control programme – Brendan Halpin (later succeeded by Jimmy Thompson) was the ODA's contribution, and Yves Cheneau was provided by France.

To avoid a repeat of the failure suffered by JP15, the aim had to be rinderpest eradication, not just control. Furthermore, the ODA insisted that the programme should focus solely upon rinderpest and avoid the complications that JP15 experienced through its dual focus on contagious bovine pleuropneumonia (CBPP) and rinderpest. In the face of growing outbreaks, mass rinderpest vaccination across the continent was seen as essential. The ODA urged that immediate action should be taken to vaccinate in the United Republic of Tanzania, to help prevent the disease crossing the Zambezi river and getting into southern Africa. This idea was accepted by the EEC, and the ODA supported it with backup supplies of vaccine.

At the 1985 technical meeting, the ODA advocated an urgent need to get the rinderpest campaign started in those countries that were sufficiently ready to mobilise mass vaccination and for the other countries to be assisted and enrolled as the journey progressed. This view eventually held sway, and the meeting resolved that the EEC-funded Pan-African Rinderpest Campaign (PARC) should start without further delay.

In line with this decision, nationwide mass vaccination campaigns were undertaken in the United Republic of Tanzania with the support of the EEC in 1985, 1986 and 1987. The Animal Virus Research Institute (Pirbright) was contracted to assist with the logistics of these campaigns and to undertake seromonitoring; Pirbright's indirect enzyme-linked immunosorbent assay (ELISA) test was validated in the course of this work, which administered 23 million doses of vaccine.

Concurrently, the EEC in collaboration with its Member States, particularly the United Kingdom, and France, formulated recommendations for the eradication of rinderpest, and IBAR provided the technical and financial details and proposed a schedule for the pan-African campaign. In 1986, after a considerable gestation, PARC was launched.

ODA support continued, principally as a major donor to the EEC European Development Funds (EDFs) but also through bilateral contributions and support for research projects at Pirbright in the United Kingdom. For example, the ODA funded the groundbreaking work to differentiate the geographical lineages of rinderpest virus (4).

The ODA remained an active, innovative and influential member of the EEC Livestock Technical Committee advising on the needs and way forward for the continuing PARC programme. The ODA also played an active part in the discussions leading to the formulation and operation of PARC's successor, the Pan-African Programme for the Control of Epizootics (PACE; Chapter 4.3). The United Kingdom was very insistent that the final elimination of rinderpest should remain the prime focus of this 'control of epizootics'.

The ODA continued to provide a technical adviser to IBAR right through to the end of PARC. The adviser was then absorbed, under EU funding, into PACE.

In 1997, the ODA became a ministry within the UK Government and was renamed the Department for International Development (DFID). DFID continued to fund the EU EDF and specifically supported PACE through the Community-based Animal Health and Participatory Epidemiology (CAPE, 2000–2005) project. CAPE supported the establishment of sustainable animal health services in pastoralist areas of the Greater Horn of Africa. CAPE had a multipronged approach: building the capacity of IBAR to champion institutional reforms in the animal health sector, establishing community-based animal health delivery systems capable of epizootic disease control and surveillance, strengthening policy and legislation to enable those community-based delivery systems to be privatised in pastoral areas, gathering the relevant data and information to support policy change, and scaling up community-based animal health (CAH) services. Significant publications included those on the alignment of CAH services with OIE guidelines (5), the contribution to the OIE policy through the *Ad hoc* Group on the role of private veterinarians and paraprofessionals in the provision of animal health services (6), and an analysis of policy processes in the livestock sector (7).

Building on research funded in the early 1990s to develop a recombinant capripoxvirus vaccine against rinderpest, DFID continued to fund the Pirbright Institute from 1997 to 2003, to develop both a marker rinderpest vaccine and an accompanying penside test. A marker vaccine was developed, and it differentiated animals that had been vaccinated from those that had been infected with, and recovered from, rinderpest virus (8, 9). Such marker or 'DIVA' (differentiating infected from vaccinated animals) vaccines allow ring vaccination of outbreaks and assist in the monitoring of sanitary cordons. An accompanying penside test that was capable of quickly identifying rinderpest-vaccinated animals from those naturally infected was also developed (10, 11). Neither the vaccine nor the penside test were ever registered for use or commercially manufactured, because by the time they were developed rinderpest had almost been eradicated, and the remaining foci of disease were in areas of extreme civil unrest in Somalia and the neighbouring areas of Kenya (12).

DFID, through its funding of UK Aid Direct, continues to contribute to the EDF and to directly fund animal health research. One example is the Programme for Combating Infectious Diseases of Livestock for International Development (CIDLID, 2010–2015). CIDLID has developed a penside test for peste des petits ruminants (PPR) (13) and a new PPR vaccine technology that is heat stable and marked to allow differentiation between vaccinated and naturally infected animals (14). Furthermore, DFID-funded research has attempted to produce a multivalent PPR vaccine (15). All of these are potentially valuable tools for the planned disease eradication effort against PPR (16).

CONCLUSION

The UK Government through its various overseas aid instruments has supported rinderpest control and eradication efforts for well over 50 years. This support included notable achievements in terms of disease control strategy development and research into new vaccine and diagnostic test technologies. The UK Government continues to fund research on the development of novel vaccines and tests for PPR.

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CHAPTER 5.12

ROLE OF UNDP AND FAO PARTNERSHIP IN RINDERPEST ERADICATION

K.J. WOJCIECHOWSKI [1] & F. NJEUMI [2]*

(1) 6, The Village Gate, Dalkey, Co. Dublin, Ireland
(2) Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, Rome, Italy

*Corresponding author: felix.njeumi@fao.org

SUMMARY **The United Nations Development Programme (UNDP) commenced on 1 January 1966 when the United Nations Special Funds were merged with the Expanded Programme of Technical Assistance (EPTA). Under the EPTA, which covered the period from 1949 to 1966 when the UNDP was created, US$130 million was directed by the Food and Agriculture Organization of the United Nations (FAO) to the livestock sector of which rinderpest control and eradication was the major beneficiary. The programme supported seminars/workshops, regional coordination of disease control, diagnostic laboratories and vaccine production. The FAO–UNDP partnership not only promoted the eradication of rinderpest but also laid the foundation for the establishment/strengthening of Veterinary Services and livestock development in developing countries.**

KEYWORDS **EPTA – Expanded Programme of Technical Assistance – Laboratory – Rinderpest – Surveillance – Training – UNDP – United Nations Development Programme – Vaccine.**

INTRODUCTION

The signatories of the UN Charter in 1945 were aware that the organisation should not only attempt to maintain international peace and security but also promote the economic and social conditions conducive to peace. They, therefore, pledged in Article 55 to work for 'higher standards of living, full employment and conditions of economic and social progress and development' (1). At that time, underdeveloped countries faced two major problems – constant pressure on the land and illiteracy – together creating a vicious circle of poverty. Poverty prevented:

a) investment in new agricultural equipment that would produce better crops and greater employment;
b) access to both the resources and the ability to treat and/or eradicate disease.

In response to this situation in underdeveloped countries, the FAO was tasked with providing expertise in agriculture, including livestock, fisheries and forestry, initially through the EPTA (1). On 1 January 1966, the EPTA was strengthened by the incorporation of the UN Special Funds and renamed the UNDP (2).

This chapter reviews the important role that the EPTA and then the UNDP played in the eradication of rinderpest.

THE EXPANDED PROGRAMME OF TECHNICAL ASSISTANCE

For the first distribution of funds from the EPTA in 1949, the United Nations Educational, Scientific and Cultural Organization (UNESCO) was allocated 14% of the total, compared with 11% allocated to the International Labour Organization (ILO) and 29% to FAO. At these early stages of 'agency programming', specialised agencies tended to prescribe the aid needed to a Member State: agencies identified the needs and then allocated their percentage of the EPTA according to these needs (3). Over the first 16 years, the 29% allotment to FAO was partly dedicated to livestock, of which rinderpest control was a major part. This focused on organising seminars/workshops, creating regional coordination mechanisms, establishing laboratories for diagnosis and vaccine production, and effective use of vaccines and other aspects of rinderpest control.

THE UNITED NATIONS DEVELOPMENT PROGRAMME

Effective as of 1 January 1966, the EPTA and UN Special Fund were amalgamated to form the UNDP. UNDP financial support for rinderpest control and eradication was sometimes given alone or combined with the contributions of other donors, such as the European Development Fund (EDF), the World Bank and a number of individual countries including Canada, France, Germany, Ireland, Italy, Japan, the United Kingdom of Great Britain and Northern Ireland and the United States, as well as the infected and at-risk countries involved. Table I summarises a few of the UNDP projects and other donors that jointly supported rinderpest activities. The FAO interventions using these funds are divided into several aspects, including laboratory, vaccine production and quality assurance, surveillance, training, research and communication.

ESTABLISHING AND STRENGTHENING VETERINARY LABORATORY CAPACITIES

In the late 1970s, few countries had basic laboratory capacities. The UNDP's role, through FAO, was to support the establishment of laboratories or the strengthening of those that already existed. In Afghanistan (through the project AFG/90/006), there were attempts to rebuild the basic structures of veterinary services (veterinary clinics). The Project Afghan Agricultural Sector Rehabilitation Programme (UNO/AFG/104/UNA) was aimed at increased efficiency of state veterinary services through rehabilitation of its field structures, clinics and diagnostic laboratories, as well as safety for veterinary field operations.

In the Niger, between 1982 and 1985 through NER/81/019 and NER/82/001 'Renforcement du Laboratoire Central de l'Élevage à Niamey', the laboratory was equipped and modernised.

Between 1988 and 1993, the PAK/86/027 laboratory was improved in Gilgit, in the northern territory of Pakistan. This laboratory is located in an area where rinderpest was diagnosed several times. The Central Veterinary Laboratory for Sind, Tando Jam, near Karachi in Pakistan, was established between 1986 and 1994 through PAK/84/008 and PAK/90/050. The management in the final stage of the project was outstanding, with regard to construction and modernisation, but unfortunately the project made many mistakes regarding the detection of rinderpest, which affected the FAO's epidemiological assessment and the requisite action. This area was one of the major concerns when the Global Rinderpest Eradication Programme (GREP) was established in 1994.

These above-mentioned projects covered, inter alia, delivery of laboratory equipment, especially freeze-dryers, vaccine seeds and consultant advice on the production and quality control of rinderpest vaccine as well as training of personnel.

VETERINARY VACCINE PRODUCTION, DISTRIBUTION AND WIDESPREAD VACCINATION

The FAO Standing Committee on Animal Health at its meeting in New York (April 1947) recommended that FAO should assist in the establishment of laboratories, training personnel, and the production, distribution and use of rinderpest vaccine (4). FAO understood that its major role should be to assist countries to produce low-cost vaccines that are safe and efficacious. In the 1950s, FAO supported the use of attenuated vaccines called lapinised vaccine, lapinised–avianised vaccine and attenuated tissue culture rinderpest vaccine (TCRV), as described in Chapter 3.4. In 1970, FAO recommended that this TCRV should be used in all countries in the Middle East. The vaccine was also recommended for India and other countries in South Asia.

TABLE I
THE UNDP-FUNDED PROJECTS

Symbol (budget)	Period	Title	Major activities
GCP/RAF/218/JPN (US$3.5 million)	1987–1992	Technical support to PARC	The pan-African project covering organisation and conducting of so-called Epidemiology Units for eastern, southern and central Africa in Nairobi, Kenya, (OAU/IBAR) and for central and western Africa (francophone) in Bamako, Mali
GCP/RAF/G.4870	1994–1996	PARC monitoring and control	Seromonitoring post-vaccination
Follow-up to GCP/RAF/218/JPN. UNDP/RAF/87/15	1988–1999	Technical support to PARC	Establishment of an International Animal Disease Diagnostic Centre for Africa
RAF/88/049 linked with RAF/88/047	Unknown	Multi-sectoral Assistance to the Economic Community of Central African States (ECCAS)	Capacity building in laboratory and surveillance Sector analysis on animal and seed production
RAF/89/061 and RAF/89/061 linked with RAF/88/047 and RAF/88/049	Unknown	Assistance to the Union douanière et économique de l'Afrique centrale (UDEAC)	Review and adapt animal and plant legislation
UNDP/RAF/88/050 PANVAC	05/1988–10/1993	Pan-African Veterinary Vaccine Centre (PANVAC), veterinary Vaccine Production and Quality Control in Africa (Ethiopia and Senegal)	Reinforce PANVAC, veterinary vaccine production and quality control in Africa (Ethiopia and Senegal)
GCP/RAF/G.4932 follow up to RAF/88/050	1991	Strengthening of Veterinary Vaccine Production and Quality Control in Africa through PANVAC, phase I	Strengthening of veterinary vaccine production and quality control in Africa through PANVAC
GCP/RAF/G.5120	1993	Strengthening of Veterinary Vaccine Production and Quality Control through PANVAC, phase II	Strengthening of veterinary vaccine production and quality control through PANVAC
GCP/RAF/305/EEC	05/1994–07/1995	Quality control services of PANVAC	Ensure quality control of vaccines
GCP/RAF/4870 follow up to GCP/RAF/218/JPN	1995–1997	The global PARC Monitoring and Control Unit	Identify indicators for progress monitoring Training on use of indicators
RAF/G.4706/	1993–1995	Support to PARC in communication	PARC training of national communication officers in Organisation of African Unity (OAU) countries
GCP/RAF/269 BEL	1990–1991	PARC communication, coordination and training phase I	Staff trained on communication for development Prepare, print and disseminate communication materials
F/G.4871 Linked to TCP/RAF/8855	1991–1993	PARC communication and coordination, phase II	Staff trained on communication for development Prepare, print and disseminate communication materials
GCP/RAF/G.4706	1991–1995	–	PARC training of national communication officers in OAU countries
GCP/RAF/0164 (US$319 000)	Unknown	Assistance of PARC communication and epidemiology coordination (OAU-Interafrican Bureau for Animal Resources, IBAR)	Staff trained on communication for development Prepare, print and disseminate communication materials
GCP/INT/598/IFD	1995	Regional Animal Disease Surveillance and Control Network for North Africa, the Middle East and the Arab Peninsula (RADISCON)	Strengthen surveillance Establish surveillance network
Technical Assistance Grant (TAG) Information 309 (US$1.25 million)	1996–2000	Technical assistance to RADISCON	The Government of Canada provided the services of a veterinary epidemiologist Associate Professional Officer for two years to work in the RADISCON
RAB/86/024	1989–1993	West Asia Rinderpest Eradication Campaign Coordination (WARECC), Near East	Project of rinderpest control and eradication in the countries of the Middle East. Epidemiology diagnostics, serological surveys, information campaigns and strengthening of quarantine. The project was coordinated from Baghdad (until 1990), and, after the war in the Persian Gulf, it was moved to Aman (Jordan)
GCP/INT/598/IFD	Unknown	Regional Animal Disease Surveillance and Control	Coordinate surveillance activities
RAB/91/006	1992	Umbrella Project – Gulf Crisis: rinderpest control, Islamic Republic of Iran, Iraq, Turkey	The violent epidemic of rinderpest in 1991–1992 in Turkey created a need for immediate vaccination in the Islamic Republic of Iran and Iraq and to upgrade the diagnostic capability. The project covered delivery of vaccine, equipment and supplies as well as the consultancy advice
RAS/86/023	1993–1997	–	South Asia Rinderpest Eradication Campaign (SAREC)
GCP/RAS/5094	Unknown	Strengthening of livestock services in South Asia through rinderpest control/eradication	Strengthening of Veterinary Services' control of rinderpest
GCP/REM/023/MUL	1987–1993	The Middle and Near East Regional Animal Production and Health Project (MINEADEP)	See Chapter 4.9
UNDP/AFG/76/009	Unknown	Basic veterinary project in Afghanistan	Procure veterinary and laboratory equipment for disease control
AFG/74/022, AFG/82/007 Faculty	1982–1984	Development of the curricula of veterinary science, Kabul University	Training on rinderpest diagnosis, surveillance and control

TABLE I (CONT.)

Symbol (budget)	Period	Title	Major activities
AFG/82/001 Kabul, Afghanistan	Unknown	Strengthening Central Diagnostic Laboratory and Department of Veterinary Services	Improving laboratory capacity
AFG/86/016 Kabul, Afghanistan	1986–1992	Development of livestock disease surveillance and control planning, phase II	Disease surveillance and control capacity
AFG/90/006	1990–1992	Support to veterinary clinics	Establish veterinary clinic in remote areas
UNO/AFG/104/UNA	1990–1991	Support project for Afghan Agricultural Sector Rehabilitation Programme	Disease control
ALG/77/004 Algerie	1992	Amélioration de la Santé Animale	Disease surveillance and control capacity
UNDP ANG/80/051 Angola	1994	Appui aux laboratoires vétérinaires	Equipment of laboratory
UNDP/ANG/90/	1994–1995	Renforcement des laboratoires vétérinaires pour la surveillance épidemiologique et la prophylaxie des maladies animales	Strengthening laboratory capacity Surveillance Disease control
BGD/79/033	1982–1987	Cooperative dairy organisation and extension, phases I, II and III	Part of the training concerned rinderpest control
BGD/83/010	Unknown	Assistance to second Agricultural Research Project	Carry out research on vaccine and seed production and use
UNDP/BHU/76/001 Timphu, Bhutan	Unknown	Establishment of a Veterinary Diagnostic Laboratory	Particular attention was given to rinderpest
UNDP/BUL/BG/001 and BUL/86/001	1990–1992	Centre for exotic diseases control (phases I, II and III)	Training on rinderpest diagnosis
BUR/80/001 and MYA/84/001 Rangoon	1982–1987	Development of animal virus vaccines, phases I and II	Capacity building in vaccine production
CYP/81/010 Cyprus	1982	Emergency diseases control	Training on rinderpest emergency contingency plan
HUN/87/011	1988–1991	Fellowships and study tours in the field of biotechnology	Study tour
IND/85/065	Unknown	–	Establishment of High Security Animal Diseases Laboratory, phase II, (Bhopal)
ROK/82/012 Korea	1984–1986	Strengthening the Veterinary Services	Early warning and early reaction
LAO/83/006 Lao People's Democratic Republic	1984–1987	Strengthening the National Institute on Vaccine Production, phase I	Capacity building for vaccine production

Funded by the UNDP, technical assistance was provided through FAO to implement the above recommendations, along with the appointment of a well-recognised expert to assist infected countries. Dr R. Daubney, formerly Director of Veterinary Services in Kenya, for example, advised the governments of Egypt and India on the control of rinderpest by mass national vaccination campaigns, which when implemented were spectacularly successful in the 1950s. Concurrently in Cambodia, Drs K. Fukusho, T. Furutani and H.L. Stoddart established a production plant for a lapinised–avianised rinderpest vaccine and how to use these in the field to control the disease. Dr J.R. Hudson was similarly occupied in Thailand. For nearly two decades, Dr V.G. Hinds was a peripatetic consultant in Bangladesh, India and Pakistan, designing, constructing and operating biological plants producing lyophilised rinderpest vaccine. In the late 1950s, Dr H.B. Shaki established a Veterinary Service in Nepal to combat rinderpest. Ten years later, a fresh invasion of Nepal was curbed by the organisational skills of Dr C. Seetharaman. The eminent Japanese virologist Dr Junji Nakamura advised the governments of Egypt and Nigeria on the production of rinderpest vaccine. Concurrently, Dr S.A. Evans similarly advised the Sudan government (5, 6).

The rinderpest unit of the Near East Animal Health Institute (NEAHI) was established in Cairo and was equipped to diagnose rinderpest and produce TCRV (7). Subsequent projects in the Middle East, namely Near East Animal Production and Health Development (NEADEC) and the Middle and Near East Regional Animal Production and Health Project (MINEADEP), were also funded by the UNDP as well as participating countries. These are extensively described in Chapters 4.7, 4.8 and 4.9. When Joint Programme 15 (JP15) was extended to eastern Africa, using funds from the UNDP, FAO ran training schemes in Ethiopia and Somalia (8). In the same decade, emergency missions were dispatched to Indonesia to contain a rinderpest-like disease, known locally as Jembrana disease, using avianised–lapinised rinderpest vaccine. A major success was the virtual eradication of rinderpest from the Near East, after a pandemic had swept across the region. Control procedures in affected countries were coordinated by Dr K.V. Singh, the FAO Regional Rinderpest Laboratory Coordinator stationed in the NEAHI in Beirut (9).

In Africa, several laboratories started or continued the production of rinderpest vaccine, with the help of UNDP funds (e.g. Cameroon, Chad, Egypt, Ethiopia, Kenya, Nigeria, Mali, Senegal and Sudan).

VACCINE QUALITY ASSURANCE

From 1982 onwards, the UNDP, Japan, European Economic Community and FAO–Technical Cooperation Programme (TCP) assisted in improving the quality of rinderpest vaccine at PANVAC (Table I).

SURVEILLANCE

Between 1977 and 1981, one of the first country-wide serological surveys was carried out in Afghanistan to assess the presence of rinderpest antibodies in sporadically vaccinated cattle. Around 30% positivity was observed in cattle populations that had been vaccinated using the Alma-Ata (USSR) TCRV. This was followed by the development of livestock disease surveillance and planning to control rinderpest (AFG/86/016) in two phases up to 1992. The main emphasis was rinderpest, followed by other transmissible animal diseases. The project was interrupted in 1992 because of the war in the country and entire region. Using experiences from previous projects, the UNDP – in conjunction with Italian support –restarted surveillance in central Asia in early 2000 (10).

COMMUNICATION

The UNDP, together with other agencies and donors, provided communication materials for the eradication of rinderpest. For example, information kits for the national information campaigns of the Pan-African Rinderpest Campaign (PARC) were distributed to 34 African countries, and training was provided for national communication officers. The first ever modern video on 'rinderpest diagnosis' was produced during the regional training course on laboratory diagnosis of rinderpest (under TCP/RAF/4408) at the National Veterinary Institute, Debre-Zeit, from 4 to 7 March 1985. FAO-TCP/RAF/4413 and other donors supported several communication tools that were used for rinderpest eradication.

TRAINING AND MEETINGS

In Afghanistan, under the AFG/74/022 and AFG/82/007 (1982–1991) projects supporting the Faculty of Veterinary Science, Kabul University, curricula were developed for the training of personnel in laboratories and veterinary clinics, and the preparation of the theoretical and practical aspects of rinderpest control. The Central Diagnostic Laboratory was strengthened through the AFG/82/001 project on improving laboratory techniques, applicable to Afghan field conditions for the implementation of the rinderpest eradication plans. The UNDP and FAO organised several training courses on the diagnosis of rinderpest (e.g. Cairo, Egypt, 5–23 December 1970). The course was designed to demonstrate to participants the various laboratory techniques currently used for the differential diagnosis of rinderpest (i.e. isolation and identification of the virus in tissue culture, serum-neutralisation, complement fixation and gel-precipitation tests) (5, 6).

RESEARCH

In 1987, the Bangladesh 'Assistance to second agricultural research BGD/83/010 project' was established to plan country-wide veterinary research on rinderpest as well as prophylaxis and control of infectious and parasitic diseases. The subsequent projects, 'UNDP/BGD/83/013 assistance to Bangladesh Livestock Research Institute, Dhaka' undertook research on rinderpest diagnosis and serosurveillance. It was carried out from 1987 to 1994 in several phases.

In India, several projects (1986–1993) were implemented:

a) IND/85/020: advanced centres on post-graduate agricultural education and research;
b) sub-project 04: centre on post-graduate education and research in immuno-biotechnology – Indian Veterinary Research Institute (IVRI);
c) a multi-institutional and multicomponent project aimed at the provision of 11 scientific institutes and DNA technology, this under the aegis of the Indian Council for Agricultural Research (ICAR).

These were followed by IND/85/065 for the establishment of the high-security animal disease laboratory (Bhopal) focused on genetic recombinants to be applied in diagnostics and vaccine production.

CONCLUSION

The UNDP, similar to other UN institutions, through partnership with FAO, played an important role in achieving a rinderpest-free world. Among other achievements, the improved laboratory capacities established in several countries by the UNDP provided the springboard for the International Atomic Energy Agency to establish a laboratory network, as described in Chapter 5.4.

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CHAPTER 5.13

ROLE OF NON-GOVERNMENTAL ORGANISATIONS IN RINDERPEST ERADICATION IN SOMALIA AND SOUTH SUDAN

B.A. JONES [(1)*], **V. CAGNOLATI** [(2)], **S. CRAFTER** [(3)], **W. DUEHNEN** [(4)] **& E. GUERNE-BLEICH** [(5)]

(1) Department of Epidemiological Sciences, Animal and Plant Health Agency (APHA), APHA – Weybridge, Woodham Lane, New Haw, Addlestone, Surrey KT15 3NB, United Kingdom
(2) Attaché, Programme Manager, Cooperation Section, Delegation of the European Union to the African Union, Roosevelt Street, Kirkos Sub City, Kebele 10, P.O. Box 25223/1000, Addis Ababa, Ethiopia
(3) 31 Esplanade, Port Willunga, South Australia 5174, Australia
(4) Vétérinaires Sans Frontières Germany, 671 Ngong Road, Piedmont Plaza, PO Box 25653-00603, Nairobi, Kenya
(5) Food and Agriculture Organization of the United Nations (FAO) Djibouti, Lotissement du Héron, Immeuble Moussa Bouraleh, Lot No.16, P.O. Box 2588, Djibouti

*Corresponding author: bryony.jones@apha.gov.uk

SUMMARY

Some of the last places to harbour rinderpest infection were pastoralist areas with large cattle populations where government Veterinary Services were unable to provide high vaccination coverage or effective surveillance because of conflict or other constraints. Alternative systems were therefore required if the global eradication programme were to succeed. We describe here two examples of the successful elimination of rinderpest from persistent foci of infection, Somalia and South Sudan, where non-governmental organisations (NGOs) played key roles in developing and supporting animal health service delivery and the eradication programme, under the guidance and coordination of the African Union Interafrican Bureau for Animal Resources (AU-IBAR), the Pan-African Rinderpest Campaign (PARC), Pan-African Programme for the Control of Epizootics (PACE) and the Food and Agriculture Organization of the United Nations (FAO) Global Rinderpest Eradication Programme.

In Somalia, after the collapse of the Somali state in the early 1990s, international NGOs and FAO provided training and support to emerging public administrations and private veterinary associations to deliver animal health services, rinderpest vaccination and active surveillance to demonstrate rinderpest elimination.

In South Sudan, a region of chronic conflict, a consortium of NGOs and United Nations (UN) agencies supported community-based animal health services to deliver rinderpest vaccination and report outbreaks, leading to the elimination of disease, and then established a surveillance system to demonstrate freedom from infection.

These experiences are highly relevant to other livestock sector initiatives in areas where it is difficult for conventional government-led Veterinary Services to operate effectively.

KEYWORDS **Cold chain management – Community-based animal health workers – Disease eradication – Epidemiology – Participatory – Rinderpest – Somalia – South Sudan – Surveillance – Thermostable vaccine – Vaccination.**

INTRODUCTION

Control of rinderpest was particularly challenging in countries that were struggling with internal conflict, low levels of development and poor infrastructure but that had important extensive cattle populations. In these situations, the government Veterinary Services usually had limited capacity to provide the level of vaccination coverage needed to eliminate rinderpest or to support an effective surveillance system. This chapter describes two examples in which alternative systems for delivery of disease control and surveillance were successfully applied to eliminate rinderpest from the last two foci in Africa, the Federal Republic of Somalia and the Republic of South Sudan, and in which non-governmental organisations (NGOs) played key roles in developing and supporting animal health service delivery and the eradication programme.

SOMALIA

Somalia has one of the highest ratios of livestock per capita in Africa and is one of the largest live-animal exporters. The most fertile areas of Somalia, the southern and Trans-Juba regions, host a large cattle population estimated at 3.4 million head and represents 75% of the country's cattle population. The Somali economy has been for decades dominated by livestock production and export, especially to the Middle East region and neighbouring Kenya. Although the predominant nomadic and transhumant mode of production has not changed over time, the strong demand for live animals in the nearby Middle East offered Somali pastoralists and agro-pastoralists a unique opportunity to favourably exchange animals for foodstuffs and other household goods and to reorient production towards the lucrative export sector. Livestock trade and export was considered to be the main source of foreign currency and revenue for the Somali state until the collapse of the Siad Barre regime in 1991 and the onset of civil war.

Animal health services

In the 1980s Veterinary Services were under the control of the Ministry of Livestock, Forestry and Range in the Democratic Republic of Somalia. With headquarters in Mogadishu, there were 18 regional offices, 80 district offices and many village veterinary posts. The last available data from 1986 showed the total veterinary personnel (veterinarians and veterinary assistants) to be around 200 staff, with 110 employed at central level (Ministry of Livestock, Forestry and Range, Faculty of Veterinary Medicine and Animal Husbandry, Technical School for Animal Health Assistants, Sero-Vaccine Institute and specific projects), 60 engaged in regional offices and laboratories and the remaining 30 engaged at field level in specific projects.

The majority of the veterinary workforce was represented by veterinary assistants trained at the Technical School for Animal Health Assistants, established in 1967, which had produced around 1,700 technicians in animal health and laboratory diagnosis by 1985. Veterinarians and animal husbandry personnel were trained abroad until 1974, when the Faculty of Veterinary Medicine and Animal Husbandry was established as part of the University of Mogadishu.

A limited number (53) of nomadic animal health auxiliaries (NAHAs) were trained by the German Technical Cooperation Agency (GTZ) in the Central Rangeland Development Project, and 21 NAHAs were trained by the French Cooperation in a project for the development of oases in northern Somalia during the 1980s.

Veterinary Service activities included curative treatment, disease prevention and drug distribution and sale. Disease prevention comprised disease surveillance, notification, reporting, laboratory diagnosis, movement control, quarantine and vaccination. Vaccination coverage was low and activities were sporadic and untargeted. A very centralised and inefficient delivery system was implemented by the Somali state to serve mostly livestock traders and exporters, and it supported, to a very limited extent, livestock producers, who were mostly urban or peri-urban based. The majority of pastoralists and agro-pastoralists never received animal health services, apart from very occasional vaccination campaigns. Only in the late 1980s were some structural changes introduced into the animal health delivery system, and there was some liberalisation of veterinary drug distribution and community-based animal health workers became involved as part of externally funded interventions.

Effect of conflict on animal health services

The onset of civil war and the collapse of the Somali state in 1991 caused major human displacement and famine and the total disintegration of public services, including the Veterinary Services. Veterinary personnel were forced to find alternative sources of employment and either engaged in veterinary-related activities, especially the sale of veterinary drugs and brucella testing for the fast-recovering export sector, especially through the northern ports of Berbera and Bossaso, or they became part of the large Somali diaspora in neighbouring countries, Europe and North America. Somali veterinary professionals (SVPs) established private practices and professional associations at regional and national level to provide curative and diagnostic services, especially for livestock traders and exporters. With the establishment of new administrations in the self-proclaimed Republic of Somaliland and the semi-autonomous State of Puntland, a very limited number of veterinary personnel were re-employed by the new administrations, especially to support the mandatory animal certification and inspection of export livestock at the two main ports.

Relief and rehabilitation

With widespread famine, prolonged droughts, massive human displacement and civil war, major relief and peacekeeping operations were launched in Somalia to save lives and rehabilitate public and private assets. In the light of the contribution of livestock to livelihoods, relief programmes were launched in 1992 by the International Committee of the Red Cross (ICRC), international NGOs and UN agencies (including the UN operation in Somalia, UNOSOM) to target livestock producers and their animals. Each organisation was involved at various levels, including some non-traditional actors in the livestock sector. For example, the ICRC implemented a countrywide programme to preserve livestock holdings through curative interventions and vaccination campaigns, including for rinderpest.

As the country started to recover and peace prevailed in some parts of the country, some of the donors left, while the European Commission developed a long-term vision for supporting the livestock sector, mostly through relief and rehabilitation interventions implemented mainly by international NGOs in partnership with local organisations. Mechanisms were also put in place to better coordinate the assistance to Somalia, with the establishment of a multi-donor consultative body, the Somali Aid Coordination Body, at the beginning of the 1990s.

Since then, international NGOs and UN agencies, especially FAO, have continued to provide support to the livestock sector in Somalia either directly or through emerging public administrations. The main areas of intervention were the provision of curative services to pastoralists in drought-affected areas; strengthening the capacity of administrations and private veterinary associations to undertake surveillance for prioritised diseases, such as rinderpest, Rift Valley fever (RVF), peste des petits ruminants (PPR), contagious bovine pleuropneumonia (CBPP) and contagious caprine pleuropneumonia (CCPP); governance of Veterinary Services and delivering services to the export sector, especially testing and animal health certification; and human resource development through technical training and formal education.

Rinderpest in Somalia: control and surveillance

An attempt to eradicate rinderpest had been made during Joint Programme 15 (JP15) through vaccination campaigns conducted throughout the country between 1968 and 1975. However, in 1983 rinderpest was suspected in the country, leading to a ban on the importation of cattle from Somalia to Saudi Arabia. Between 1983 and 1990, although there were no official reports of rinderpest in Somalia, rinderpest was suspected within Somalia and there were confirmed outbreaks in contiguous areas in north-eastern Kenya.

Coinciding with the onset of drought in 1991, two waves of rinderpest spread to Somalia from Wajir district in Kenya. The first spread through Simper Fatima in central Mandera district to cause moderate mortality in eastern Mandera district. The second wave passed through Liboi, Kenya, to enter Lower Juba, causing moderate to severe mortality (30% to 70%) at Tabta, Bilis Qooqaani, Afmadow and Badhaade in Somalia. Vaccinations in response to these outbreaks were mainly carried out within the framework of the ICRC Emergency Veterinary Programme. The outbreak in Lower Juba was under control by 1993. Following increasing concerns about the spread of rinderpest into Somalia from areas along the Kenyan border, the NGO Terra Nuova started a vaccination campaign in Gedo region in August 1996. Assisted by local knowledge, PARC Somalia projects were implemented to better understand the occurrence and pattern of rinderpest in the project area. Historical information indicated that two main epidemics of disease occurred in the 1990s; the first between 1991 and 1994, as described above, and the second between 1997 and 1999. The 1997–1999 epidemic was clinically mild and cases of rinderpest were detected in several locations of Afmadow district. Investigations carried out on unvaccinated young cattle also showed positive results in the regions of Bay, Hiran, Mudug and Galgadud in southern and central Somalia. Serum samples tested positive using rinderpest competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3) in Lower Juba, Middle Juba and Gedo regions of Somalia.

The Pan-African Programme for Control of Epizootics (PACE) replaced PARC in mid-2000. PACE had a mandate to deal with a wider range of diseases, and it extended its programme within Somalia in 2001. The elimination of rinderpest from identified or suspected foci was attempted through the vaccination of 100% of the susceptible cattle population, but the transhumant nature of cattle movements in the Somali ecosystem meant that rinderpest being detected in one area suggested that it was present in other areas. Furthermore, mild rinderpest was not perceived as a serious threat by herders and therefore was unreported, despite its potential to turn virulent.

PACE conducted epidemiological surveys in 2003–2004 in central and southern Somalia to estimate the seroprevalence of rinderpest in cattle, and the survey was extended to the cattle rearing areas of Somaliland and Puntland in 2004. Serological survey results indicated that the high prevalence of antibodies to rinderpest in all age groups was associated with both high cattle density and mobility in Gedo, Lower Juba and Middle Juba regions. No evidence of rinderpest was reported in the northern part of Somalia during this survey (Fig. 1).

Data analysis indicated a higher prevalence of infection around traditional cattle trade routes. This implied that the movement of large numbers of livestock for trade could have been an important means of spreading rinderpest. The observed high rinderpest seroprevalence in young animals suggested a recent and perhaps persistent circulation of rinderpest virus in southern and, to some extent, central Somalia. Although the lack of physical barriers and control measures made it difficult to explain the sometimes large differences in seroprevalence between adjacent regions, it appeared that differences in cattle density and mobility of the herds could have played a role in the epidemiology of the mild strain of rinderpest that was present in these areas. Factors such as wildlife movements and livestock trade routes, abundant in the south, could also serve to explain the observed differences in seroprevalence.

Rinderpest surveillance, using serology and participatory approaches, was particularly intense as indicated in Table I. The surveys were structured in two different ways, active disease searches combined with rinderpest serosurveillance using SVPs trained in epidemiological investigation during the previous training programmes and random coordinate plots. The active disease searches involved the use of participatory disease search (PDS) methods to detect the presence of rinderpest by collecting relevant background information from livestock owners and visiting various sites to clinically inspect the animals. Where there was suspicion of disease, samples were collected for laboratory examination. Cross-sectional surveys were used to determine the seroprevalence and distribution of the disease.

The rinderpest survey carried out by PACE in 2002 and 2003 in central and southern Somalia (Bakool, Bay, Galgadud, Gedo, Hiran, Mudug-South, Lower Juba, Middle Juba, Lower Shabelle and Middle Shabelle regions) combined both serological investigations and information gathered using questionnaires. The survey used a two-stage cluster sampling strategy. The between-cluster variance used for the calculation of the sample size was derived from the results generated under previous serosurveys (1999–2001) carried out in the area. A total of 11,807 serum samples from unvaccinated young cattle were collected and tested at the Kenya Agricultural Research Institute (KARI) regional rinderpest reference laboratory in Nairobi, Kenya, to assess the distribution of rinderpest in cattle herds. Additional samples (lymph node aspirates and eye swabs) for virus detection were collected and tested from a further 382 cattle showing signs of clinical disease compatible with mild rinderpest. A total of 1,318 questionnaires were administered during the cross-sectional survey.

In 2004 the survey was extended to cover the cattle rearing areas of Somaliland and Puntland. In Somaliland, it was conducted in a manner similar to that in the period 2002–2003 in collaboration with the local Ministry of Livestock. The survey in Puntland was supposed to adopt the same methodology, but drought in the area resulted in a low cattle population density, making it impossible to successfully implement a randomised survey. It was therefore decided that each investigation team would take blood samples from at least 30 animals of all age classes in 12 locations where animals were found during the drought. Although this method compromised the representative nature of the sampling, the situation on the ground did not permit the use of other approaches. The survey was conducted under the supervision of the Ministry of Livestock, Agriculture and Environment of Puntland.

Another rinderpest serosurvey was conducted under PACE in five regions in February 2005. The survey initially targeted eight regions and was based on the pattern of infection found during the previous survey, but the three central regions could not be included because of the temporary cessation of the European Community Humanitarian Organisation (ECHO) flights. Regions surveyed

FIG. 1

RINDERPEST SEROPREVALENCE BY AGE GROUP: SPATIAL DISTRIBUTION

Data source: PACE Somalia component. Shading indicates seroprevalence in cattle aged one to three years, and the bar charts indicate seroprevalence in cattle aged over three years to four years, over four years to five years and over five years of age

Source: D-maps, 2020 (2), modified to indicate seroprevalence data

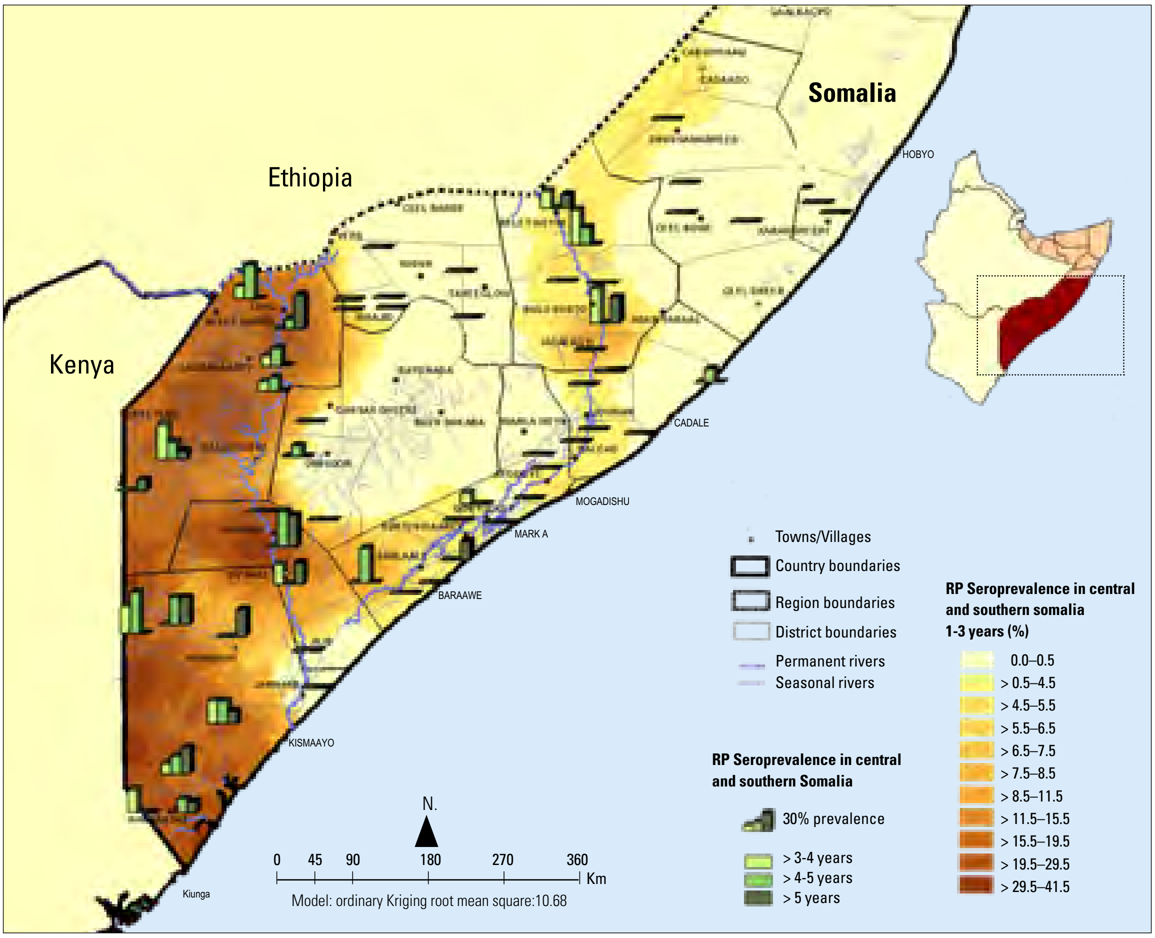


TABLE I

RINDERPEST SAMPLING ACTIVITIES IN SOMALIA (2002–2007)

Period of implementation	Regions	Sampling sites	Samples collected
September to October 2002	South Mudug, Galgadud, Hiran, Middle Shabelle, Middle Juba, Lower Juba	350	6,321
August 2003	Lower Shabelle, Bay, Bakool, Gedo	214	4,012
July 2004	Cattle rearing areas of Somaliland	40	773
August 2004	Cattle rearing areas of Puntland	21	701
February to March 2005	Bay, Bakool, Gedo, Middle Juba, Lower Juba	225	4,022
August to September 2005	Middle Shabelle, Lower Shabelle, Hiran	126	2,128
February 2006	Middle Juba, Lower Juba, western part of Bay region, Hiran, Middle Shabelle	PDS [(a)]	1,425
June to July 2006	Bay, Bakool, Gedo, Middle Juba, Lower Juba, Middle Shabelle, Lower Shabelle	477	8,098
August 2006	Lower Juba (warthog investigation with Kenya Wildlife Service)	5	33
March 2007	Middle Juba, Lower Juba	123	2,082
November 2007	Gedo, Middle Juba, Lower Juba	27	602
Total		**1,608**	**30,197**

PDS, participatory disease search – a purposive survey following rumours of disease

[(a)]Animals were sampled only if clinical signs of rinderpest were present and there was no predetermined number of sites in this case included Lower Juba, Middle Juba, Gedo, Bay and Bakool. The method used was the same as for the previous survey, except for the calculation of the between-cluster variance, which was estimated by region and was derived from the data collected in the 2002–2003 surveys. The three central regions (Middle Shabelle, Lower Shabelle and Hiran) were surveyed later in the year after the resumption of the flight service.

A PACE follow-up programme, the Somali Animal Health Services Project (SAHSP) conducted four other surveys for rinderpest during 2006 involving several regions in central and southern Somalia, such as Middle Juba, Lower Juba, Gedo, Bay, Bakool, Middle Shabelle, Lower Shabelle and Hiran. A consistent methodology was used so that the results could be compared with those of previous surveys.

Role of NGOs in animal health service delivery and rinderpest eradication

With the collapse of the Somali state in 1991, international and local NGOs and associations took on a prominent role in the delivery of animal health services and in supporting the eradication of rinderpest through vaccination, surveillance and capacity strengthening.

At the beginning of the major relief operation for Somalia, some international NGOs included an animal health component in the vast range of relief activities, while others gradually specialised in the animal health-related activities. One of the first NGOs to engage in veterinary-related relief and rehabilitation activities was ActionAid, in collaboration with VETAID, which started a project in Sanaag region in 1992. The initial aim of this project was to improve food security in Sanaag by establishing a primary animal health service based on a network of paraveterinarians. It participated in capacity-building and the provision of veterinary drugs. CARE International also implemented a veterinary service support programme between 1993 and 1994 in north-western and north-eastern Somalia. The programme supported emerging professional groups to establish veterinary pharmacies and provided training in business management. Towards the end of the emergency period (mid-1993), the European Commission began to coordinate the design and the funding of a more sustainable approach to delivering clinical veterinary services in the absence of a functioning public sector. At this time in many African countries, the privatisation of public services, including Veterinary Services, was being promoted as a means to increase efficiency and reduce public spending in the frame of the structural adjustment programmes of the World Bank. In consultation with international NGOs and spearheaded by ICRC, Somali veterinary professionals (working, where present, with local administrators) supported both the privatisation of curative services for livestock producers and the commercialisation of drug importation and distribution. The European Commission recruited a full-time technical adviser to monitor and coordinate activities funded by the Commission and developed an initial recovery strategy. In order to promote a common approach in the different areas of Somalia, Terra Nuova was initially tasked with the development of a training programme, which was to be implemented in cooperation with resident international NGOs (Fig. 2) and would facilitate coordination meetings to review field progress and devise new intervention strategies. Later, it was given the responsibility of implementing field activities in the Somali regions bordering Kenya.

With new evidence of the circulation of rinderpest in Kenya, Terra Nuova was further involved in rinderpest vaccination campaigns in the Somali regions bordering Kenya, using PARC resources and under the direct supervision of the AU-IBAR. Unfortunately, field activities had to be suspended twice because of the murder of a Kenyan veterinarian – Dr Manmohan Bhogal in Gedo region – and the kidnapping of an Italian veterinarian – Dr Stefan Sotgia – in Lower Juba region.

With the launch of the PACE initiative, the implementation of the Somali component was entrusted to a consortium composed of three international NGOs, each with a long experience in Somalia (Terra Nuova, UNA and Vétérinaires Sans Frontières (VSF) Suisse, and the community-based animal health and participatory epidemiology component (CAPE) of AU-IBAR. The consortium implemented activities in support of local administrations, the promotion of private Veterinary Services, the development of animal disease surveillance and information systems, and rinderpest eradication. The consortium received funding from PACE, the Italian and Swiss governments and CAPE.

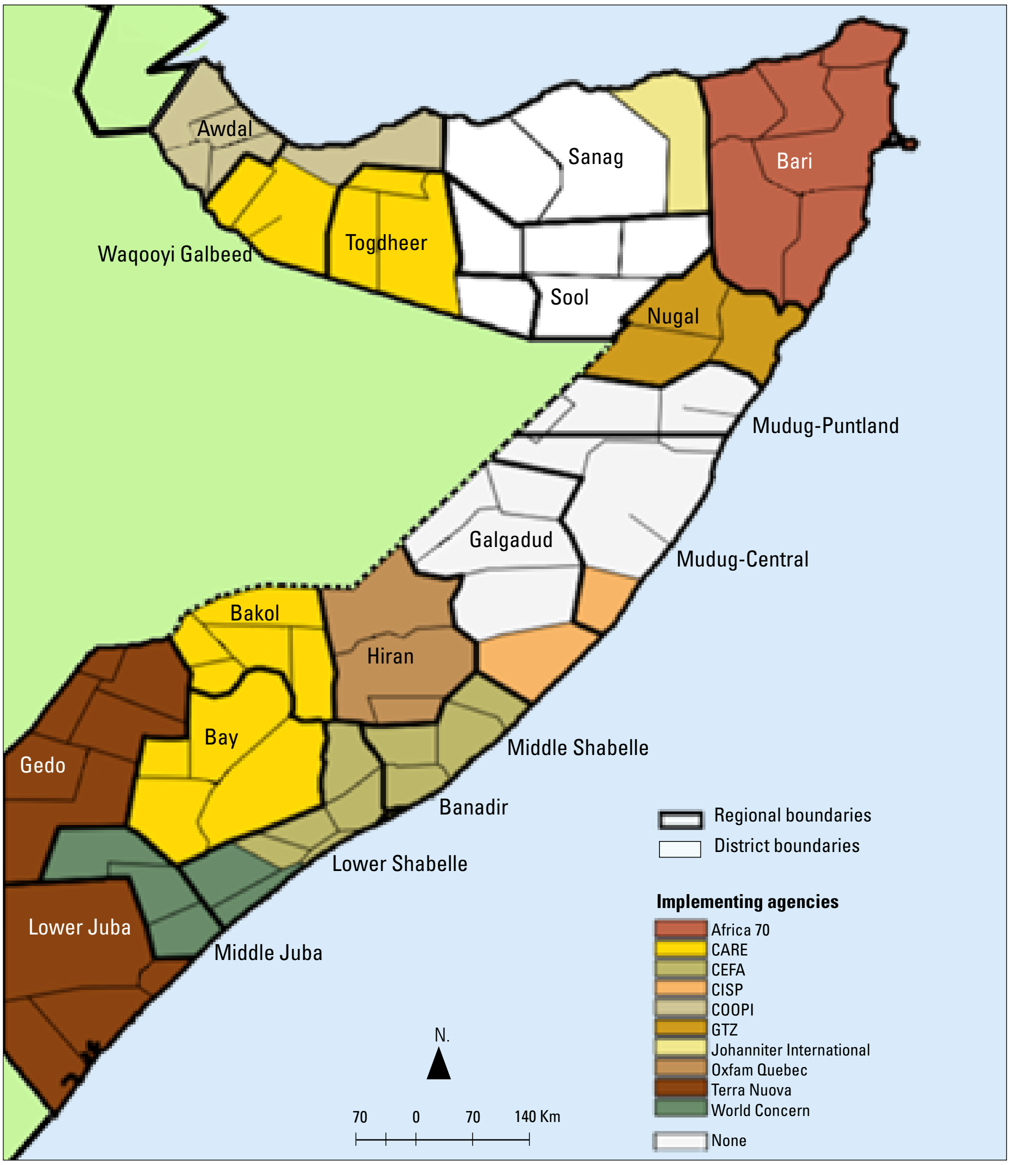
The work of international NGOs was greatly supported and in most cases made possible thanks to the cooperation of local veterinary associations, namely:

- the Puntland Livestock Professionals Association;
- the Central Regions Livestock Professionals Association;
- the South West Livestock Professionals Association;
- the Benadir Livestock Professionals Association in Mogadishu; and
- the United Livestock Professionals Association for Somaliland.

FIG. 2
GEOGRAPHICAL COVERAGE OF INTERNATIONAL NGOS IN THE SOMALI LIVESTOCK SECTOR

Implementing agencies involved in the private sector programme for Clinical Veterinary Services: coverage (1994-1996)

Source: Terra Nuova, ITP data



The five regional associations were coordinated by the Somali Livestock Professional Forum, whose core objectives were to give voice to and represent the interests of the Somali livestock industry at different levels and to help SVPs interact with local administrations. Regional associations were contracted to undertake surveillance for rinderpest and other priority diseases and ensure access to increasingly insecure areas of southern Somalia. The Somali PACE component provided support for management training for 42 executive committee members of the five regional livestock professional associations. Further support enabled the associations to hold annual general meetings. In addition, training and equipment were provided for 80 community-based animal health workers (CAHWs) in southern Somalia and 33 in Somaliland, to enhance the delivery of animal health services to pastoralists in remote areas.

SOUTH SUDAN

The elimination of rinderpest from South Sudan has been covered in detail in Chapter 3.9, so this section focuses on the role played by NGOs in that programme. South Sudan became independent from the Republic of Sudan in 2011, after rinderpest was eliminated, therefore we use the term southern Sudan in this section.

Prior to the signing of the Comprehensive Peace Agreement in 2005, the southern region of Sudan was afflicted by decades of civil war, during which the government Veterinary Services had limited access to most of the pastoralist areas because they were under the control of rebel groups and were far from major towns and passable roads. Rinderpest outbreaks were widespread in the vast grazing areas across the flood plains of the Nile and its tributaries, but rinderpest vaccination only reached areas adjacent to major towns. A major famine in the late 1980s led to the establishment of Operation Lifeline Sudan (OLS), a consortium of UN agencies and NGOs that delivered food aid and other humanitarian assistance to war-affected populations on both sides of the conflict in southern Sudan; support for water supply, sanitation, human health, education and household food security was also provided. UNICEF had recognised the important role played by cow's milk in food security and child nutrition, and it supported rinderpest vaccination to reduce the impact of rinderpest outbreaks on the cattle herds of the pastoralist and agro-pastoralist communities. Cattle vaccination against rinderpest was highly valued by livestock keepers, so UNICEF combined cattle vaccination activities with its extended programme of immunisation to increase vaccination coverage for the main childhood diseases. Rinderpest vaccination was conducted using a campaign style, with veterinarian- or veterinary assistant-led teams of vaccinators using a vaccine that required full cold chain and vehicular support. Vaccination coverage was therefore limited to more accessible areas.

Community-based animal health services and Operation Lifeline Sudan

In 1993 UNICEF OLS started a community-based livestock programme with technical support from a veterinarian, Tim Leyland. He brought his experience of community-based animal health services from Afghanistan and applied it in southern Sudan, conducting participatory rural appraisals to identify livestock keepers' problems and priorities and training livestock keepers to provide vaccination and basic treatments. He was joined by a second veterinarian, Darlington Akabwai, who had extensive experience of community-based animal health projects in northern Kenya. Tim and Darlington worked closely with local veterinary coordinators and some of the NGOs already present – Oxfam and Save the Children – to support them to set up similar activities in the areas in which they were working. In each area the livestock-keeping community selected some of their own members to be trained as CAHWs, to provide basic treatments, rinderpest vaccination, cold chain management and disease reporting. The CAHWs were able to move on foot with the cattle as they migrated in search of pasture and water, which worked well in an environment that was experiencing ongoing conflict (between north and south as well as between factions in the south), had little infrastructure or roads, and communication was possible only through high-frequency radio. In addition, a newly developed heat-stable rinderpest vaccine (1) was introduced, which allowed CAHWs to carry vaccine on foot to the cattle camps, greatly expanding vaccination coverage.

Over time, more NGOs joined the OLS livestock programme, each taking on a new area, to expand the coverage of community-based animal health services and rinderpest control. Each NGO was responsible for the activities in its own operational county or districts, including initial field assessments, community dialogue meetings, CAHW training courses, equipping and supporting CAHWs and local veterinary coordinators, and supporting vaccination campaigns and the response to disease outbreaks. The majority of the NGOs were coordinated by the UNICEF livestock programme, which provided coordination, leadership, technical advice and key inputs, such as rinderpest vaccine, vaccination equipment, sampling equipment and cold chain equipment. Some NGOs operated independently of OLS, but still voluntarily coordinated with the OLS livestock programme.

The NGOs and UNICEF worked closely with the local authorities and the humanitarian wings of the rebel movements at central and field levels to build the capacity of the local veterinary coordinators. Standard approaches were developed for conducting community dialogue, rinderpest vaccination and CAHW training, but NGOs were encouraged to innovate and adapt to suit the local context. Regular livestock programme coordination meetings brought together UNICEF, NGOs and veterinary coordinators, to share experiences and plan future activities, ensuring standardisation across different counties and districts and across areas supported by different NGOs, reducing conflict and confusion across the regions. Southern sector coordination meetings were held in Lokichokio, a small Kenyan town, close to the southern border of southern Sudan, to coordinate activities in the rebel-held areas of the south. Northern sector coordination meetings were held in Khartoum for organisations working in government-controlled areas of southern Sudan and neighbouring areas of central Sudan (the transition zone). A few representatives from UNICEF and NGOs from the southern sector attended the northern sector meetings, and a few Government of Sudan and NGO representatives from the northern sector attended southern sector meetings. This ensured sharing of information on rinderpest control and animal health service delivery from all parts of southern Sudan, in spite of the ongoing conflict.

Non-governmental organisations

Southern Sudan was a challenging place to work, and the NGOs, together with the communities that they worked with, faced many constraints, including insecurity, drought, floods, lack of transport and roads, and limited communication systems. This required the NGOs to be flexible, constantly adapting their plans and approach, withdrawing from the field when conditions interrupted activities but seizing windows of opportunity to continue activities. It was a constant challenge for NGOs to obtain funds to continue their projects and they were mainly operating with short-term (6–12 months) emergency funds provided by donors such as the United States Agency for International Development (USAID) Office of Foreign Disaster Assistance (OFDA) and ECHO, and often competed with each other to secure the limited available funds. Most were very committed to the communities they were working with and managed to maintain their field presence for many years, gaining valuable local knowledge and experience and building good relationships with the local communities and authorities. Some were specialist livestock NGOs, such as VSF Belgium, VSF Germany and VSF Suisse, and others implemented livestock projects as a component of a multisectoral programme, such as Oxfam and Save the Children. Up to 15 NGOs were involved in the southern sector (rebel-held areas) at any one time (Fig. 3), including:

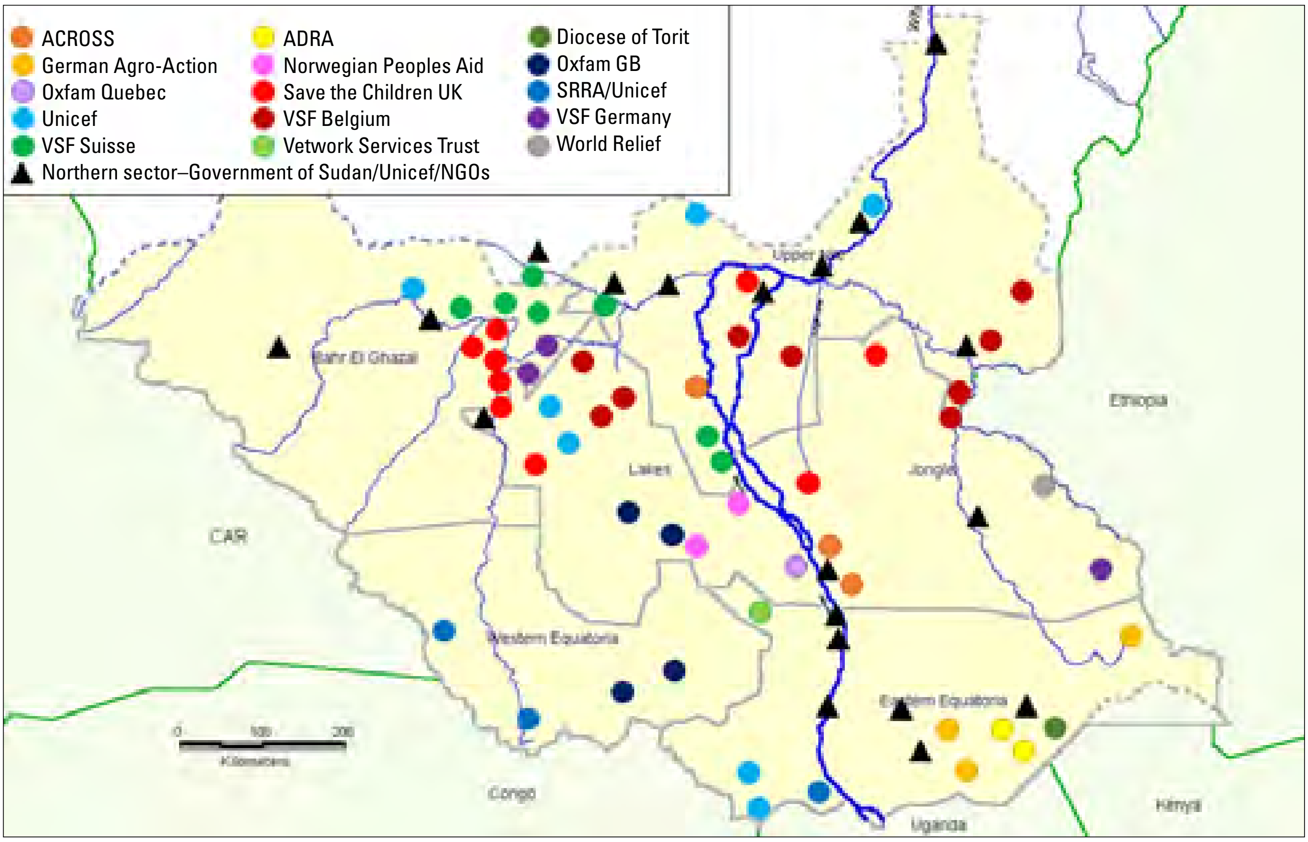
- the Agency for Co-operation and Research in Development;
- the Association of Christian Resource Organisations Serving Sudan;
- the Adventist Development and Relief Association;
- Care International;
- Cooperazione Internationale;
- the Diocese of Torit;
- Farm Africa;
- German Agro-Action;
- Naath Community Development Services;
- Norwegian People's Aid;
- Oxfam Great Britain (GB);

FIG. 3

FIELD LOCATIONS OF ORGANISATIONS SUPPORTING COMMUNITY-BASED ANIMAL HEALTH PROGRAMMES, 1999–2000

From these base locations, the community-based animal health programmes covered one or more payams or districts. Note that the western part of Bahr el Ghazal and Western Equatoria are infested with tsetse flies and have few cattle, so these areas were lower priority for interventions

Source: D-maps, 2020 (3), modified to indicate field locations



- Oxfam Quebec;
- Save the Children United Kingdom of Great Britain and Northern Ireland (SC-UK);
- VETAID;
- VSF Belgium;
- VSF Suisse;
- VSF Germany;
- the Vetwork Services Trust;
- World Relief;
- Zoa Refugee Care.

In the government-controlled areas of the south (northern sector), the following NGOs worked in partnership with government Veterinary Services to provide a similar community-based animal health service: ACCOMPLISH, Oxfam GB, Nile Milk Producers Cooperative Society and El Bir.

Through this network of NGOs, most of the accessible parts of the rebel-controlled areas were provided with basic animal health services, including rinderpest vaccination, vaccination for other priority diseases such as haemorrhagic septicaemia, anthrax, contagious bovine pleuropneumonia and blackquarter, and treatment of common diseases with anthelmintics, antibiotics and ectoparasiticides. The SC-UK veterinarian, Tim Fison, took the lead in establishing a basic veterinary laboratory in Lokichokio, Kenya, on the southern Sudan border. The laboratory received samples from all areas of southern Sudan and conducted parasitological examinations and brucellosis testing, and forwarded samples for virus testing, including rinderpest antibody and antigen testing, to Nairobi laboratories. VSF Belgium set up the Southern Sudan Animal Health Training Institute (SSAHTI) to train a mid-level cadre of animal health workers from all parts of southern Sudan, who became CAHW supervisors and local veterinary coordinators, thus embedding the management of livestock diseases in the communities in the south. SSAHTI was part of the OLS livestock programme and liaised with UNICEF, NGOs and the local authorities to determine training needs and select students for training.

Moving from rinderpest control to elimination

By the late 1990s there were about 1,500 active CAHWs and almost 200 veterinary coordinators. The number of rinderpest outbreaks had gradually reduced, with the last confirmed outbreak occurring in 1998, paving the way for ending vaccination by mid-2002 and moving into the final phase of eradication – a five-year period of surveillance from 2002 to 2007, to demonstrate freedom from rinderpest. FAO had now joined OLS and it took over the livestock programme from UNICEF in 2001. VSF Belgium was contracted by PACE to lead the rinderpest eradication phase within the OLS livestock programme.

VSF Belgium designed a surveillance system that could be implemented by the network of CAHWs, mid-level animal health workers and field veterinarians and that included components of outbreak reporting and investigation, clinical surveillance, participatory disease surveillance and serological surveillance. Supported by the VSF Belgium rinderpest project, all NGOs involved in the livestock programme integrated rinderpest eradication activities into their field projects: community awareness-raising, CAHW training, rinderpest surveillance and outbreak investigation. As part of demonstrating freedom from rinderpest infection, a serological survey was conducted in white-eared kob and buffaloes in Boma National Park by a team composed of VSF Belgium, VSF Germany, the PACE wildlife expert Richard Kock and the New Sudan Wildlife Conservation Organisation, assisted by the park warden, park rangers and local animal health workers. After the Comprehensive Peace Agreement in 2005, the South Sudan Ministry of Animal Resources and Fisheries (MARF) took responsibility for animal health services and VSF Belgium continued to support rinderpest surveillance but worked closely with MARF as they gradually built their capacity and took responsibility at regional and state levels. Data generated by this surveillance system were collated and submitted for incorporation into the Government of Sudan's applications to the World Organisation for Animal Health (OIE) for recognition of freedom from rinderpest disease (2005) and infection (2007) leading to the recognition of Sudan by the OIE as free from rinderpest infection in 2008. Without the NGO-supported community-based animal health service, the control of rinderpest through vaccination and the verification of elimination through surveillance would not have been achieved in southern Sudan, and it would have continued to be a source of rinderpest infection for northern Sudan and the neighbouring countries of Ethiopia, Kenya, Uganda, Democratic Republic of the Congo and Central African Republic, jeopardising the rinderpest eradication efforts in East Africa.

It was considered by some people to be controversial that an NGO, VSF Belgium, had been given the role of leading the rinderpest activities in southern Sudan, rather than a UN agency, but in hindsight this was an enlightened choice. Within a relatively small NGO with significant experience in southern Sudan, it was possible for the project team to maintain flexibility and respond rapidly to field needs, and decisions could be made locally so that personnel and resources could be mobilised for a rapid response to outbreak reports or to seize opportunities to access difficult areas. The project team had access to advice from the PACE epidemiology unit but could apply its knowledge and experience of the southern Sudan context to develop surveillance methods that were feasible and effective.

CONCLUSIONS

The NGO consortium was responsible for the vision to initiate the eradication of rinderpest in south Sudan when conventional authorities believed it was not possible. Further, for the most part, funding was of a short-term humanitarian nature and it was the NGO consortium that transformed these resources into one of the most important animal health development accomplishments ever attained. Specific funding for rinderpest eradication only became available at the end: without the NGOs' initiative, eradication would have failed.

The experiences we describe in Somalia and South Sudan during the rinderpest eradication programme are extremely relevant to other initiatives in the livestock sector to support food security or livelihood resilience. For any global disease control or eradication programme, there are likely to be a few countries in which it is impossible for conventional government-led Veterinary Services to conduct effective surveillance and disease control. However, even where there are major political or other constraints, it is still possible to devise ways of continuing to deliver basic animal health services, disease control and surveillance to meet local, national and international priorities, by taking time to understand the local context in which communities are continuing to keep their livestock under the prevailing conditions, building the capacity of the livestock keepers and local animal health personnel and providing them with the necessary support to conduct their work, and by working through NGOs or private veterinarians.

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PART 6
GLOBAL COORDINATION

CHAPTERS

CHAPTER 6.1

GLOBAL RINDERPEST ERADICATION PROGRAMME (GREP)

P.L. ROEDER [(1)*], F. NJEUMI [(2)] & K.J. WOJCIECHOWSKI [(3)]

(1) Hollyhedge Cottage, Spats Lane, Headley Down, Hampshire GU35 8SY, United Kingdom (Former Secretary of the Global Rinderpest Eradication Programme, Food and Agriculture Organization of the United Nations [FAO], Rome), Italy
(2) Animal Production and Health Division, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
(3) 6 The Village Gate, Dalkey, Co. Dublin, Ireland

*Corresponding author: peter.roeder@taurusah.com

SUMMARY **The Global Rinderpest Eradication Programme (GREP) refers to the sum total of all efforts aimed at the eradication of rinderpest from Europe, Asia and Africa. Leadership was provided by the GREP Secretariat, hosted by the Food and Agriculture Organization of the United Nations (FAO) in partnership with the World Organisation for Animal Health (OIE). GREP was designed as a programme to be implemented through three national and regional control campaigns, two in Asia and one in Africa. GREP was initiated in 1994 and success came quickly because of national dedication to the outcome, coordination between countries, global and regional leadership, innovative developments in surveillance and control, and having a defined pathway to follow towards accreditation of freedom from rinderpest. By 2002 it was recognised that rinderpest had ceased to occur in its natural hosts (i.e. outside laboratories). This chapter addresses the story of GREP in three phases: immediately prior to the GREP launch in 1994; eradication of rinderpest disease and embarkation on freedom from disease verification (1994 to 2007); and, the final phase of GREP, verification of freedom from infection (2007 to 2011). Once verification of freedom from infection had been achieved in 2010, this enabled FAO to announce the cessation of field programmes and, with OIE, to declare that the world was free from rinderpest. Efforts continue to ensure that all stocks of rinderpest virus, both wild and vaccinal, are accounted for and sequestered safely. Vigilance continues to ensure that outbreaks of disease that present a suspicion of rinderpest are investigated.**

KEYWORDS **Eradication – FAO – Food and Agriculture Organization of the United Nations – OIE – Partnerships – Rinderpest – Surveillance – World Organisation for Animal Health.**

INTRODUCTION

The fight against rinderpest was conducted over several centuries across Europe, Asia and Africa. Control of rinderpest was the major preoccupation for the official Veterinary Services of African and Asian countries during the 20th century. The concepts of progressive control and eradication were late developments, however, being conceived and promoted only from the mid-20th century. The speed of progress varied across different regions, but cumulative actions prepared the platform from which rinderpest eradication could be launched. A dramatic resurgence of rinderpest in Sahelian and sub-Sahelian Africa in the 1980s could not be contained by the veterinary authorities because financial and physical resources were lacking. Combined with a recognition that rinderpest outbreaks were still occurring in eastern Africa, this led to the birth of both the Pan-African Rinderpest Campaign (PARC) and ultimately the Global Rinderpest Eradication Programme (GREP). The havoc being experienced as a result of this pandemic caused grave concern both to the countries dependent on livestock agriculture and to international agencies engaged in aid and development assistance. It was the international effort from 1992 onwards that saw real progress as a result of an initiative by the Food and Agriculture Organization of the United Nations (FAO), the European Commission (EC) and the Organization of African Unity Inter-African Bureau for Animal Resources (OAU-IBAR), now the African Union Interafrican Bureau for Animal Resources (AU-IBAR). After extensive consultation and discussion, it was agreed that there should be another special programme for rinderpest control in Africa and that FAO should take the initiative to develop a broader programme. With endorsement from Dr Jacques Diouf after his election as FAO Director-General, these efforts culminated in the FAO GREP. However, it should be understood that, overall, the term GREP, as used in this document, is intended to represent the sum total of all efforts aimed at eradicating rinderpest. Once GREP had been conceived and implemented, progressive control of rinderpest was sustained.

Two sets of issues were critical to progressing rinderpest eradication. The technical considerations such as vaccines, diagnostic methodology and disease epidemiology were critically important but no more so than the practical step-by-step guidelines that provided the structure within which the progressive control of rinderpest could proceed to accreditation of global freedom. It was having the conviction that rinderpest eradication was feasible, and developing the vision of how to proceed, that motivated the eradication process and ensured its eventual success.

This chapter will summarise the approach taken from immediately before GREP became functional in 1994 until verified eradication was achieved and proclaimed internationally in 2011. Space is too short to allow for a full description of rinderpest in recent history, but detailed accounts are available to consult (1, 2, 3). Similarly, there is insufficient space to describe fully the multitude of meetings convened and projects implemented in the run-up to GREP; a brief indication here will have to suffice.

THE PERIOD IMMEDIATELY PRECEDING THE GLOBAL RINDERPEST ERADICATION PROGRAMME (UP TO 1994)

FAO was heavily involved in rinderpest control from its start in 1948; indeed it was a prime reason for its founding. Much of this involvement concerned vaccine development and emergency responses to rinderpest epidemics. In the decade before GREP started, FAO used its regular programme funds through Technical Cooperation Programme (TCP) projects and trust fund projects funded by Members to implement many projects relating to emergency control of outbreaks, capacity development and preparation of campaigns in a future global programme. This is illustrated by the response to emergency calls from Members in Africa for help to contain the second great rinderpest pandemic in the mid-1980s. FAO provided US$11 million for 62 national projects in 30 countries for the cost of vaccines, vaccination equipment and campaign logistics. Nineteen regional projects were mounted dealing with the preparation of PARC, capacity development for diagnosis, vaccine production and quality control, serosurveillance communication, equipment maintenance, legislation and coordination. Projects were implemented jointly with the OAU-IBAR (now the AU-IBAR) and complemented other emergency action funded by the European Economic Community (now the European Union) and other donors. FAO continued to be active in supporting the advancement of rinderpest control in other regions. For example, the establishment of a central veterinary laboratory in Tando Jam, Pakistan, was a project implemented in two phases from 1986 to 1994. Situated in a province plagued by rinderpest in its buffalo dairy colonies, this disease was the major focus of its attention. Projects for rinderpest control were also provided for Turkey between 1984 and 1991. An expert consultation on rinderpest diagnosis, vaccine production and quality control was convened in 1984.

The Global Rinderpest Eradication Programme concept and its evolution

A global strategy was the subject of an expert consultation for control and eradication of rinderpest held in Rome in 1987. The contemporary rinderpest control strategy invoked pulsed, area-wide mass vaccination over a period of three years and containment vaccinations with buffer zones, usually along national borders, maintained over an indefinite period. As in earlier rinderpest control programme planning, it is clear in retrospect that there was too much reliance on laboratories, vaccines, pulsed vaccination campaigns and diagnostics, and that insufficient attention was paid to the epidemiology of the virus. Although it had been mooted as a concept as long ago as 1949 (4), eradication, rather than control, did not feature strongly as a concept, nor was it understood how it was to be demonstrated that eradication had been achieved. Leading up to the FAO expert consultation on the strategy for rinderpest eradication in 1992, FAO commissioned an independent study, led by Gordon Scott and Alain Provost, to review the status of rinderpest control and propose a mechanism for future action. The meeting recommended a programme, rather than a campaign approach, with operational arms in countries and in regional organisations and suggested that eradication could be achieved within 20 years.

In 1993, in recognition of the lack of a mechanism to determine freedom from disease/infection, FAO and the World Organisation for Animal Health (OIE) convened a group to consider how best to provide guidance to countries participating in the proposed GREP. The outcome was to be the 'OIE Pathway' (see Chapter 7.1), which outlined a progression from an initial self-declaration of provisional freedom from disease with cessation of vaccination to the OIE-accredited stages of freedom from disease and freedom from infection. Combined with the concept that GREP was to be a time-limited exercise with a finite life span ending in 2010, this set the scene for eradication.

FAO understood that its role in GREP was largely to promote the eradication of rinderpest through the FAO Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES) by providing leadership and guidance. Examples of activities that were undertaken included:

- convening annual EMPRES/GREP international technical and expert consultations to monitor progress towards eradication and to guide strategy development and implementation;
- establishing the World Reference Laboratory for Rinderpest at the UK Animal Virus Research Institute, Pirbright (now the Pirbright Institute), to conduct molecular epidemiological studies and develop diagnostic tests;
- establishing and managing the Pan-African Veterinary Vaccine Centre to provide quality assurance of rinderpest vaccines and standard operating procedures for vaccine production (see Chapter 5.6);
- commissioning and undertaking epidemiological studies to define rinderpest distribution and monitor progress towards eradication;
- participating in and contributing to the OIE's *Ad hoc* Group for accreditation of rinderpest freedom;
- helping to formulate the chapter on rinderpest and related chapters of the *Terrestrial Animal Health Code* (OIE *Terrestrial Code*) and the *Manual of Standards for Diagnostic and Vaccines* (OIE *Terrestrial Manual*).

Thus, GREP was designed from the outset as a programme providing advice and guidelines rather than as a campaign undertaking the control measures itself. One of its most valuable attributes was that it was a time-bound programme with a deadline of 2010 to achieve accredited global freedom. The concept had developed that rinderpest control should proceed with international coordination on three fronts: the Pan-African Rinderpest Campaign in Africa (see Chapter 4.2), the West Asia Rinderpest Eradication Campaign (WAREC; see Chapter 4.10), and the South Asia Rinderpest Eradication Campaign (SAREC; see Chapter 4.13). The geographical range of these campaigns is illustrated in Figure 1. These were to be independent campaigns with only minimal involvement of FAO in field activities. The international community was expected to fund the campaigns, usually with fairly nominal national contributions, and regional organisations would coordinate implementation at country level.

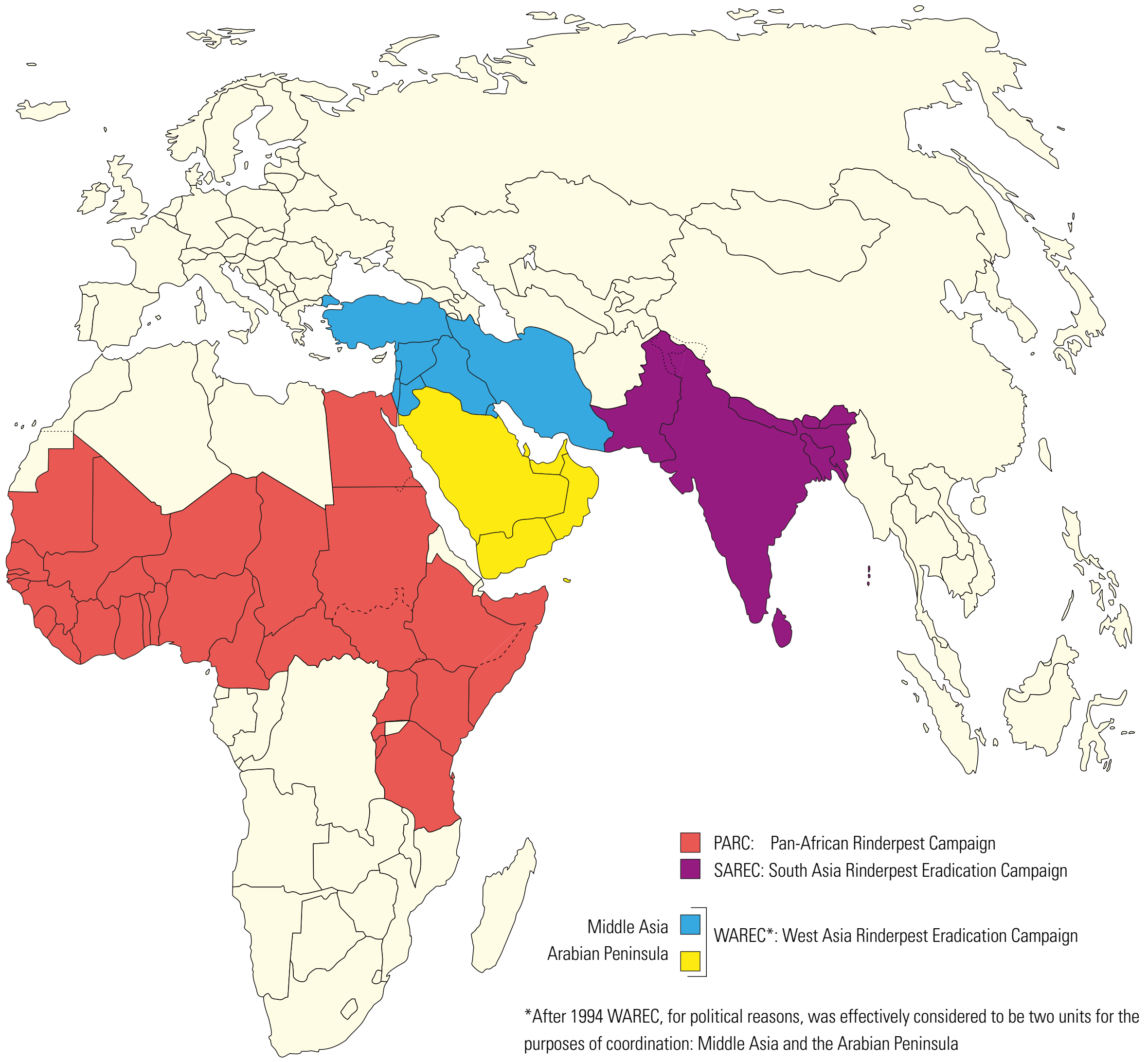
PARC was initiated in 1986 and was implemented under the auspices of the OAU-IBAR with funding from the EC and national authorities and with significant additional funding from the Governments of Sweden, Japan, United Kingdom of Great Britain and Northern Ireland, France and United States of America (USA), FAO, the World Bank and the International Atomic Energy Agency (IAEA). PARC operated through to 1998 when, after a short hiatus in funding, it was superseded in 1999 by the Pan-African Control of Epizootics programme (PACE; see Chapter 4.3), again primarily EU-funded. This continued until 2006, after which a small funding provision supported the Somali Ecosystem Rinderpest Eradication Coordination Unit (SERECU; see Chapter 4.4), which continued to oversee verification of rinderpest freedom in the Somali pastoral ecosystem in East Africa until 2010.

The West Asia Rinderpest Eradication Campaign was proposed in 1986 as an extension of the Middle and Near East Regional Animal Production and Health Project (MINEADEP; see Chapter 4.9), which itself followed on from the Near East Animal Production and Health Centre (NEADEC; see Chapter 4.8) within the envelope of the Near East Animal Health Institutes (NEAHI; see Chapter 4.7), both of which had a major focus

FIG. 1
THE CAMPAIGNS ENVISAGED TO DELIVER THE ERADICATION OF RINDERPEST

The West Asia Rinderpest Eradication Campaign (WAREC) did not function as a single entity, which is why it is shown here as combining two elements: the Middle Asia and the Arabian Peninsula components

Source: D-maps, 2020 (19), modified to indicate campaigns using FAO GREP data. Final boundary between the Sudan and South Sudan has not yet been determined. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties



on rinderpest control. WAREC was implemented using United Nations Development Programme (UNDP) funding and brought a degree of coordination to the Middle East from 1989 to 1994 until the Gulf War caused its collapse.

The South Asia Rinderpest Eradication Campaign, proposed in 1984, was never implemented, although FAO spent a great deal of time and resources trying, unsuccessfully, to achieve agreement between the South Asian countries and the EC, the potential donor, to formulate and implement a programme under the leadership of the South Asian Association for Regional Cooperation (SAARC). Although this ultimately failed, the EC subsequently funded a number of national projects in India, Bangladesh, Nepal and Pakistan that contributed significantly to the eradication of rinderpest in South Asia. India had prior ownership of two robust national rinderpest control programmes: the National Rinderpest Eradication Programme, which ran from 1956 to 1984, and Operation Rinderpest Zero, running from to 1985 to 1990. Supplemented by an EU investment budget, a third programme, the National Project for Rinderpest Eradication, began in 1990 and was active until 1996 (see Chapter 4.13.4).

From the mid-1980s, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture's

Animal Production and Health Section provided technical guidance and assistance. The activities of the Joint Division aided significantly in the development and adoption of laboratory technology such as the monoclonal antibody-based competitive enzyme-linked immunosorbent assay (c-ELISA; see Chapter 3.3) for rinderpest antibodies through TCPs feeding into regional laboratory networks (see Chapter 6.3). The latter brought together laboratory workers and those responsible for rinderpest control and were virtually the only means of promoting understanding, motivation and a common technical approach. Initially, an emphasis was placed on the use of serological testing for monitoring vaccination programmes. Later, the expertise developed proved to be invaluable for conducting serological surveillance, together with other surveillance techniques, for the accreditation of rinderpest freedom. The work in Africa was initially done with the OAU-IBAR and continued as a PACE activity until 2004, funded by the EC through FAO. A matching network established in West Asia provided a technical support base, invaluable fora for information exchange, and the coordination of technology transfer to participating countries.

ERADICATION OF RINDERPEST DISEASE AND EMBARKING ON VERIFICATION OF FREEDOM (1994 TO 2007)

Funding

The funds provided directly to FAO for GREP were very limited, in keeping with the original concept of GREP as a coordination mechanism rather than pursuing an executive campaign-style approach. Only relatively late was it realised that strict adherence to the original GREP concept meant that there was no guidance or assistance provided for regions such as Central Asia, China and the Russian Federation, where help was required to finalise rinderpest eradication and provide assurance of eradication. There were a number of other gaps in the national and regional programmes that had to be addressed, and it fell to FAO GREP to take this on directly by implementing programmes in places such as southern Sudan, Afghanistan and Yemen. Sometimes this was done in anticipation of internationally funded programmes coming on line, such as in Bangladesh, Nepal and Pakistan, where there was a need for urgent actions to sustain GREP by conducting epidemiological studies and helping to mount control programmes. Although going against its advisory mandate, the GREP Secretariat's operation of rinderpest control and surveillance programmes in key countries such as Turkey, Iraq, the Islamic Republic of Iran, Pakistan, Sudan, the United Republic of Tanzania, Kenya and Yemen contributed greatly to the success of the global programme and the verification of rinderpest freedom. The programmes were conducted with a combination of FAO TCP funding and donor trust funds, which were primarily from the EC and the USA. By incorporating rinderpest control into humanitarian aid programmes, such as those in Sudan (Operation Lifeline Sudan), Iraq (United Nations Oil-for-Food Programme) and Afghanistan, the programmes were linked to supportive FAO regular programme funding.

While Secretariat staff and funding were very limited, in all its work the GREP Secretariat was greatly aided by independent consultants and national teams. Resources were gleaned from whatever programmes were interested in funding activities contributing to rinderpest eradication. For example, the following were of special significance: in Sudan humanitarian aid programmes, overseen by FAO with other UN agencies, the EC and the United States (US) Government; and in Iraq the Oil-for-Food Programme, as well as programmes in Somalia and Afghanistan. GREP field activities were largely funded, where needed, by FAO TCP and trust fund projects that worked closely with national authorities, international agencies and non-governmental organisations (NGOs). The Irish Government's modest, but nonetheless valuable, direct funding for a number of years was particularly valuable for preparing promotional material, such as posters, flyers and videos, and for organising field activities.

In Africa, a succession of EC-funded programmes comprising emergency funding and the PARC/PACE programmes supported the national efforts of some 38 countries to eliminate rinderpest and achieve international accreditation of freedom. In many places FAO provided support for unplanned activities, such as control of disease outbreaks, and for complementary programmes where there were gaps or unexpected delays in planned funding.

Funding for this was derived from numerous different sources, and many activities were included in programmes not explicitly designed for rinderpest control, for example household food security, privatisation of Veterinary Services and control of other diseases such as contagious bovine pleuropneumonia (CBPP) and African swine fever (ASF). It is difficult, if not impossible, to define precisely what sums were made available for rinderpest control and eradication and the total cost of rinderpest eradication. Despite this constraint, there have been a number of attempts made, retrospectively, to assess the costs and benefits (see, for example, 2, 5, 6).

The technical approach

The most important task that the Secretariat had to undertake at the inception of GREP was to determine the extent of rinderpest infection in the world and the determinants of its persistence and spread. The rinderpest status of countries in the Middle East and the rest of Asia was far from clear. It was a similar situation even in Africa, which had received the most attention. Working closely with national authorities, the OAU-IBAR, through its PARC, and international agencies worked on a comprehensive understanding of rinderpest distribution. In this the GREP Secretariat were greatly aided by independent consultants and national teams, for example in the Islamic Republic of Iran, Pakistan and Central Asia. Molecular characterisation of rinderpest viruses performed at the Animal Virus Research Institute Pirbright laboratory (currently the Pirbright Institute), designated by FAO as the World Reference Laboratory for Rinderpest, helped to resolve some of the uncertainties. Molecular epidemiology provided an understanding of the relationship between reservoirs of infection and outbreaks. Although the number of viruses available for molecular characterisation was very limited, their typing demonstrated three extant clades (lineages), designated Africa lineage 1, African lineage 2 and the Asian lineage. It was also possible to discern relationships at the subclade level. This was of particular importance in Africa, where differentiation between viruses of clades 1 and 2 helped considerably in the identification of reservoirs of infection. An understanding of the distribution of rinderpest and the relationship between the reservoirs and outbreaks outside them provided a growing understanding of rinderpest epidemiology and enabled sound eradication strategies to be generated. This in turn led on to clarification of other issues such as the likelihood of virus survival in populations of different sizes and the periodicity of upsurges in rinderpest incidence using mathematical modelling (7). This helped considerably to make sense of what was happening in the field. Again this was of most value in determining the strategy for eastern Africa. For example, detection of rinderpest near Nairobi in Kenya in 1995 steered those involved in rinderpest control to believe that the virus must have derived from the most recent rinderpest viruses detected, which belonged to African lineage 1 in southern Sudan. Finding that the virus involved was in fact of African lineage 2 and related closely to wildlife viruses not seen for decades in eastern Africa presented an enigma that was only resolved when a rinderpest reservoir was confirmed in the Somali pastoral ecosystem of Kenya and Somalia. There had in fact been indications of persistent endemic mild rinderpest in Somalia well before its confirmation in 1996 but proof had been lacking. This finding was critical for elimination of this focus of infection (8).

Developments in the understanding of rinderpest epidemiology were incorporated into 'blueprints' detailing rinderpest status by country and region, essentially guided by the understanding of rinderpest reservoirs and the actions required to eliminate rinderpest from the reservoirs. These were presented and discussed at EMPRES GREP technical and expert consultations, and action plans were agreed from 1996 onwards (see, for example, 9).

By the EMPRES Fourth Expert Consultation (9) it was possible to recognise that rinderpest persisted as a number of discrete reservoirs of infection, in which the virus circulated uninterrupted (or had done so until recently) and from which the virus sometimes extended into neighbouring areas, aided largely by trade in cattle and buffaloes and warfare.

The areas where rinderpest was known or suspected to be present in the 1990s and 2000–2001, and the history of rinderpest in them (8), were:

1. An area comprising *western Ethiopia and southern Sudan* where cattle trading by the transhumant pastoral tribes (the Toposa/Iteso grouping) provided an opportunity for the virus to spread to western Ethiopia. Until 1996 this was linked to the virus in the Karamoja region of Uganda, from where it repeatedly spread to western Kenya by cattle rustling and trade. Another subreservoir was present in an area to the west of Lake Tana in Ethiopia. Viruses from here were closely related to each other within African lineage 1 and were linked to a slightly different virus present in the Afar region of north-eastern Ethiopia. Outbreaks of rinderpest in the southern Rift Valley of Ethiopia in the 1970s to 1990s were often related to a traditional system of heifer and plough oxen exchange between the Afar people and the residents of the Rift Valley (called *gudantu* in Amharic). Ethiopia eliminated the reservoirs of rinderpest infection between 1993 and 1995, and Uganda did so in 1996. The virus continued to circulate in the cattle of pastoralists in southern Sudan until 2001.
2. The area that came to be known as the *Somali pastoral ecosystem*, which comprised southern Somalia, north-eastern Kenya and the border area of southern Ethiopia was the most difficult of the reservoirs to understand because of the difficulty in accessing the migratory Somali livestock in a very insecure environment devoid

of a unifying government. Trade considerations constantly served to conceal the presence of disease, and serosurveillance was confounded by many factors. As a result, the rinderpest virus (African lineage 2) continued to migrate across the Kenya–Somalia border, sometimes penetrating well into the Rift Valley, until 2001, when it was last detected in buffaloes in Meru National Park (see Chapter 2.5), arguably for the last time.

3. In *the Arabian Peninsula and adjoining 'Kurdish triangle'*, which comprises Iraq, Turkey and the Islamic Republic of Iran, viruses of the Asian lineage were repeatedly reintroduced through trade from South Asia until 1996. Introduced into Iraq with cattle from as far away as India, the virus repeatedly spread westwards in Turkey, even extending into Thrace. The Islamic Republic of Iran suffered severely from rinderpest introduced into the west of the country from Iraq in the early 1990s. In Iraq the virus was last seen in 1996, when coordinated action was taken by the national authority and FAO, through the Oil-for-Food Programme, to remove foci of persisting infection in the marsh buffaloes of southern Iraq, the dairy buffalo colonies close to Baghdad, and feedlots in the northern governorates. In 1994, rinderpest was introduced into Oman from Pakistan via the United Arab Emirates through the importation of highly sought-after fighting bulls. In the recent past, Saudi Arabia had suffered several introductions through cattle traded from Yemen and through markets in the United Arab Emirates; the virus persisted until the mid-1990s in feedlots. The virus remained in Yemen until 1997 in remote hill communities in the south of the country. Elimination of the virus from India and Pakistan brought a halt to the spread of virus by the cattle trade, enabling the last foci of infection to be dealt with. Although only a few viruses are available in the database for the Arabian Peninsula, whole genome sequencing of viruses from the Islamic Republic of Iran, Iraq, Kuwait, Lebanon, Oman and two from Yemen clearly shows them to be derived from South Asia. Surprisingly, none of the viruses tested were seen to have been derived from Africa, despite the volume of trade in livestock between the two regions (10).
4. *India* had a long history of rinderpest virus epidemics, emanating from the southern part of the peninsula and spreading into the buffalo dairying areas in the centre and north of the country. Carried out under the EC-funded Indian Rinderpest Eradication Programme, epidemiological studies provided evidence that by the early 1990s the virus was restricted to small-scale village cattle breeding and trade associated with it. The virus was eliminated by 1995.
5. Although probably associated with India in the past, the recent rinderpest virus history in *Pakistan and Afghanistan* was independent. The pattern that emerged from studies conducted between 1996 and 1998 was that the virus was persisting in the buffalo dairy herds of the southern part of the Indus river, from where it spread through trade to cause slowly evolving point epidemics in the other areas of the country where buffalo dairying was practised, and even into Afghanistan. The situation in Afghanistan was recognised to be dependent on rinderpest introduced through livestock trade from Pakistan. Once this was understood, an intensive programme of rinderpest vaccine quality assurance, farmer and veterinary education, virus removal and intensive surveillance led to the recognition that the last cases of infection occurred in Sindh province in 2000.
6. After the Somali pastoral ecosystem, the most enigmatic rinderpest occurrence to resolve involved *the Russian Federation, China and Mongolia*. Outbreaks in Mongolia in 1993 and 1994 and in Amur region in the Russia Federation in 1998 led to a stalemate situation, where each of the countries considered the other two to be harbouring rinderpest. This situation was resolved when it was shown that the virus detected in affected cattle and that used to produce rinderpest attenuated vaccine (designated K37/70) were genetically very similar and suggested a linkage to the outbreak that started in 1998 in Georgia, then part of the Union of Soviet Socialist Republics (USSR). The vaccine, used for many years to vaccinate a protective buffer along the border of the USSR from China to Europe, had clearly reverted to virulence on several occasions. Once the vaccination programme ceased there were no further outbreaks (see Chapter 2.7).

At the time of the FAO Technical Consultation Meeting in 1999 it was possible to be confident that the rest of the world, outside these six areas, was free from rinderpest and had been for some time, indeed in some countries for decades. Accordingly, a decision was taken to embark on an intensified eradication programme for five years from 1999 to 2003, with specific actions designed to define and eliminate the remaining reservoirs of infection as had been done in Ethiopia.

Working closely with national authorities in affected countries, the programme was remarkably successful. In retrospect it is clear that the incident in 2001, when rinderpest was detected in buffaloes in the Meru National Park in Kenya, marked the global demise of rinderpest, although it took some time for this to be proven and generally accepted. The focus of GREP attention then became not the eradication of rinderpest virus but the verification of rinderpest freedom by surveillance, in accord with what was known as the OIE Pathway. During its evolution as the principal international standard-setting organisation, the OIE came to command an increasingly important role in GREP, by publishing guidelines such as those for surveillance and freedom accreditation in association with the rinderpest chapter in the *Terrestrial Code*, together with the diagnostic and vaccine standards contained in the *Terrestrial Manual* (see Chapter 3.3). At all stages of the process, the GREP Secretariat and Joint FAO/IAEA Division staff contributed to the formulation of technical guidelines and were active partners in the processes, just as the OIE contributed to GREP technical consultations organised by FAO. The OIE was also involved with FAO in PARC and PACE as members of steering committees and played an active role in guiding strategy decisions. As GREP evolved and the rinderpest freedom accreditation process became the predominant focus, the OIE assumed responsibility for providing guidelines for application and for policing the accreditation of countries through its Scientific Commission, aided by the establishment of the OIE *Ad hoc* Group on rinderpest.

Innovative tools for rinderpest surveillance and control

Several seminal advances in understanding added considerably to the effectiveness of rinderpest control and empowered eradication efforts in the following fields.

Vaccines and their delivery

Vaccination using the freeze-dried live cell culture-adapted rinderpest vaccine was the prime tool used to eliminate the virus from infected populations. Initially primary bovine kidney cells provided the substrate for vaccine production, but this was later changed to the Vero cell line to overcome problems encountered with adventitious virus infections. Finally, the vaccine was further improved by amending the freeze-drying protocol to produce a relatively thermostable vaccine (11). The freeze-dried vaccine greatly facilitated vaccine delivery to remote areas with high ambient temperatures.

The development of community-based animal health (CAH) programmes by NGOs under the aegis of the United Nations Children's Fund (UNICEF) and operating within Operation Lifeline Sudan improved considerably both the delivery of rinderpest vaccines to remote marginalised communities and the understanding of rinderpest epidemiology in them. An added advantage of this system was that the CAH workers made valuable inputs into disease surveillance and the understanding of rinderpest epidemiology in remote pastoral communities (12).

Serological testing

Initially an indirect ELISA test was used extensively for assessing the efficacy of vaccination programmes but, although sensitive, it suffered problems of specificity. This was overcome by developing a c-ELISA (13), which had a sensitivity of around 70% combined with a specificity of 99.5%. This test became the approved one for evaluating aged cohorts of cattle and water buffaloes for use in searching for rinderpest-infected populations and demonstrating absence of infection, once vaccination was withdrawn. Guidance for conducting serosurveillance using statistically significant sampling frames was prepared and disseminated by the Joint Division and the GREP Secretariat. Table I illustrates the contribution of serology to demonstrating freedom from rinderpest in Pakistan.

Detection of rinderpest virus

Between the 1960s and the 1980s a field diagnosis of rinderpest was based on the clinical and post-mortem signs presented. A confirmatory agar-gel immunodiffusion test was also popular with field veterinarians but sourcing reagents was always a problem. From the time that cell culture techniques became available in reference laboratories, virus isolation became the gold standard confirmatory test, employing either primary calf kidney cultures or Vero cells (14). The advent of molecular techniques for virus characterisation simplified laboratory diagnosis, although not without adding its own constraints when attempting to move the technology into national laboratories. Finally, it was the development of a monoclonal antibody-based immunocapture ELISA, available in kit form, that brought reliable testing to national laboratories. Diagnosis was further refined when affordable lateral flow immunochromatographic devices became affordable for use as 'penside tests'. Although not available until near the end of the eradication programme, these tests were

TABLE I
SEROSURVEILLANCE STUDIES UNDERTAKEN IN PAKISTAN FOR ACCREDITATION OF RINDERPEST FREEDOM

Province	Year					
	2003		2004/2005		2006	
	Tested	Positive (%)	Tested	Positive (%)	Tested	Positive (%)
Azad Jammu and Kashmir	760	0 (0)	2,394	1 (0)	2,960	0 (0)
Balochistan	1,000	7 (0.7)	6,101	13 (0.2)	6,960	2 (0)
Islamabad Capital Territory	507	2 (0.4)	452	2 (0.4)	1,000	0 (0)
Northern Areas	760	2 (0.3)	2,462	55 (2.2)	2,949	12 (0.4)
North-West Frontier	1,000	4 (0.4)	5,800	7 (0.1)	6,974	6 (0)
Punjab	2,107	4 ((0.2)	6,068	6 (0.1)	7,022	8 (0.1)
Sindh	2,455	13 (0.5)	5,939	16 (0.3)	8,000	23 (0.3)
Total	**8,589**	**32 (0.4)**	**29,216**	**100 (0.3)**	**35,865**	**51 (0.1)**

Sera were collected from each province in proportion to the livestock population. Guidelines to field staff were that sera from buffaloes and cattle were to be collected from animals over one year of age but less than three years of age and therefore unvaccinated because they had been born after the cessation of vaccination in 2000. The cohort was defined by dentition; ages of cattle and buffaloes were estimated according to very conservative estimates of tooth eruption. When clusters of seropositive animals were detected, these were followed up by village visits to ascertain if there was any suspicion of disease in the source population. These investigations were always negative. For example, the seropositive rate of 2.2% in the Northern Areas in the 2004/2005 sample was shown to have resulted from the illicit use of rinderpest vaccine after the ban had been put in place

nevertheless of great value in Pakistan and to a lesser extent in Sudan.

Surveillance

Participatory disease surveillance (PDS) was developed in support of rinderpest eradication primarily in eastern Africa. Later, because it proved to be such a useful tool, its use was extended to very good effect across the countries in GREP undertaking freedom accreditation (15) from the Middle East to Central Asia (Fig. 2). It proved of particular value in Pakistan; Table II illustrates the scope of the disease searching by PDS undertaken there.

FIG. 2
A VILLAGE INTERVIEW CONDUCTED IN TAJIKISTAN TO DEFINE THE KNOWLEDGE AND IMPACT OF THE MAJOR LIVESTOCK DISEASES, INCLUDING RINDERPEST
Courtesy of the authors

Eradication strategy

In Ethiopia a pattern of rinderpest persistence in discrete reservoirs, and the expansion of epidemics from these reservoirs, was established by careful field studies (3). This understanding was used as the basis for developing a novel eradication strategy that relied on surveillance and epidemiological analysis to define areas of rinderpest persistence and the focusing on them of intensive vaccination over a short period. The intention was to vaccinate as close to 100% of the population in the shortest possible time and then to withdraw vaccine completely, while being vigilant for any resurgence of infection. This approach proved to be extremely successful; within three years the Ethiopian foci of infection were eliminated. These tactics were therefore applied in other sectors.

THE FINAL PHASE OF THE GLOBAL RINDERPEST ERADICATION PROGRAMME: VERIFICATION OF FREEDOM FROM INFECTION (2007 TO 2011)

The basis of verification of freedom from infection

FAO GREP supported strongly the verification of freedom from rinderpest by encouraging and assisting countries to adhere to the OIE Pathway. Refined over time, this required each country to assemble convincing

TABLE II
NUMBERS OF VILLAGES IN PAKISTAN IN WHICH RINDERPEST SEARCHING WAS UNDERTAKEN USING PARTICIPATORY DISEASE SURVEILLANCE

Province	Year				Total
	2003	2004	2005	2006	
Azad Jammu and Kashmir	203	451	329	100	1,083
Balochistan	174	309	159	246	888
Islamabad Capital Territory	13	30	15	52	110
Northern Areas	127	596	0	100	823
North-West Frontier	285	415	380	248	1,328
Punjab	659	1,385	579	350	2,973
Sindh	793	1,214	730	405	3,142
Total	**2,354**	**4,400**	**2,192**	**1,401**	**10,347**

Teams of veterinarians, both men and women, were trained in the participatory disease surveillance philosophy and techniques. The total number of villages searched by conducting interviews with livestock owners in the four years of the study amounted to 20.5% of the total number of villages in the country. No indication of the presence of rinderpest was disclosed prior to the year 2000. Accessing the farmers' knowledge and memory of their experience of rinderpest provided very reliable assurance of the absence of rinderpest

surveillance data into a dossier for submission to OIE. There were three key technical areas that came to be the mainstay of the surveillance techniques that were used as evidence for rinderpest freedom:

1. an assured and effective disease reporting system to show the absence of reports of clinical disease;
2. serosurveillance data from randomly conducted surveys that provided clear evidence of freedom from infection, performed in accordance with guidelines;
3. evidence from PDS using enhanced village search techniques to demonstrate the absence of disease.

FAO consultative meetings 2007, 2009, 2010 and 2011

As the follow-up of the 2007 OIE General Session and with a view to consolidating achievements to date and preparing recommendations for the future, GREP organised a workshop at FAO headquarters in September 2007 with the following objectives:

1. provide an update on the status of rinderpest disease verification or absence;
2. discuss the modalities for drafting a global declaration;
3. identify the role of each actor in the global declaration process;
4. agree on a work plan and memorandum of understanding between FAO and the OIE.

The meeting concluded that, whereas the eradication of rinderpest had been proposed as a time-bound programme to be completed by 2010, a mechanism was needed to facilitate the joint activities of the two world bodies concerned with animal health (FAO and the OIE). The recommendations requested FAO and the OIE to agree on the mechanism for making a global announcement that the world was free from rinderpest due to the success of GREP. The same meeting also advised on the need for rinderpest virus sequestration activities to reduce the risk of environmental recontamination by the escape of rinderpest virus from research, diagnostic and vaccine manufacturing laboratories.

FIG. 3
PARTICIPANTS AT THE GLOBAL RINDERPEST ERADICATION PROGRAMME (GREP) EXPERT CONSULTATION, 2009

Seated left to right with backs to camera, F. Njeumi, J. Lubroth and Y. Ozawa. GREP Secretary Peter Roeder is mid table on right in dark jacket

Courtesy of the authors

In organising another GREP expert consultation meeting at FAO headquarters in 2009, entitled 'Will rinderpest virus ever die? What lies beyond 2010' (Fig. 3) (9), FAO requested the assembled experts to advise on:

- establishing procedures for the FAO/OIE Joint Declaration and recognition of the roles of major stakeholders;
- proposing mechanisms for the sequestration of rinderpest viruses held in diagnostic laboratories, research facilities and vaccine manufacturing units (including vaccine master seeds, samples from outbreaks and research materials);
- learning from the procedures undertaken by the World Health Organization (WHO) and World Health Assembly in promulgating the success of their smallpox eradication campaign;
- recognising the need for ongoing monitoring of other morbilliviruses of concern to food security, animal health and agricultural development.

It was considered neither necessary nor desirable to link the declaration of global freedom with the sequestration of viruses. The declaration of global freedom reflected the cessation of rinderpest circulation in its natural hosts, an issue separate from that of viruses being stored in laboratories. The experts requested both organisations to establish a body that would be tasked to review the accreditation process and advise if the world could be declared free from rinderpest.

Other GREP symposia were organised. The GREP 2010 symposium, 'Lessons learnt from the eradication of rinderpest for controlling other Transboundary Animal Diseases (TADs)', was held in conjunction with the FAO World Food Day 2010 (16). In line with the GREP deadline of 2010, the FAO Director-General stated in his World Food Day 2010 speech that **'FAO was concluding its field operations and expects to formally declare eradication by mid-2011 together with the OIE'**. GREP officially came to an end in October 2010. The recommendations of that symposium were as follows:

1. The success of the global eradication of rinderpest should be widely publicised and encompass:
   - the roles played by all stakeholders including livestock owners;
   - the benefits that eradication has brought and will continue to bring for individuals as well as the economy at large;
   - the lessons learnt during the eradication process and their potential application to other diseases including documenting of the process of eradication;
   - the post-eradication strategy including monitoring and sequestration of all stocks of virus.
2. International and regional organisations and all stakeholders should apply the lessons learnt from the eradication of rinderpest to other diseases, in particular the progressive control and eventual eradication of peste des petits ruminants (PPR). FAO should play a lead role in organising the preliminary steps necessary for initiating this global initiative and in identifying appropriate partnerships to drive and implement the activities required.

Between October 2010 and June 2011, the FAO GREP convened a series of meetings to celebrate the eradication of rinderpest and to consolidate the strategy for rinderpest surveillance and management in the post-eradication era. In order to collect stakeholders views on achievement and obligations, between May and June 2011, six regional workshops on 'The world without rinderpest' and 'Maintaining vigilance for diseases caused by morbilliviruses' were organised for Africa, the Middle East and Asia. The purpose of the workshops was to gather thoughts on lessons learnt and concerns about the global, regional and national post-eradication strategies for rinderpest, and to summarise these concerns for presentation to the global June 2011 symposium.

The last meeting on 'Achievements and obligations' was organised in June 2011 to coincide with the global declaration, in which the eradication of rinderpest was communicated to the international community (see Chapter 7.2). This also coincided with the 37th FAO conference, at which the representatives of FAO Members approved a resolution stating that rinderpest has been eradicated globally, as described elsewhere.

The OIE Pathway and assistance to countries with the accreditation process

As time passed after the last cases of rinderpest were detected in southern Sudan in 1998 (see Chapter 4.6.19) – suspected near Pibor in southern Sudan in 2001 (see Chapter 3.9) and confirmed from Kenya in 2001 – confidence started to grow that rinderpest had been eradicated. The focus of FAO GREP therefore turned to maintaining vigilance to ensure that events raising suspicion of rinderpest were investigated and to verifying global freedom from rinderpest, by helping the remaining countries to demonstrate that freedom. The OIE accreditation process was addressed by submitting convincing dossiers of surveillance data for consideration by the OIE *Ad hoc* Group on rinderpest and the Scientific Commission. For some important countries, such as Kazakhstan, Mongolia and the Russian Federation, this required FAO to work with the Joint FAO/IAEA Division in Vienna to provide financial and technical assistance.

The OIE Pathway served well as a template for countries to follow until 2007 when it became evident that rinderpest had indeed ceased to be present in its natural hosts everywhere, except, just possibly, in a mild form in the Somali pastoral ecosystem. However, based on recent experience and on the global epidemiological situation of the disease (with mild rinderpest in the Somali pastoral ecosystem) as well as the cessation of vaccination in most countries, the GREP Secretariat and the OAU-IBAR wished to refine the pathway. This request was taken into account in the adoption of a new *Terrestrial Code* rinderpest chapter and annex by the OIE General Session in May 2007, marking the start of the final thrust to achieve global rinderpest freedom accreditation by 2010. This simplified and accelerated the path to a global declaration of rinderpest freedom. For the purposes of the *Terrestrial Code*, countries that had still not been declared infection-free were grouped into three categories or 'rules' relating to their history of rinderpest presence and the use of rinderpest vaccines. Rule 1 referred to countries never affected by rinderpest, whereas Rule 2 applied to those where there had been no rinderpest nor rinderpest vaccination within the last 25 years. Rule 3 applied to countries that had experienced rinderpest within the last 25 years but not within the last ten years and had not used rinderpest vaccine within the last ten years. Rule 1 countries needed only to submit a declaration letter, while countries under both Rules 2 and 3 needed to submit a full dossier covering the preceding 25 years. For Rule 3 countries, the dossier had to be additionally supported by serological surveillance data. The country lists were continuously updated and used as working documents to follow the progress of rinderpest-free status recognition.

Towards the end, the process of country accreditation was impeded in a handful of countries by problems that had very little to do directly with rinderpest eradication. These related to such issues as the availability of funding for serological surveys and dossier preparation, national disinterest in validating rinderpest freedom, and the lack of OIE membership. However, assistance was provided for serological testing and dossier preparation, and diplomatic solutions were found to allow official recognition that the end point of global eradication had been achieved.

The countries and territories were assisted by the GREP Secretariat to prepare documents for OIE accreditation; FAO TCP funds and FAO trust funds were critical to this process. The project 'TCP/RAF/3202: Surveillance for accreditation for freedom from rinderpest in Africa' was implemented in Cameroon, Central African Republic, Chad, Djibouti, Kenya, the Niger and Nigeria to cover the lack of surveillance data at the end of PACE. During the active field surveillance carried out in these countries, more than 20,000 sera were collected from cattle and tested by the project. For the Central Asia region, comprising Afghanistan, Pakistan, Tajikistan, Turkmenistan and Uzbekistan, assistance for developing surveillance skills and conducting serosurveillance was made available through a pre-existing Italian trust fund project (FAO GTFS/INT/907/ITA: Controlling transboundary animal diseases in Central Asian countries).

The percentage of positive animals detected by the serological testing was within the range expected from the known test performance characteristics, thus confirming that there was no evidence that rinderpest virus had been circulating in these populations in the recent past and being in agreement with the absence of any suspicion of clinical disease. All participating countries submitted their country dossiers for evaluation of infection freedom and received OIE accreditation of rinderpest freedom in May 2010.

Eastern Africa was the most problematic region primarily because serological data at one time seemed to suggest that rinderpest virus was still circulating in the Somali pastoral ecosystem. As an accompaniment to PACE, IBAR had established a project called the Somali Ecosystem Rinderpest Eradication Coordination Unit (SERECU), which worked closely with national authorities, NGOs and FAO GREP from 2006 to 2010, to establish what the true situation was. SERECU was a partnership between IBAR, FAO and national governments, mandated to develop a harmonised and coordinated surveillance programme and a strategy for rinderpest eradication and to achieve 'freedom from rinderpest' in the Somali ecosystem. SERECU was funded by the EC, FAO GREP and the AU-IBAR (15). In addition to the technical assistance provided, FAO funded the bridging phase of SERECU between March 2007 and April 2008. FAO was also an implementing partner (jointly with three NGOs: Terra Nuova, Cooperazione Internazionale and a consortium of seven other NGOs associated with Una Terra Mondo di Tutti (UNA) in the Somali Animal Health Services Project phase II, during which the Somalia rinderpest eradication dossier was prepared and submitted to the OIE.

The SERECU strategy was to delineate endemic areas of rinderpest infection in which focused, intensive vaccination was to be applied to achieve immunosterilisation of the targeted population. In the absence of rinderpest endemicity, countries were to pursue rinderpest freedom accreditation following the OIE Pathway. FAO GREP commissioned a meta-analysis aimed at estimating the sensitivity of seven different components of the rinderpest surveillance system in Kenya, Somalia and Ethiopia, from 2004 to 2008, including passive disease reporting and serological surveillance of both livestock and wildlife, livestock market surveillance, participatory disease searching, and zero reporting systems. The study concluded that all components, except the wildlife sero logical surveys, were able to meet or greatly exceed the recommended standards for rinderpest surveillance sensitivity. Despite a variety of weaknesses due to gaps in the reporting pathway, the passive livestock disease reporting system provided the greatest ability to detect disease outbreaks at a low level, because of the high coverage of the population. The study found that by combining evidence over multiple time periods, the surveillance system generated a probability of greater than 99% that the three countries did not have a single infected herd. Uneven coverage of the population suggested that caution was warranted, but even in those parts of the population with lowest confidence (wildlife and central Somalia), the normally rapid spread of rinderpest in naive populations means that, after five years, its chance of remaining hidden was very low (16). From 2000 to 2008, a total of 157,025 sera were collected from cattle, sheep and goats in the Somali ecosystem – see Table III. A more detailed analysis of serological results from cattle is given in Table IV, which gives the percentage of rinderpest seropositive cattle in each sampling area (district or sampling site).

Elsewhere, FAO Irish trust funds and FAO regular funds assisted with the accreditation process as the need arose. Between 2007 and 2011, GREP with the assistance of OIE and partner institutions assisted a total of 104 countries and territories to present dossiers for accreditation (Table V).

In January 2011, the OIE *Ad hoc* Group on rinderpest evaluated the status of the last remaining countries and with this the process of reviewing the rinderpest freedom of all 198 relevant countries and territories (having susceptible animal populations) in the world was completed, only one year later than the date that FAO had aimed for from the start. In that year, it was announced by the OIE that rinderpest had been eliminated and by FAO that it was no longer present in its natural hosts.

Post-eradication activities for biosecurity

More than 40 national and international consultants were recruited to assist the Secretariat to write the rinderpest eradication national history as well as key guidelines for the future.

TABLE III
SEROSURVEILLANCE FOR RINDERPEST IN THE SOMALI PASTORAL ECOSYSTEM: NUMBERS OF LIVESTOCK SAMPLED BETWEEN 2000 AND 2008

The seroprevalence decreased from year to year. For example, in Somalia, initial seroprevalence studies showed a decreasing prevalence over time (Table IV). A cross-sectional survey carried out in 2002–2003 revealed an apparent seroprevalence of 18% and in the same area in 2009 it was 0.23% (16). The designations of high and low risk refer to imprecise areas and so are designated by virtue of their possible association with areas of perceived rinderpest persistence. High risk in Somalia refers to the area between the Juba river and the international borders with Kenya and Ethiopia. The high-risk areas in Kenya and Ethiopia are those bordering the high-risk area of Somalia

Country	Risk level	Species	2008	2007	2006	2005	2004	2003	2002	2001	2000
Kenya	High risk	Cattle	2,453	280	3,406	368	495	1,778	879	9,465	0
		Sheep	0	0	0	0	138	0	120	336	0
		Goat	0	0	0	0	377	0	150	116	0
	Low risk	Cattle	6,923	0	11,484	96	9,581	928	2,464	0	0
		Sheep	0	0	0	0	0	0	4	0	0
		Goat	0	0	0	0	0	0	6	0	0
Somalia	High risk	Cattle	5,319	2,160	3,599	3,599	1,440	2,879	3,599	720	720
	Low risk	Cattle	2,070	840	1,401	1,401	560	1,121	1,401	280	280
Ethiopia	High risk	Cattle	0	0	6,000	2,543	1,114	0	200	0	0
	Low risk	Cattle	0	1,219	8,435	8,800	10,424	2,280	11,680	12,260	6,834
		Total	**16,765**	**4,499**	**34,325**	**16,807**	**24,129**	**8,986**	**20,503**	**23,177**	**7,834**

TABLE IV
SEROLOGICAL RESULTS FOR CATTLE INDICATING THE PROPORTION OF RINDERPEST-POSITIVE ANIMALS AT EACH SITE, 2000–2006

This table brings together the results of numerous exercises to assess the immune status of cattle populations in southern Somalia and the adjoining border areas of Ethiopia and Kenya. Constraints to field exercises prevented standard protocols being applied. The data shown for Somalia were the reason for suspicion that rinderpest was persisting in the Somali pastoral ecosystem. The reason for the high seroprevalence in southern Somalia up to 2005 was never explained, although continuing illicit vaccination and incorrect application of sampling frame guidelines must be considered to be possibilities. Data provided by courtesy of the Organisation of African Unity Inter-African Bureau for Animal Resources, Pan African Programme for the Control of Epizootics (PACE) and the PACE projects in Ethiopia and Kenya, and the national authorities of Ethiopia and Kenya

Somalia district	2002 and/or 2003		2005		2006	
	Number tested	Positive (%)	Number tested	Positive (%)	Number tested	Positive (%)
Mudug	590	0	–	–	–	–
Galgadug	637	8 (1.3)	–	–	–	–
Hiran	810	39 (4.8)	847	0 (0)	847	4 (0.5)
Lower Shaballe	1,201	30 (2.5)	999	2 (0.2)	595	4 (0,7)
Middle Shaballe	1,189	8 (0.7)	265	0 (0)	653	3 (0.5)
Bakool	913	5 (0.6)	505	5 (1.0)	979	3 (0.3)
Bay	845	3 (0.4)	409	1 (0.2)	1,428	1 (0)
Lower Juba	1,203	207 (17.2)	1,170	20 (1.2)	1,462	17 (1.2)
Gedo	1,057	185 (17.5)	847	45 (5.3)	1,408	37 (2.6)
Middle Juba	1,261	202 (16.0)	982	38 (3.9)	510	15 (2.9)
Total	**8,479**	**679 (8.0)**	**6,024**	**11 (1.8)**	**7,882**	**84 (1.1)**
Southern Somalia [a]	–	–	–	–	2,136	13 (0.6)
Ethiopia						
Dolo Olo	–	–	2,503	2 (0.1)	6,116	4 (0.1)
Kenya						
Kenya (east) [a]	–	–	–	–	3,786	0 (0)
Kenya 'clean area' [a]	–	–	–	–	7,768	84 (1.1)
Kenya	–	–	–	–	1,972	2 (0.1)

The figures in red indicate results that were of particular concern

[a] Results from non-random purposive studies undertaken to check on earlier results

TABLE V
NUMBER OF COUNTRIES ACCREDITED AS RINDERPEST-FREE BY THE OIE IN EACH YEAR

Year	Number
2007	10
2008	40
2009	25
2010	22
2011	7

Jointly with partners, FAO GREP developed a global exit strategy that included the post-eradication disease management strategy, surveillance in high-risk ecosystems and the preparation of the rinderpest training manuals for final year veterinary schools in countries that had not experienced rinderpest but needed to be aware of the disease. The exit strategy was used to inform trade-sensitive projects, specifically in Africa. An International Rinderpest Contingency Plan (ICRP) was to be prepared and a manual focusing on rinderpest syndromic surveillance as well as risk-based surveillance was published.

To aid contingency planning for rinderpest's re-emergence, a letter of agreement was signed between FAO and the UK Royal Veterinary College in April 2011, to assess the risk of rinderpest reintroduction in the post-eradication era (17). Another agreement was signed with the Pirbright Institute, to analyse 20,000 sera collected in the Somali ecosystem for cross-analysis with national laboratory results and to review the Institute's support to GREP.

In early 2010, more than 800 questionnaires were sent to chief veterinary officers and heads of veterinary faculties/schools and laboratories in the GREP arena aiming to assess where materials containing rinderpest virus materials were being held. As a follow-up, a workshop on biosafety, sequestration and risk analysis for laboratories holding rinderpest virus was held in July 2011 at the National Veterinary Institute in Debre Zeit. It was attended by 23 representatives of 17 laboratories in Africa, Asia, Europe and North America that had stocks of rinderpest virus. The workshop made significant progress towards rinderpest risk reduction through increased national commitment to the destruction and sequestration of the virus.

The African Union Pan-African Veterinary Vaccine Centre (AU-PANVAC) laboratory's capacity in Debre Zeit, Ethiopia, was strengthened so that it could act as a secure rinderpest material repository. A total of 1.5 million doses of rinderpest vaccine were procured (for the global contingency plan) from the Laboratoire National Vétérinaire of Garoua (Cameroon) and the National Veterinary Institute of Debre Zeit. They were tested for quality and stored at AU-PANVAC for emergency use in case rinderpest resurged. A protocol for the transfer of rinderpest material from countries to AU-PANVAC and the management of biosecurity materials at AU/PANVAC, and a draft agreement for the ownership of the rinderpest virus-containing materials were developed. Activities to identify remaining virus stocks are continuing, while a formal framework for their sequestration is being prepared; FAO continues to monitor and respond to events that raise a suspicion of rinderpest (18).

CONCLUSION

Rinderpest was finally eradicated from the globe by 2002, and this was acknowledged formally in 2011. Undoubtedly, there were many reasons why rinderpest eradication was achievable, including the availability of a highly effective, safe and affordable vaccine, robust diagnostic tools and an innovative strategy based on epidemiological understanding and implemented with the benefit of strong leadership from FAO. These factors combined to enable countries, organisations and GREP to succeed in their aspiration of achieving global freedom from the dreaded cattle plague. That there has been no resurgence of rinderpest since the formal declaration of freedom, indeed not since the last case was detected in Kenya in 2001, is testimony to the robustness of the accreditation process followed. How eradication was achieved in the seven-year time frame after the formation of GREP is a subject of some debate, but there are certainly lessons to be learnt and applied to other eradication attempts. What was undertaken under GREP would, to a large degree, be applicable to the eradication of the related morbillivirus disease, peste des petits ruminants (PPR), and would provide lessons for other diseases.

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CHAPTER 6.2

COMMUNICATION STRATEGY AND AWARENESS MATERIALS TOWARDS RINDERPEST ERADICATION

F. NJEUMI [(1)*], R. BESSIN [(1)], L. KAMBIRIGI [(2)] & G. KHOURI [(1)]

(1) Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy
(2) 3 rue de la Station, C2 4430 ANS, Liège, Belgium

*Corresponding author: felix.njeumi@fao.org

SUMMARY **Without the comprehensive cooperation of all stakeholders, any animal disease control and/or eradication campaign will be more costly and take longer to complete or even fail entirely. Before the 1980s, rinderpest control activities did not consider communication as a tool for improving the implementation of field activities. Communication was an approach that helped stakeholders themselves realise the beneficial value of eradication, inviting them to join the process, increasing consensus and motivating them to take action. It created validity, momentum and a recognised brand for the effort. In general, communication on rinderpest was a sophisticated set of actions; it accelerated the achievement of vital objectives and increased the value of the activities it served for all parties. Several types of media or tools were used in implementing the communication strategy. Efforts to enhance communication hastened the process of disease eradication by helping to mitigate its social and economic impacts and challenges. The tools used were, among others, newsletters, posters, campaign logos, stickers, flags and banners, photographic displays of campaign activities, the occasional video and shortwave radio programme and a series of news releases, and when there was worthwhile news, a press conference for international broadcasters and journalists.**

KEYWORDS **Communication – Rinderpest – Strategy.**

INTRODUCTION

Eradicating rinderpest involved strong participation and engagement from all stakeholders, including government officials, scientists and other experts, livestock owners/keepers, traders, consumers and farmers. Efforts to enhance communication hastened the process by helping to mitigate the disease's social and economic impacts and challenges. Communication on rinderpest included sharing what was valuable in the control and eradication of the disease. It was a sophisticated set of actions; it accelerated the achievement of vital objectives and increased the value of the activities it served for all parties. This enabled people to commit to investing their time, effort – including developing large and small innovations – and money to do so. Communication includes knowing (and finding out) what is valuable to stakeholders so that the aim of the campaign is aligned with what they value (1). The communication approach itself – listening and informing, telling the story, adapting methods to local needs, supporting joint efforts – was key to simplifying the act of transferring information from one place to another. This could be through:

a) written communication (letters, e-mails, books, magazines, the Internet or via other media);
b) verbal and non-verbal communication (body language, gestures, how we dress or act, face-to-face discussion, telephone, radio or television and other media);
c) visualisation (graphs and charts, maps, logos and other visualisations can communicate messages).

For this purpose, training of veterinary officers took place, and communication units were established at global, continental, regional and national levels. To some extent, all of these (written, visual, verbal or non-verbal) methods were used when implementing the communication strategy.

THE OBJECTIVE OF THE COMMUNICATION STRATEGY FOR THE RINDERPEST ERADICATION CAMPAIGN

In the early 1960s when a major vaccination campaign started in Africa, effective means of communication were not always available. The communication was to impart or exchange information by speaking, writing or using some other medium. Communications took place at various levels: internationally, nationally, and between urban/town-based technical staff and rural livestock owners/keepers, for various important purposes. Many livestock owner/keepers were illiterate or living in remote areas. If not informed, the vaccination teams were forced to go back to the same areas several times to make sure that many animals were immunised. Without comprehensive cooperation from stakeholders, any animal control and/or disease eradication campaign would have been more costly and taken longer to complete or even failed entirely. Moreover, to ensure that such a campaign achieved sufficient momentum and priority at national and international levels because of the transboundary nature of rinderpest, it was highly important to increase the awareness of various organisations and the general public of what the campaign entailed and what it intended to achieve. Owing to the small number of veterinarians and the centralised approach in the livestock sector, the information flow between the livestock services and owners was limited to occasional top-down person-to-person communication. This happened especially when the veterinarians had the opportunity to visit rural areas and did not allow the much-needed bottom-up flow of information (1, 2).

A COMMUNICATION STRATEGY FOR THE RINDERPEST ERADICATION CAMPAIGN (ADAPTED FROM AU-IBAR PACE COMMUNICATION STRATEGY)

This section describes the objective, the targets and impact indicators and the key audience, messages and tools used. The objective of the communication strategy was to increase mutual understanding between all parties concerned: cattle owners, Veterinary Services, policy-makers, law enforcement agencies, educational institutions, the private sector, research bodies and other development partners. Through mutual understanding, there is increased awareness of and knowledge on motivating people to take action or to allow action to be taken by others. These actions range from field practices of livestock movement control and vaccination to setting up and investing in the human and material resources needed to perform the campaign. The strategy needed to communicate the value of the campaign as beneficial to stakeholders from their point of view. Moreover, the communication strategy (3) was also intended to promote policy reforms and international actions against rinderpest, as well as ensure the creation and dissemination of audio-visual material to a variety of decision-makers and the general public (Table I).

Specifically, the communication strategies and tools adopted sought to gain the cooperation of livestock owners regarding the vaccination, ear-punching and sero-sampling of cattle, and the reporting of suspected outbreaks. This, and in addition by informing and motivating field staff, served to ensure that the vaccine cold chain was maintained and that immunisation procedures were properly carried out. In addition, the capacities of Veterinary Services were strengthened to carry out communication activities through improved linkages with national media and educational and extension institutions. The communication strategy was intended to influence people's attitudes, behaviour and decisions. It also aimed to learn and share knowledge about the attitudes of cattle owners and other key groups of people. Knowledge about people's attitudes and needs helps to overcome serious obstacles (3, 4, 5).

According to Villet (4), by informing and motivating people, the communication strategy aimed to address five questions:

1. Why must we take action against rinderpest?
2. What will the immunisation campaign achieve for everyone?
3. Who will be directly affected by the programme?
4. How will the programme operate and what will be expected from people?

TABLE I
OUTLINE OF THE COMMUNICATION STRATEGY ADOPTED FOR THE RINDERPEST ERADICATION CAMPAIGN (ADAPTED FROM AFRICAN UNION INTERAFRICAN BUREAU FOR ANIMAL RESOURCES; PAN-AFRICAN PROGRAMME FOR THE CONTROL OF EPIZOOTICS [AU-IBAR PACE] COMMUNICATION STRATEGY)

	Knowledge/information management	Participatory communication management	Networking epidemio-surveillance and outcomes
Objective	Creating and sharing knowledge and know-how could be used in animal health services	The objectives were to ensure that methods (technology, innovations) are relevant and useful, to increase appreciation of their value and to motivate people to use them so that they could improve their lives and, in this case, eradicate a disease	The objective was to strengthen the epidemio-surveillance network through social and education communication – the outcome was better reporting and strategic intervention
Targeted impact	Technical capacity within the programme's long-term perspectives of sharing knowledge was augmented	Qualitative progress within the programme's development was guaranteed	There should be equity (upwards and downwards information flow) in information sharing between all participants in the epidemio-surveillance network
Impact indicators	Stability of information shared with partner organisations	The value of communication is improved inside Veterinary Services, including augmentation of budgets and improvement of equipment	Pilot projects were to be initiated in the short term; in the mid-term, guidelines and communication in epidemio-surveillance were to be established; information was to flow inside the network in the long term
Key audience	Subject matter peer group, young professional veterinarians, universities and institutions working in the field of animal health care, and also livestock owners, drug suppliers, consultants, human resources, development organisations	Communication officers, project coordinators, chief veterinary officers and other decision-makers in animal health programmes, public and private subject matter specialists, project beneficiaries	Community-based animal health workers, private veterinarians, governmental structures, non-governmental organisations and livestock owners/keepers – as regards outcomes, all stakeholder were involved
Technical message	Knowledge exchange in all matters of animal health care, from disease control to trade to economically viable and socially responsible animal products	Channelled through communication work sessions and planning workshops with national programmes	Participating in the epidemio-surveillance is improving animal health
Message development	Through inter-institutional knowledge management with partner institutions	Know-how in identification, research, planning and implementation of communication for animal health services Its methods are to learn from stakeholders, adapt what is being offered so that it is relevant to stakeholders, and engage with them to allow, advocate and sometimes themselves carry out the actions of the campaign	Through formative research, cross-cultural media production and pre-testing of promotional and communications material in different languages
Tools/ products	Electronic conferences, website in French and English, active mailing group, distance-learning programme, database, intranet, participation in and organisation of events in knowledge management, training programme for young professional veterinarians and students, online library and membership of electronic databases and networks	Workshops and workshop reports, communication strategy outline, communication work plans, field communication products	Case studies, exchange of local approaches to social mobilisation, field project documentation, project proposals, written and audiovisual communication tools

5. When and where will the programme take place?

Stakeholders were informed about the clinical signs and impact of rinderpest, when, where and by whom the immunisation campaign would be carried out and its role in protecting their animals. In addition to the vaccination, emphasis was given to the role that other components of disease management (e.g. surveillance) played and how the programme was operated and by whom. The list of major stakeholders was shared through different types of media.

TOOL KIT AND TYPES OF MEDIA USED AS PART OF THE COMMUNICATION STRATEGY

To get cooperation from livestock owner/keepers, police, veterinary para-professionals and others involved in the campaign, several types of media were used according to the audience (e.g. radio in Haoussa for Peuls in the Sahel zone or radio in Somali, which was preferable to anything in written form, as many were illiterate). Communication materials were made for direct use by field staff for dissemination in the rural areas where they worked

(2). Some of these materials, such as flipcharts, were durable and suitable for repeated use. Others were inexpensive enough to make in large quantities, meaning that even remote communities could receive copies.

Flipcharts

These were designed with the input of both field staff and rural people and were produced by local artists and printers using local materials. The flipcharts helped field staff and extension agents tell a story, explain a situation or explain a technique step by step. They were used best to create situations for dialogue, leading to improved relationships between veterinarian field staff and livestock owners/keepers, often with the latter telling the story themselves in group situations. Flipcharts were silk-screen printed on washable cloth and bound with wood and were able to withstand rain, dust and being knocked around in the field. Several benefits of flipcharts are that the large picture attracts attention; even illiterate people clearly see important ideas for discussion; discussions are relevant because the pictures show local people, animals and situations; both the problem and the solution can be seen; technical details can be examined; technical information is consistent; the presenter can check that each point has been understood by the audience; the whole story (or course of events over time) can be seen picture by picture in one short session; the story can be adapted to examine local situations to create a consensus for action; and the pictures of problems stimulate a search for solutions (2).

Posters

These were good for quickly raising awareness of people who work indoors, such as government staff, merchants and some community leaders. Poster messages were about the importance of the campaign, vital technical information, what to do if an outbreak occurs, the value of the ear notch and the danger of not cooperating with the campaign. Posters were used during the Pan-African Rinderpest Campaign (PARC) (2, 6) as well as in the Middle East and Pakistan.

Leaflets

These were used to show clinical signs of rinderpest and the need to report the disease. They were a valuable reminder about key technical points. With posters and leaflets, the campaign was more visible, dynamic and important; mass awareness of the campaign was achieved; campaign workers felt part of a national effort; technical information (such as disease symptoms, what to do if an outbreak occurs) was widely distributed in a consistent form; various communities were informed through the use of local language versions; field staff had an attractive and colourful gift to give to influential individuals and offices. On the practical side, posters and leaflets could be printed in large quantities and in local language versions without much additional expense (2, 6).

Extension scripts

These helped field staff and extension services outline the subjects that they should address when talking to cattle owners. It helped to ensure that information was presented consistently in the field.

Printed national dress, caps and fabrics

These were a cheap and popular way to spread messages, as national dress, caps or fabrics are likely to attract people's attention.

Logos

Specifically in Africa, PARC and the Pan-African Programme for the Control of Epizootics (PACE) logos, as well as the Global Rinderpest Eradication Programme (GREP) logos at the global level, were used for equipment, property, buildings, doors, stationery, cards and TV announcements (Fig. 1). Calendars were a colourful reminder of campaign

FIG. 1
PARC AND GREP LOGOS
Courtesy of the authors

themes all year long. The banners and flags proclaimed the high importance of the programme on various occasions, such as district meetings, training courses, campaign/programme launching, market days and international meetings (2, 6).

Postage stamps

These were used to create a wider awareness of the campaign (Fig. 2). Postage stamps were part of national-level activities to give validity and pride to the campaign.

Radio

Radio programmes were made in a participatory manner and featured cattle owners themselves, who did much of the talking, as well as cultural themes. Broadcasting was used to inform and involve a wide variety of audiences through interviews, news, announcements, entertainment, educational programmes, rural radio and participatory programmes with cattle owners. The programmes were broadcast in the language best understood by each particular audience.

Television

With the advent of TV occurring almost at the end of disease eradication, short spots were used to promote the rinderpest eradication campaign. Video footage including interviews with stakeholders were also produced and used. TV programmes were also used to describe the importance of cattle/buffaloes to the economy and to agriculture in specific countries.

FIG. 2
RINDERPEST STAMPS USED IN SEVERAL COUNTRIES
Courtesy of the authors

News services

These included press releases targeting newspapers and magazines and organising media field trips for journalists. Information provided included updates about the number of vaccinations completed, vaccination schedules, and facts and figures on vaccines and other equipment and supplies, staff training and important meetings. At its inception in 1924, the World Organisation for Animal Health's (OIE's) mandate, among others, was to inform its Members of epidemics and provide them with the scientific information they needed to improve their animal disease control measures. Among this information was the publication of recommended standards for the establishment of rinderpest epidemio-surveillance systems as well as notifying the disease at its first incursion or regular reporting. The *World Animal Yearbook*, initiated in 1956, assisted in disseminating information on disease outbreaks and how to manage them, and key messages to all stakeholders (Fig. 3).

Meeting reports

The reports of the first international conference and the first OIE session are part of these meeting proceedings. Since the 1940s, for each meeting/workshop/training session, the recommendations, major outcomes and role/responsibility of each participant or stakeholder were summarised in the event proceedings. This assisted in monitoring the rinderpest eradication campaign's progress. Figure 4 presents the report of the second Near East meeting on animal health held in Damascus, Syrian Arab Republic, from 5 to 10 March 1956.

Puppet shows

This form of entertainment served to get the message across to rural people in cattle markets or other places where these communities gathered.

Filmstrips

These were used to tell stories, present ideas or help train people in new techniques (Fig. 5). Filmstrips were used at the beginning of the campaign, but as technology advanced these were burned onto CDs or placed on YouTube.

Market day demonstrations

At such events (market, watering/grazing points), well-known leaders were invited to speak publicly about the importance of vaccination. They also informed people about the meaning of the clover-leaf ear-punch mark on cattle for sale, stressing that cattle with this vaccination mark were more valuable, because they were protected against rinderpest. This also served to warn buyers that cattle without the official cloverleaf identification mark could catch rinderpest and die (Fig. 6).

Community visits

These were organised to discuss issues with local leaders, to hear the attitudes, problems and suggestions of people in general and to reach a consensus. This worked during the preparatory phase or during the immunisation programme itself to keep the budget for petrol and staff per diems to a minimum.

LEVELS OF COMMUNICATION

Communication at national level was quite different from that at community and international levels. The national livestock services were encouraged to use information techniques to attract increased administrative and financial support from their governments. Do livestock field staff understand why pastoralists do or do not cooperate? How well do pastoralists understand why there are exact procedures for cattle vaccination, ear notching and sero-sampling, why they may need to control the movement of their herds or why they should pay a fair price to livestock services? Are they able to identify any sign of the disease (Fig. 7). Mutual understanding depends on discussion, face to face, between field staff and pastoralists using illustrated materials. This builds a new familiarity, confidence and consensus on action plans (2).

National project managers were advised to find means, including the national news media, of documenting their efforts in the field, portraying their efforts as part of an international effort to defeat rinderpest and emphasising the importance of livestock for the national economy and welfare. National launches or celebrations of the campaign, featuring national leaders, also helped to capture people's attention. High-level dignitaries, such as the country's national leader or a top minister, as well as representatives from various agencies and organisations were involved (2, 6, 7).

At the regional level, the communication work was similar to public relations efforts to assist regional institutions to build their leadership

FIG. 3

THE *ANIMAL HEALTH YEARBOOK* OR *WORLD ANIMAL REVIEW* JOURNAL

FAO & OIE (1958). - Animal Health Yearbook. Rome & Paris; FAO, WHO & OIE (1958). - Animal Health Yearbook. Rome, Geneva & Paris.

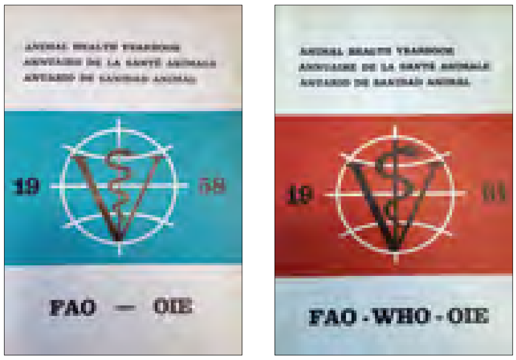


FIG. 4

REPORT OF THE SECOND NEAR EAST MEETING ON ANIMAL HEALTH, HELD IN DAMASCUS, SYRIAN ARAB REPUBLIC, FROM 5 TO 10 MARCH 1956

FAO & OIE (1956). - World Livestock Disease Report. Rome & Paris; FAO (1956). - Report of the Second Near East Meeting on Animal Health. Rome.

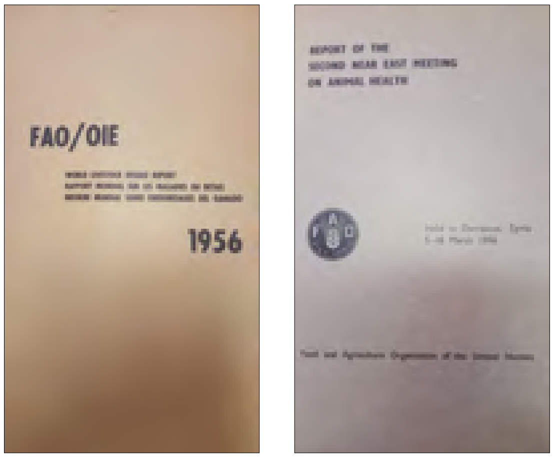


FIG. 5

STRIPS WERE USED TO TELL A STORY, PRESENT IDEAS OR HELP TRAIN PEOPLE ON NEW TECHNIQUES

Courtesy of the authors

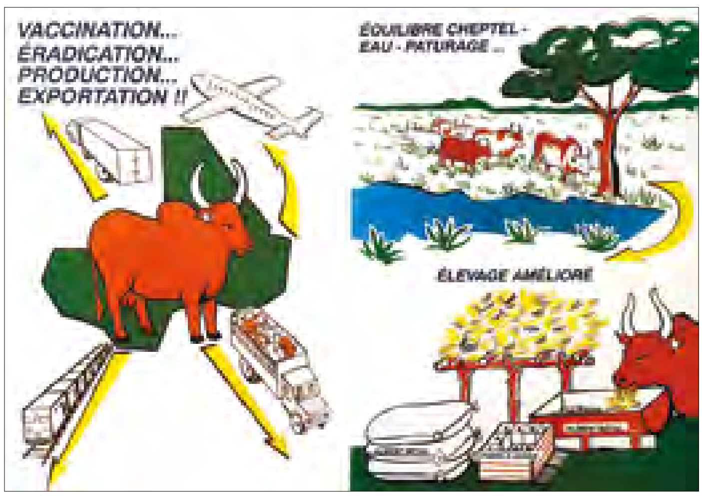
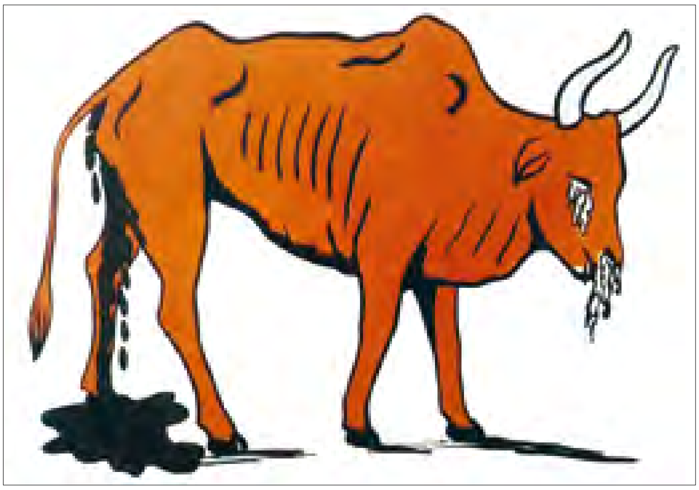


FIG. 6
MAASAI MEN EXCHANGING MONEY FOR THE SALE OF A COW AT THE CATTLE MARKET
Source: FAO/Simon Maina

FIG. 7
POSTER SHOWING SIGNS OF RINDERPEST
Source: FAO/Alessandra Benedetti (for Ms Anggun)



roles. The 'cross-border harmonisation' meetings (e.g. Central Asia and the Somali ecosystem) were an example where veterinarians located on either side of a national border were meeting to agree on the coordination of the immunisation and surveillance efforts. This was indispensable to the cohesion and momentum of the campaign and to building credibility by showing real activities and reporting on newsworthy events. These meetings sometimes became a major event, almost reaching the diplomatic level, where groups of livestock professionals became acquainted with similar groups in neighbouring countries. The targets at this level were donors, technical agencies and national decision-makers (2, 6, 7, 8).

At the international level, the local production and use of communication materials showed the international community (donors, technical organisations) that national organisers were serious about the programme. It was important that representatives of the international community received copies of all the materials and learnt about the communication activities going on (2, 6, 7). This was also useful for advocacy, helping to fund the eradication efforts.

Multimedia strategy

The multimedia strategy aimed to address as many target audiences through as many media as possible. The different target audiences were in contact with each other for many reasons: family, business, work, politics, education, administration and so forth. The communication campaign tried to take advantage of this contact to maximise the spread of information sharing. Messages were presented in ways that were relevant to and could be understood by different audiences. One strategy was, for example, to target schoolteachers who influenced community leaders. These in turn also influenced cattle owners. Schoolteachers could also influence students, who in turn could describe the importance of disease control to their parents. The multimedia strategy helped to address doubts and questions about the rinderpest eradication campaign so that farmers would already know something about the programme by the time the vaccination or surveillance team arrived in their area (2, 6, 7, 8).

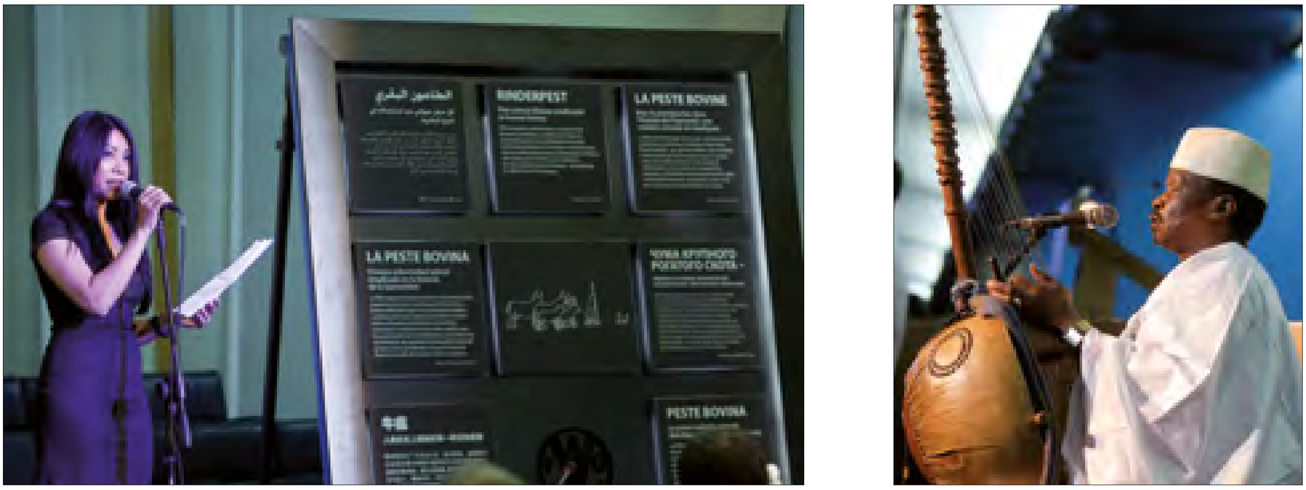
Among the challenges faced in implementing the multimedia strategy were the remoteness of cattle owners, migration, limited access to types of media, relationships between cattle owners and veterinarians, insecurity and limited literacy. One way to reach out and inform migratory people about the rinderpest eradication programme/campaign was to learn more about their attitudes and concerns. If radio was used, it would focus on topics interesting to migratory listeners and that included information on planned rinderpest-related activities. At a regional level, as part of the multimedia strategy, transparencies, newsletters, and annual and conference reports were produced. Awareness-raising for decision-makers was achieved through letters, press conferences, press releases, TV news items, animal health bulletins (Fig. 8) and awareness-raising booklets (6, 7, 8, 9, 10 11, 12).

At national level, the strategy included production plans, field implementation plans and the identification of budgets. National communications staff were trained in communication for development. Training reference materials and manuals were produced and disseminated. Review workshops and visits to national communications staff were carried out to monitor the impact of training. Key issues were identified through participatory rural

FIG. 8

FAO GOODWILL AMBASSADORS ANGGUN AND MORY KANTÉ'S EXHIBITION DURING THE GLOBAL FREEDOM FROM RINDERPEST COMMEMORATIVE CEREMONY HELD IN ROME AT FAO HEADQUARTERS ON 25 JUNE 2011

Source: FAO/Giulio Napolitano (for Mr Mory Kanté)



communication appraisal and were well described in the project reports or proceedings of meetings and training sessions (6, 7, 8, 9, 10 11, 12). Towards the end of the programme, e-mail was also used. Goodwill ambassadors were useful during the campaign but more important during the global eradication ceremony.

COMMUNICATION APPROACH TO PERSUADING LOCAL PEOPLE TO TRUST THE LIVESTOCK SERVICES

The approach intended to:

a) show how national teams adapted many of the communication templates provided in the kit and give instructions on how to do it;
b) rely on people's help to bring their animals for vaccination, allow ear notching, responsibly report suspected rinderpest outbreaks and allow serum samples to be collected, among other things.

Each rural livestock owner and their family was in essence a powerful decision-maker that could effectively speed up or slow down the process of any disease control eradication programme. If enough local people do not trust the livestock service, a rinderpest vaccination campaign could completely collapse. The following approaches were used (13):

- Firstly, to ensure adherence to the rinderpest vaccination programme and thus its success, the communication strategy relied on giving nationals of the countries involved the responsibility of carrying out the communication efforts on the ground.
- Secondly, national authorities were advised to focus their communication efforts mainly on rural areas in order to increase dialogue between the livestock services and rural livestock owners. It was hoped that this would lead to greater mutual understanding, consensus and locally made decisions about how to make the campaign a success.
- Thirdly, the veterinary field staff were chosen to also perform the role of field communicators. This was done for several reasons, including building national capacity to communicate better with rural communities, gain feedback and collaborate with them. Animal health assistants and drivers were often drawn from local communities, providing entry points to these groups.
- Fourthly, the vaccination programme aimed to prepare and equip field communicators with communication approaches and media materials that were practical and effective. They were supported not only by other communication channels to reach rural communities, primarily rural radio, but also by various local leaders, schools and presentations at markets, as well as through the local administration and information systems.
- Fifthly, field communicators and others involved gathered information on people's attitudes, local problems and opportunities, and analysed this information before passing it on to programme managers.
- Finally, villagers were told about the programme through loudspeakers on Land Rovers or through meaningful dialogue with people.

The communication officers were effective in supporting communication activities at national level. Sometimes, communication and data management activities were merged with the combined information and communications technology (ICT) unit. This unit was unable to provide satisfactory support for institutional communication at central and regional levels, although it is noted that communication activities within individual countries appear to have continued satisfactorily with some support from communication officers regarding newsletters, posters, leaflets, handbooks for agents and manuals for community-based animal health workers (CAHWs), etc.

During PARC, for example, a fundamental conclusion was reached that, in order for a Veterinary Service to eradicate rinderpest, it must be effective in the field. In part, this effectiveness depends upon having a trusting and productive relationship with rural livestock owners. Many livestock services deteriorated severely in the 1970s and 1980s, and rural livestock owners lost confidence in their effectiveness and sometimes even in their honesty and integrity. Yet, for PARC to succeed, the veterinarians had to rely on people's help to bring their animals for vaccination, to allow ear notching, to responsibly report suspected rinderpest outbreaks and to allow serum samples to be collected, among other things (Fig. 9).

To convince stakeholders of the need to control rinderpest, several publications were produced (Fig. 10). These included the special edition of the FAO/WHO/OIE *Animal Health Yearbook*, which contained available epidemiological information on animal diseases including rinderpest, the *Manual on the Diagnosis of Rinderpest* (14), specific manuals for the rinderpest campaign field personnel, reports on the production and quality control of rinderpest vaccine, manuals on standard operating procedures for rinderpest vaccine production and quality control, and audiovisual aids, including films, on diagnosis and epidemiology of rinderpest (15).

FIG. 9
PARC AWARENESS-RAISING MATERIAL
FAO & AU-IBAR (nd). – Sensibilsation des populations rurales par la radio rurale. Guide du producteur. Rome.

FIG. 10
PACE BULLETIN
Source: AU-IBAR (2001). – *PACE Bulletin*, No. I (I)

OTHER COMPONENTS OF THE COMMUNICATION STRATEGY

Other components of the communication strategy were:

a) The corporate identity/corporate design, accompanied by the creation of a communication advisory team tasked with overseeing the communication policy and approving key messages and promotional materials.
b) The capacity-building process component entailed training sessions, team-building workshops, skills development courses and institutional assessment.
c) The component on privatisation in the Veterinary Services was to communicate the benefits of introducing the private sector into the animal health service. This needed to be clearly understood by all stakeholders from

livestock owners to decision-makers. The group involved in this component were veterinarians, segmented clients, testimonial agents and the media.

d) The component on OIE norms and principles, the Pathway and animal trade was to raise the awareness of stakeholders (government and non-governmental public, in particular livestock traders) so that, with specific communication plans, they knew about OIE norms and principles and the Pathway to be implemented in key countries. The message was developed by conducting audience field research, developing awareness-raising strategies, pretesting the design of communication tools, implementing awareness-raising campaigns and measuring impact.

e) The public relations policy aimed to increase knowledge of animal health through proactive public relation policy development and information exchange with partner organisations. The tools used were press clippings, press kits, inter-institutional address books, inter-institutional art buying, event management and exchange of press releases on important global events.

f) International cooperation created and maintained sustainable contact, with key audiences being international decision-makers, bi- and multilateral donors, private foundations, economic, environmental and social chambers, press and television (video co-production). The tools were letters, e-mails, meetings, photos, activity reports (e.g. annual reports), institutional documentation, case studies in brochure form, project videos, institutional videos and project proposals.

g) The Information and Communication Unit (ICU) was to create and enhance information and communication management capacities, in particular disease surveillance information and communication. The ICU cross-cut all other units: epidemiology, wildlife, laboratory, among others. One of the lessons learnt was that it was important to separate information management from public communication.

IMPACT OF THE VALUE-ADDED BY INFORMATION COMMUNICATION

The communication strategy for rinderpest eradication, through the processes of information collection and dissemination, provided some additional impacts, such as an improvement in the accuracy of animal resources-related data. In addition, various national Veterinary Services used the comprehensive information management tools based on Oracle that were produced for the rinderpest eradication campaign for the storage, transfer, analysis and sharing of data related, among other things, to (2):

a) animal health: passive surveillance and disease reporting, outbreak emergency reporting, abattoir surveillance and active surveillance of major transboundary animal diseases;

b) veterinary institutional management: animal health infrastructures and equipment, human resources in terms of the number and distribution of public and private professionals;

c) in-built performance indicators to monitor and evaluate Veterinary Services, livestock production and numbers, trade in animals and animal products and its economic value, and the population and its spatial distribution;

d) the importance of coordinating and harmonising the management of the results of animal disease diagnostic tests, control strategies and rumour investigations.

The bulk of data collected from African Union member states was related to monthly disease occurrence figures. These were analysed and used to compile information and communications in the *Pan-African Animal Health Yearbook* published by the ICU. This provided:

a) a general map of infected and disease-free countries, areas, ecosystems and zones;

b) the density of cattle;

c) cattle movement patterns;

d) national parks and buffalo distribution;

e) recent rinderpest outbreaks;

f) a rinderpest zonation map;

g) combined information.

ACHIEVEMENTS AND LESSONS LEARNT

The main objective of the communication strategy for the rinderpest eradication campaign was to develop and introduce a sustainable information system and to advise, facilitate, support, harmonise, catalyse and inform the campaign on appropriate data collection, transmission and analysis and information dissemination. This was done by making use of appropriate ICT. The experiences acquired during the process and the system established have provided a basis for future communications strategies including an information management system.

Communication activities on rinderpest helped people, even those from different social groups within a community, to share information and exchange ideas in a positive and productive fashion. This dialogue enriched an understanding of how development issues such as rinderpest outbreaks affect them, discovering what others think in other communities and seeing what other communities have achieved. These were effective methods for helping people to reach a consensus and find common ground for action, based on their own needs and capabilities. Dialogue was initiated and guided by field staff who had good interpersonal communication skills. Discussion tools, such as flipcharts, audio cassettes, slides and even videos, were used to help people visualise and reflect upon their own reality. Rural radio in Hausa and other dialects was a popular forum where local people did most of the talking about technical and cultural topics.

Lessons learnt

- Each type of media has its specific message and also targets specific stakeholders (e.g. all types of media were used for farmers and veterinarians, whereas for donors, leaflets, television, radio and news services were used).
- Communication packages or multi-media approaches aimed to convince people who are reluctant to communicate to take the trouble to do so and often achieved this by helping them to communicate well. This was through discussion tools (flipcharts, leaflets, posters, booklets), community visits (listening to change attitudes, identify problems and make suggestions for consensus), communication workshops (providing the opportunity for rural people to voice their opinions), rural radio/television programmes and campaign images to accentuate the apolitical and international objectives of the campaign (13).
- The communications strategy built capacity in staff working for national programmes in areas of communication and information management and created manpower that could be used for other livestock management programmes.
- Communities were educated on rinderpest outbreak reporting. For Sudan (now South Sudan), the community was rewarded for each reported outbreak that was confirmed in the laboratory as rinderpest. The outcomes for Veterinary Services were measured by the number of cases of the disease reported from the field to the central laboratory and then to the OIE.
- Performance indicators were established for both epidemiological surveillance and laboratories to measure the performance of the system.
- At country, regional or global level, the proceedings of meetings were to assess and report the outcomes of the projects/programmes (e.g. GREP experts' consultative meetings).
- Information was provided on vaccination campaigns, epidemiology and other activities in member countries by creating an appropriate communication strategy and data collection methods, involving national Veterinary Services, CAHWs/non-governmental organisations and other sources, for setting out assessment, control and/or research priorities.
- Member countries were assisted to build capacity and to establish/strengthen the management and dissemination of information on animal health and exchange it with neighbouring countries.
- The communication production team with the printer should take a systematic approach to preparing the communication materials to make the production process less time consuming, less costly and more effective.
- Because donors were kept informed of the campaign's activities, they understood that a regional campaign is possible in Africa and that regional coordination could be difficult in the Middle East and Asia. This led to the funding of separate country projects. However, farmers were informed through the different types of media.
- A livestock programme should create a national discussion tool kit, including flipcharts, posters, leaflets and booklets, to (i) spark positive discussions among and gain participation from stakeholders, (ii) improve the communication skills of field staff, (iii) reinforce technical knowledge, involve rural people and learn their points of view, (iv) promote action and maintain interest, and (v) spread information. These discussions involved field staff, rural people and even decision-makers in powerful new ways.
- The communication strategy laid the foundation for establishing a sustainable animal health and production information system, which makes use of modern ICT and approaches enabling global/regional institutions to prioritise, plan, make decisions, advise users and monitor activities related to animal resources.
- ICT for data management was developed for the African Union Interafrican Bureau for Animal Resources (AU-IBAR) (Animal Resource Information System, ARIS) and the FAO (Transboundary Animal Disease Information System, TADinfo) at the global level. ARIS and TADinfo were in competition in Africa, but TADinfo was more successful in Asia. Both were used almost at the last stage of eradication.
- Vaccination also failed because of the small number of veterinarians and the centralised approach in the livestock sector; the information flow between the livestock services and owners was limited to occasional top-down, person-to-person communication.
- On a few occasions, the communication did not target the right audience (e.g. awareness-raising via the radio in French or English in illiterate zones) and therefore failed to achieve its goal. Although communication was more organised regionally in Africa, in the Middle East and Asia

it was on a case-by-case basis at the country level. In both regions, the above types of media were implemented at different levels.

- With the advent of a community-based animal health programme from 1992 (e.g. Sudan, Pakistan, Afghanistan and Somalia), the use of different media became very important for local planning of vaccination campaigns – community meetings, timing with cattle movements. This was through (i) integration of rinderpest eradication activities into community-based animal health services, (ii) collaboration and co-ordination with all other livestock agencies, (iii) promoting participation of all stakeholders, (iv) training and awareness-raising (community dialogue guidelines, a CAHW training module, a training course for animal health assistants and veterinarians), (v) appropriate communication methods for awareness-raising (cloth flip charts, photo cards, posters, songs, t-shirts), and (vi) motivation of animal health workers (payments and rewards).
- Communication enables planners, when identifying and formulating development programmes, to consult with people to take into account their needs, attitudes and traditional knowledge. Only with communication will the project beneficiaries become the principal actors in making development programmes successful. Helping people at all levels to communicate empowers them to recognise important issues and find common ground for action and builds a sense of identity and participation motivating them to implement their decisions.
- Several challenges occurred when implementing the communication strategy: lack of funding; personnel not appropriate; lack of stakeholder coordination and collaboration (promoting and maintaining participation, common goal); not understanding the context (culture, livestock production system, diseases, local knowledge and practices); flexibility (constant changes, adaptation, rapid decision-making, resource mobilisation); and fatigue due to loss of interest and environmental difficulties (instability, seasons), among others.

CONCLUSION

Conveying the communication approach or strategy at the field level is particularly important. It was the means to accelerate change, in this case people taking or allowing action to eradicate the disease. The strategy was to help stakeholders realise the beneficial value of disease control methods leading to eradication, and how it was relevant to them and better than the alternatives, so that they would allow, advocate and take action themselves.

It is a process of listening to people, adapting activities/methods as much as possible to what those people value and find agreeable, having them help convey the benefits of action, providing supporting information and building trust. The process leads to people agreeing to adopt behaviour and take action to improve their own lives: presenting livestock for vaccination and marking, ensuring others do too, allowing serosurveillance, reporting suspected outbreaks and associated activities.

Rinderpest, like many other diseases, goes hand in hand with war, civil unrest and lack of reliable norms. Building trust and common cause in rural areas is vital. So, it is more than increasing awareness through information dissemination. People need to care. Communication at the macro-level too is important – giving the campaign an attractive brand, conveying it as a valuable experience, complete with a vision, a 'look and feel' and even a logo and colours that all can rally round. Again, people need to care about it.

The aim of the communication strategy for the rinderpest eradication campaign was to provide communications support to all stakeholders and enable their participation. With this understanding, communities were aware of and sensitised to the aims of the campaign and motivated to participate in and comply with the eradication programme. Veterinary services, farmers and donors were kept well informed of campaign activities through diverse means of communication, including the media. In addition, communities were educated on disease reporting, particularly regarding rinderpest outbreaks and presenting their animals for sampling and vaccination. Also brought on board were governments and other policy-makers who availed themselves of national resources for the campaign. Finally, donors and technical agencies that provided financial and technical support were central to the successful eradication of rinderpest.

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CHAPTER 6.3

THE RINDERPEST DIAGNOSTIC AND SURVEILLANCE LABORATORY NETWORK

A. DIALLO [(1)*], J. DARGIE [(2)], G. VILJOEN [(3)] & M. JEGGO [(4)*]

(1) Institut sénégalais de recherches agricoles – Laboratoire national de l'élevage et de recherches vétérinaires (ISRA-LNERV), Route du Front de Terre, BP5027, Dakar-Hann, Sénégal and UMR Centre de coopération internationale en recherche agronomique pour le développement (CIRAD-INRA) ASTRE, Campus international de Baillarguet, 34398 Montpellier cedex 05, France (Former Head, Animal Production and Health Laboratory, Joint Food and Agriculture Organization of the United Nations (FAO)/International Atomic Energy Agency (IAEA) Agriculture and Biotechnology Laboratory, IAEA Laboratories, Seibersdorf, Austria)

(2) Former Head, Animal Production and Health Section and Former Director of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria

(3) Head, Animal Production and Health Section, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria

(4) Geelong Centre for Emerging Infectious Diseases, Medical Faculty, Deakin University, Geelong, Australia (Former IAEA Technical Cooperation Regional Expert in Animal Health and Former Head, Animal Production and Health Section, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria)

*Corresponding authors: adama.diallo@cirad.fr (Diallo); jeggo.martyn@gmail.com (Jeggo)

SUMMARY **The International Atomic Energy Agency (IAEA), through its Joint Division with the Food and Agriculture Organization of the United Nation (FAO), took the lead in supporting and strengthening veterinary diagnostic laboratories in countries involved in the eradication programme. Central to the process was the establishment and support of regional rinderpest surveillance laboratory networks that proved to be a critical element of the successful eradication of rinderpest. Support for laboratories included not only the provision of supplies and equipment but also human capacity building through training and the transfer of new technologies for rinderpest diagnosis and surveillance.**

KEYWORDS **ELISA – Enzyme-linked immunosorbent assay – Eradication – Global Rinderpest Eradication Programme – GREP – Joint FAO/IAEA Division – Network – Rinderpest – Surveillance.**

INTRODUCTION – PLACE OF THE DIAGNOSTIC LABORATORIES AND NETWORKS IN THE GLOBAL RINDERPEST ERADICATION PROGRAMME (GREP)

At the end of the 1970s, rinderpest was well controlled in Africa following the implementation of the continental rinderpest vaccination campaign known as Joint Programme 15 (JP15; Chapter 4.1). Unfortunately, a few years later, the disease re-emerged, and this was a driver for the Heads of State of the Organization of African Unity (OAU) to launch a new continental disease control campaign, the Pan-African Rinderpest Campaign (PARC; Chapter 4.2), which began field operations in 34 countries simultaneously. Although at the end of JP15 two small rinderpest foci were left in West and East Africa, the new initiative was aimed at ensuring, through thorough disease surveillance, that all rinderpest activity had been eliminated from the continent. Thus, as the programme progressed, the process became more one of targeted vaccination in critical endemic areas. Central to all these approaches was the need for effective laboratory support in terms of disease diagnosis, monitoring of vaccination programmes and/or creating evidence for the absence of infection for demonstration of freedom.

Therefore, it was fundamental that the programme had a functioning laboratory component that could both test serum for antibodies to rinderpest and confirm a suspect clinical case. This would apply not only to PARC but also to the global rinderpest eradication campaigns in other regions. It was therefore vital that sampling and test methodologies were implemented in a comparable manner between countries and regions, with results that could be relied upon as correct. Thus, standardisation and quality assurance were key elements of the overall approach to testing. Serological monitoring for such an ambitious campaign would require testing a very large number of sera. This would have been difficult, if not impossible, with the only test that was available at that time for rinderpest serology, the virus neutralisation test (VNT) (1). Not only was it time consuming, but it was also very difficult to ensure quality assurance and standardisation. Fortunately, at that time, a new methodology, the enzyme-linked immunosorbent assay (ELISA), was under development for the serological diagnosis of many diseases, including rinderpest (see Chapter 3.3). Unlike the VNT, the result could be read by a machine, and it was possible to handle a large number of test samples at the same time. Furthermore, the high degree of standardisation in reagents, in test operation and in reading the results made quality assurance a serious possibility.

At the commencement of PARC, many national veterinary laboratories in Africa were in a poor state, with little functional equipment and poorly trained staff. As indicated in an earlier chapter (see Chapter 5.4) of this book, the Joint FAO/IAEA Division committed itself to PARC through support for a laboratory network and by using the twin mechanisms IAEA Technical Cooperation Projects (TCPs) and FAO/IAEA Coordinated Research Projects (CRPs) for resource allocation. They were able to provide the level of support required for veterinary diagnostic laboratory activities during the programme's implementation by:

1. transferring new technology(ies) for rinderpest seromonitoring and disease surveillance;
2. strengthening the laboratories' capacities.

The support provided through a regional CRP for a laboratory network proved critical in ensuring close collaboration and coordination of activities between the countries involved – a vital element in controlling a transboundary disease such as rinderpest. Not only does it ensure a uniform approach and the ability to compare data from different countries, but it provides a forum that fosters information exchange and is ideal for training and ultimately building trust and partnerships between network members and countries.

STRENGTHENING VETERINARY DIAGNOSTIC LABORATORIES WITHIN THE NETWORKS

From the outset of its involvement in PARC, the Joint FAO/IAEA Division established a network of around 20 national laboratories in Africa (Fig. 1). As indicated earlier, the support for that network was first provided through the IAEA CRP mechanism, which is ideal for this kind of task, by bringing together scientists from both rinderpest endemic countries and more advanced economies where most of the research on new tests and approaches was being undertaken. Appropriate diagnosticians in each PARC laboratory were awarded research contracts that provided crucial funding for both key laboratories and field activities. They were awarded on an annual basis, and the funds provided were primarily used to purchase basic ELISA equipment, reagents, kits and plates. In some cases, a portion of the research grant was made available locally to support sample collection.

Research coordination meetings (RCMs) occurred annually and helped ensure that results were delivered and shared collectively. They provided an opportunity to inform PARC and GREP of progress throughout the network. At each meeting, contract holders were required to give a presentation of their work during the previous 12 months, and a generalised work plan for the following 12 months was agreed upon, taking into account the differing situation in each country. Equipment needs and further training requirements were dealt with on an individual basis. During the presentations and through specialised sessions, problems encountered during sample collection, with the tests, with the equipment or with the interpretation of results were discussed openly, and solutions were agreed by consensus. To cope with the duality of language found in the PARC programme region, the rinderpest laboratory network programme was operated in both French and English, with major publications being available in both languages.

Critically, the support provided to the PARC rinderpest laboratory network went well beyond that available through an FAO/IAEA CRP. IAEA TCPs, at both national and regional levels, provided additional extensive support. Under a TCP, it is possible to provide a range of laboratory equipment, to send in experts, to provide fellowships and to provide training courses tailored to the needs of specific rinderpest laboratory activities. The TCP in fact proved to be of even more importance outside Africa. It was not possible to gain funding for CRPs outside PARC, thus support for West Asia Rinderpest Eradication Campaign (WAREC) and South Asia Rinderpest Eradication Campaign (SAREC) countries, and ultimately to all GREP countries, was provided through IAEA TCPs. In total, some 150 TCPs supported the eradication programme, with much of this delivered through regional TCPs in Africa, West Asia and South Asia. Through the two IAEA funding mechanisms, CRPs and TCPs, the Joint FAO/IAEA Division provided continuous support for over 25 years in more than 50 laboratories involved in the rinderpest eradication process, with a total cost of about US$20 million. Fig. 2 summarises the yearly breakdown of the IAEA contribution to GREP.

A key component of this programme was the provision of adequate and appropriate training. This was carried out both at the annual CRP coordination meetings and through the provision of extensive TCP support in individual laboratories. Technical officers from the division and outside FAO/IAEA experts visited each laboratory in the network at least once a year. This proved invaluable in providing staff laboratory training locally and augmented greatly what was provided to contract holders during the RCMs.

The subject matter covered during training was introduced in a stepwise, logical manner. The initial emphasis was therefore on the use of ELISA, both as a general diagnostic tool and more specifically as used in the FAO/IAEA rinderpest ELISA kit. Once it was clear that contract holders could reliably test samples using the ELISA-based system, the training's emphasis moved towards basic and applied epidemiology to ensure that the samples collected would provide the information required. Towards the completion of the programme, training was provided in the use of computers and specialised computer software to store and manipulate the

FIG. 1

AFRICA RINDERPEST MONITORING LABORATORY NETWORK

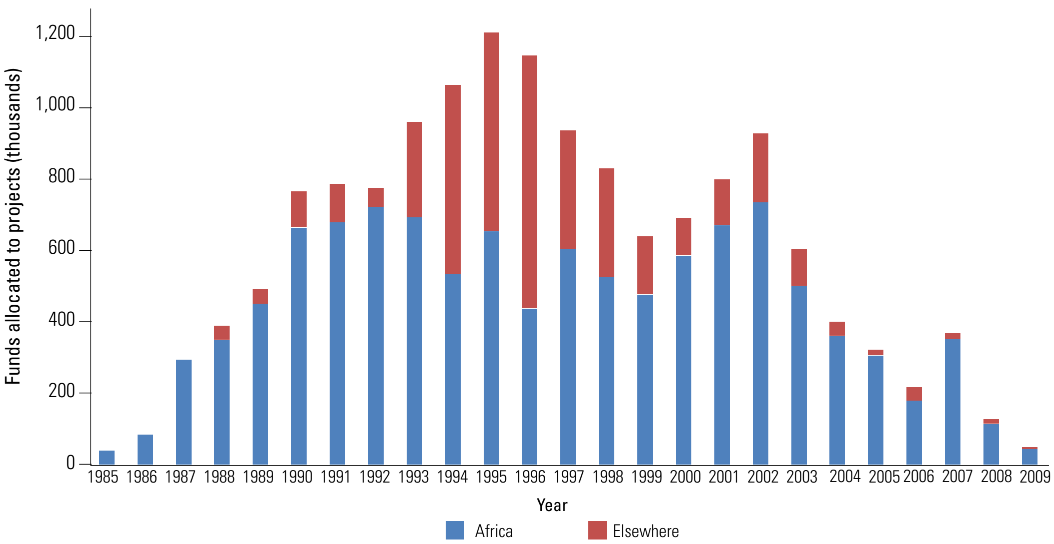
Final boundary between the Sudan and South Sudan has not yet been determined

Source: Andreas 06, 2006 (17); modified to indicate network

FIG. 2

THE YEARLY BREAKDOWN OF THE JOINT FAO/IAEA DIVISION AND IAEA TCP FUNDS CONTRIBUTION TO THE GLOBAL RINDERPEST ERADICATION PROGRAMME

Courtesy of the authors



data. The frequent visits made by FAO/IAEA technical officers and IAEA experts to participating laboratories served to identify many of the difficulties experienced locally and provided considerable impetus to resolve these. Training, and in fact the laboratory strengthening at large, was a gradual process within the network. In the early stages of PARC, no two countries were at the same stage in the programme's implementation. However, the network approach enabled expertise in individual laboratories to be brought to the same level much more quickly than would otherwise have been possible.

Along with the training, the IAEA support to veterinary laboratories in the network included the supply of kits, reagents and equipment (ELISA readers, pipettes, incubators, freezers, water distillation units and/or deionising equipment, balances, pH meters, shakers, etc.), guidelines and epidemiological support for the development of the national sampling frames and epidemiological computer programmes. The reagents for rinderpest diagnosis were provided in kit form with a standardised manual.

As countries ceased rinderpest vaccination towards the end of PARC, the focus of the laboratory network switched from the seromonitoring of rinderpest vaccination to surveillance for the disease and the demonstration of rinderpest freedom – the focus of the PARC follow-on programme, the Pan-African Programme for the Control of Epizootics (PACE; Chapter 4.3).

TRANSFER OF NEW DIAGNOSTIC TESTS

The transfer and use of rinderpest indirect ELISA in the rinderpest laboratory network

As indicated earlier, rinderpest seromonitoring during the mass vaccination campaigns and disease surveillance later in the eradication programme were the backbone of PARC and later the whole GREP (2). All of these activities would clearly require considerable laboratory testing for the presence of rinderpest antibodies or rinderpest virus. At the time of the PARC programme's development, the detection of antibodies against the rinderpest virus was made by the VNT. As this test was not convenient for large-scale serological testing, it was replaced by an indirect rinderpest ELISA – i-ELISA – that was newly developed at the Animal Virus Research Institute (AVRI, now Pirbright Institute) in the United Kingdom of Great Britain and Northern Ireland (3). However, before that replacement, it was necessary to initially demonstrate its utility outside the research laboratory and in a 'real world' situation. Through an FAO TCP, the assay was used in 1986–1987 for serologically monitoring antibodies in a national herd. This proved the validity of both the assay and the value of serological testing, and a good agreement was found between the VNT and this new assay. In conjunction with the Joint FAO/IAEA Division, this rinderpest i-ELISA was further validated and designed as a kit to be used in the sorts of conditions likely to be encountered in laboratories in Africa. While preparing this kit, it was necessary to consider a number of important factors relating to its supply and use:

a) The reagents should be able to withstand prolonged exposure to high temperatures (20–30°C) and high humidity, as the kits might well have to spend some time in transit to laboratories in Africa.
b) The reagents should comply with regulations governing the transport of chemicals by air, as laid down by the civil aviation authorities. This, for example, precluded the inclusion of sulphuric acid as a reagent stopper in the kit.
c) The box containing the kit should be relatively small but contain sufficient reagents for testing the number of sera that are likely to be collected in one year –an initial conservative estimate was 20,000. This precluded the dispatch of antigen-coated plates.
d) The actual ELISA system adopted should be as simple and robust as possible. In this context, the assay used in the United Republic of Tanzania was an i-ELISA and used well-established reagents. However, it was necessary to conduct trials on the stability of these reagents and on their ability to withstand high temperatures and freeze-drying.
e) The kit should contain *all* the necessary reagents. Thus, all the buffers required had to be included, along with the more obvious conjugate and substrate.
f) The kit should be supplied with a detailed manual. This should cover all aspects of the use of the kit as well as some practical information regarding buffer composition, troubleshooting interpretation of results, sera collection and references.
g) The kit and the manual should be flexible enough to allow for the incorporation of changes as problems were encountered and solutions found. This was particularly relevant to reagent packaging (e.g. the later use of tablets instead of powders) and the updating of the manual (i.e. a loose-leaf approach was essential).
h) Components of the kit, including the plates, should be available in bulk to ensure standardisation.

Having taken into account these various factors and on completion of the reagent stability trials, the FAO/IAEA rinderpest i-ELISA kit was ready for use in mid-1987. During the subsequent four years, a great deal of experience was gained in the use of this kit, in problems relating to its dispatch to individual laboratories and in interpreting the results. When examining problems relating to its use, it was found that, in nearly all cases, these related to the quality of the water used for reconstitution of the various reagents supplied. In particular, in reconstituting those components that were supplied freeze-dried (antigen, reference sera and conjugate), it was found to be essential that properly deionised water was used. Although in many cases, the pH of the water was checked and found to be correct, other extraneous ions or pyrogens were interfering with the functioning of the reconstituted reagents. In 1990, sufficient water and glass vials for the reconstitution of all freeze-dried reagents were thus included in the kit. The only other significant change over time to the kit was the supply of most reagents in tablet rather than powder form. Although this was more expensive, the reagents remained in better condition in tablet form, and the use of tablets enabled the reagent solutions to be prepared in smaller and more convenient volumes.

Transfer and use of the rinderpest c-ELISA in rinderpest laboratory network

i-ELISA, for the detection of antibodies to rinderpest (4), was successfully transferred and used for the evaluation of the immune response, following rinderpest vaccination throughout Africa. However, as PARC moved into phase II, most cattle had been vaccinated and were therefore antibody positive, and thus, for the detection of the circulating virus, serosurveillance of other animal species became increasingly important. This involved the testing of sera from sheep, goats and game animals, all of which are susceptible to the rinderpest virus. Difficulties would be experienced in the development of an i-ELISA for sheep and goat sera, owing to the high non-specific reactivity of such sera. The situation was further complicated by the presence in many countries of a closely related virus, peste des petits ruminants (PPR). Antibodies to PPR cross-reacted with the rinderpest virus in the rinderpest i-ELISA. The lack of commercially available enzyme conjugates suitable for the various species of game animals was another constraint. To overcome these problems, a rinderpest competitive ELISA (c-ELISA; see Chapter 3.3) was developed, based on the measurement of the competition between the selected specific monoclonal antibody (mAb) anti-rinderpest virus and the anti-rinderpest virus antibodies in serum for binding to virus protein. As the measurement of that competition is through the binding of a conjugate to the mAb, the system will work potentially with any serum, whatever the species. The rinderpest c-ELISA, developed at Pirbright Laboratory and evaluated within the rinderpest laboratory network, fully replaced the i-ELISA in 1991 and was used until the complete eradication of rinderpest (5). A major advantage of mAb-based assays was in test standardisation. mAbs are homogeneous in nature, available in unlimited quantities and offer the possibility for every laboratory to have identical diagnostic reagents. These attributes, allied to the FAO/IAEA approach of bulk buying quality-controlled plates and enzyme conjugates, ensured optimal standardisation throughout GREP.

Computerisation

It became clear during the early stages of the establishment of the network that a great deal of information and data would be generated and that computers could significantly assist in the storage and management of these data. To address this need, computers were provided to laboratories, and training was provided at RCMs and supplemented during the visits of FAO/IAEA technical staff and experts to individual laboratories. ELISA readers could be linked to computers for collation and manipulation of the data generated to provide simple positive/negative results for each serum sample. At the same time, the computer could carry out internal quality control checks on the assay itself, provide information on this process and highlight any problems encountered. A software programme EDI (ELISA Data Information) was developed for these tasks. The second task was to collate all field information relating to a particular serum. To meet this need, the commercial programme PANACEA (PAN Livestock Ltd, United Kingdom) was adapted to provide a customised package called SID (Serum Information Data). This programme had the added advantage of standardising the information collected in each country and a method for submitting reports to GREP management.

QUALITY ASSURANCE IN VETERINARY DIAGNOSTIC LABORATORIES WITHIN THE RINDERPEST SURVEILLANCE NETWORK

While the number of different assays that had to be established in national testing laboratories was minimal, and such assays became fully standardised, it was essential that results could be relied upon as correct and could be compared between all participating laboratories. This demanded a range of quality assurance processes to be established across the network of rinderpest testing laboratories (6).

Stage 1 – the FAO/IAEA i-ELISA kit quality assurance programme

A system for quality assurance was first introduced into the rinderpest seromonitoring network in 1989 and was designed to ascertain how well the FAO/IAEA rinderpest i-ELISA kit was evaluated. By using a standardised protocol and set of reagents for conducting rinderpest seromonitoring in the laboratories involved in PARC, it was hoped that uniformity in the ability of each laboratory to test cattle sera for antibodies to the rinderpest virus would be achieved. However, the mere use of these reagents and adherence to the protocol did not ensure this, and thus it was deemed necessary to operate a quality assurance programme. Involvement in the programme would not only enable individual laboratories to ascertain if they were using the kit correctly but also demonstrate to all interested parties that the results being obtained were reliable and comparable from one laboratory to another (5, 7, 8).

The aim of these first quality assurance exercises was to compare the reproducibility and sensitivity of the FAO/IAEA rinderpest ELISA system between laboratories. It was agreed that the results would be treated in strict confidence, and the laboratories involved were asked to send a copy of the results, including the actual optical density values, graphs and frequency distribution plots, in confidence to the FAO/IAEA network coordinator. The results of the first quality assurance round revealed that, in every laboratory, the local negative population gave a lower value than the kit reference negative sera. The examination of local negative sera and the establishment of the mean local population negative value were essential to the establishment of the test in any laboratory. An examination of individual laboratory results indicated that, where problems were encountered, it was invariably due to the use of poor-quality water for the reconstitution of reagents. This confirmed the need to supply sterile deionised water for the reconstitution of all kit reagents. The results from this quality assurance exercise proved vital in identifying problems with the kit itself and with the use of the kit in individual laboratories. A lesson learnt from this first exercise was the decision to organise a ring test on a panel of sera to be distributed to all participating laboratories once a year (6).

Stage 2 – the FAO/IAEA c-ELISA kit quality assurance programme

In 1991, all network laboratories were supplied with the rinderpest c-ELISA kit. They were all equipped with computers, and the results were processed automatically using an FAO/IAEA software programme, EDI.

In 1992, an FAO/IAEA consultants' meeting was convened to define and establish, for the ELISA, standards for internal quality control of reagents and procedures and for the expression of results (5). The recommendations of that meeting were adopted by the World Organisation for Animal Health (OIE). The primary function of the internal quality controls was to ensure that the assay was performing within defined limits. The procedures for ascertaining this assurance would form the basis of an external quality assurance programme (EQAP). Between 1990 and 1993, as part of establishing an EQAP, laboratories using the FAO/IAEA ELISA kits for rinderpest seromonitoring in Africa were sent a panel of 40 sera to assess the proficiency of each laboratory on an annual basis. The results were compiled to indicate to managers of PARC that results from these laboratories could be relied upon as correct. Eighteen of the 20 laboratories involved in seromonitoring submitted results within one month of receiving the panel of 40 test sera. The results showed an overall agreement of 95% between laboratories, indicating a high level of proficiency in all testing laboratories and the clear advantage of using a single standardised and validated assay kit.

Stage 3 – The establishment of a quality assurance system for veterinary laboratories

A laboratory quality assurance system is the sum total of a laboratory's activities, aimed at achieving an acceptable level of proficiency. A quality assurance system within a laboratory includes the application of quality assurance principles to factors such as staff training, administrative procedures, management structures, auditing, process control and the final output of results. In the establishment, maintenance and improvement of total quality assurance within a laboratory, internal quality control (IQC) and external quality assurance, in particular proficiency testing, are critical components.

For the external recognition of a laboratory's capabilities, it is necessary to ensure not only that essential procedures are in place but also that these procedures are regularly monitored and their efficiency and effectiveness are measured. An EQAP coordinated by an independent third party is an internationally recognised approach for the implementation of such quality systems in laboratories.

In September 1994, an FAO/IAEA consultants' meeting was convened, with the aim of extending and further improving this EQAP for veterinary laboratories in developing countries, using FAO/IAEA ELISA kits. The meeting focused on establishing procedures that would recognise veterinary laboratories as competent in utilising FAO/IAEA ELISA kits for specific diseases and tasks, with the hope that the system would be expanded to form the basis of a wider system that can encompass a variety of diagnostic procedures and laboratories. Quality assurance activities were introduced continually into the activities of laboratories in the network. Starting with the introduction of an IQC test on all samples tested, this progressed to the introduction of the testing of an external proficiency panel of unknown samples. This then progressed to the introduction of a comprehensive EQAP as a way of monitoring and evaluating laboratory activities and providing considerable assurance to senior national managers that the results from their laboratories could be relied upon as correct (6).

The EQAP consisted of three equally important components: the questionnaire, the monitoring of the IQC data and the external quality control test panel. It was conducted twice a year. Overall, the results of this EQAP round showed that the majority of participating laboratories had an acceptable proficiency in conducting the rinderpest FAO/IAEA ELISA test. It should be noted that this approach eventually became the basis for ISO 17025, the quality assurance management system adopted globally for veterinary laboratories.

THE LABORATORY NETWORK WORK MANAGEMENT

Samples for seromonitoring were collected by the laboratory scientists and veterinary services staff, in accordance with the guidelines developed by the IAEA, FAO and PARC coordinators in OAU-Inter-African Bureau for Animal Resources (IBAR) in Nairobi (www-naweb.iaea.org/nafa/aph/public/OAU-BAR-PARC-1988.pdf). Once the results from the laboratories were fully collated, they were submitted to the rinderpest national coordinators for consideration and for appropriate action. In some cases, the national coordinator was based in the laboratory and was responsible for laboratory testing and the results generated. The results were also published by the IAEA, with a view to providing national authorities, the OAU-IBAR (now AU-IBAR) and donors with an up-to-date account of PARC's progress (9, 10, 11, 12). The results enabled the national coordinators to review vaccination coverage during the vaccination phase and to consider further vaccination in areas with evidence of poor seroconversion in sampled animals. It also provided the national coordinators with an opportunity to compare vaccine coverage submitted by field teams with the results obtained by seromonitoring. This initially caused some friction where there were discrepancies, but explanations were usually found – often involving poor-quality vaccine, vaccine used incorrectly or data irregularities. In the latter stages of disease surveillance, the laboratory data were used to search out suspected areas of apparent virus activity and to provide data for the OIE submissions on freedom from rinderpest. For this objective, guidelines for disease surveillance were published by the IAEA (13, 14).

CONCLUSIONS AND LESSONS LEARNT

The FAO/IAEA rinderpest laboratory network was first established in 1987, with a focus on seromonitoring the rinderpest vaccination programme, initially in Africa but subsequently across all countries infected with rinderpest. The approach and technologies established under PARC in Africa were transferred to other rinderpest eradication programmes and eventually embedded in GREP. This network contributed immensely to the success of GREP at all stages of the programme, from the vaccination seromonitoring to the disease surveillance. Through the programme, the FAO/IAEA Joint Division successfully strengthened veterinary diagnostic laboratories in countries that were involved in the eradication of rinderpest through:

a) human capacity building by carrying out training;
b) transfer of new assays for rinderpest diagnosis (test ELISA for antibody detection, immunocapture ELISA for rinderpest virus antigen detection (15) and molecular-based assays for rinderpest virus detection and virus identification (16);
c) the provision of required equipment and supplies;
d) computers and software for data management;
e) the introduction of a quality assurance system in the laboratories.

Lessons learnt from this experience can be summarised as follows:

1. Effective laboratory support is essential for an eradication programme with a nature similar to that of GREP.
2. Support to laboratories must be broadly based and include the essential equipment and reagents, training, expert assistance and, where required, operational funds. Without the latter, the laboratory cannot effectively support the programme.
3. Support for individuals within the laboratory is as essential as the general process. The ability to operate within the framework of a network with routine meetings and sharing results has

immense value and reward for individuals and is a prerequisite for success in the laboratory.

4. Standardisation is the only way to achieve effective comparison of results between laboratories. A harmonised approach, particularly in developing country settings, is highly unlikely to succeed. The process of standardisation should be applied across the whole range of laboratory-linked activities and **not** just to the test itself.
5. Quality assurance is an essential component of any laboratory activity. It should be used as a supportive tool to develop and enhance the network and not for identifying poor performance.
6. Although the technology needs within the laboratory are likely to change during an eradication programme, once a network has been established it is relatively straightforward to validate and implement the necessary technology transfer and use.
7. Laboratories must be supported and obliged to prepare and submit results on a routine basis. Not only does this ensure the effectiveness of the programme, but it also ensures the continual operation of laboratory activities. Maintaining a functioning laboratory component is a far more cost-effective approach than the routine resurrection of such capabilities.
8. Training was essential to all aspects of the work and should be considered a continuous task.
9. The establishment of international frameworks around the process is essential, e.g. internationally validated kits, agreed sampling frames and accreditation procedures for veterinary laboratories and the interpretation of ELISA results.
10. Laboratory activities must be linked to all activities of the programme, but being funded independently proved to be of real value (laboratory activities should not be in competition with the funding of Veterinary Services activities!).

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CHAPTER 6.4

SOCIO-ECONOMIC IMPACTS OF RINDERPEST ERADICATION

M.J. OTTE [(1)*], D.W. ROLAND-HOLST [(1)] & K.M. RICH [(2)]

(1) Berkeley Advising and Economic Research (BEAR), 1442A Walnut Street, Suite 108, Berkeley, California 94705, United States of America

(2) Faculty of Agribusiness and Commerce, C-222 Commerce Building, PO Box 85084, Lincoln University, Lincoln 7647, Christchurch, New Zealand

*Corresponding author: mjotte@bearecon.com

SUMMARY **At the outset of international rinderpest eradication efforts in the 1960s, 80% of the human population in affected countries lived in rural areas, with agriculture forming the basis of their livelihoods. Livestock were an essential component of farming systems, providing draught power, fertiliser, food and an array of other services. In addition to their direct contributions to rural livelihoods, livestock made a substantial contribution to local economies by stimulating the demand for non-tradable non-farm products. Evidence from selected country case studies suggests that the impact of livestock on household incomes resulting from this multiplier effect was among the highest in their economies. In the case of Pakistan and the United Republic of Tanzania, investments in livestock gave particularly high economy-wide returns, with multipliers of over five. Many socio-economic assessments of disease control omit these potentially large benefits accruing to wider segments of society. These multiplier effects were included in two detailed socio-economic country case studies, Chad and India, yielding economy-wide benefit–cost ratio (BCR) estimates of around 18, four to five times higher than the sector-level estimates. In the case of India, still larger benefits accrued from market access as a result of eradication, leading to an estimated BCR of over 64. However, even these economy-wide analyses fall short of capturing all of the benefits of rinderpest eradication, as they do not consider externalities, such as the protection of susceptible wildlife populations. In conclusion, there can be little doubt that the benefits of eradication far outweighed its costs and that, at the time, few investments would have yielded similar returns.**

KEYWORDS **Benefits – Costs – Eradication – Food security – Livestock – Multiplier effect – Rinderpest – Rural livelihoods – Socio-economic.**

INTRODUCTION

Rinderpest, one of the most dreaded diseases of large ruminants (cattle and buffaloes), was the only disease of livestock to have been eradicated globally at the turn of the millennium. As elucidated in previous chapters, this historic success was the result of the concerted efforts of livestock owners and the national Veterinary Services, whose actions were coordinated by inter-governmental institutions and supported by international research efforts.

This chapter aims to:

1. provide the socio-economic background at the outset of the coordinated rinderpest eradication efforts in sub-Saharan Africa (excluding southern Africa), West Asia and South Asia in the 1960s;
2. elucidate the role of livestock in the livelihoods of rural households in these regions;
3. illustrate the role of the livestock subsector in the overall economic development of agrarian economies;
4. provide quantitative information about the socio-economic impacts of rinderpest eradication through selected country case studies.

SOCIO-ECONOMIC STATUS OF SUB-SAHARAN AFRICA, WEST ASIA AND SOUTH ASIA IN THE 1960S

In the 1960s, when major rinderpest eradication efforts were initiated in West, East and Central Africa as well as in West and South Asia, the human populations in these regions were less than half the size of their populations in the first decade of the 21st century, when rinderpest had finally been eradicated (Table I).

TABLE I
HUMAN POPULATIONS (MILLION) IN 1965 AND 2005 BY AFRICAN AND ASIAN REGIONS

	1965	2005	1965 as % of 2005
West Africa	94,293	266,358	35.4
Central Africa	35,775	108,366	33.0
East Africa	96,210	298,112	32.3
West Asia	75,453	205,262	36.8
South Asia	663,602	1,569,454	42.3

Source: FAOSTAT

With the exception of West Asia, where urbanisation had reached around 40% in 1965, more than 80% of the human population in these regions was classified as 'rural' (Table II). The vast majority of the rural populace was engaged in agriculture, as either its primary or its secondary source of livelihood. At the time, agriculture generated between 20% and 60% of the gross domestic product in the countries of the regions.

The density of the rural human population (calculated over agricultural land) was rather low across the three African regions and West Asia (between 18 and 34 people/km^2), while in South Asia the rural population density, at 165 people/km^2, was five to eight times higher. The South Asia figure is largely determined by the much larger share of 'arable' land as opposed to 'permanent pasture', unsuitable for cropping, in land classified as 'agricultural' (Table III). In South Asia, around 70% of agricultural land was arable, while in the other four regions permanent pastures constituted 70% to 85% of agricultural land. In addition, the proportion of irrigated cropland was much higher in South Asia than in the other regions, and thus it was able to support larger human population densities.

TABLE II
1965 URBAN AND RURAL HUMAN POPULATIONS (MILLION) AND RURAL POPULATION DENSITY (RURAL POPULATION/AGRICULTURAL AREA IN KM^2) BY REGION

	Urban population (%)	Rural population (%)	Rural population density
West Africa	15.7 (16.6)	78.6 (83.4)	33.8
Central Africa	7.0 (19.7)	28.7 (80.3)	18.1
East Africa	8.5 (8.9)	87.7 (91.1)	30.7
West Asia	30.9 (40.4)	45.0 (59.6)	25.8
South Asia	121.9 (18.4)	541.7 (81.6)	165.4

Source: FAOSTAT

TABLE III
AGRICULTURAL LAND AVAILABILITY (1,000 HA) BY REGION IN 1965

	Agricultural land	Permanent pastures	Share of pastures in agricultural land (%)
West Africa	232,935	166,409	71.4
Central Africa	158,999	137,255	86.3
East Africa	285,603	242,988	85.1
West Asia	174,564	132,610	76.0
South Asia	327,474	96,598	29.5

Source: FAOSTAT

The per rural capita (p.r.c.) availability of arable land (irrigated and rainfed) in the regions ranged from 0.43 ha in South Asia to 0.93 ha in West Asia, while the availability of permanent pasture ranged from a low of 0.18 ha p.r.c. in South Asia to a high of 4.78 ha p.r.c. in Central Africa (Table IV).

The scarcity of arable land and pasture in South Asia gave rise to predominantly sedentary agriculture systems, incorporating mainly ruminant livestock, which provided draught power and manure while being fed on crop residues. In West Asia and the three African regions, the relative abundance of vast areas of permanent pasture had promoted the evolution of pastoral livestock production systems, in which ruminants were predominantly used to exploit lands that were not fit to grow crops. In South Asia, where draught power was one of the most important contributions of

TABLE IV
PER CAPITA (RURAL POPULATION) AGRICULTURAL LAND AVAILABILITY (HA) BY REGION (1965)

	Agricultural land	Crop land	Permanent pastures
West Africa	2.96	0.85	2.12
Central Africa	5.53	0.76	4.78
East Africa	3.26	0.49	2.77
West Asia	3.88	0.93	2.95
South Asia	0.60	0.43	0.18

Source: FAOSTAT

livestock to agriculture, large ruminants (cattle and water buffaloes) outnumbered small ruminants (sheep and goats), while in the other regions, where a large proportion of livestock was kept in pastoral systems, small ruminants outnumbered large ruminants. The latter was particularly the case in West Asia, where small ruminants were nearly five times as abundant as large ruminants (Table V).

Overall, with nearly 300 million head, the population of large ruminants in South Asia was about three times that of West, Central and East Africa combined. By comparison, the large ruminant population of West Asia, around 18 million head, was rather small.

The annual meat offtake per head of cattle/buffalo was estimated to be low, ranging from 6 kg in South Asia to 13 kg in Central Africa. The annual milk offtake per head was also low, being just above 10 kg in South Asia, around 15 kg in the three African regions and close to 40 kg in West Asia (Table VI). These low performance indicators are a reflection of the prevailing low-input production systems, based either on crop residues or natural pastures, and of the importance of the non-food functions/services provided by cattle and buffaloes to rural households.

Despite its low performance in terms of annual meat and milk offtake, livestock directly contributed

TABLE V
1965 RUMINANT POPULATIONS BY REGION

	Large ruminant populations (LR)	Small ruminant populations (SR)	SR:LR
West Africa	26,615,120	42,204,810	1.59
Central Africa	9,165,583	10,336,840	1.13
East Africa	66,191,812	87,946,814	1.33
West Asia	18,567,632	85,348,146	4.60
South Asia	291,956,985	208,828,802	0.72

Source: FAOSTAT

between 15% and 30% of the total net value of agricultural production, which, at the time, was in the range of PPP$150 to 200 (purchasing power parity dollars: a hypothetical currency with the same purchasing power of goods and services in all countries, 2004–2006) per rural inhabitant in the African regions and South Asia, while it was close to PPP$400 (2004–2006) in West Asia, the region with, at the time, the most developed agriculture sector (Table VII). However, the net value of meat and milk (and skin and hides) grossly underestimates the importance of livestock to agricultural production, food security and livelihood support, as will be illustrated in the next section.

THE ROLE OF LIVESTOCK IN FOOD SECURITY AND RURAL LIVELIHOODS

Household food security

Undernutrition was (and remains) widespread in the developing world. The impact of undernutrition in the short term includes poor growth and development of children and the increased risk of morbidity and mortality resulting from infectious diseases. Over the long term it impairs cognitive development and school performance, and in adults it reduces work performance and productivity (1). This lowers human capital development and constrains the potential for economic growth.

Within the household, livestock contributes to improved nutrition, particularly of children, in any of three ways. Diets may be improved by:

- occasionally consuming milk, eggs or meat;
- using the income earned from the sale of livestock products to buy food;
- increasing crop production, as a result of mixed farming.

Small livestock species (e.g. sheep and goats) are a more convenient source of household meat than cattle and other large ruminants (e.g. buffaloes), meat from large ruminants may spoil before it can all be consumed by a single household (2). Dairy animals are particularly important for pastoralists, whereby, during a normal wet season, milk provides more than half the mean energy and protein requirements of a one-year-old (3).

In mixed farming systems, the main benefits for a household of owning livestock are manure production and the provision of animal draught power. Crop yields are increased by the use of manure as fertiliser, while the use of animal draught power increases the area under crops and/or the cropping

TABLE VI
1965 MEAT AND MILK OFFTAKE FROM LARGE RUMINANTS

(per head in kg; total in tonnes)

	Meat offtake per head	Milk offtake per head	Total meat offtake	Total milk offtake
West Africa	12.9	16.5	343,437	730,349
Central Africa	13.3	17.4	121,845	274,852
East Africa	11.1	14.9	734,337	2,693,838
West Asia	11.8	37.7	218,834	6,727,791
South Asia	6.0	10.8	1,746,209	27,893,730

Source: FAOSTAT

TABLE VII
1965 NET VALUE OF AGRICULTURAL PRODUCTION (MILLION PPP$, 2004–2006), NET VALUE OF AGRICULTURAL PRODUCTION PER RURAL CAPITA (PPP$, 2004–2006), AND PROPORTION OF NET VALUE OF AGRICULTURAL PRODUCTION FROM LIVESTOCK (%)

	Net value of agricultural production	Net value of agricultural production per rural inhabitant	Proportion of net value of agricultural production from livestock
West Africa	15,744	200	15.0
Central Africa	5,635	196	19.3
East Africa	14,932	170	32.6
West Asia	16,951	377	32.1
South Asia	80,532	149	24.0

Source: FAOSTAT

intensity (4). Increases in crop production can then contribute to improved livelihoods and better nutrition. Additional income derived from the sale of crops, livestock or livestock products can be used to purchase food items to supplement the farm-derived diet.

Resilience to shocks: insurance, risk spreading and savings

Two salient challenges for rural households are risk and vulnerability. In response to this, farmers have developed multiple strategies for (*ex ante*) risk management and (*ex post*) coping with shocks (5, 6). The former involves diversification into livestock, which is a common strategy in a wide spectrum of rural households. The latter involves reducing the variability in food consumption in spite of any fluctuations in crop yields and/or income. Here, livestock offer many advantages. Livestock are generally more adaptable to environmental shocks than are crops. They are mobile, which increases survivability, and may also be able to digest a wide variety of feedstuffs and thereby have the capacity to survive dramatic reductions in specific feed resources. The provision of food, such as milk and eggs, by livestock provides nutritional insurance that can be used to smooth household food consumption levels. The potential source of food represented by animals 'on the hoof' is also an important aspect of food security. At times of excessive availability of fodder and/or grains, these can be temporarily 'stored' in livestock and 'liquidated' in times of food shortage. In addition, the time to realise asset value is more flexible for livestock than for many other agricultural products, which provides a further buffer against climatic and/or market risks.

In the absence of well-functioning markets for finance and insurance, livestock embody savings and provide a reserve against emergencies. If an urgent need for money arises, for a special occasion or to cope with a disaster such as a drought, animals may be sold to raise the required amount. The savings function of livestock is evidenced by households that sell livestock in times of cash needs while purchasing livestock at times when their income exceeds their expenditure (7).

As a result of the flexibility in the use of livestock and because of the diversification of income sources, incomes on small farms are much less variable from year to year if they produce crops and livestock than if they produce crops alone (8). Both as a store of savings and as a risk reserve, small stock (sheep, goats, pigs and poultry) have advantages over larger animals (cattle, buffaloes and camels) in terms of greater convenience.

Farm/household production and productivity

As noted in the previous section, rural households, on average, only have ownership of or user rights to small amounts of agricultural land, while pastoralists have user rights to non-privately owned rangelands. For all of these households, investment in livestock raises production and productivity by:

- mediating access to common property (grazing and scavenging) resources;
- converting low-quality organic material (rangeland grasses and shrubs, crop residues, organic wastes, scavengeable protein) into high(er) value products;
- extending the land area that can be cultivated by using draught power;
- facilitating the diversification into more demanding crops by using organic fertiliser and draught power;
- smoothing demand on family labour over seasons, gender and generations.

Livestock offer one of the most efficient means of utilising resources, such as dryland vegetation, crop residues and organic wastes, in both rural and urban areas, that would otherwise go unexploited. In addition to adding value to material not suitable for human consumption, livestock enable low-income households to convert common property resources into private assets.

It has been estimated that at the turn of the millennium about half of the total cropped area in developing countries, at least 320 million hectares, was still cultivated using animal draught power provided by cattle, buffaloes, horses, donkeys and mules (9). Livestock such as donkeys also free household labour by carrying water and fuel for household use, by serving as pack animals and by pulling carts to take agricultural produce to markets or to bring agricultural inputs back to the farms, and, in the case of landless nomadic households, livestock allow the migration of all or parts of the family.

Many soils contain insufficient nutrients to sustain efficient crop production, and so complementary relationships between crops and livestock are exploited, through nutrient recycling, with animals feeding on crop residues and the manure being returned to the soil. As a result, production of both crops and livestock is increased. In areas where livestock graze on range or pasture, they transfer plant nutrients from non-arable to arable land. Manure has been shown to increase yields to levels similar to those achieved using chemical fertilisers, adding to livestock's role in increasing human food supply.

Given that livestock-related activities are generally not as seasonally circumscribed as those related to crops, such as field preparation, planting or harvesting, which often have high labour demands at critical times in the crop lifecycle, livestock are a means of more evenly spreading the requirements for household labour across gender, age and time of the year.

Income generation: linking to the cash economy and value addition

Purely subsistence households are relatively rare, and the vast majority of rural households are partly engaged in market activities, despite also aiming to produce food for the family. Most households sell part of their agricultural production, and poorer households are not significantly less likely to sell agricultural products than the better off rural households. Although the contribution of livestock to the total rural household income may not be very high, its contribution to the cash income is often higher. Small streams of recurrent cash income derived from 'flow' products such as milk and eggs are particularly useful to meet minor everyday cash outlays.

In addition to the direct sale of livestock and/or their primary products (meat, milk, eggs, wool, etc.), some of the latter can be processed at a household level, either by livestock keeper households themselves or by other rural households, thereby contributing to wealth generation and poverty reduction. Given the 'mobility' restrictions faced by women and the elderly in many rural societies, value addition within the household setting provides an important avenue for the household to increase and diversify its income. In most parts of the world, women are essential participants in the process of adding value to milk, hides and skins, and fibres of livestock origin.

Social and cultural functions

In many societies, livestock serve social and cultural functions. They may have special roles in religious ceremonies and other social institutions, providing a tangible measure of personal or family status. Important social occasions are often marked by the consumption of livestock products. Weddings or the birth of children are also often commemorated with gifts of livestock, and in some areas dowries or bride-prices are paid in livestock. The ability to participate in these activities may be essential for establishing and maintaining the social networks through which risk is managed.

Livestock are also an important means of conferring income and status on women. In both traditional inheritance systems and in many land reform and settlement schemes, land rights are generally transferred to males as the 'head of household'. Female-headed households, resulting from death or extended migration of the husband, or divorce, generally control less land than male-headed households. Although women seldom hold property or usage rights to land, they often independently own small livestock, such as goats in West Africa (10) and 'backyard' poultry in many developing countries. These animals, which normally scavenge or are fed on household waste, represent an important asset and a source of income for women, who then control and allocate the proceeds according to their needs.

Status should not be considered an intangible benefit, as it may translate into influence and the subsequent increase in access to resources. Apart from the intangible benefits of conferring status, livestock ownership may facilitate access to credit. In addition to facilitating access to formal credit, livestock obtained as loans-in-kind are a popular way for poor households to improve their access to other goods and services.

ECONOMIC MULTIPLIERS OF LIVESTOCK PRODUCTION

Indirectly, livestock make a substantial contribution to local economies by stimulating the demand for non-tradable non-farm products. Evidence from selected case study countries suggests that the impact of livestock on household incomes as a result of this multiplier effect is among the highest compared with other sectors and subsectors of their economies (11, 12). For instance, Roeder and Rich (11), in their evaluation of the economic impact of rinderpest eradication, used a social accounting matrix (SAM) to calculate the multiplier effect on downstream sectors. A SAM provides a ledger of disaggregated, economy-wide activities (called accounts), and can be used both to assess the structure of an economy and as an input to more sophisticated computable general equilibrium (CGE) models that calculate macro-level impacts. A multiplier estimates the effects from an assumed one-dollar increase in government spending, investment or export demand on:

a) economy-wide activities;
b) household incomes.

In the Roeder and Rich study (11), multipliers were calculated for five countries – Ethiopia, Kenya, Pakistan, the United Republic of Tanzania and Uganda.

In Table VIII, multipliers from the livestock sector are reported from the five case studies, with the rank of the relevant livestock sector relative to other sectors provided in parentheses. The level of disaggregation from the SAM for livestock accounts varies – in Kenya for instance, there is more detailed information on specific livestock activities (beef, poultry, etc.), while in other countries (Ethiopia, United Republic of Tanzania, Uganda) all livestock activities are aggregated into one account. An important assumption and caveat to the analysis is that the multipliers reported from the SAM are constant over time, which may not be the case if there are large structural changes in the economy. It is very possible that, over the course of the rinderpest eradication campaign, these multipliers would have been higher or lower than those reported from the 2000s in the chosen SAMs. Nonetheless, we would not expect multipliers to be hugely variable over time, although their relative importance compared with other sectors may change.

As noted in Table VIII, the livestock sector ranks highly relative to other sectors and in aggregate in previously rinderpest-impacted countries. In the case of Pakistan and the United Republic of Tanzania, investments in livestock have particularly high economy-wide returns, with multipliers of over five. In the case of Ethiopia, livestock provides the highest gain among all economic sectors in terms of generating household income. When household sectors are disaggregated by type in Ethiopia, the SAM analysis revealed that livestock also generated the highest multipliers for vulnerable groups, such as the rural poor (multiplier of 0.84), and for factor income in pastoral and drought-prone areas (multiplier of 0.42) (11).

TABLE VIII
SUMMARY OF SAM MULTIPLIERS IN FIVE CASE STUDY COUNTRIES

Country (sector in SAM)	Activity multiplier (rank in country/ number of sectors)	Household income multiplier (rank in country/number of sectors)
Ethiopia (livestock)	3.31 (4/22)	2.65 (1/22)
Kenya (beef)	2.89 (15/50)	1.22 (20/50)
Pakistan (cattle)	5.18 (5/33)	2.68 (4/33)
Tanzania (United Republic of) (livestock)	5.07 (10/43)	3.13 (10/43)
Uganda (livestock)	3.84 (8/26)	2.96 (7/26)

Source: Roeder and Rich (11)

TABLE IX
ESTIMATES OF HOUSEHOLD-LEVEL INCOME EFFECTS OF RINDERPEST INTERVENTIONS IN SELECTED COUNTRIES

Country	Estimated household income benefits from rinderpest-related interventions during selected time period (million ECU)
Ethiopia (1989/1990–1995/1996)	38.1
Kenya (1997/1998)	4.2
Pakistan (1999–2005)	8.0
Tanzania (United Republic of) (1992/1993–1996/1997)	11.5
Uganda (1991/1992–1996/1997)	16.0

Source: Roeder and Rich (11)

When these multipliers are applied to the economic impacts of specific rinderpest eradication programmes, the economy-wide gains are quite revealing. Roeder and Rich (11) extrapolated the impacts of the different rinderpest eradication programmes (Pan-African Rinderpest Campaign [PARC] for the four African cases, Food and Agriculture Organization of the United Nations programmes for Pakistan) on household incomes in the same five case studies and found significant benefits, particularly in Ethiopia where household incomes increased by over ECU 38 million (European currency units), the overwhelming majority of which (ECU 34 million) accrued in rural areas (Table IX).

COUNTRY-SPECIFIC CASE STUDIES OF IMPACTS OF RINDERPEST ERADICATION

In this section, we profile two case studies of the impacts of rinderpest eradication. Our analysis focuses particularly on Chad and India, where significant efforts have been made to retrospectively analyse the impacts of eradication (13).

In the Chad and India case studies, the counterfactual scenarios used the DynMod model (14), which calculates herd demographics and is calibrated for use in pastoral and developing country settings. In the counterfactual scenarios, a number of scenarios of additional mortality that existed before rinderpest control programmes were enacted to extrapolate the population trend that would have existed in the absence of rinderpest control. Climatic events such as droughts were also taken into account, as were morbidity effects associated with the loss of milk production. This provided a benchmark to calculate the avoided losses from rinderpest eradication against the costs of different rinderpest control programmes. More details of the methodology can be found in Rich *et al.* (13).

Chad

Rinderpest affected Chad quite severely. Nearly 70% of the country's cattle (one million animals) were killed in an outbreak during 1913 and 1914, while a major outbreak in 1983 killed up to 337,500 animals (13). The presence of rinderpest also exacerbated the stress on animal populations (and their owners) that arises from the periodic droughts that occur in Chad.

While rinderpest control efforts began in 1933, it was only in 1962 that international control efforts began through the Joint Programme 15 (JP15) programme. In the course of this programme, from 1962 to 1970, vaccination coverage increased significantly, although it was erratic after the first year of the programme (83% coverage). After JP15, vaccination coverage fell to 29–44% in the mid-1970s before stopping entirely prior to the 1983 drought. Vaccine coverage increased afterwards, but only reached JP15 levels with the start of PARC in the late 1980s and early 1990s (13).

The total additional benefits and costs associated with the rinderpest eradication campaigns during the period 1963–2002 were computed under a variety of scenarios. Under baseline scenarios, which assume that the additional mortality resulting from rinderpest would be 0.32%, the discounted net present value of the avoided losses resulting from rinderpest campaigns was calculated at CFA 32.46 billion (West African francs) (in 2000 prices), against programme costs of CFA 8.08 billion, resulting in a benefit–cost ratio (BCR) of 4.02. Under high-mortality scenarios (1.54% additional mortality from rinderpest), the BCR rises to 47.15, while under low-mortality scenarios the BCR is negative on account of the 1983 drought that generates a cattle population trend that is higher post drought than the observed trend (13).

The above results consider only the farm-level net benefits associated with rinderpest control. Based on a SAM for Chad in 2000, Roeder and Rich (11) estimated that the multiplier associated with livestock is 4.63, which would yield an economy-wide BCR of over 18 if applied to the farm-level BCR. Distributional effects within the economy through the use of the Chad SAM show that rural households are 2.5% worse off under a scenario of no control than under one of control. Moreover, a CGE modelling exercise using the Chad SAM reveals that livestock production could have been 27% lower, projected to 2030, under a scenario of no control, while exports of livestock would have been 28% lower.

India

India had a long history of rinderpest, with control efforts starting in the 1930s. Concerted efforts began in the mid-1950s under the aegis of the National Rinderpest Eradication Programme, which piloted a vaccination programme that was subsequently scaled out country-wide (13). While India was able to control rinderpest through a large-scale vaccination programme combined with buffer areas, surveillance and movement restrictions, minor outbreaks re-emerged periodically in certain states. Eradication was fostered by an intensive three-year vaccination programme that raised coverage to 90% in endemic states, complemented by a targeted vaccination in others. India was certified free from rinderpest in 1995 (13).

One valuable property of the Indian input–output data is an activity account for animal services, which is primarily composed of animal traction. This account was included in the Indian system for national accounts (SNA) for reasons that should be more widely recognised, especially in Asia and Africa: although meat consumption at the village level is limited (particularly in India), the service of animal traction is part of the bedrock of local economic activity, not only in farm production but also in commercial distribution and other transport services. Moreover, this service would be quite sensitive to bovine health status, and as such offers an important assessment metric for rinderpest damages. Multipliers from animal services are large and widely dispersed across stakeholders in the Indian economy (total activity multiplier of 4.48, household multiplier of 1.69, and total multiplier of 8.15), reflecting the importance of animal traction in the smallholder agri-food supply chain and that supply chain's extensive linkages across the Indian economy.

Rich *et al.* (13) looked at the impact of rinderpest eradication in India in three scenarios. First, they considered the impact of the mass vaccination strategy compared with a more modest, 'limited vaccination' strategy that was similar to that used in the 1950s. Second, they compared the mass vaccination strategy with a 'no control' scenario that was calibrated to mortality rates that prevailed between 1920 and 1940. Third, they looked at the market access impacts of rinderpest control post-1992 compared with a scenario of no control.

For the first scenario, mass vaccination had slightly less of a return than a more scaled back, limited vaccination programme, although this only takes farm-level effects into account. On the other hand, the BCR of mass vaccination compared with no control (5.42) clearly indicates benefits for control. The most interesting effects emerge from the market access impacts that arose after rinderpest control. With increased market access, partly engendered by rinderpest eradication (alongside rising demand from the Middle East, Africa and Asia), exports from India of buffalo meat boomed from the early 1990s, rising from just under 100,000 tonnes to around 500,000 tonnes by 2007; India is currently the world's largest exporter of bovine meat. Such developments, compared with a scenario of pre-1992 trend growth under a no-control scenario, give rise to a BCR from market access in the 1990s of over 64 (13).

Multiplier effects, as computed from a CGE model of India, reveal strong gains from rinderpest eradication. Projected to 2030, in the absence of rinderpest eradication, real GDP would be 6% lower; milk production would be 34% lower; and other livestock production would be 21% lower. Exports of leather would be 20% lower; exports of milk would be 34% lower; and exports of other livestock products would be 22% lower (13).

DISCUSSION

Global disease eradication is an extremely difficult undertaking given the required degree of international coordination and cooperation over a prolonged period, the challenges of ensuring sufficient vaccination coverage to maintain herd protection everywhere in the often long period between the disease being eradicated locally and it being eradicated globally, and the continual risk that cases will be exported back into territories that were previously free of the disease, as a result of war or political instability. Against this background, and considering the vast geographical scope as well as the socio-economic conditions prevailing at the outset of the global rinderpest eradication efforts, its success must be considered a truly iconic achievement of the 20th century.

Many economic assessments of disease control programmes take into account merely the benefits accruing to producers, thereby omitting potentially large benefits accruing to wider segments of society. In the case of rinderpest, even the narrow focus on livestock producers has consistently provided positive (but not always high) BCRs for all African countries considered by Tambi *et al.* (15). However, given that rural households diversify into a variety of activities within the livestock value chain, shocks to livestock production have knock-on effects on rural households through impacts on marketing and processing activities. Consequently, the benefits of rinderpest eradication will include a multiplicity of non-livestock-related benefits as well.

Even the economy-wide analyses by Rich *et al.* (13) fall short of capturing all the benefits of rinderpest eradication, as they do not consider externalities of eradication, such as the protection of susceptible wildlife populations across continents, which safeguards the biodiversity and resilience of ecological systems, or the improvement in animal health systems, which enhances national capacities to control other detrimental livestock diseases. Furthermore, the analyses do not capture the benefits of eradication accruing to countries that have historically been free from rinderpest through savings on recurrent expenditure to safeguard against its introduction.

Although none of the available socio-economic analyses of rinderpest eradication can be considered comprehensive, there can be little doubt that the benefits far outweighed the costs and that few investments would have yielded higher returns, particularly in countries with rural poor majorities. As Barrett (16) observes, maintaining a high level of control can never be optimal given the technical feasibility of eradication because the latter provides an enormous health benefit that stretches far into the future.

As livestock make an essential contribution to poor people's food security and livelihoods, especially in rural areas where the majority of global poverty persists, sustained initiatives to reduce the incidence and persistence of animal diseases are an essential component of global development policy, supporting vital capacity for the poor to advance their own circumstances.

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PART 7
GLOBAL FREEDOM

CHAPTERS

CHAPTER 7.1

THE OIE RINDERPEST PATHWAY

G. BRÜCKNER [(1)], A. RIPANI [(2)*] & L. WEBER-VINTZEL [(3)]

(1) President of the Scientific Commission for Animal Diseases (SCAD) of the World Organisation for Animal Health (OIE), 30 Schoongezicht, 1 Scholtz Street, The Links, Somerset West 7130, South Africa
(2) World Organisation for Animal Health (OIE), Sub-Regional Representation for North Africa, 17 Avenue d'Afrique – El Menzah V, 2091 Tunis, Tunisia
(3) World Organisation for Animal Health (OIE), Headquarters, 12, rue de Prony, 75017 Paris, France

*Corresponding author: a.ripani@oie.int

SUMMARY **Since the 1960s, the World Organisation for Animal Health (OIE), the Food and Agriculture Organization of the United Nations (FAO) and regional organisations have worked together to initiate and launch extensive programmes to reinforce the capacities of countries where rinderpest was endemic to eradicate the disease. A process known as the OIE Rinderpest Pathway evolved from 1989 to 2011, to address the changing global rinderpest epidemiological situation.**

Prerequisites along this pathway were that OIE Members had a disease surveillance system in place that would detect rinderpest if it were present and that they could control the movement of livestock across their borders. To provide more guidance to its Members for conducting surveillance of rinderpest, with the aim of firstly achieving national freedom from rinderpest for Members and eventually global eradication, the OIE convened the Expert Consultation on Rinderpest Surveillance Systems, which was held in Paris in August 1989. The mandated experts elaborated standards for the epidemiological surveillance of rinderpest along with the chronological sequence of the steps required to objectively measure and demonstrate progress made by the Members along the defined OIE Pathway in eradicating rinderpest and finally gaining the official international recognition of freedom from rinderpest infection by the OIE.

The process was initially aimed at only OIE Members, but to expedite the process it was later extended to non-OIE Members and contiguous territories. This chapter also describes how the pathway was adopted during the process to eventually focus on countries and territories that were free from rinderpest, rather than allowing zonal freedom from rinderpest.

Setting international standards for all players to respect and adhere to helped assure international buy-in to a common commitment to rid the world of rinderpest. The OIE Pathway provided the assurance that the global declaration of freedom, in 2011, was achieved by following and not compromising international standards for animal disease control.

KEYWORDS **Global declaration – OIE Pathway – Standards – Surveillance.**

INTRODUCTION

The World Organisation for Animal Health (OIE) is the intergovernmental organisation accountable for improving animal health and welfare worldwide, and it is recognised as a reference organisation by the World Trade Organization (WTO) and as an international standard-setting body for animal health, including zoonoses and animal welfare (1, 2). The OIE was established in 1924 to ensure transparency in the global animal disease situation in response to the recurrence of rinderpest in Belgium in 1920 after infected zebu passed through Antwerp en route to Brazil from India (3) (see also Chapter 5.2). Eighty-seven years after its creation, the OIE – in collaboration with the Food and Agriculture Organization of the United Nations (FAO) – declared at the 79th OIE General Session, held in 2011 in Paris, that the entire world was free of rinderpest and announced its global eradication (4). Not only was this the first animal disease that has been officially eradicated worldwide, but it is also fitting that it would be the very disease that initiated the establishment of the OIE in 1924. This was thereafter confirmed at the 37th FAO Conference.

Since the 1960s, the OIE, FAO and regional organisations have worked together to initiate and launch extensive programmes to reinforce the capacities of countries where rinderpest was endemic to eradicate the disease and – in parallel – to control other significant transboundary diseases (5). These initiatives facilitated – through the use of vaccination – the eradication of rinderpest in almost all areas of the world between the 1960s and mid-1970s, and, in particular, from the African continent under the Joint Programme 15 (JP15). The JP15, a multinational project, was the first pan-African rinderpest eradication programme, based mainly on vaccination (6) (see also Chapter 4.1).

However, vaccination resulted in the disappearance of the clinical signs of the disease, which consequently resulted in a decrease in the intensity of vaccination campaigns, with the inevitable recrudescence of rinderpest in the 1980s in Africa, the Middle East and South Asia. The disease persisted until the last outbreak was recorded in the world in 2001 in wild buffaloes in Kenya (5).

DEVELOPMENT, IMPLEMENTATION AND EVOLUTION OF THE OIE RINDERPEST PATHWAY

To provide more guidance to its Members for conducting surveillance of rinderpest, with the aim of firstly achieving national freedom from the disease for Members and eventually global eradication, the OIE convened the Expert Consultation on Rinderpest Surveillance Systems, which was held in Paris in August 1989 (7). The mandated experts drew up standards for the epidemiological surveillance of rinderpest and the sequence of steps required to objectively measure and demonstrate the progress made by Members in eradicating rinderpest (8).

This process – known as the OIE Rinderpest Pathway – evolved from 1989 to 2011 to better address the changing global epidemiological situation. Three major phases can be distinguished:

1. 1989–1998: In this phase the update, subsequent revisions and adoption of the international standards for the epidemiological surveillance of rinderpest were established.
2. 1998–2006: In this phase the first official recognition of countries that were free from rinderpest was recorded, through the establishment of a baseline list of historically free countries. During this period a stepwise procedure was implemented for OIE Members and zones, in which Members could progress towards freedom from rinderpest from initial provisional freedom to freedom from disease and eventually to freedom from infection. At the Global Rinderpest Eradication Programme (GREP) Experts consultative meeting in September 2007, it was recommended that the OIE 'include the issue of the Global Declaration, during its annual general session', it was also recommended that 'GREP with OIE starts immediately to prepare for the final evidence-based approval of global rinderpest freedom by the establishment of a global scientific commission. OIE and FAO (GREP and the FAO-IAEA Joint division) create a standing committee to monitor and drive the process of ensuring that all countries become accredited as rinderpest free by 2010. The Standing Committee will also drive the process of establishing the Global Scientific Commission charged with the final evaluation of rinderpest freedom to be notified by the two partner Organisations in 2010. OIE and FAO initiate developing a legal framework for the Declaration and the associated national obligations for assuring the maintenance of the Global freedom including the code of practice for virulent rinderpest virus' (9). This Commission became the joint FAO/OIE Committee for global declaration (Chapter 7.2).
3. 2007–2011: In this phase a tentative target date for global eradication was set for 2010 (further postponed to 2011), and consequently the need to expedite the process to move towards rinderpest eradication was identified.

The expedited process included further development of the OIE Rinderpest Pathway: including in the eradication process non-contiguous territories associated with a Member that may not be geographically attached to the mainland but are under the jurisdiction of the same Veterinary Authority. It also included overseas territories and non-OIE Members.

This step undoubtedly paved the way for a legal international mandate to move in a structured way towards global eradication and the eventual declaration of worldwide freedom from rinderpest in 2011.

1989–1998: ELABORATION AND ADOPTION OF THE OIE RINDERPEST PATHWAY

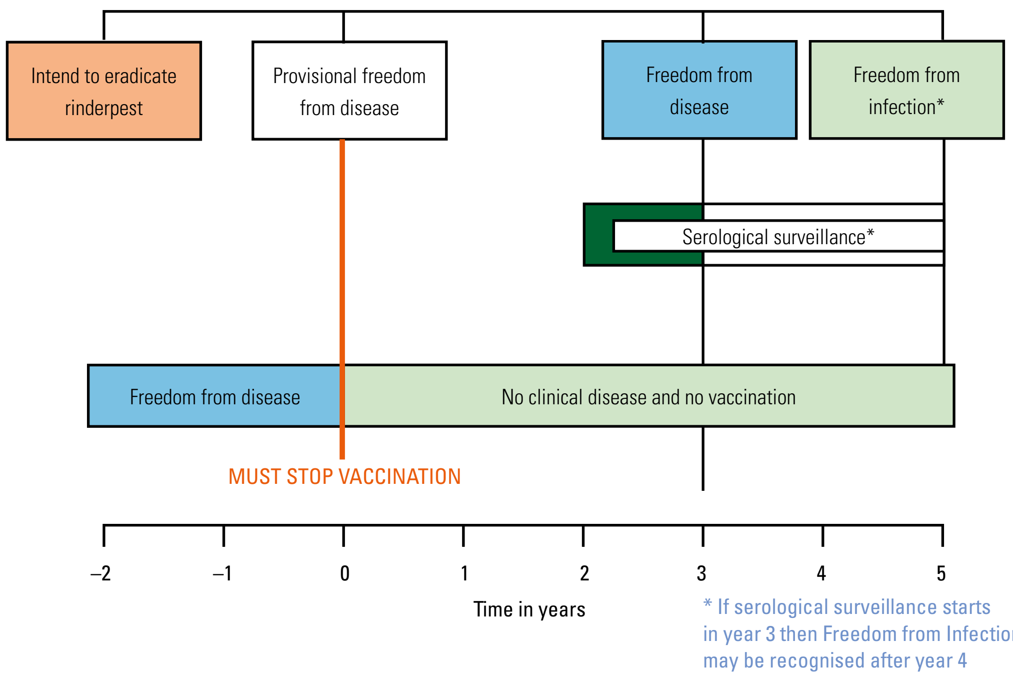
The OIE Rinderpest Pathway originated from the recommendations of the OIE Expert Consultation on Rinderpest Surveillance Systems, held in August 1989. These were subsequently renamed as the *Recommended Standards for Epidemiological Surveillance for Rinderpest* and were subject to further revision over the years, under the supervision and mandate of the OIE Foot-and-Mouth Disease and Other Epizootics Commission and in collaboration with international recognised experts on rinderpest. (From 2003 onwards, the Commission was renamed the OIE Scientific Commission for Animal Diseases.) During the 66th OIE General Session (May 1998), the *Recommended Standards for Epidemiological Surveillance Systems for Rinderpest* were adopted by the International Committee of the OIE (today called the World Assembly of Delegates) through OIE Resolution No. IX, and subsequently became 'standards' as part of the OIE *Terrestrial Animal Health Code (Terrestrial Code)* (10).

THE RATIONALE AND REASONING FOR THE PROCEDURES AND REQUIREMENTS FROM 1998 TO 2006

General overview

The OIE Rinderpest Pathway, and the related guide for rinderpest surveillance, had the central objective of assisting previously infected Members to demonstrate freedom from rinderpest through a stepwise pathway, starting with a self-declaration of freedom from rinderpest and eventually moving towards OIE official recognition. The cessation of vaccination against rinderpest was a prerequisite to embarking on and proceeding through the phases of the pathway leading to freedom from disease (10). Figure 1 illustrates the scheme of the OIE Rinderpest Pathway and the interrelated time-bound steps. Essentially, OIE Members that had not detected clinical signs of the disease for two years and had ceased vaccination could proclaim 'Provisional freedom from the disease (self-declaration)'.

FIG. 1
THE STEPWISE APPROACH OF THE OIE RINDERPEST PATHWAY
Courtesy of the authors



* If a country wanted to be declared free from rinderpest infection at the end of year 4, serological surveillance of unvaccinated animals was in operation at the end of year 2, to prove that there were no seropositive cases in the country for at least two years

Thereafter, these Members could request, on a voluntary basis, official assessment(s) – under the auspices of the OIE – of their progress along the OIE Rinderpest Pathway towards international recognition as a rinderpest-free country. Thus, three years from self-declaring provisional freedom, OIE Members that recorded no clinical disease and applied no vaccination could apply to the OIE for 'freedom from the disease'. The final phase of 'freedom from infection' was recognised when a country met more stringent criteria: a minimum of one year after the OIE declaration of freedom from the disease, provided that the results of the serosurveillance system in place for at least two years were consistent with the absence of disease infection.

Prerequisites along this pathway were that OIE Members had a disease surveillance system in place that would detect rinderpest if it were present and that they could control the movement of livestock across their borders (Fig. 1) (11).

In summary, the OIE Pathway was a tool – for countries previously infected – based on a confidence-building procedure that started with a national declaration of provisional freedom from rinderpest disease followed first by an official international recognition of freedom from rinderpest disease and finally by official international recognition of freedom from rinderpest infection, under the auspices of the OIE.

In the framework of the OIE certification process to officially achieve rinderpest-free status – and to facilitate it – three different options were developed, based on the epidemiological situation in the OIE Member. Only the third option relates directly to the pathway.

1. Historically free countries (from a historically free region) could directly apply for recognition of being free from infection through a letter of declaration signed by the OIE Delegate (usually the Chief Veterinary Officer). This fast-track procedure was opened for applicant countries for one year in 1999 and allowed the establishment of a baseline list of historically rinderpest-free countries, which was officially adopted in 2000 (12).
2. Countries having eradicated rinderpest for at least ten years should have provided specific documentation for demonstrating freedom from rinderpest, based on the requirements laid out in the relevant chapter of the *Terrestrial Code* on general principles for recognising a country or zone free from rinderpest for:
   a) historically free countries where the eradication was achieved or rinderpest disease/infection had not occurred for at least 25 years, and in which the following had been in place for the past ten years:
      – no vaccination against rinderpest had taken place;
      – rinderpest was a notifiable disease;
      – an early detection system was in place;
      – measures to prevent disease/infection introduction were in place;
      – infection was not known to be established in wildlife.

      Those countries could apply without conducting agent-specific surveillance.

   b) countries that had the last occurrence between 10 and 25 years previously and in which appropriate specific surveillance had been applied to demonstrate the absence of the agent in addition to the requirements listed in point (*a*) above.
3. Countries infected with rinderpest within the past ten years should have provided a dossier containing all the data and information in accordance with the *Recommended Standards for Epidemiological Surveillance for Rinderpest* (the OIE Rinderpest Pathway).

THE OIE RINDERPEST PATHWAY: CAPTURING THE RECOMMENDED STANDARDS FOR EPIDEMIOLOGICAL SURVEILLANCE SYSTEMS FOR RINDERPEST IN THE TERRESTRIAL CODE AND SETTING A MANDATE FOR GLOBAL ERADICATION

Since its first publication in 1968, the OIE *Terrestrial Code* has set out international standards for the improvement of terrestrial animal health and welfare and veterinary public health worldwide as well as standards to ensure safe international trade in terrestrial animals and their products. Therefore, the recommended standards for epidemiological surveillance systems for rinderpest – once adopted by the International Committee of the OIE in 1998 – were included in the *Terrestrial Code* as Appendix 3.8.2 to complement Chapter 2.2.12. The appendix was dedicated to rinderpest and, specifically, laid down the provisions to obtain the rinderpest status for the susceptible livestock population in a country as well as additional recommendations for trade in animals and products.

In accordance with Appendix 3.8.2 and to gain OIE recognition of freedom from rinderpest, the Veterinary Authority of a Member needed to present to the OIE for consideration a dossier reflecting information relating to its livestock production systems, rinderpest vaccination and eradication history, and the functioning of the Veterinary Services. The dossier had to provide convincing evidence – derived from the disease surveillance system – to demonstrate that the presence of rinderpest virus would have been disclosed if present. The serosurveillance strategy to be applied was described in Appendix 3.8.2, Article 3.8.2.3, as were the relevant criteria for the stratification of the host population and the field procedures and sample sizes needed, with the fundamental concept being that annual sample sizes should be sufficient to provide 95% probability of detecting evidence of rinderpest if present, at a prevalence of 1% of herds or other sampling units, and 5% within herds or other sampling units. Basically, the standards described the criteria:

– for the declaration of freedom from rinderpest (provisional freedom from the disease (self-declaration);
– to prove that a country or a zone is free from rinderpest (freedom from disease and freedom from infection.

The specific criteria proposed for each stage of the OIE Rinderpest Pathway are described in the next sections.

Provisional freedom from rinderpest (self-declaration)

A country that had not detected clinical disease for at least two years could self-declare itself as provisionally free from rinderpest, provided that it maintained effective Veterinary Services that were able to investigate all clinical evidence suggestive of rinderpest. The country should have in place a reliable system for preventing the introduction of infection and provide evidence that all vaccinations against rinderpest had been stopped by the date of the declaration. Self-declarations were also applicable to zones.

It is important to note that the self-declaration of freedom from rinderpest was totally under the responsibility of the Member concerned and that the OIE was not responsible for inaccurate publication of a self-declaration.

Freedom from rinderpest disease (country or zone)

To obtain the status of 'free from rinderpest disease', a country had to submit a dossier to the OIE for international verification. The evaluation of the dossier was under the responsibility of the Foot-and-Mouth Disease (FMD) and Other Epizootics Commission, which in turn, as appropriate, could ask the Director-General of the OIE to appoint an expert panel (geographically representative experts with high levels of expertise) to help the Commission in reaching an informed decision to present to the International Committee for official recognition.

There were two ways for a country to be officially recognised as free from rinderpest disease:

1. A country that had declared itself (or a zone within the country) to be provisionally free from rinderpest could be recognised officially by the OIE as free from rinderpest disease, provided that no clinical rinderpest had been detected for at least the past five years and no vaccines against rinderpest (including heterologous vaccines) had been used for at least the past three years. Additional major criteria were to have in place operational clinical surveillance and disease-reporting systems that allowed the investigation of all clinical evidence suggestive of rinderpest (by field and laboratory methods) and effective measures to prevent the reintroduction of the disease.
2. A country or a zone that had not vaccinated against rinderpest for at least the past five years and had throughout that period no evidence of rinderpest was also able to apply directly to the OIE for recognition of freedom from rinderpest disease without going through the 'provisionally free' step. Such a country was required to demonstrate that throughout that period it had permanently maintained an adequate disease-reporting system.

To maintain the status of 'free from rinderpest disease', a country had to continue meeting these requirements until it would be recognised as free from rinderpest infection and had to submit an annual report to the OIE on its progress on moving towards freedom from rinderpest infection.

Countries that could not apply for their entire national territory to be free from rinderpest disease were offered the possibility of applying to the OIE for the official recognition of a zone within the country to be officially recognised as free from rinderpest disease. The major requirements to achieve this status were to have well-defined boundaries of the proposed zone and to keep it separated from the rest of the country and from neighbouring infected countries by a surveillance zone or by physical or geographical barriers and zoosanitary measures that effectively prevented the entry of infection. The proposed rinderpest-free zone should also comply with requirements similar to those of a country that was free from rinderpest disease.

Recovery of status

Should a localised temporary outbreak of the disease have occurred as a result of the reintroduction of rinderpest into a country or zone, the status of 'free from rinderpest disease' would have been suspended. For countries that had taken special measures (including intensive vaccination around the focus of infection) to eradicate the outbreak, at least one year from the date of the last case or the last vaccination (whichever occurred later) was required before the country or zone became eligible to reapply for freedom from rinderpest disease. In making such an application under these special circumstances, the country had to satisfy the FMD and Other Epizootics Commission that the outbreak did not represent an endemic infection and that the disease had been eradicated by the actions taken.

Freedom from rinderpest infection (only for country)

The last step of the OIE Pathway, the status of a country free from rinderpest infection, could be reached via two paths:

1. Countries officially recognised as free from rinderpest disease – for at least one year – could apply for the status of freedom from rinderpest infection, provided that:
   a) They continued to meet the requirements for that status.
   b) There was an effective serosurveillance system in operation for a period of at least two years, and the findings were consistent with freedom from infection; this serosurveillance had to include other susceptible domestic livestock in addition to cattle.
   c) Investigations (including sampling when possible) into infection in wild susceptible species had been carried out where these species occurred in significant numbers, and additional strategic sampling of domestic livestock had also been done in areas adjacent to large game populations to enhance the possibility of detecting the presence of virus in the game.
2. A country that had not vaccinated against rinderpest for at least ten years and had throughout that period no evidence of rinderpest disease or rinderpest virus infection could be directly recognised as officially free from rinderpest infection by the OIE, based on the conclusions of the FMD and Other Epizootics Commission and the final approval of the International Committee. A prerequisite for the recognition was evidence of the existence and maintenance of a permanent and adequate disease-reporting system throughout that period (Fig. 2).

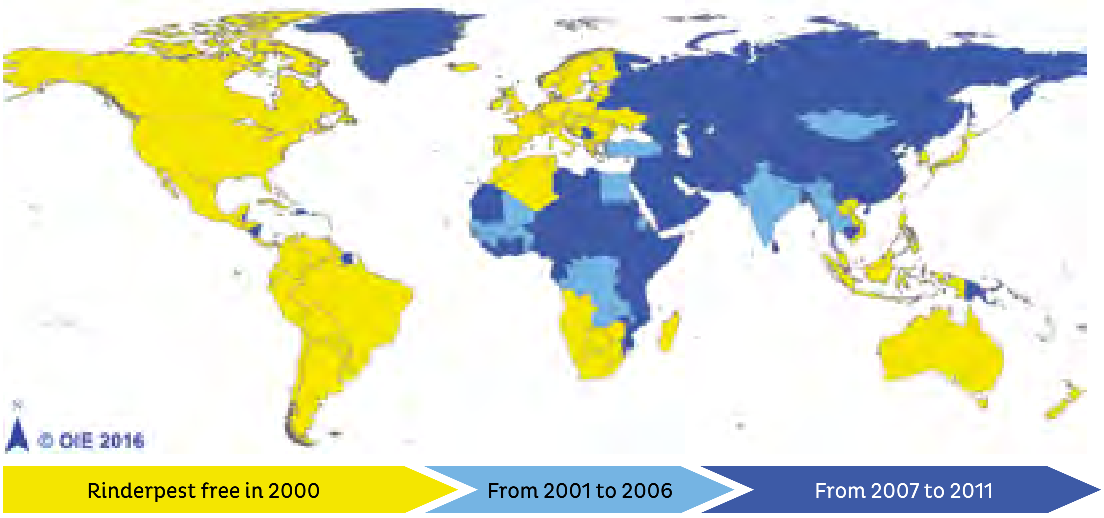
By meeting these requirements, a country could apply to the OIE to be recognised as free from rinderpest infection. The recognition of freedom from rinderpest infection was only eligible for the country as a whole, and not for zones within a country.

Recovery of status

Should a localised temporary outbreak of disease have occurred as a result of the reintroduction of rinderpest to a country, its status of 'free from rinderpest infection' would have been suspended within one year of the recognition of freedom from rinderpest infection. In circumstances where countries implemented special measures to stamp out the outbreak without any use of vaccine, the country had to wait at least one year from the date of the last case before it became eligible to

FIG. 2
ILLUSTRATION OF THE EVOLUTION OF COUNTRIES RECOGNISED AS FREE FROM RINDERPEST INFECTION IN 2000, IN 2006 AND IN 2011, WHEN THE ERADICATION OF RINDERPEST WAS ANNOUNCED

Source: OIE-WAHIS. Final boundary between the Sudan and South Sudan has not yet been determined. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by parties



reapply for the status of free from rinderpest infection. During that year an effective serosurveillance system should have been in operation to prove that the virus did not disseminate. In making such an application under these special circumstances, the country should have satisfied the FMD and Other Epizootics Commission that the outbreak did not represent endemic infection and that the disease had been eradicated by the actions taken.

THE PROCEDURE AND REQUIREMENTS FROM 2007 TO 2011

Following the implementation of the global programme for the eradication of rinderpest (GREP), FAO/OIE jointly in 2001 committed themselves to eradicating rinderpest (and to provide the necessary supporting evidence) with a target date set for 2010. In 2007, in order to expedite the process of global eradication, two amendments were proposed to the OIE Rinderpest Pathway (13).

May 2007: adoption of new requirements for the OIE Rinderpest Pathway

Chapter 2.2.12 of the *Terrestrial Code* on rinderpest and its supporting surveillance guidelines (Appendix 3.8.2) were revised considerably by a dedicated *ad hoc* group and endorsed by the Scientific Commission, in an attempt to speed up the movement towards proving global rinderpest eradication.

They proposed to restrict the provisions of Chapter 2.2.12 to the sole recognition of rinderpest-free status for a country. The concept of provisional freedom, rinderpest disease freedom and zonal freedom, previously included in the OIE Rinderpest Pathway, were deleted from the *Terrestrial Code* chapter, making new applications for recognition of these statuses no longer valid. Appendix 3.8.2 was also modified accordingly, thus reducing the OIE Rinderpest Pathway to a single step of acknowledging freedom from rinderpest, which was equivalent to the previous freedom from rinderpest infection, for the country as a whole. In parallel, the OIE developed a questionnaire (14) to provide guidance to countries willing to submit a dossier for freedom from rinderpest.

When revising the OIE Rinderpest Pathway, the experts considered that the majority of countries in the world had reached the point of abandoning rinderpest vaccination for a sufficient length of time to substantiate freedom from rinderpest through two years of appropriate surveillance. The requirements for freedom from rinderpest were reviewed in depth after considering the fact that most of the previously infected countries had controlled rinderpest through vaccination and that serological surveillance would have been meaningful only in unvaccinated cohorts. Therefore, these revised conditions focused on the absence of rinderpest outbreaks and rinderpest virus infection, and vaccination against rinderpest during the past two years, while requiring that surveillance and regulatory measures be in place, as described in Table I and Box 1.

The importance of compliance by Members with disease-reporting obligations and the performance of their Veterinary Services, in accordance with the requirements of Chapter 1.1.2, 1.3.3 and 1.3.4, were also highlighted in the revised 2007 edition of the *Terrestrial Code*.

Two situations were differentiated: (i) Members that were previously infected with rinderpest and which had not employed rinderpest vaccine for the last 25 years (a slightly revised historical freedom concept) and (ii) Members that had eradicated rinderpest within the last 25 years. The main difference between these two situations was that Members applying on historical grounds should have demonstrated the absence of rinderpest infection without pathogen-specific surveillance over the past ten years (in accordance with Chapter 3.8.1 of the *Terrestrial Code* on surveillance), while Members that had eradicated rinderpest within the last 25 years should have demonstrated absence of infection through two years' surveillance (including a serological surveillance) and provided information on their vaccine stock policy, as stated in Table I. In summary, option (i) (historical freedom) required a different surveillance approach to demonstrate the absence of rinderpest infection by applying a set of criteria less severe than those needed for option (ii).

These proposed changes were adopted by the International Committee during the 75th General Session, in May 2007, through Resolution XXXII (15).

Recovery of status

The revised chapter on rinderpest significantly updated the requirements for a country previously free from rinderpest, and now facing rinderpest infection, to regain its previous status. Countries applying a stamping-out policy and conducting serological surveillance could now regain their rinderpest-free status more quickly, depending on the use of emergency vaccination. Countries conducting emergency vaccination without slaughtering the vaccinated animals ('vaccination-to-live' strategy) could have recovered their status six months after the last rinderpest-infected animal

TABLE I
THE TWO OPTIONS OFFERED IN THE 2007 *TERRESTRIAL ANIMAL HEALTH CODE* FOR OIE MEMBERS WILLING TO APPLY FOR FREEDOM FROM RINDERPEST RECOGNITION, ACCORDING TO ARTICLE 3.8.2.7

Criteria	Option 1: Historical freedom	Option 2
	OIE Members that were previously infected with rinderpest and that have not employed rinderpest vaccine for the last 25 years	OIE Members that have eradicated rinderpest within the last 25 years
Absence of rinderpest occurrence	For at least the past 25 years	For at least the past 2 years
No use of vaccine against rinderpest	For at least the past 25 years	For at least the past 2 years
Surveillance	In accordance with Article 3.8.1.6 (without pathogen-specific surveillance)	In accordance with rinderpest Chapter 2.2.12 (including conducting appropriate serological surveys)
	For at least the past 10 years	For at least the past 2 years
	–	Additional requirements related to rinderpest vaccine destruction, limitation and control

BOX 1
2008 TERRESTRIAL ANIMAL HEALTH CODE
(SIMILAR TO THE 2007 EDITION EXCEPT THE ADDITION OF THE PARAGRAPH IN ITALICS)

Article 8.12.2: Rinderpest-free country
To qualify for inclusion in the existing list of rinderpest-free countries, a Member should:
have a record of regular and prompt animal disease reporting;
send a declaration to the OIE stating that:

a) there has been no outbreak of rinderpest during the past 24 months,
b) no evidence of rinderpest virus infection has been found during the past 24 months,
c) no vaccination against rinderpest has been carried out during the past 24 months, supply documented evidence that surveillance for both rinderpest and rinderpest virus infection in accordance with Articles 8.12.20 to 8.12.27 is in operation and that regulatory measures for the prevention and control of rinderpest have been implemented; not have imported, since the cessation of vaccination, any animals vaccinated against rinderpest.

The Member Country will be included in the list only after the submitted evidence has been accepted by the OIE.

Retention on the list requires that the information in points 2a, 2b and 2c above be resubmitted annually and changes in the epidemiological situation or other significant events should be reported to the OIE according to the requirements in Chapter 1.1.

was slaughtered or the last vaccination conducted (whichever occurred last); countries that did not conduct emergency vaccination or had slaughtered all the vaccinated animals ('vaccination-before-removal' strategy) could recover their status three months after the last infected animal (or vaccinated animal) was slaughtered.

The shortening of the waiting period for recovery of status was in support of the mandate given to the OIE Scientific Commission for Animal Diseases by the OIE World Assembly to recognise that a country had regained its previous status without further consultation of the Assembly (by adoption of Resolution No. XVII of the 65th General Session in May 1997). This procedure, combined with the revised requirements for recovery of status, gave countries the incentive to quickly control any incursion of rinderpest and allowed for quick recovery of their previously recognised rinderpest-free status.

May 2008 and following months: adoption of a facilitating procedure for the OIE Rinderpest Pathway

In May 2008, during the 76th General Session, the World Assembly acknowledged that the majority of OIE Members had already been recognised as free from rinderpest infection and that there was growing confidence that rinderpest had been eradicated from the globe. The OIE Director-General announced that the OIE and the FAO were committed to moving forwards to finally achieving the global eradication of rinderpest and subsequent worldwide official recognition, and to implementing the last efforts to obtain the necessary assurances and documented evidence for the absence of rinderpest virus circulation in the world (16). The OIE Director-General subsequently informed the World Assembly in 2008 that the OIE would further structure and expedite the procedure for the official recognition of freedom from rinderpest.

For this purpose, the OIE proceeded to contact any country or territory with rinderpest-susceptible livestock, including (via FAO) non-OIE Members, that was not yet officially recognised as rinderpest free to actively support the goal to move towards global rinderpest eradication (17).

Remaining OIE Members

A simplified procedure to apply for rinderpest status recognition was implemented. Countries and territories were grouped according to their historical risk of exposure or non-exposure to rinderpest to determine the detail of information that was required for the evaluation. Three groups of countries were identified:

a) countries located in regions where there had historically been no significant occurrence of rinderpest;
b) countries that had a history of absence of rinderpest epidemics for at least 25 years;
c) countries that had a history of rinderpest epidemics during the last 25 years.

The procedures for countries complying with the last two situations (b and c) were unchanged (official recognition was based on submission of conventional dossiers demonstrating freedom).

By contrast, countries located in historically free regions were given the option of applying by submitting a letter by the OIE Delegate, following a process similar to that used when the Scientific Commission had established a baseline list of historically free countries in 2000. A letter explaining the simplified procedure was sent to the OIE Delegates of the Members concerned in 2008 inviting them to apply for recognition of freedom from rinderpest.

OIE Members with non-contiguous territories

In 2008, the OIE also clarified the situation of those OIE Members having non-contiguous associated territories that might not be geographically linked or attached to the mainland. The main question was related to the possible differences in veterinary legislation or to the variations in the degree of autonomy over animal disease control matters for some of these non-contiguous territories that may have had an impact on freedom from rinderpest. The OIE Delegates of these Members were requested to clarify whether the associated non-contiguous territories were included in the original application to the OIE for the recognition of rinderpest-free status. They were also informed that all relevant non-contiguous territories should have been included in the letter submitted to the OIE annually to confirm the maintenance of their rinderpest status.

Non-OIE Members

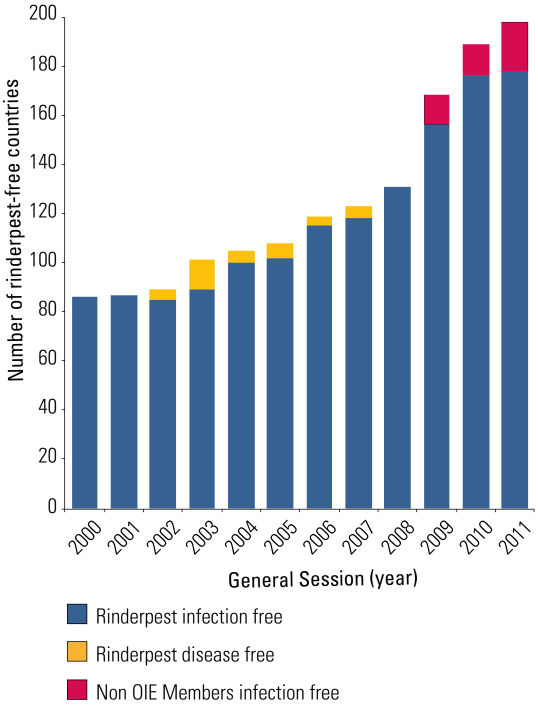
Finally, to enable a global declaration of freedom from rinderpest that included all countries of the globe (including those that were not Members of the OIE), all non-OIE Members that had rinderpest-susceptible livestock were contacted and requested to apply through the OIE Rinderpest Pathway. Some countries were approached by regional organisations such as the Secretariat of the Pacific Community or through the OIE regional representations. Some other countries identified as having an official relationship with the United Nations were contacted by FAO so that applications to be considered rinderpest-free were submitted to FAO and subsequently transferred to the OIE. In the case of Liberia, a dossier was prepared without serological data but with confirmation that passive surveillance was in place.

The success of this approach was immediate, as the International Committee recognised the rinderpest status of non-OIE Members in accordance with the provisions of the OIE *Terrestrial Code* and published them in a separate list as from 2009 (4). It is also worth noting that this resolution clearly recognised for the first time the official status of non-contiguous territories (Fig. 3).

In September 2009, the OIE *Ad hoc* Group on evaluation of rinderpest disease status of Members expressed its concern that it might not be possible to meet the target deadline for global freedom by 2010 as proposed and widely announced by GREP and suggested postponing it to 2011. Indeed, 39 countries/territories had not completed the accreditation process because of problems of an administrative or political nature or because they faced problems generating or compiling scientific data to demonstrate their rinderpest-free status. Those countries were given specific attention (18). This postponement was announced at the OIE 48th General Session in May 2010 (19).

FIG. 3
ILLUSTRATION OF THE EVOLUTION OF COUNTRIES RECOGNISED AS FREE FROM RINDERPEST DISEASE AND INFECTION AND THE IMPACT FROM 2009 OF THE 2007–2008 DECISIONS

Courtesy of the authors



Two years later in February 2011, the OIE experts responsible for recommending rinderpest-free status recognition in the framework of the OIE Rinderpest Pathway to the Scientific Commission for Animal Diseases gave the green light for recognising the rinderpest-free status of the last eight countries. As a consequence, in May 2011, the OIE World Assembly recognised the last countries and territories as free from rinderpest infection (4). At the 79th General Session, the OIE World Assembly adopted Resolution No. XVIII, which officially recognised that all 198 countries and territories with rinderpest-susceptible animals in the world were free of the disease (4).

During the full process, between 2000 and 2011, 82 countries applied for the recognition of the status of free from infection through the submission and evaluation of a dossier (80 OIE Members, two non-OIE Members), while 154 letters were considered from 98 OIE Members, 22 non-OIE Members and 34 non-contiguous territories of OIE Members that were applying for recognition of being free from infection based on the historical freedom from rinderpest (Tables II and III).

TABLE II
COUNTRIES THAT SUBMITTED DOSSIERS FOR RECOGNITION OF BEING HISTORICALLY FREE FROM RINDERPEST 86 BASELINE COUNTRIES – MAY 2000

Albania	Ecuador	Lesotho	Romania
Algeria	El Salvador	Lithuania	Singapore
Andorra	Estonia	Luxembourg	Slovakia
Angola	Finland	Madagascar	Slovenia
Argentina	Former Yugoslav Republic of Macedonia	Malaysia	South Africa
Australia	France	Malta	Spain
Austria	Germany	Mauritius	Swaziland
Belgium	Greece	Mexico	Sweden
Bolivia	Guatemala	Moldova	Switzerland
Bosnia and Herzegovina	Guyana	Morocco	Taipei China
Botswana	Haiti	Namibia	Trinidad and Tobago
Brazil	Honduras	Netherlands	Tunisia
Bulgaria	Hungary	New Caledonia	Ukraine
Canada	Iceland	New Zealand	United Kingdom
Chile	Indonesia	Norway	United States of America
Colombia	Ireland	Panama	Uruguay
Costa Rica	Italy	Paraguay	Vanuatu
Croatia	Jamaica	Peru	Venezuela
Cuba	Japan	Philippines	Viet Nam
Cyprus	Korea (Republic of)	Poland	Yugoslavia
Czech Republic	Lao People's Democratic Republic	Portugal	Zimbabwe
Denmark	Latvia		

Note: The former Yugoslav Republic of Macedonia is now known as North Macedonia & Swaziland is now Eswatini

TABLE III

DOSSIERS EVALUATED AND SELF-DECLARATION OF PROVISIONAL FREEDOM FROM RINDERPEST FROM MAY 2000 (OFFICIAL STATUS ADOPTED DURING GENERAL SESSION [GS] OF THE OIE WORLD ASSEMBLY OF DELEGATES)

Year /Country	Disease-free status	Infection-free status	Outcome
GS 2000			
Lebanon			Provisionally free
GS 2001			
Barbados		X	
GS 2002			
Congo			Provisionally free
Gabon (zonal)			Provisionally free
India (zonal, 3 zones)	X		
Myanmar	X		
Nepal		X	
Thailand	X		
Uganda			Provisionally free 21 November
GS 2003			
Bangladesh			Provisionally free June
Benin	X		
Bhutan	X		
Burkina Faso	X		
Burundi			Provisionally free 5 November
Democratic Republic of the Congo			Provisionally free 3 October
Djibouti			Provisionally free 20 October
Egypt	X		
Ghana	X		
Guinea	X		
India (16 states)	X		
Islamic Republic of Iran			Provisionally free 10 June
Kuwait			Provisionally free July
Malawi		X	
Mali	X		
Mauritania	X		
Niger	X		
Pakistan			Provisionally free 8 February
Senegal	X		
Togo	X		
Turkey	X		
Yemen			Provisionally free 21 October
GS 2004			
Chad (zonal)	X		
Côte d'Ivoire	X		
Eritrea	X		
India	X		
Mauritania			Recovery
Mongolia	X		
Oman			Provisionally free 14 July

Year /Country	Disease-free status	Infection-free status	Outcome
Saudi Arabia			Provisionally free 1 August
Sudan			Provisionally free 23 December
Thailand		X	
GS 2005			
Afghanistan			Provisionally free 14 September
Benin		X	
Bhutan		X	
Eritrea		X	
Ethiopia (zonal)	X		
Gabon			Provisionally free December
Kenya (zonal)	X		
Lebanon	X		
Mongolia		X	
Nigeria	X		
Senegal		X	
Sudan (zonal)	X		
Tanzania (United Republic of)	X		
Tajikistan			Provisionally free 1 September
Togo		X	
Turkey		X	
United Arab Emirates			Provisionally free 1 October
Uzbekistan			Provisionally free 20 October
GS 2006			
Burkina Faso		X	
Burundi		X	
Chad	X		
Congo		X	
Democratic Republic of the Congo		X	
Egypt		X	
Guinea-Bissau		X	
Guinea-Conakry		X	
India		X	
Iraq			Provisionally free 4 April
Kenya (zonal 2)	X		
Mali		X	
Myanmar		X	
Rwanda		X	
Sudan	X		
Uganda	X		
Zambia		X	
GS 2007			
Cameroon	X		
Central African Republic	X		

TABLE III (CONT.)

Year /Country	Disease-free status	Infection-free status	Outcome
GS 2007 (cont.)			
Côte d'Ivoire		X	
Ethiopia	X		
Ethiopia		X	
Gambia	X		
Ghana		X	
Kenya (zonal)			Provisionally free March
Mauritania		X	
Mozambique		X	Historically free
Pakistan		X	
Somalia			Provisionally free January
Tajikistan	X		
Tanzania (United Republic of)		X	
GS 2008			
Afghanistan		X	
Belarus		X	Historically free
China		X	Historically free
Equatorial Guinea		X	Historically free
Ethiopia		X	
Gabon		X	Historically free
Islamic Republic of Iran		X	
Jordan		X	Historically free
Lebanon		X	
Serbia		X	Historically free
Sudan		X	
Tajikistan		X	Historically free
Uganda		X	
Uzbekistan		X	Historically free
GS 2009			
Armenia		X	
Bahrain		X	
Belize		X	LD
Brunei		X	
Cape Verde		X	
Cook Islands		X	LD, not OIE Member
Dominican Republic		X	LD
Fiji Islands		X	LD
Holy See		X	LD, not OIE Member
Iraq		X	
Kenya		X	
Korea (Democratic People's Republic)		X	
Libya		X	
Liechtenstein		X	LD
Marshall Islands		X	LD, not OIE Member
Montenegro		X	
Nauru		X	LD, not OIE Member

Year /Country	Disease-free status	Infection-free status	Outcome
Nicaragua		X	LD
Niue		X	LD, not OIE Member
Oman		X	
Palau		X	LD, not OIE Member
Papua New Guinea		X	LD
Samoa		X	LD, not OIE Member
San Marino		X	LD
Seychelles		X	LD, not OIE Member
Solomon Islands		X	LD, not OIE Member
Saint Vincent and the Grenadines		X	LD, not OIE Member
Surinam		X	LD
Timor-Leste		X	LD, not OIE Member
GS 2010			
Bangladesh		X	
Cambodia		X	
Cameroon		X	
Central African Republic		X	
Chad		X	
Djibouti		X	
Dominica		X	LD, not OIE Member
Georgia		X	
Israel		X	
Kuwait		X	
Maldives		X	LD
Niger		X	
Nigeria		X	
Palestinian Autonomous Territories		X	Not OIE Member
Qatar		X	
Russian Federation		X	
Somalia		X	
Syrian Arab Republic		X	
Tonga		X	LD, not OIE Member
Yemen		X	
GS 2011			
Antigua and Barbuda		X	LD, not OIE Member
Azerbaijan		X	
Bahamas		X	LD
Comoros		X	
Federated States of Micronesia		X	LD
Gambia		X	
Grenada		X	LD, not OIE Member
Kazakhstan		X	

TABLE III (CONT.)

Year /Country	Disease-free status	Infection-free status	Outcome
GS 2011 (cont.)			
Kiribati		X	LD, not OIE Member
Kosovo		X	LD, not OIE Member
Kyrgyzstan		X	Explanatory LD
Lao People's Democratic Republic		X	
Liberia		X	Not OIE Member
Saint Kitts and Nevis		X	LD, not OIE Member
Saint Lucia		X	LD, not OIE Member
São Tomé and Príncipe		X	
Saudi Arabia		X	
Sierra Leone		X	
Sri Lanka		X	
Turkmenistan		X	Explanatory information
Tuvalu		X	LD, not OIE Member
United Arab Emirates		X	

LD, letter of declaration (baseline list, historically free)

The resolution on the *Declaration of Global Freedom from Rinderpest and on the Implementation of Follow-up Measures to Maintain World Freedom* was subsequently also adopted by the 192 FAO Members at the 37th FAO Conference in June 2011, recognising this outstanding global achievement and the successful collaboration of a multitude of governments, international and regional organisations, the veterinary profession and the scientific community (20).

CONCLUSION

The global eradication of rinderpest is without any doubt a major and historic achievement in the international history of animal disease control. However, looking back to the events that made this possible, several notable milestones stand out very clearly. The first was the achievement of global disease mitigation through strict vaccination regimes that resulted in the elimination of clinical manifestations of the disease, thereby strengthening the international realisation that rinderpest could indeed be eliminated globally. This resulted in the realisation of the need for close international cooperation between leading international organisations, notably the OIE and FAO, together with regional organisations. However, the prerequisite for such close and successful international cooperation would not have been possible if not mandated and supported by the international standards for surveillance, control and eventual eradication of rinderpest – the OIE Rinderpest Pathway. Setting international standards for all players to respect and adhere to assured international buy-in to a common commitment to rid the world of rinderpest.

It could be reasoned that the expedited and more flexible approach that was followed from 2007 onwards could have been implemented earlier, with a possible earlier declaration of global freedom. However, the expedited process and the bringing on board of all players, notably non-OIE Members and non-contiguous territories, was dependent on the assurance that the surveillance strategy could be sufficiently modified after the preceding strict global vaccination strategy in affected countries. It took 50 years to achieve this goal, and many lessons were learnt – one of the most important being that without credible Veterinary Services, no national animal disease eradication programme could succeed. It could thus be acknowledged that the lessons learnt from the global eradication of rinderpest also paved the way for the implementation of the OIE Pathway for the Performance of Veterinary Services – the PVS Pathway. Thus, by doing just that, the international community received the assurance that the global declaration of freedom in 2011, was achieved by following, and not compromising, international standards for animal disease control.

This historic achievement paved the way to control and eradicate other diseases; since rinderpest's eradication, the OIE and FAO developed in 2012 the Global Control Strategy for FMD and more recently, in 2015, the Global Strategy for the Control and Eradication of Peste des Petits Ruminants (PPR). Acknowledging the lessons learnt during the rinderpest eradication phases, the FMD and PPR strategies include a specific component related to the strengthening of Veterinary Services, as they are considered major actors for the success of any disease control or eradication strategy.

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CHAPTER 7.2

THE JOINT FAO/OIE COMMITTEE ON GLOBAL RINDERPEST ERADICATION

S. EDWARDS [(1)*,], J.-F. CHARY [(2)**], Y. OZAWA [(3)†***], J.E. PEARSON [(4)†**], A. SHIMSHONY [(5)***], D. SYLLA [(6)***] & W.P. TAYLOR [(7)]**

(1) Oak House, Vowchurch, Hereford, HR2 0RB, United Kingdom
(Formerly of the Veterinary Laboratories Agency, New Haw, Addlestone, KT15 3NB, United Kingdom)
(2) Ministère de l'agriculture, 757 rue de la Forge, 69620 Frontenas, France
(3) 1-15-2 (3404) Tamagawa, Setagaya-Ku, Tokyo 158-0094, Japan
(4) 4016 Phoenix, Ames, Iowa 50014-3918, United States of America
(5) Tabenkin Street 37a, Tel-Aviv 69353, Israel
(6) B.P. 2376, Bamako, Mali
(7) 16 Mill Road, Angmering, West Sussex BN16 4HT, United Kingdom

*Corresponding author
**World Organisation for Animal Health (OIE) representatives on the Joint Committee on Global Rinderpest Eradication
***Food and Agriculture Organization of the United Nations (FAO) members of the Joint Committee on Global Rinderpest Eradication
†Deceased

SUMMARY

The Joint Food and Agriculture Organization of the United Nations (FAO)/World Organisation for Animal Health (OIE) Committee on Global Rinderpest Eradication (hereafter referred to as the Joint Committee) was composed of the seven individuals authoring this text. Each organisation nominated three of its previous associates to serve as committee members; Dr William P. Taylor was nominated as the unaffiliated Chairman, Dr James Pearson was nominated as Deputy Chairman and Professor Steven Edwards acted as Secretary to the Joint Committee. Minutes of committee meetings were prepared by Dr Felix Njeumi, FAO.

While eradication can be considered an event measurable in terms of absence of the disease or evidence of its presence, to be legally valid for international livestock trade, countries previously infected by rinderpest needed to provide evidence that it was no longer in circulation. With the involvement of both FAO and the OIE in securing the successful elimination of rinderpest from its last endemic foci, a declaration of freedom from rinderpest became a matter of closure for the OIE General Session. This issue was pursued either by the development of a comprehensive list of countries around the globe accepted as being rinderpest free, based on their either never having been part of the world contaminated by rinderpest virus or of having been rinderpest infected but subsequently free for more than 25 years and deemed historically free (by the OIE), or, finally, after having eliminated endemic infection and ceased vaccination, accrued evidence demonstrating an absence of the circulating virus. Between 2009 and 2011 an FAO/OIE Joint Committee was convened tasked with tracking the completion and soundness of the global list and recommending that the 79th OIE General Session of 2011, and the

37th FAO Conference of the same year, should pass resolutions declaring that rinderpest had been globally eradicated. In addition, the Joint Committee made recommendations regarding the guardianship of remaining rinderpest virus stocks and steps to contain the risk of any reintroduction.

KEYWORDS **Recommendations – Security of global list – Sequestration.**

INTRODUCTION

After many decades of rinderpest control efforts, a final push towards eradication was launched in 1994 by the Food and Agriculture Organization of the United Nations (FAO) as the Global Rinderpest Eradication Programme (GREP). This was supported by the World Organisation for Animal Health (OIE) through its mechanisms for international disease surveillance and reporting, standard setting and formal certification of country freedom. During the first decade of the 21st century there was increasing confidence that the virus had ceased circulating and a move towards a global declaration could be considered. The Joint FAO/OIE Committee on Global Rinderpest Eradication was established in 2009 by agreement between the Director-General of OIE, Dr Bernard Vallat, and the FAO Assistant Director-General (Agriculture and Consumer Protection), Dr Modibo T. Traoré. The remit of the Joint Committee was to provide assurance to FAO and the OIE on the global rinderpest status, in preparation for a formal declaration, and to propose procedures for future surveillance monitoring, sequestration of remaining virus stocks and provision of contingency vaccines. It should also assist in collating information for preparing a history of rinderpest and its eradication. The Joint Committee met four times between December 2009 and January 2011, leading up to the formal declaration by the OIE and FAO of rinderpest global eradication in 2011.

TERMS OF REFERENCE

- Receive reports from the OIE on the infection-free status of countries and territories and other related information as well as ongoing FAO and OIE activities to assist countries and territories to submit the required dossiers for official recognition of their free status by OIE.
- Advise the Directors-General of both organisations indicating whether the evidence presented to the Committee entitled them to announce that rinderpest virus has ceased to circulate in the world.
- Review all FAO projects (including the FAO/International Atomic Energy Agency [IAEA] Joint Division) devoted to rinderpest surveillance, diagnosis, containment and research, including those projects in which FAO may not have been a lead organisation.
- Prepare, based on the technical assistance of the OIE Biological Standards Commission, a draft international agreement on the elimination of rinderpest virus and other potentially dangerous biological materials in laboratories and other places and on the choice of a limited number of centres where sample materials could be stored safely for research or vaccine production purposes.
- Advise OIE and FAO on surveillance and emergency vaccination policy applicable after eradication.
- Finally, contribute to guiding the preparation of a book describing the history of rinderpest and its global eradication.

More prosaically, the Joint Committee was required to:

1. Ensure that all countries around the world had declared to the Director-General of the OIE that they were free of rinderpest based on a history of freedom or actual proof of eradication.
2. Ensure the evaluation of the validity of these declarations in accordance with the OIE Rinderpest Pathway by the OIE Scientific Commission for Animal Diseases for adoption by the OIE World Assembly.
3. Submit a report permitting the President of the OIE World Assembly to declare the end of rinderpest virus circulation in the world.
4. Draft an international agreement outlining principles and responsibilities for oversight and regulatory actions to ensure rinderpest freedom in the post-eradication era.

FUNCTIONING OF THE JOINT COMMITTEE

The Joint Committee met on the following four occasions:

- First Meeting: 3 December 2009, FAO headquarters, Rome (Fig. 1);
- Second Meeting: 13–14 April 2010, OIE headquarters, Paris;
- Third Meeting: 15–16 July 2010, Joint FAO/IAEA Division, IAEA headquarters, Vienna;

FIG. 1

MEMBERS AND GUESTS OF THE JOINT COMMITTEE ON THE OCCASION OF THEIR FIRST MEETING AT FAO ROME, DECEMBER 2009

Seated, left to right, Professor J.F. Chary; Dr Daouda Sylla; Dr William Taylor; Prof. Steve Edwards; Dr Jim Pearson†; Dr Arnon Shimshony and Dr Y. Ozawa†

Standing, left to right, Dr Juan Lubroth, Chief Animal Health Officer, FAO, Rome; Dr Gerrit Viljoen, Head, Animal Production and Health Section of the Joint FAO/IAEA Division, Vienna; Dr David Ulaeto, Department of Biomedical Sciences, Defence Science and Technology Laboratory Porton Down, United Kingdom; Dr Bernard Vallat, Director-General, OIE; Dr Modibo T. Traoré, Assistant Director-General, FAO, Rome; Dr Samuel Jutzi, Director, Animal Health and Production Division, FAO, Rome; Dr Kazuaki Miyagishima, Deputy Director-General, OIE; Dr Felix Njeumi, Animal Health Officer, GREP Secretary, FAO, Rome

Source: FAO/Giulio Napolitano

– Fourth Meeting: 13–14 January 2011, OIE headquarters, Paris.

In the course of the meetings, members of the Joint Committee received presentations addressing specific topics from FAO and OIE staff members as well as from invited experts.

In addition, between 28 March and 2 April 2010, Drs Pearson and Sylla attended a meeting of the Somali Ecosystem Rinderpest Eradication Coordination Unit (SERECU) in Addis Ababa, Ethiopia, to discuss the Somali ecosystem.

Dr Taylor was accorded observer status at a meeting of the OIE *Ad hoc* Group on the evaluation of rinderpest disease status of Members, held in Paris between 19 and 21 January 2010.

Drs Shimshony, Taylor and Ozawa made presentations relevant to the work of the Joint Committee at an FAO workshop on post-eradication activities with the participation of the OIE, held on 12 October 2010 at FAO headquarters.

The Committee was presented with a CD containing the minutes of the OIE *Ad hoc* Group on the evaluation of rinderpest disease status of Members. It may be noted that the *Ad hoc* Group was called into being to make a detailed assessment of the robustness of the surveillance evidence of Members that had followed the OIE Pathway. The minutes of the *Ad hoc* Group's meetings merely record whether or not the evidence was satisfactory but do not provide a detailed summary of it. These minutes were used to complete the listings given in Appendix 1 detailing the dates on which countries were placed on a global list of rinderpest-free countries. The comprehensive nature of the global list enabled the Joint Committee to fulfil its remit and to report its findings, which can be found in its final report (1).

THE GLOBAL LIST

In the run up to certifying the global eradication of smallpox in 1979, the World Health Organization

(WHO) decided that there was a need to convince public health officials and medical scientists around the world that eradication had really been achieved (2). This was undertaken by teams of respected scientists and health officials, independently of both national authorities concerned and of the WHO, visiting countries as the 'International Commission for the Certification of Smallpox Eradication', examining local records and assessing surveillance capabilities; their findings were ultimately endorsed by a Global Commission for the Certification of Smallpox Eradication with the pronouncement that smallpox was dead.

Accordingly, FAO and the OIE became engaged in a process similar to that of the WHO, aiming at achieving an independently authenticated understanding of worldwide freedom from rinderpest. As the custodian of data relating to the presence or absence of infectious diseases among its Members via their reporting obligations, it fell to the OIE to develop a global list of countries shown to be free from rinderpest infection, either on the basis of historical absence or based on evidence that the fight against the virus had been won.

In 1999, OIE Delegates endorsed the decision to establish a baseline list of historically rinderpest-free OIE Members. It was proposed that countries situated in regions of the world never endemically infected by rinderpest (essentially the Americas and Europe; see Chapter 2.1) should subscribe to the so-called baseline list; this they could do under the signature of the OIE Delegate for the respective country. In 2000, the first list of 86 countries officially recognised as rinderpest free was adopted by the General Session (now the World Assembly) of the OIE Delegates (see Baseline historical list, Appendix 1).

As some eligible countries had not met the 2000 deadline, the GREP secretariat prepared a list of additional countries in selected regions that could be evaluated by the same criteria as the 86 countries on the baseline list. This additional list was submitted to the OIE *Ad hoc* Group, resulting in a recommendation to the OIE World Assembly to add the countries to the list (see Additional Historical List, Appendix 1). This comprised countries located in world regions that had never faced rinderpest outbreaks (the Americas [except Brazil], the Caribbean, New Zealand and Oceania) and countries located in regions where rinderpest had been eradicated several decades earlier (western Europe, Brazil and Australia).

When it subsequently became apparent that endemically infected countries were starting to demonstrate freedom from infection (see below), with a target of 2010 when all such countries should be on the global list, it was imperative to renew the process of attracting requests for a historically free listing. However, in addition to being situated in a historically free region, the concept of historical freedom was widened to include countries of a hitherto endemically infected region that:

– had not experienced rinderpest for more than 25 years (and had not used rinderpest vaccine during the last ten years); in such cases accession to the historically rinderpest-free list was permitted on the basis of the signature of the OIE Delegate;
– had had cases within the last 10–25 years but had not used vaccine during the last 10 years; in such cases accession to the rinderpest historically free list required the submission of evidence of surveillance, including serological data.

In all other cases it was necessary for countries to cease rinderpest vaccination (when it was deemed safe to do so) and thereafter to follow the OIE Rinderpest Pathway (Chapter 7.1), finally submitting a national dossier providing evidence, both serological and clinical, that rinderpest no longer existed within its population of domestic ruminants (and, if appropriate, its wildlife population).

The Scientific Commission for Animal Diseases within the OIE had the responsibility to monitor the progress of rinderpest eradication in the different regions of the world. After 2004, the Scientific Commission requested the support of an *ad hoc* group, composed of rinderpest experts, to evaluate country dossiers, in particular of those Members not historically free, and to provide its recommendations to the commission for its consideration. The Scientific Commission, in turn, put forward its proposals on the recognition of rinderpest-free status of countries and territories to the OIE World Assembly for adoption. Dossiers from countries not historically free contained evidence of freedom from rinderpest as detailed in the 1989 OIE standards to assist surveillance and animal movement control. In January 2011, the *Ad hoc* Group completed its evaluations (see listing as 'Dossier of evidence to OIE', Appendix 1) thereby completing the process of reviewing the rinderpest freedom of all 198 relevant countries and territories with susceptible animal populations.

This then was the background against which FAO and the OIE sought to devise a method of facilitating an independent assessment of whether or not an international declaration of global freedom from rinderpest had been achieved. The main function of the Joint Committee was to ensure that at the global level all countries had been properly assessed for inclusion on a global list and to provide a report of its findings to the Directors-General of FAO and the OIE, stating whether they were confident that the world could be declared free of rinderpest and/or recommending the actions to be taken for this achievement to be preserved. In this capacity as an independent recommending body, the Joint Committee reviewed the workings of both the *Ad hoc* Group, namely the reports of the 13 meetings held by that group between 2004 and 2011 and the relevant reports of the OIE Scientific Commission and concluded that all countries on the 198-strong global list (Appendix 1) had been correctly evaluated and accessioned.

INPUTS BY FAO AND THE OIE TOWARDS THE ERADICATION OF RINDERPEST

Through a series of briefings the Committee recognised the invaluable role of FAO and the OIE in the provision of emergency support to countries combatting the disease. In addition they found that both FAO and the OIE (and its sister organisation, the Joint FAO/IAEA Division) had played a priceless role in the provision of support to countries combatting rinderpest including that of donor mobiliser, international strategy developer and international campaign coordinator. Technically, they had instigated programmes for the furtherance of international standards for laboratory diagnosis of rinderpest and its antibodies and for the manufacture of rinderpest vaccines.

Recognising that rinderpest eradication had not been secured until it had been jointly demonstrated that all recently infected countries had both eliminated the virus and provided themselves with evidence that this had happened, two turnkey developments brought this about. The first of these was the development of a pathway allowing recently infected countries, on the basis of submitted evidence, to be internationally recognised as having freed themselves from the virus; the second was a double coordination programme (FAO Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases [FAO-EMPRES] and GREP) which sought to conclude the process of recognising the world as free of rinderpest within as short a timeframe as possible. FAO had done much to assist countries in developing the necessary surveillance evidence.

More detailed accounts of FAO's role in rinderpest eradication and of the workings of the Joint FAO/IAEA Division are given in chapters in this book by Dr Tekola (Chapter 5.3), Drs Jeggo and Dargie (Chapter 5.4) and Dr Roeder (Chapter 6.1). The role of the OIE is dealt with by Drs Thibier and Chaisemartin (Chapter 5.2). The subjects covered during meetings of the Joint Committee can be found in the minutes of the four meetings (summarised in the final report [1]). FAO documentation relating to the work of FAO-EMPRES and GREP in paving the way to the verified end to rinderpest virus transmission can also be found in the Joint Committee's final report as well as other chapters (e.g. Chapters 4.1, 4.4, 4.7, 4.8, 5.7, 5.12, 6.2 and 8.1).

VIRUS SEQUESTRATION

In its concluding report the Joint Committee noted that virulent and attenuated rinderpest virus samples and vaccine stocks continued to be held in laboratories in a number of countries worldwide, as referred to by OIE Resolution No. XVIII, adopted in 2011 during the 79th General Session. It was also noted that FAO and the OIE were in the process of establishing an inventory of institutes holding rinderpest virus-containing material through questionnaire surveys and that preliminary results indicated that virus-containing material was stored in variable biosecurity conditions in over 20 countries. The Joint Committee had been informed of the WHO's experience of smallpox eradication and noted that many approaches taken by the WHO would be applicable to rinderpest when designing post-eradication activities.

CONCLUSIONS

The Joint Committee drew the following conclusions:

1. In the light of its ability to compile a comprehensive global list by January 2011, it could be concluded that rinderpest had been eliminated from the world as a freely circulating viral disease entity. A report to this effect was presented by the Joint Committee Chairman to the OIE President on 25 March 2011, facilitating the International Committee of the OIE to announce the eradication of rinderpest. The presentation of the Joint Committee Chairman is attached in Appendix 2.
2. The presence of virulent or attenuated rinderpest virus in laboratories constituted a potential threat to global biosecurity. Consequently, and as envisaged in its terms of reference, the Joint Committee and the OIE Biological Standards Commission jointly endorsed a set of *Guidelines for the Sequestration of Rinderpest Virus* (Appendix 5). The extent to which these proved of practical significance is discussed in a later chapter (Chapter 8.2).

RECOMMENDATIONS

The Joint Committee made the following recommendations:

1. A resolution should be taken forward by FAO and the OIE, for adoption by their governing bodies, declaring global rinderpest eradication and implementing subsequent necessary measures (see Appendices 3 and 4).
2. Guidelines on rinderpest virus sequestration, as agreed by the Joint Committee in consultation with the OIE Biological Standards Commission, should be implemented by national veterinary authorities, the OIE and FAO (Appendix 5).
3. FAO and the OIE should, as a matter of urgency, continue to work in close collaboration on the following:
   a) developing a strategic plan to guide post-eradication activities at international level;
   b) completing an analysis of the risks of re-emergence of rinderpest virus and its consequences,
   c) preparing an international contingency plan based on the risk analysis;
   d) setting up a joint FAO/OIE advisory body on rinderpest, defining terms of reference and membership; this advisory body may set up subcommittees, for example to monitor rinderpest research activities.
4. National Veterinary Authorities should update national contingency plans in line with the guidelines for rinderpest virus sequestration and the international contingency plan.
5. FAO and the OIE should establish an appropriately funded mechanism for oversight and approval of facilities holding rinderpest virus-containing material, in conjunction with national regulatory authorities and, where appropriate, with other international organisations.
6. FAO and the OIE should maintain archives of existing documents (including country dossiers); digitisation of files should be considered where possible, as well as identification of documentation that should be made publicly accessible.
7. FAO and the OIE should find and collate suitable education and training materials, particularly films of rinderpest disease, and package them in a way that is accessible to as wide an audience as possible, through official websites and other publicly accessible file depositories on the Internet.
8. National authorities should ensure that:
   a) Rinderpest remains a notifiable disease.
   b) A surveillance system (including rumour tracking and early detection) should be maintained to detect disease events.
   c) Suspect cases are rapidly investigated (using existing mechanisms or, where appropriate, the FAO/OIE Crisis Management Centre) and necessary actions are promptly taken.
9. Ongoing support for FAO/OIE Rinderpest Reference laboratories should include adequate funding for maintenance of diagnostic capability.
10. FAO/OIE Rinderpest Reference Laboratories should ensure inter-collaboration.
11. The use of rinderpest vaccines should be forbidden except for emergency use in the case of a rinderpest outbreak.
12. FAO and the OIE should provide guidelines on control procedures, including the use of emergency vaccination.
13. Research on historical strains of rinderpest should continue, given that full sequencing promotes greater understanding of morbillivirus evolution and full sequence data reduce the need to retain live virus stocks.
14. Re-creation of rinderpest virus from full genome sequences should be forbidden except in an authorised biosecure facility on approval by FAO and the OIE.
15. An international morbillivirus discovery and monitoring programme should be promoted, and knowledge gained in rinderpest eradication should be transferred to potential control programmes for other morbillivirus infections.
16. The need for possible novel (e.g. differentiating infected from vaccinated animals) vaccines and diagnostic tests should be determined by the FAO/OIE advisory body on rinderpest in the light of the risk analysis.
17. Vaccines (including related equipment) should be manufactured in accordance with the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (*Terrestrial Manual*) and held in sustainably funded vaccine repositories (vaccine banks), coordinated by FAO and/or other appropriate bodies and in liaison with manufacturers; the minimum number of repositories should be determined by the advisory body on rinderpest in the light of the risk analysis.
18. FAO and the OIE should vigorously pursue the publication of their experiences of rinderpest control and eradication in a book.
19. International standards and guidelines on rinderpest, including the OIE *Terrestrial Animal Health Code* (*Terrestrial Code*), the OIE *Terrestrial Manual* and FAO manuals, should be updated in the light of global eradication.
20. Finally, a specialist rinderpest secretariat should be maintained by FAO and the OIE with adequate resources to deliver the rest of these recommendations, including support for the activities of the FAO/OIE advisory body on rinderpest.

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APPENDIX 1

THE GLOBAL LIST OF COUNTRIES OFFICIALLY RECOGNISED AS FREE FROM RINDERPEST INFECTION (MAY 2011)

OIE Member	Last outbreak	Date of listing and listing criterion
Afghanistan	1995	2008; **dossier of evidence to the OIE**
Albania	1934	2000; baseline historical list
Algeria	Never reported	2000; baseline historical list
Andorra	Never reported	2000; baseline historical list
Angola	Never reported	2000; baseline historical list
Antigua and Barbados	Never reported	2011; additional historical list
Argentina	Never reported	2000; baseline historical list
Armenia	1928	2009; additional historical list
Australia	1923 (imported)	2000; baseline historical list
Austria	1881	2000; baseline historical list
Azerbaijan	1928	2011; additional historical list
Bahamas	Never reported	2011; additional historical list
Bahrain	1980	2009; additional historical list
Bangladesh	1958	2010; additional historical list
Barbados	Never reported	2001; additional historical list
Belarus	Never reported	2008; additional historical list
Belgium	1920 (imported)	2000; baseline historical list
Belize	Never reported	2009; additional historical list
Benin	1987	2005; **dossier of evidence to the OIE**
Bhutan	1971	2005; **dossier of evidence to the OIE**
Bolivia	Never reported	2000; baseline historical list
Bosnia and Herzegovina	1883	2000; baseline historical list
Botswana	1899	2000; baseline historical list
Brazil	1921 (imported)	2000; baseline historical list
Brunei	Never reported	2009; additional historical list
Bulgaria	1913	2000; baseline historical list
Burkina Faso	1988	2006; **dossier of evidence to the OIE**
Burundi	1934	2006; additional historical list
Cambodia	1964	2010; additional historical list
Cameroon	1986	2010; **dossier of evidence to the OIE**
Canada	Never reported	2000; baseline historical list
Cabo Verde	Never reported	2009; additional historical list
Central African Republic	1984	2010; **dossier of evidence to the OIE**
Chad	1983	2010; **dossier of evidence to the OIE**
Chile	Never reported	2000; baseline historical list
China	1956	2008; additional historical list (25-year rule)
Chinese Taipei	1949	2000; baseline historical list
Colombia	Never reported	2000; baseline historical list
Comoros	Never reported	2011; additional historical list
Congo	Never reported	2006; additional historic list
Cook Islands	Never reported	2009; additional historical list
Costa Rica	Never reported	2000; baseline historical list

OIE Member	Last outbreak	Date of listing and listing criterion
Côte d'Ivoire	1986	2007; **dossier of evidence to the OIE**
Croatia	1883	2000; baseline historical list
Cuba	Never reported	2000; baseline historical list
Cyprus	Never reported	2000; baseline historical list
Czechia	1881	2000; baseline historical list
Democratic Republic of the Congo	1961	2006; additional historical list (ten-year rule)
Denmark	1782	2000; baseline historical list
Djibouti	1985	2010; **dossier of evidence to the OIE**
Dominica	Never reported	2010; additional historical list
Dominican Republic	Never reported	2009; additional historical list
Ecuador	Never reported	2000; baseline historical list
Egypt	1986	2006; **dossier of evidence to the OIE**
El Salvador	Never reported	2000; baseline historical list
Equatorial Guinea	Never reported	2008; additional historical list
Eritrea	1995	2005; **dossier of evidence to the OIE**
Estonia	Never reported	2000; baseline historical list
Ethiopia	1995	2008; **dossier of evidence to the OIE**
Fiji	Never reported	2009; additional historical list
Finland	1877	2000; baseline historical list
France	1870	2000; baseline historical list
Gabon	Never reported	2008; additional historical list
Gambia	1965	2011; **dossier of evidence to the OIE**
Georgia	1989	2010; additional historical list
Germany	1870	2000; baseline historical list
Ghana	1988	2007; **dossier of evidence to the OIE**
Greece	1926	2000; baseline historical list
Grenada	Never reported	2011; additional historical list
Guatemala	Never reported	2000; baseline historical list
Guinea	1967	2006; **dossier of evidence to the OIE**
Guinea-Bissau	1967	2006; additional historical list
Guyana	Never reported	2000; baseline historical list
Haiti	Never reported	2000; baseline historical list
Honduras	Never reported	2000; baseline historical list
Hungary	1881	2000; baseline historical list
Iceland	Never reported	2000; baseline historical list
India	1995	2006; **dossier of evidence to the OIE**
Indonesia	1907	2000; Baseline Historic List
Iran (Islamic Republic of)	1994	**2008; dossier of evidence to the OIE**
Iraq	1996	**2009; dossier of evidence to the OIE**
Ireland	1866	2000; baseline historical list
Israel	1983	2010; **dossier of evidence to the OIE**
Italy	1947 (imported)	2000; baseline historical list
Jamaica	Never reported	2000; baseline historical list
Japan	1924	2000; baseline historical list
Jordan	1972	2008; additional historical list
Kazakhstan	1927	2011; **dossier of evidence to the OIE/ historical**
Kenya	2001	2009; **dossier of evidence to the OIE**
Kiribati	Never reported	2011; additional historical list
Korea (Democratic People's Republic of)	1948	2009; additional historical list
Korea (Republic of)	1931	2000; baseline historical list
Kosovo ([a])	1890s	2011; additional historical list
Kuwait	1985	2010; **dossier of evidence to the OIE**
Kyrgyzstan	1928	2011; additional historical list

OIE Member	Last outbreak	Date of listing and listing criterion
Lao People's Democratic Republic	1966	2011; additional historical list
Latvia	1921	2000; baseline historical list
Lebanon	1982	2008; additional historical list
Lesotho	1896	2000; baseline historical list
Liberia	Never reported	2011; additional historical list
Libya	1963	2009; additional historical list
Liechtenstein	19th century	2009; additional historical list
Lithuania	Never reported	2000; baseline historical list
Luxembourg	Never reported	2000; baseline historical list
Madagascar	Never reported	2000; baseline historical list
Malawi	Never reported	2003; historical ten-year rule
Malaysia	1935	2000; baseline historical list
Maldives	Never reported	2010; additional historical list
Mali	1986	2006; **dossier of evidence to the OIE**
Malta	Never reported	2000; baseline historical list
Marshall Islands	Never reported	2009; additional historical list
Mauritania	1986	2007; **dossier of evidence to the OIE**
Mauritius	Never reported	2000; baseline historical list
Mexico	Never reported	2000; baseline historical list
Micronesia	Never reported	2011; additional historical list
Moldova	Never reported	2000; baseline historical list
Mongolia	1992	2005; **dossier of evidence to the OIE**
Montenegro	1883	2009; additional historical list
Morocco	Never reported	2000; baseline historic list
Mozambique	1896	2007; additional historical list
Myanmar	1957	2006; **dossier of evidence to the OIE/ historical**
Namibia	1905	2000; baseline historical list
Nauru	Never reported	2009; additional historical list
Nepal	1990	2002; **dossier of evidence to the OIE**
Netherlands	1869	2000; baseline historical list
New Caledonia	Never reported	2000; baseline historical list
New Zealand	Never reported	2000; baseline historical list
Nicaragua	Never reported	2009; additional historical list
Niger	1986	2010; **dossier of evidence to the OIE**
Nigeria	1987	2010; **dossier of evidence to the OIE**
Niue	Never reported	2009; additional historical list
North Macedonia	1883	2000; baseline historical list
Norway	Never reported	2000; baseline historical list
Oman	1995	2009; **dossier of evidence to the OIE**
Pakistan	2000	2007; **dossier of evidence to the OIE**
Palau	Never reported	2009; additional historical list
Palestinian Autonomous Territories	1983	2010; additional historical list
Panama	Never reported	2000; baseline historical list
Papua New Guinea	Never reported	2009; additional historical list
Paraguay	Never reported	2000; baseline historical list
Peru	Never reported	2000; baseline historical list
Philippines	1955	2000; baseline historical list
Poland	1921	2000; baseline historical list
Portugal	Never reported	2000; baseline historical list
Qatar	1987	2010: **dossier of evidence to the OIE**
Romania	1886	2000; baseline historical list
Russian Federation	1998	2010; **dossier of evidence to the OIE**
Rwanda	1932	2006; additional historical list

OIE Member	Last outbreak	Date of listing and listing criterion
Saint Kitts and Nevis	Never reported	2011; additional historical list
Saint Lucia	Never reported	2011; additional historical list
Saint Vincent and the Grenadines	Never reported	2009; additional historical list
San Marino	Never reported	2009; additional historical list
Samoa	Never reported	2009; additional historic list
São Tomé and Príncipe	1950s (imported)	2011; additional historical list
Saudi Arabia	1999	2011; **dossier of evidence to the OIE**
Senegal	1979	2005; **dossier of evidence to the OIE**
Serbia	1883	2008; additional historical list
Seychelles	Never reported	2009; additional historical list
Sierra Leone	1958	2011; additional historical list
Singapore	1930	2000; baseline historical list
Slovakia	1881	2000; baseline historical list
Slovenia	1883	2000; baseline historical list
Solomon Islands	Never reported	2009; additional historical list
Somalia	1993	2010; **dossier of evidence to the OIE**
South Africa	1904	2000; baseline historical list
Spain	Never reported	2000; baseline historical list
Sri Lanka	1994	2011; **dossier of evidence to the OIE**
Sudan	1998	2008; **dossier of evidence to the OIE**
Suriname	Never reported	2009; additional historical list
Swaziland	1898	2000; baseline historical list
Sweden	1700	2000; baseline historical list
Switzerland	1871	2000; baseline historical list
Syrian Arab Republic	1983	2010; **dossier of evidence to the OIE**
Tajikistan	1949	2008; **dossier of evidence to the OIE**
Tanzania (United Republic of)	1997	2007; **dossier of evidence to the OIE**
Thailand	1956	2004; **dossier to the OIE**
Timor Leste	Never reported	2009; additional historical list
Tonga	Never reported	2010; additional historical list
Togo	1986	2005; **dossier of evidence to the OIE**
Trinidad and Tobago	Never reported	2000; baseline historical list
Tunisia	Never reported	2000; baseline historical list
Turkey	1996	2005; **dossier of evidence to the OIE**
Turkmenistan	1954	2011; **dossier of evidence to the OIE**
Tuvalu	Never reported	2010; additional historical list
Uganda	1994	2008; **dossier of evidence to the OIE**
Ukraine	Never reported	2000; baseline historical list
United Arab Emirates	1995	2011; **dossier of evidence to the OIE**
United Kingdom	1900	2000; baseline historical list
United States of America	Never reported	2000; baseline historical list
Uruguay	Never reported	2000; baseline historical list
Uzbekistan	1928	2008; **dossier of evidence to the OIE**
Vanuatu	Never reported	2000; baseline historical list
Venezuela	Never reported	2000; baseline historical list
Viet Nam	1977	2000; baseline historical list
Yemen	1995	2010; **dossier of evidence to the OIE**
Zambia	1896	2006; additional historical list
Zimbabwe	1898	2000; baseline historical list

[a] Under United Nations Security Council Resolution 1244/99

APPENDIX 2

PRESENTATION OF THE FINAL REPORT OF THE JOINT FAO/OIE COMMITTEE ON GLOBAL RINDERPEST ERADICATION TO THE OIE WORLD ASSEMBLY, 2011, BY THE COMMITTEE CHAIRMAN, DR WILLIAM P. TAYLOR

CHAIRMAN OF THE JOINT COMMITTEE ADDRESSING THE OIE WORLD ASSEMBLY, 25 MAY 2011

Source: Jean Taylor. See also: www.youtube.com/watch?v=aEWxGbzJg84

'Dr Carlos Correa, President of the OIE World Assembly, Dr Bernard Vallat, Director-General, Ms Ann Tutwiler, Deputy Director-General of FAO, Honourable Ministers, Distinguished Delegates, Ladies and Gentlemen,

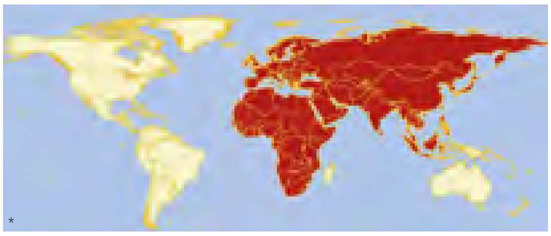
I was last asked to address an OIE General Session in 1993 to talk about the theoretical aspects of rinderpest control and whether eradication was an achievable objective. Although we all said it was, truly, we did not know that within the space of a few years our ambition would have been fulfilled. I am therefore deeply honoured to be here today to listen to the announcement that the OIE President will shortly make, signalling a very proud moment in the history of the veterinary profession.

This moment has been secured by a process of self-certification by Member Countries regarding the absence of rinderpest at national level, followed by a General Session resolution requesting inclusion by the Director-General on a list of countries free from rinderpest in accordance with the provisions of the *Terrestrial Code*. In 2009 the OIE and FAO nominated a group of experts to a Joint Committee tasked with reviewing the security of the underlying evidence that rinderpest no longer exists as a transmissible disease of livestock. Today I have the pleasure of representing that Committee.

For the past few years, very much in preparation for today, the OIE, assisted by FAO, has been assimilating evidence to show that rinderpest has gone. So what is the evidence? There are several threads to be taken into account, but the first of these is the historical record.

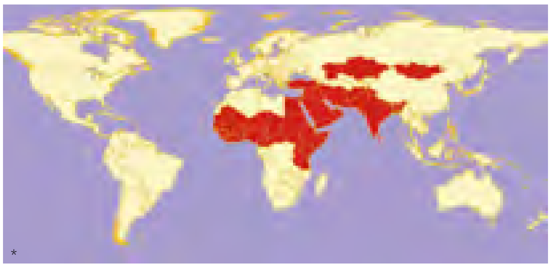
Rinderpest probably evolved on the steppes of Central Asia around 2,000 years ago. Thereafter it spread across the Eurasian landmass where it enjoyed an endemic domain of varying magnitude. It also made a brief foray (of around 100 years' duration) into Africa. Although other continents were occasionally exposed through trade involving infected livestock, rinderpest never established itself in the Americas or Oceania. The extent of its distribution is shown [in the figures] below.'

THE HISTORICAL RINDERPEST WORLD



The historical record for the 19th and 20th centuries shows that, within China, Europe, the Russian Federation and Japan, successful national battles against rinderpest were being fought and won, almost entirely based on zoosanitary control methods. Moreover, if we look at the rinderpest world as it existed between 1960 and 1980, during which period the OIE disease reporting system was the effective means of identifying the distribution of residually infected countries, the picture is as shown below. However, the most important fact here is that countries that had already eradicated the virus without recourse to vaccination were providing clear evidence that no carrier state or cryptic foci existed. This fact could and did lead to the development of a list of previously infected countries able to self-certify historical freedom from rinderpest.

THE RINDERPEST WORLD CIRCA 1980



The remaining countries, both in Africa and on the Indian subcontinent, which until recently had been reporting rinderpest and controlling it, became part of the global effort to eradicate the virus using rinderpest vaccine.

In 1989 the OIE developed a framework for speeding the recognition of a transition from an endemically infected – to accredited free – status. This framework became known as 'the OIE Pathway' – a series of progressive protocols aimed at demonstrating that a zero incidence timeline result, developed under vaccination, was correct. This required a preparedness to cease vaccination in order to provide rapid clinical and serological assessments that the country really was rinderpest free.

OIE PATHWAY

Encouraging countries to engage with the pathway routines and bringing them to a point where they can certify that rinderpest has ceased to circulate has taken around 30 years and has been a success story (see Fig. 1, Chapter 7.1). The result is as shown below.

THE SITUATION IN 2011 – NO UN-CERTIFICATED COUNTRY

'We have to thank the Director-General of the OIE for encouraging Member Countries to provide their evidence to the Scientific Commission, and further to thank FAO and the International Atomic Energy Agency (IAEA) for providing the technologies and, frequently, the resources to undertake clinical and serological search routines and the compilation of dossiers.

It is the conclusion of the Joint Committee that all historically infected countries have registered this as the basis of their freedom from rinderpest and that all endemically infected countries have submitted evidence that the OIE has correctly evaluated as consistent with a lack of a rinderpest transmission chain. Accordingly:

- The Committee is aware of the presence of residual rinderpest stocks in certain laboratories.
- Nevertheless, the Committee has concluded that a declaration of the end of rinderpest as a transmissible virus is soundly based and may be made.
- Finally, without the supreme and steadfast efforts of the officers of the national Veterinary Services involved, this achievement would not have been possible.

The Committee's report is now passed to the Director-General for his consideration.'

*Source: United Nations (2020). – Map of the world. Available at: https://www.un.org/geospatial/content/map-world (accessed on 9 June 2021); modified to indicate rinderpest spread. Final boundary between the Sudan and South Sudan has not yet been determined. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

APPENDIX 3

RESOLUTION NO. 18 (2011)

Declaration of global eradication of rinderpest and implementation of follow-up measures to maintain world freedom from rinderpest

ACKNOWLEDGING the efforts made by Members, non-Members, the OIE, FAO, IAEA, other international organisations, regional organisations, the veterinary profession, the scientific community, donors and other partners to eradicate rinderpest;

CONSIDERING the contributions made by the OIE and FAO towards global freedom from rinderpest;

NOTING the conclusions of the final report of the Joint FAO/OIE Committee on Global Rinderpest Eradication that rinderpest virus has ceased to circulate in animals;

REITERATING the importance of reducing the number of existing rinderpest virus stocks through the destruction of virus in a safe manner and/or the transfer of virus stocks to internationally recognised reference institutions; and

MINDFUL of the need for the international community and the responsibility of national authorities to take the necessary measures to ensure that the world remains free from rinderpest,

THE ASSEMBLY

1. **DECLARES** solemnly that the world has achieved freedom from rinderpest in its natural setting, one of the most dreadful animal diseases with severe impacts on livelihoods;
2. **EXPRESSES** its deep gratitude to all nations, organisations and individuals who contributed to the fight against rinderpest and the successful eradication of the disease;
3. **UNDERTAKES** to reduce, around the world, the number of institutions holding rinderpest virus-containing material other than attenuated vaccines, under approved conditions and according to relevant guidelines;
4. **URGES** the membership:
   - to maintain, in accordance with the relevant provisions of the OIE Terrestrial Animal Health Code, appropriate surveillance systems for rinderpest and immediately notify the OIE of suspect or confirmed cases of rinderpest;
   - to collaborate with the OIE and FAO in managing confirmed or suspected outbreaks of rinderpest through the provision of information, support and facilitation;
   - to put in place and update national contingency plans consistent with international guidance from the OIE and FAO;
   - to destroy, under the supervision of the Veterinary Authority, rinderpest virus-containing materials or assure the storage or use of these materials in a biosecure facility in their country or, where applicable, assure the safe transfer to an approved laboratory in another country in agreement with the Veterinary Authority of the receiving country and complying with the standards of the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* and the guidelines elaborated by the Joint FAO/OIE Committee on Global Rinderpest Eradication (Appendix);
   - to take effective measures to forbid synthesis of rinderpest full-length infectious clones unless approved by the relevant authorities, the OIE and FAO;
   - to use rinderpest vaccines solely for the emergency management of confirmed rinderpest outbreaks under the authority of the Veterinary Services following international and regional guidelines and not to use rinderpest vaccines to protect animal populations from other morbillivirus infections;
   - to ensure that rinderpest occupies an appropriate place in veterinary education curricula and training programmes to maintain professional knowledge and adequate diagnostic capabilities at national levels.
5. **REQUESTS** the Director-General:
   - to approve, jointly with FAO, facilities in which rinderpest virus-containing material can be held, and conduct regular site visits to those facilities to verify whether their biosafety/biosecurity conditions are adequate;
   - to maintain and regularly update, jointly with FAO, an inventory of facilities holding rinderpest virus-containing material;

- to establish, jointly with FAO, an advisory body that assists both organisations in (i) the approval of facilities for holding rinderpest virus-containing material and of facilities that produce and/or hold rinderpest vaccines, (ii) the approval of requests for research and other manipulations of the rinderpest virus, (iii) reviewing the plans and results of regular site visits of virus repositories, and (iv) planning and implementing other rinderpest-related activities as required;
- to develop and update, in collaboration with FAO, a plan of action for post-eradication activities at the international level;
- to facilitate and make sustainable, in collaboration with FAO, the provision of technical assistance to OIE Members in the maintenance of adequate surveillance systems and national preparedness and to facilitate their access to diagnostic reagents or facilities and relevant rinderpest vaccines;
- to ensure that OIE Members are informed of the status of rinderpest virus sequestration and research involving rinderpest virus;

6. **REQUESTS** the relevant specialist commissions to complete the necessary revisions to the relevant chapters of the *Terrestrial Animal Health Code* and the *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* as soon as possible.

(Adopted by the World Assembly of Delegates of the OIE on 25 May 2011)

APPENDIX 4

DECLARATION ON RINDERPEST ERADICATION BY THE 37TH CONFERENCE OF THE FAO, 2 JULY 2011

DECLARATION ON RINDERPEST ERADICATION

The Conference adopted the following Resolution: Resolution 14/2011 "Declaration on Global Freedom from Rinderpest and on the Implementation of Follow-up Measures to Maintain World Freedom from Rinderpest"

Mindful of the devastation caused by rinderpest, a viral disease of cattle, buffalo and many wildlife species that led to famines, demise of livelihoods in Africa, Asia and Europe, and loss of animal genetic resources over centuries and of the crucial importance that its global eradication is widely acknowledged and the world protected from its re-occurrence;

Acknowledging the successful collaboration of FAO with many Governments, international and regional organ-iza-tions, the veterinary profession and the scientific commu-nity to achieve this ambitious goal, recalling its vision of a world free from hunger and malnutrition, where the food and agriculture sectors contribute to improving the living standards of all in an economically, socially and envi-ron-mentally sustainable manner, and reiterating the global goals set out by the FAO Members to foster the achievement of this vision as formulated in the Organization's Strategic Framework 2010-19;

Recalling the establishment of the Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES) in 1994, in particular its Global Rinderpest Eradication Programme, including a goal for worldwide eradication by 2010;

Considering the announcement of the Director-General in October 2010 that the Organization had ended all its field operations after having obtained reliable and conclusive evidence that all countries were free from rinderpest and that the disease had been eradicated in its natural setting;

Noting the conclusions reached by the Joint FAO/OIE Committee on Global Rinderpest Eradication and the adoption of Resolution 18/2011 by the 79th General Session of May 2011 of the World Assembly of Delegates of the World Organisation for Animal Health (OIE);

Noting further the technical findings of FAO, OIE and IAEA concerning the evidence of rinderpest eradication;

Acknowledging the responsibility of Governments to reduce the number of existing rinderpest virus stocks through their safe destruction, or through their transfer to internationally recognised reference institutions;

1. **Declares** solemnly that the world has achieved freedom from rinderpest in its natural setting;

2. **Expresses** its deep gratitude to all nations, orga-ni-zations and individuals who contributed to the fight against rinderpest and the successful eradica-tion of the disease;

3. **Calls** upon FAO to assume its responsibility for undertaking the measures to maintain worldwide freedom from rinderpest, as recommended by the Joint FAO/OIE Committee on Global Rinderpest Eradication;

3. **Encourages** FAO to take full advantage of the rinderpest eradication achievement and apply the lessons learned to prevent and control other diseases impacting food security, public health, the sustainability of agriculture systems and rural development; and,

4. **Urges** all Members of FAO:

   i. to maintain, in accordance with the relevant pro-visions of OIE's *Terrestrial Animal Health Code*, appropriate surveillance systems for rinderpest and immediately notify the OIE and the FAO/OIE/WHO Global Early Warning System of suspect or confirmed cases of rinderpest;

   ii. to put in place and update national contingency plans consistent with FAO and OIE global guidance;

   iii. to destroy, under the supervision of the Veterinary Authority, rinderpest virus-containing materials or assure the storage of these materials in a biosecure facility in their country or, where applicable, assure their safe transfer to an approved laboratory in another country in agreement with the Veterinary Authority;

   iv. to ensure that rinderpest occupies an appropriate place in veterinary education curricula and training programmes to maintain professional knowledge and adequate diagnostic capabilities at national levels; and,

   v. to support all technical measures required to minimize the risk of rinderpest re-emergence, or its synthetic manufacture.

(Adopted on 2 July 2011)

The Conference also took note of the statements made by the Director-General of FAO, the Deputy Director-Gener-al of the World Organisation for Animal Health, the Minister of Health of Italy, the Nobel Prize laureate P. Doherty and the Assistant Director-General, Agriculture and Consumer Protection Department, as well as the statements made by the European Union and by Brazil.

References: C2011/15; C2011/LIM/12; C2011/I/PV/2; C2011/I/PV/5; C2011/PV/11.

APPENDIX 5

GUIDELINES FOR RINDERPEST VIRUS SEQUESTRATION

Endorsed with amendments on 28 January 2010 by the Biological Standards Commission of the OIE

Endorsed with amendments on 14 April 2010 by the Joint FAO/OIE Committee on Global Rinderpest Eradication

INTRODUCTION

The global eradication of rinderpest creates a duty for the international community to prevent the re-emergence of the disease through release of virus from laboratory sources. To this end FAO and the OIE shall establish the principle of international oversight and regulation of facilities holding rinderpest virus-containing material. The objective of the present guidelines is to ensure secure handling and sequestration of rinderpest virus in the post-eradication era. FAO and the OIE and Member Countries undertake to reduce the number of virus repositories in order to minimise the risk of accidental release.

FAO and the OIE, in collaboration with Member Countries, will put in place global contingency plans and will ensure approval of a minimum number of repositories and Reference Centres/Reference Laboratories necessary to maintain preparedness against releases of the virus into the environment. These plans will include, among others, vaccine production, vaccine banks and deployment of vaccines in cases of emergency. Vaccines should be available to countries for immediate dissemination in cases of emergency. The following guidelines deal with biosafety and biocontainment measures to be observed in laboratories and other facilities holding rinderpest virus-containing material.

DEFINITIONS

For the purpose of these guidelines, the following definitions apply:

An *approved BSL3 facility* means a facility that is jointly approved by FAO and the OIE and subject to joint regular inspection. The facility meets BSL3 standards as defined in Chapter 1.1.2 of the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (version of the *Terrestrial Manual* in force at the time, 2010), is certified by the *Veterinary Authority*, and in addition has mandatory shower-out for staff and either an exclusion zone or a restricted movement zone for rinderpest-susceptible species around the facility. Staff are subject to restrictions on contact with susceptible species (e.g. on farms, in zoos). A detailed protocol on the approval and inspection process for BSL3 facilities will be jointly developed by FAO and the OIE.

Rinderpest virus-containing material means field and laboratory strains of rinderpest virus; vaccine strains of rinderpest virus including valid and expired vaccine stocks; tissues, sera and other clinical material from infected or suspect animals; and diagnostic material containing or encoding live virus. Recombinant morbilliviruses (segmented or non-segmented) containing unique rinderpest virus nucleic acid or amino acid sequences are considered to be rinderpest virus. Full length genomic material including virus RNA and cDNA copies of virus RNA is considered to be *rinderpest virus-containing material*. Sub-genomic fragments of morbillivirus nucleic acid that are not capable of being incorporated in a replicating morbillivirus or morbillivirus-like virus are not considered *rinderpest virus-containing material*.

Veterinary Authority means the governmental authority of an OIE/FAO Member, comprising veterinarians, other professionals and para-professionals, having the responsibility and competence for ensuring or supervising the implementation of animal health and welfare measures, international veterinary certification and other standards and recommendations in the OIE *Terrestrial Animal Health Code* in the whole territory.

GUIDELINES FOR RINDERPEST VIRUS SEQUESTRATION

1. All manipulation of *rinderpest virus-containing materials*, including vaccine production, shall be forbidden unless approved the *Veterinary Authority* and by FAO and the OIE. An advisory body, jointly established by FAO and the OIE, shall be tasked to approve in advance and monitor any activities involving the use of *rinderpest virus-containing material*.

2. All countries shall either destroy or transparently audit and manage all remaining *rinderpest virus-containing material* under biologically secure conditions. The *Veterinary Authority* shall be kept aware of and be held responsible for any activity involving *rinderpest virus-containing material*.

3. *Rinderpest virus-containing material*, with the exception of stocks of packaged, manufactured vaccines, must only be kept, and can only be manipulated, in an *approved BSL3 facility*.

4. Master seed stocks must be maintained in, and tested by, the *approved BSL3 facilities* designated by FAO and the OIE. Stocks of packaged, manufactured vaccines, as covered under *rinderpest virus-containing material,* shall only be kept in FAO- and OIE-approved facilities that are subject to joint regular inspection. Any expired vaccine stocks shall be destroyed by a validated process.

5. *Rinderpest virus-containing material* that is not in an *approved BSL3 facility* shall be destroyed by a validated process or transferred to an *approved BSL3 facility*. Its relocation or destruction shall be supervised and documented by the *Veterinary Authority* and be notified to FAO and the OIE.

6. Transfers of *rinderpest virus-containing material* to an *approved BSL3 facility* located in another country must be notified to FAO and the OIE; such material may remain the property of the country of origin.

7. Transport (intra- and inter-country) arrangements for *rinderpest virus-containing material* shall be agreed by the relevant *Veterinary Authorities* in advance and in accordance with Chapter 1.1.1 of the OIE *Manual of Diagnostic Tests and the Vaccines for Terrestrial Animals*.

8. FAO and OIE shall establish and maintain a single global inventory of all existing *rinderpest virus-containing materials*, including vaccine stocks and the facilities holding such stocks and any movement of such materials. The global database shall be kept up to date on a permanent basis.

9. FAO and the OIE shall develop a mechanism to facilitate and standardise reporting of *rinderpest virus-containing material* by *Veterinary Authorities* to update the global database.

10. FAO and the OIE shall widely publicise the availability of internationally accessible rinderpest vaccine stocks to assist in convincing national authorities that they do not need to continue holding *rinderpest virus-containing material*.

11. FAO and the OIE shall develop a set of guidelines and standard operating procedures to govern the maintenance of rinderpest vaccine stocks and their use for emergency purposes.

12. FAO and the OIE, through their Reference Centres and Reference Laboratories, (including the laboratory of the Joint FAO/IAEA division) shall advise regional, national and international partners on laboratory-related issues having to do with rinderpest virus, including virus sequestration, destruction and disinfection protocols and diagnostic quality control.

13. FAO and the OIE shall oversee the development of diagnostic kits that do not require the use of live virus within the kit itself or during the manufacture of the kit.

CHAPTER 7.3

GLOBAL RINDERPEST FREEDOM CEREMONIES

F. NJEUMI [(1)*], L. KAMBIRIGI [(2)], C. NDI [(3)], J.-F. CHARY [(4)] & G. GYANENDRA [(5)]

(1) Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy
(2) Independent Communication Expert, 3 rue de la Station, C2 4430 Ans, Liège, Belgium (Former FAO Communication Officer for Africa)
(3) Animal Production/Animal Health Consultant, P.O. Box 737, Bamenda, Cameroon
(4) Ministère de l'agriculture, 757 rue de la Forge, 69620 Frontenas, France
(5) Former Chief Veterinary Epidemiologist, Veterinary Epidemiology Centre, Directorate of Animal Health, Kathmandu, Nepal

*Corresponding author: felix.njeumi@fao.org

SUMMARY **The Global Rinderpest Eradication Programme (GREP) was conceived in 1994 with the deadline of achieving global freedom from the disease by 2010. Based on the use of vaccines, the global epidemiological situation and the number of countries already free of rinderpest, in close association with the Director General of the World Organisation for Animal Health (OIE), the Director-General of FAO during World Food Week in 2010 was in a position to make a statement declaring that GREP had achieved its mandate and was awaiting the official global declaration of freedom in 2011. From October 2010 to June 2011, several events were organised, leading to the global declaration of rinderpest.**

KEYWORDS **Freedom – Global declaration – Global Rinderpest Eradication Programme – GREP – National ceremonies – National testimonies and rinderpest.**

A STORY WORTH TELLING

Tuesday 28 June 2011 was not just another sunny day in Rome: it was an ideal day to celebrate a world free of rinderpest. Dignitaries dressed in their national costumes had come together to mark the first major eradication of a disease in the livestock sector: the global eradication of rinderpest. Several national, regional and global events were organised from October 2010 to June 2011, leading to the declaration of global rinderpest eradication. That day was marked by statements from dignitaries and a Nobel laureate, followed by the erection of the rinderpest monuments and the unveiling of a plaque.

During World Food Week, 9–16 October 2010, the GREP organised a symposium (Fig. 1) entitled 'The World after Rinderpest: lessons learnt from the eradication of rinderpest for the control of other transboundary animal diseases'. The symposium was organised to celebrate the end of field activities in the last infected countries. More than 100 participants from over 40 countries attended the symposium. In addition to FAO staff, Joint FAO/IAEA (International Atomic Energy Agency) Division staff, chief veterinary officers (CVOs), virologists, epidemiologists, representatives from international organisations (World Organisation for Animal Health [OIE], African Union Interafrican Bureau for Animal Resources [AU-IBAR], African Union Pan-African Veterinary Vaccine Centre [AU-PANVAC], Biological Weapons Convention Secretariat and world reference laboratories), rinderpest campaign managers and other experts were in attendance. The deliberations focused on application of the lessons learnt from rinderpest eradication for control of other transboundary animal diseases (TADs), particularly peste des petits ruminants (PPR) (1). Some of the lessons learnt are described in Chapter 8.1.

GLOBAL RINDERPEST ERADICATION PROGRAMME HIGH-LEVEL MEETING

In addition, a high-level meeting was organised on 14 October 2010, attended by ministers of agriculture/livestock, CVOs and other invited guests. They shared their experiences and recognised the outstanding global contributions towards the eradication of rinderpest. During the meeting, the major outcomes of the GREP symposium were presented – the economic impact of rinderpest eradication and how GREP success stories could be applied for the control of other diseases, such as in the strategy for global control of PPR. It was a milestone meeting that brought together participants from around the world who had played an active role in the global eradication of rinderpest (1).

FAO DIRECTOR-GENERAL'S STATEMENT: 'ERADICATION IS NEAR'

> 'FAO is concluding its field operations and we can expect to declare eradication formally by mid-2011, together with OIE' (1). This historic announcement was made by the then FAO Director-General, Dr Jacques Diouf, on World Food Day, 16 October 2010.'

Despite stiff competition from other newsworthy stories, the media coverage of rinderpest's impending eradication was remarkable. Global media outlets, such as the *New York Times*, the BBC, the *Financial Times*, *Süddeutsche Zeitung* and many others, reported the approaching rinderpest eradication as a major scientific accomplishment, with FAO at the helm.

Even in the early days of online and social media, the news created major activity on popular microblogging sites such as Twitter.

CELEBRATION AT NATIONAL AND REGIONAL LEVELS

FAO supported national freedom ceremonies in Bangladesh, Cameroon, Ethiopia, Gambia, Ghana, India, Kenya, Mali, Nepal, the Niger, Nigeria,

FIG. 1

PARTICIPANTS AT THE GREP SYMPOSIUM 'THE WORLD AFTER RINDERPEST: LESSONS LEARNT FROM THE ERADICATION OF RINDERPEST FOR THE CONTROL OF OTHER TRANSBOUNDARY ANIMAL DISEASES'

Source: © FAO/Giulio Napolitano

Pakistan, Sri Lanka, Sudan, the United Republic of Tanzania, Uganda, Yemen and many other countries. The objective was to celebrate this major achievement of the veterinary profession, at the national level, and also to create awareness of the role that animal disease control plays in poverty alleviation. During these events, countries were also requested to identify other potential TADs to be targeted for eradication.

To commemorate this impressive achievement, monuments were erected in Ethiopia (Fig. 2), India (see Fig. 3, Chapter 4.13.15) and Kenya (see Fig. 4, Chapter 4.5.12).

FIG. 2

MONUMENT IN ETHIOPIA MARKING THE ERADICATION OF RINDERPEST

Courtesy of the authors

The monument in Ethiopia signifies FAO's first investment in rinderpest and the Ethiopian government's continued commitment to working with all of the partners. The monument in India commemorates the first rinderpest vaccine produced in Asia and the leading role played by India towards achieving global freedom. On 26 November 2010, the Honourable President of Kenya, Mr Mwai Kibaki, unveiled a massive bronze statue of a wild buffalo near the entrance to Meru National Park. It is an important landmark in the fight against rinderpest, the site of the world's last-confirmed case (2001) of rinderpest.

With the agreement of the CVOs of 52 countries, national consultants were recruited to assist in writing up national testimonies of rinderpest eradication, providing the information incorporated in Chapters 4.5, 4.11, 4.13, 4.15 and 4.17.

A series of regional workshops was also convened by GREP to consolidate the strategy for rinderpest surveillance and management in the post-eradication era. Three regional workshops, entitled 'The world after rinderpest', were organised for CVOs in Nairobi, Kenya (Fig. 3), Bangkok, Thailand, and Rabat, Morocco. The workshops saw senior decision-makers and technical staff come together to formulate global, regional and national post-eradication strategies for rinderpest. Their suggestions and strategies were presented at the global symposium held in June 2011 in Rome. A number of proposals then being developed by FAO and its partners, including the OIE, Joint FAO/IAEA Division, AU-IBAR and AU-PANVAC, were presented at the workshop and discussed in an open forum (2, 3, 4).

HISTORY CREATED AT THE 140TH SESSION OF THE FAO COUNCIL

At the 140th Session of the FAO Council a discussion item was introduced as: Declaration on Global Rinderpest Eradication for adoption in the 37th Session of the FAO Conference in June 2011. The elements for discussion and adoption by the Council (4) were as follows:

1. The Council may discuss the draft Declaration on Global Rinderpest Eradication as agreed between FAO and OIE.
2. The Council may decide to forward this text to the FAO Conference for adoption during its meeting of June 2011.
3. The Council may consider suggesting that the Director-General invite the Director-General of the OIE and executives of key stakeholders to attend the FAO Conference in June 2011 for the session on the adoption of the Declaration on Global Rinderpest Eradication.
4. The Council may consider recommending to the FAO membership that the resolution, after adoption by the FAO Conference, is signed by the heads of delegation of all Members to document both the significance of the resolution and the resolve of the international community to safeguard this global achievement.

A STRENGTHENED FAO/OIE COLLABORATION ON RINDERPEST

In January 2011, the members of the OIE *Ad hoc* Group on rinderpest met in Paris.

FIG. 3

PARTICIPANTS AT THE FAO REGIONAL WORKSHOP, NAIROBI, 5 AND 6 MAY 2011

Courtesy of the authors

Dossiers from the remaining countries (Comoros, Kazakhstan, Liberia, Micronesia [Federated States of], São Tomé and Principe, and Sri Lanka) were satisfactorily assessed. Two other pending evaluations (Kyrgyzstan and Turkmenistan) had also reached a satisfactory status following submission of further documentation. It was concluded that all countries with rinderpest-susceptible livestock, both Members and non-Members of OIE, and their non-contiguous territories were now considered rinderpest-free.

The Joint FAO/OIE Committee on Rinderpest Eradication, in its last meeting held on 13 and 14 January 2011, acknowledged the recommendations of the *Ad hoc* Group and recognised the effort put in by the experts of the group, by FAO and the OIE and by the Members to achieve this status. The draft resolution, written jointly by FAO and OIE, 'Declaration of Global Eradication of Rinderpest and Implementation of Follow-up Measures to Maintain a World Free of Rinderpest', was presented. It was proposed for adoption at the OIE World Assembly in May 2011 and at the FAO Conference in June 2011.

CORPORATE RECOGNITION, INTERNATIONAL CELEBRATIONS, GLOBAL DECLARATION

During the 79th General Session of the OIE (22–27 May 2011), the remaining countries mentioned above were added to the global list of countries free from rinderpest. The report of the Joint FAO/OIE Committee on Rinderpest Eradication was presented (see Chapter 7.2). This was followed by the statements by the Deputy Director-General of FAO and the President of the OIE. The global list of 198 countries and territories was approved by all OIE delegates. The OIE delegates adopted Resolution 18/2011 recognising a world free from rinderpest and identifying the technical follow-up steps for virus sequestration and safe management of remaining virus stocks (2, 5).

During the 37th Session of the FAO Conference in June 2011, at the FAO's headquarters in Rome, global freedom from rinderpest was officially declared. During the ceremony (Fig. 4), a commemorative plaque (Fig. 5) was unveiled in the presence of heads of state, 192 ministers of agriculture and other dignitaries. The FAO's goodwill ambassadors, Anggun and Mory Kanté, and other personalities also participated in the event. More than 450 international media outlets (Fig. 6) captured the event, and it was broadcast by North American and European media (Fig. 7). An exposition in the atrium of the FAO's headquarters presented the perception of stakeholders and what livestock, as well as rinderpest, represent for their livelihood. Figure 8 illustrates how science combined with partnership led to the eradication of rinderpest, thereby improving stakeholders' livelihoods.

Several statements were made by the FAO Director-General, Presidents of Chad and Togo,

FIG. 4

FAO PLENARY CONFERENCE ROOM DURING THE DECLARATION OF GLOBAL FREEDOM FROM RINDERPEST AT THE 37TH SESSION OF THE FAO CONFERENCE, ROME

Source: FAO/Giulio Napolitano

FIG. 5
UNVEILING THE PLAQUE DURING THE 37TH SESSION OF THE FAO CONFERENCE AT THE FAO'S HEADQUARTERS IN ROME

From left to right: Dr B. Vallat, Director General of OIE; His Excellency F. Grasinbe, President of Togo; Mr K. Annan, former Secretary-General of the United Nations; Dr J. Diouf, Director-General of FAO; His Excellency Idriss Déby, President of Chad, Her Excellency Isatou Njie-Saidy, Vice-President of Gambia

Source: FAO/Giulio Napolitano

FIG. 6
MEDIA COVERAGE OF RINDERPEST, 24–30 JUNE 2011

(number of articles from all sources – except Arabic)

Courtesy of the authors

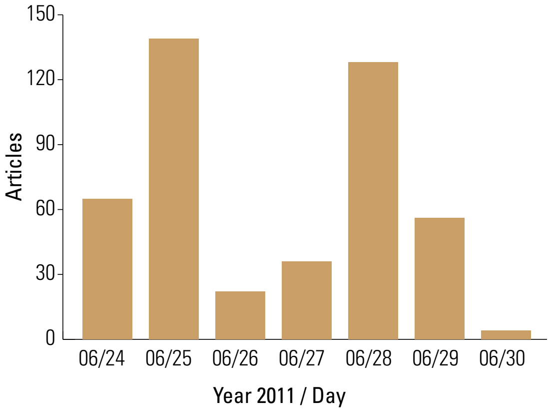


FIG. 7
MEDIA COVERAGE OF RINDERPEST BY REGION

(percentage of total, all sources – except Arabic)

Courtesy of the authors

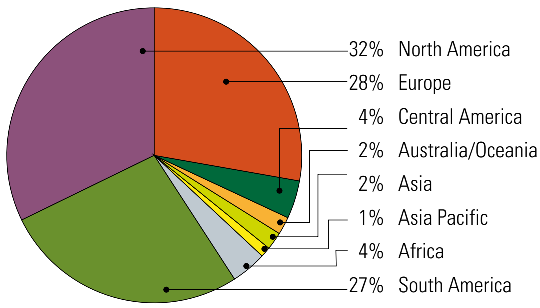


FIG. 8
SCIENCE AND PARTNERSHIP COMBINING TO ERADICATE RINDERPEST

Courtesy of the authors

Vice-President of Gambia, Director-General of the OIE and goodwill ambassadors (2, 6) at a high-level meeting on rinderpest eradication, aiming to celebrate the elimination of rinderpest and exchange views on the future of animal health management in the post-eradication era.

In a gesture to mark this historic achievement, FAO and the Italian Ministry of Health unveiled a commemorative monument (Fig. 9) on 18 October 2011 in Rome.

Dr Jacques Diouf, FAO Director-General, said: 'Century after century, rinderpest destroyed hundreds of millions of animals, both domestic and wild, taking a heavy toll on biodiversity – undermining the livelihoods of people, food security, nutrition and agricultural development. Funded by the Italian Government, the history of rinderpest and the success of its eradication are represented in this work of art. In unveiling this monument, commemorating this major achievement, we may be reminded of how from 1715 to June 2011, the eradication of the disease has benefited human health and well-being.'

The ceremony saw Dr Bernard Vallat, the Director-General of the OIE, Mr Ferruccio Fazio, the Italian Minister of Health, Ms Laura Marsilio, the Deputy Mayor of Rome (Fig. 10), and several other high-ranking members of FAO's Global Framework for Progressive Control of Transboundary Animal Diseases (GF-TADs) in attendance.

FIG. 9
MONUMENT IN THE SQUARE IN FRONT OF THE ITALIAN MINISTRY OF HEALTH COMMEMORATING THE ERADICATION OF RINDERPEST

Source: FAO/Giulio Napolitano

FIG. 10
UNVEILING CEREMONY OF THE MONUMENT, 18 OCTOBER 2011

From right to left: Ms Laura Marsilio (representing the Mayor of Rome), Mr Ferruccio Fazio (Italian Minister of Health), Dr Jacques Diouf, (Director-General of the FAO) and Dr Bernard Vallat (Director General of the OIE)

Source: FAO/Giulio Napolitano

FIG. 11
MEDAL AWARDED FOR OUTSTANDING PROFESSIONAL CONTRIBUTIONS TO THE ERADICATION OF RINDERPEST

Source: FAO/Giulio Napolitano

FIG. 12
CERTIFICATE MARKING OUTSTANDING PROFESSIONAL CONTRIBUTIONS TO THE ERADICATION OF RINDERPEST

Courtesy of the authors

On the African continent, on 12 January 2011 the African Union Interafrican Bureau for Animal Resources (AU-IBAR) celebrated its 60th anniversary and highlighted the importance of rinderpest eradication in Africa.

A symposium was organised during the FAO Conference to highlight the activities that national authorities and international agencies need to implement to safeguard a rinderpest-free world. During the symposium, a number of individuals were presented with an FAO medal, in recognition of their very significant contributions to the global eradication of rinderpest (Fig. 11). In addition, candidates were also presented with a certificate (Fig. 12). Table I records the specific contributions that each person made to this global achievement.

The recommendations of the 'Symposium on rinderpest eradication: achievements and obligations' are well described elsewhere (2).

TABLE I
AWARDEES FOR OUTSTANDING CONTRIBUTIONS TO THE ERADICATION OF RINDERPEST

Name	Justification	Institution or country
J.T. Edwards	Passaged a bovine strain of rinderpest virus serially through goats to 'fix' it and, fortuitously, produced a stable goat-adapted virus in 1926	United Kingdom
Thomas Barrett	Morbillivirus expert and author; identified the existence of geographical lineages within rinderpest virus	United Kingdom
Junji Nakamura	Identified lapinised–avianised rinderpest strains that were used extensively as vaccine in highly susceptible cattle in eastern Asia, including Japan, China and Korea (late 1920s)	Japan
Yves Cheneau	For services to the Pan-African Rinderpest Campaign (PARC), both in persuading the major donor to underwrite another vaccine-based rinderpest eradication project and in the setting up and monitoring of national projects in keeping with Jan Mulder's five dialogue points	France
W.G. Beaton	First Director of the Inter-African Bureau for Animal Health (IBAH) to have marshalled international support for coordinated rinderpest control in tropical Africa, under Joint Programme 15 (JP15)	United Kingdom
Titus Lwebandiza	Elimination of rinderpest from the United Republic of Tanzania by the mid-1960s, being the first country in East Africa to achieve this	United Republic of Tanzania
Walter Plowright	Rinderpest cell culture, virus characterisation and development of cell culture adapted and attenuated virus that became universally employed for regional control of rinderpest in Africa, West Asia and South Asia; also epidemiological work	United Kingdom
Alain Provost	Well known for his invaluable contribution to our understanding of the biology, pathology and epidemiology of the disease	France
Gordon Scott	He was irrevocably linked with the control and eradication of rinderpest. From 1950 to 1962, his research, initially at Kabete and then Muguga laboratories in Kenya, contributed significantly to improved diagnosis and control of rinderpest. In 1992, he and Dr Alain Provost produced the background document for the establishment of the Global Rinderpest Eradication Programme	United Kingdom
Ian Macfarlane	International Coordinator, Organisation of African Unity/Scientific and Technical Research Commission Joint Campaign against rinderpest in East Africa	East Africa
Henri Lepissier	International Coordinator, Organisation of African Unity/Scientific and Technical Research Commission Joint Campaign against rinderpest in Central and West Africa; also understanding the need for zoosanitary controls, as well as vaccination	Central and West Africa
Roland Geiger	Quality assurance; external quality control; Caucasus and Central Asia; capacity-building; performance elements, validation and comparison of enzyme-linked immunosorbent assays (ELISAs)	Germany
John Anderson	World reference laboratory; reference diagnostics; competitive ELISA; technology transfer	United Kingdom
Protus Atang	Director of IBAH (later Interafrican Bureau for Animal Resources, AU-IBAR) who continued to provide leadership to JP15. His joint paper with Plowright drew attention to the risk of mild rinderpest for rinderpest control in East Africa	Cameroon
S.P. Anbumani	Director of Veterinary Services, Tamil Nadu, responsible for focusing intensive vaccination in 1995/96 on districts still retaining endemic rinderpest, thereby eradicating the virus from India	Tamil Nadu
Berhanu Admassu	Masterminding the attack on rinderpest's last focus in Ethiopia in the Afar region in 1995	Ethiopia
John Crowther	Analytical and diagnostic technology transfer and capacity-building, especially ELISA technology and surveillance of thousands of samples	United Kingdom
Manzoor Hussein	National Project Coordinator responsible for completion of large-scale serological surveillance and participatory disease surveillance, and clinical surveillance; Coordinator in Central Asia	Pakistan
Andrew James	Socio-economic models and understanding of market chains and the herd as a reservoir rather than the individual	United Kingdom
Martyn Jeggo	International coordination of serosurveillance; development of performance indicators for the rinderpest eradication programme; quality control; training	United Kingdom
Gholam Ali Kiani	Control of rinderpest incursions into the Islamic Republic of Iran from Iraq and services to GREP in clarification of rinderpest epidemiology in the Islamic Republic of Iran, Central Asia, Afghanistan and Pakistan during the 1990s	Islamic Republic of Iran
Richard Kock	Wildlife investigations and the role of wildlife in epidemiology and as indicator species	United Kingdom
Tim Leyland	Building community-based animal health worker programmes in Sudan, Uganda and Kenya; participatory epidemiology for targeting vaccinations and clinical surveillance in remote areas in Africa	United Kingdom and New Zealand
Jeff Mariner	Thermostable vaccine; vaccination strategies; participatory epidemiology; rinderpest modelling	United States of America
Walter Masiga	Regional coordination; Director of AU-IBAR	Kenya
Sheikh Masood	Rinderpest Monitoring Officer, Strengthening Livestock Services Project, for services in the clinical and serological investigation of non-specific ELISA-positive samples through back-tracing	Balochistan, Pakistan
J.N. Mollel	Officer in charge of the Veterinary Investigation Centre (VIC) in Arusha when rinderpest invaded the United Republic of Tanzania in 1997; responsible for maintaining a veterinary investigation ethic in the face of severe resource constraints and for organising immunosterilisation of affected districts	VIC Arusha, United Republic of Tanzania
Dinker Ramchandra Nawathe	For drawing attention to the deteriorating situation in Nigeria in 1980–1982 and showing that two lineages of the virus were present at the same time, that from Sudan being more virulent than that from Mali	Nigeria
Felix Njeumi	Second GREP Secretary (2007–2011) and member of the OIE *Ad hoc* Group on rinderpest; devotion to ensure that the last 50 countries or so submitted acceptable dossiers to the OIE following the OIE Pathway	Cameroon

TABLE I (CONT.)

Name	Justification	Institution or country
Suresh Pandya	Rinderpest Eradication Officer, Gujarat. Charted and reported the spread of the last major outbreak of rinderpest in India in 1986/87 that showed the failure of the previous 30 years' rinderpest control measures and prompted the Government of India to launch its task force review	Gujarat, India
Yoshiro Ozawa	Laboratory support to Near East Campaign and later as FAO Chief of the Animal Health Service masterminded the drive towards the acceptance of the concept of global rinderpest eradication by FAO and OIE; masterminded the development of the OIE Pathway by calling an expert consultation in Paris that laid out the need to stop vaccinating and then undertake surveillance within a time-bound framework – the tool that forced the risky step of ending vaccination, which was pivotal to success	Japan
Rafaqat Raja	As Animal Husbandry Commissioner accepted that ongoing vaccination served no purpose and recommended state directors to stop vaccinating, allowing Pakistan to declare provisional freedom	Pakistan
M. Rajasekhar	Set up the National Project on Rinderpest Eradication ELISA Training and Data Management Centre; introduced the ELISA technique to India; developed serosurveillance protocols	India
Peter Roeder	First Secretary of GREP – coordination and scientific support to national and regional programmes; work in southern and eastern Africa, Central Asia, Pakistan; strategic thinker	United Kingdom
Leslie Rowe	For serological work in JP15 showing that a third round of vaccination failed to improve immunity prevalence levels; for services to the Overseas Development Agency (ODA) in support of rinderpest vaccine manufacturing in Bangladesh; for services to ODA in support of vaccine manufacture for Yemen; for assisting FAO in vaccine training	Nigeria, Bangladesh and United Kingdom
Mark Rweyemamu	Head of EMPRES and scientific oversight of GREP; Director of PANVAC; strategic thinker	United Republic of Tanzania
Daouda Sylla	Championing efforts and engaging African vaccine manufacturers and persuading them to submit samples for international scrutiny (FAO-IAH [Institute of Animal Health]) and showing the need for supranational quality assurance, hence PANVAC. Director of PANVAC	Mali
William Taylor	Application of laboratory findings to field conditions; understanding ecology of rinderpest; investigator and strategist in numerous countries and regional programmes; work in Pakistan, eastern and western Africa, Muguga, Vom, IAH, PARC, India	United Kingdom
Nick Taylor	Rinderpest clinical surveillance	United Kingdom
Emily Twinamisko	How to undertake seromonitoring in the face of civil conflict	Uganda
Lindsay Tyler	For developing a strong FAO involvement in rinderpest epidemiology during the PARC programme	United Kingdom
Gijs van't Klooster	Guiding Ethiopia to the successful eradication of rinderpest; major contribution to PARC and Pan-African Programme for the Control of Epizootics regional programmes	Netherlands and Ethiopia
Henry Wamwayi	First demonstration of rinderpest virus lineages; pathogenicity of lineage 2 rinderpest; later coordination of rinderpest surveillance in Somalia	Kenya
	PACE Council	
Bouna Diop	PACE Coordinator West and Central Africa	Senegal
Bernard Vallat	OIE	France
Amadou Samba Sidibe	PARC/PACE Coordinator for West and Central Africa	Mali
Solomon Haile Mariam	PARC Coordinator for East Africa	Ethiopia
René Bessin	PACE Coordinator	Burkina Faso
Karamoko Wague	Contribution to rinderpest eradication in Mali	Mali
Datsun Kariuki	Undertake jointly with colleagues work on the economic impact of rinderpest and contributed to PARC	Kenya
Institutional partners	**Who will receive the medal on behalf of the institution**	**Countries**
World Organisation for Animal Health (OIE)	Kazuaki Miyagishima	France
International Atomic Energy Agency (IAEA)	Liang Qu	Austria
International Atomic Energy Agency (IAEA)	Adama Diallo	Austria
Centre de coopération internationale en recherche agronomique pour le développement (CIRAD)	Geneviève Libeau	France
European Union/ Commission	Alain Valdermissen	Belgium
African Union Interafrican Bureau for Animal Resources (AU-IBAR)	A. El Sawalhy	AU/Kenya

TABLE I (CONT.)

Name	Justification	Institution or country
African Union Pan-African Veterinary Centre (AU-PANVAC)	AUC/AU-PANVAC Director – harmonised vaccine quality control in Africa	AU/Ethiopia
Muguga	CVO or Henry Wamwayi – research in vaccine efficacy, virology and field work in the Somali ecosystem	Kenya
Mukteswar	CVO of India	India
Institute for Animal Health (IAH), Pirbright	CVO or John Anderson	United Kingdom
European Commission	Otto Möller	European Union
	Funding partners	
United States Agency for International Development (USAID)	US Mission/USAID	United States of America
UK Department for International Development (DfID)	CVO of the United Kingdom	United Kingdom
Swedish International Development Cooperation Agency (SIDA)	CVO of Sweden	Sweden
Italian Cooperation	CVO of Italy	Italy
Ireland	CVO of Ireland	Ireland
Japan International Cooperation Agency	CVO of Japan	Japan
	The FAO/GREP Medals Committee consisted of Drs Y. Ozawa, W. Taylor, P. Roeder, M. Jeggo, M. Rweyemamu and S. Jutzi (members of PACE Council considered on their own merit by FAO)	

A LONG-AWAITED RESOLUTION

After the speech by the Director-General of FAO, Dr P. Doherty (Nobel Laureate 1989 in Physiology or Medicine) focused on the role of science in disease eradication. This was followed by statements from the Italian Minister of Health, F. Fazio, and the Deputy Director-General of the OIE, K. Miyagishima, and the introduction to the resolution by M. Traoré, followed by discussion of the draft resolution by the representatives of the Member Nations.

The Conference was invited to:

- adopt the Resolution containing the Declaration of Global Freedom from Rinderpest and the Implementation of Follow-up Measures to Maintain World Freedom from Rinderpest;
- request FAO to implement follow-up measures to maintain worldwide freedom from rinderpest;
- urge the membership to assume its duties and responsibilities to safeguard world freedom from rinderpest.

In accordance with FAO procedures during ministerial conferences, the resolution was finally adopted on 2 July 2011 by all Member Nations of the United Nations (see Appendix 4 in Chapter 7.2) (7).

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PART 8
POST-ERADICATION PERIOD

CHAPTERS

CHAPTER 8.1

REASONS FOR SUCCESS AND LESSONS LEARNT FROM THE GLOBAL RINDERPEST ERADICATION PROGRAMME (GREP)

P.L. ROEDER

Hollyhedge Cottage, Spats Lane, Headley Down, Hampshire GU35 8SY, United Kingdom (Former Secretary of the Global Rinderpest Eradication Programme, Food and Agriculture Organization of the United Nations [FAO], Rome)

SUMMARY **After centuries of rinderpest ravaging cattle production in the continents of Eurasia and Africa, it took less than 20 years to proceed from widespread endemicity and periodic epidemics to total global freedom and international accreditation of freedom. In order to achieve this, it was necessary to maintain focus on the goal of eradication within a time-bound programme. It is likely that there will be other disease eradication attempts made and it is therefore essential that the reasons why rinderpest eradication proved to be achievable be defined and used to inform future strategies. As outlined here, the factors included both technical issues, such as surveillance, epidemiology and laboratory technology, as well as coordination and leadership. This analysis emphasises the essential role of dynamic guidance and collaboration between different groups of players, from national Veterinary Services to global-level institutions.**

While eradication was successful, it must be remembered that rinderpest virus is still preserved in various laboratories and vigilance must be maintained against reintroduction into its hosts.

KEYWORDS **Epidemiology – Eradication – Leadership – Rinderpest – Strategy.**

INTRODUCTION

Achieving global eradication and accreditation of rinderpest freedom was a major step forward in the history of control of epidemic diseases. After many years of institutionalised control, it was achieved in a remarkably short time once a concerted effort was implemented based on lessons learnt in the early stages of the Global Rinderpest Eradication Programme (GREP). GREP was initiated in 1994, and it is now known that rinderpest was eliminated from the last foci of infection in 2002, even though it was not until 2011 that global verification of freedom had succeeded to the point at which the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) could make a formal announcement that eradication had been achieved. How this was achieved provides lessons that need to be learnt if other global eradication programmes are contemplated. This chapter explores those lessons from the point of view of the GREP Secretary. Inevitably, others with a different perspective will dispute some of the issues raised here.

THE OVERWHELMING IMPORTANCE OF EPIDEMIOLOGY IN DESIGNING AN ERADICATION PROGRAMME

The need for progressive control programmes to be based on a sound epidemiological platform is without doubt the most important lesson that was learnt from GREP. Although there had been considerable effort in developing the rinderpest control process in the years leading up to the inauguration of GREP, it bears stressing that rinderpest was eradicated only once major strides had been made in understanding the epidemiology of the disease. At the start of GREP, it came as a surprise to realise that so little was known about the global distribution of rinderpest and the mechanisms by which it was being maintained in different populations. Intensive studies soon revealed the discontinuous nature of virus persistence and the understanding that the virus was being maintained in relatively small reservoirs with epidemic extensions occurring into adjoining areas. In particular, this related to an understanding of how the disease was being maintained in the pastoral cattle herds of eastern Africa and in the village cattle and buffalo herds of southern Asia. This understanding led to launching the Intensified Global Rinderpest Eradication Programme, which focused eradication efforts on the reservoirs of infection (1), while elsewhere the drive was to achieve accreditation of rinderpest freedom. Once that understanding was applied to control programmes, evolving over time, in different populations of susceptible species (2), success came quickly. Interventions led to rapid eradication when the programme targeted critical points in virus transmission using information from surveillance and epidemiological assessments. This lesson can be applied across the board with some modification to take into account socio-economic and epidemiological differences, no matter which disease is under consideration.

It is axiomatic that disease information is indispensable for epidemiological studies to progress, and thus functioning national surveillance systems are essential to serve a disease eradication programme. A national surveillance system encompasses many elements from passive disease reporting to serosurveillance programmes, participatory disease surveillance (3, 4) and disease modelling (5). International disease reporting is another important facet facilitating global coordination (see Chapter 5.1), and this requires integrity on the part of national Veterinary Authorities to be honest and open with neighbouring countries and international organisations. Unfortunately, this has not always been the case, as trade issues can present a severe constraint to openness. Fortunately, in recent years following the OIE's attention to this problem, the situation has improved considerably. However, the situation is not perfect and serious deficits in epidemiological expertise remain in many countries. Repeated high-level meetings for decision-makers are needed to ensure that this is understood. Training for field staff and disease investigation teams, and retraining, is of great value in increasing the personal motivation of field staff, and this feeds into programme momentum. Experience with rinderpest eradication showed clearly that putting effort into awareness building at all levels as a continuous activity brings considerable rewards.

WHITHER MANAGEMENT, LEADERSHIP AND COORDINATION?

The single most consistently mentioned lesson in virtually all publications is that good coordination and partnerships were the keys to final success (6). For GREP, the coordination function was primarily provided by FAO, which established the programme in 1994 and sustained it until rinderpest eradication had been declared in 2011 (and subsequently in terms of virus sequestration efforts). However, what is important is that trustworthy and technically sound leadership be provided and not the identity of the organisation charged with the task of providing it. Many have assumed that it is necessarily the role of FAO and/or the OIE to take on coordination of international disease control, yet, perhaps, this assumption merits further study in the light of the changed circumstances and attitudes existing today with respect to the funding of international organisations. It is questionable whether the required expertise, whether technical, managerial or political, resides in a single organisation or a group of people, nor should any one organisation be allowed to seek out ownership of the global effort, although high-quality leadership and coordination is, undoubtedly, required to ensure that momentum is sustained. It has been argued that this would best be provided by an inclusive coordination mechanism that is independent of any individual organisational hierarchy and is in partnership with governments, international organisations, civil society, the private sector and communities themselves (7). Such an autonomous coordinating mechanism, in which personnel are recruited and overseen by a multipartite body representative of the range of stakeholders participating in the programme, could support an inclusive ethos that ensures fair representation of all interested parties (8). The Global Fund to Fight AIDS, Tuberculosis and Malaria could provide a useful model in this regard (7). In support of this understanding, an editorial in *The Economist* magazine stated bluntly that 'the fund itself must not be devoured by a voracious UN bureaucracy' (9). Problems can be caused by donors who wish to dominate the technical direction of a programme for reasons relating to political correctness and alternative political agendas, without understanding, or caring about, the technical results that would occur. Withholding funding from a country in a regional control programme because of a political dispute, even though that country is known to constitute a reservoir of infection, is one such example. The Global Fund mechanism (9) could assist in coordinating the inputs of various donors and avoid such issues arising. It is reasonable that a donor will wish to ensure that funds are being wisely spent, but monitoring and evaluation of an eradication programme should be primarily the function of a trustworthy umbrella organisation.

Coordination and guidance of a global programme by a single organisation is feasible, but implementation is difficult to achieve effectively without an excessive army of implementers. There is no reason why this should not be attempted if regional organisations can be facilitated to take on this role under the guidance of the global programme. In the case of rinderpest, the role played by the Organisation of African Unity (OAU) Interafrican Bureau for Animal Resources (now AU-IBAR) was exemplary because for the most part constituent countries enthusiastically participated (see Chapter 5.5). Elsewhere relationships between the regional partners and the major donor were problematic and progress stalled. One reason for this was that in Africa the governments of the OAU Member States were committed to rinderpest eradication; elsewhere political endorsement was less strong. This stresses the need for strong political support to be ensured at an early stage of planning.

FORMULATING A DISEASE ERADICATION PROGRAMME: HAVE THE LESSONS BEEN LEARNT FROM GREP?

It is not possible to achieve success by setting the agenda for an eradication programme and following it slavishly year after year. Adaptive management is a key issue to achieving success (8).

ADAPTIVE MANAGEMENT

Adaptive management (AM), also known as adaptive resource management (ARM) or adaptive environmental assessment and management (AEAM), is a structured, iterative process of vigorous *decision-making* in the face of uncertainty with the aim of reducing uncertainty over time through monitoring. It is essentially based on a learning process.

Rinderpest control/eradication programmes were sometimes rendered ineffective by setting unrealistic vaccination targets across whole populations or even countries as opposed to first conducting epidemiological studies to identify high-risk populations in which the virus was circulating before setting the vaccination targets. The Joint Programme for rinderpest control in Africa (JP15, 10, see also Chapter 4.1), which preceded GREP between the 1950s and 1970s, was ultimately unsuccessful for a number of reasons relating to a lack of clear vision of how to achieve eradication (if indeed global eradication was its intention), how eradication was to be determined and what mechanism was to be applied for declaring freedom from rinderpest in Africa. Most importantly there was no time limit set for JP15, and as a result it slowly faded away as countries lost interest, exhausted their funding or had never been engaged in the first place because there was no holistic understanding of what needed to be achieved. From its conception, FAO rightly designed GREP as a time-bound programme with a tight schedule.

The Office International des Epizooties (OIE, now the World Organisation for Animal Health) in collaboration with FAO provided the solution to many of these issues. At a meeting in 1993 they defined what became known as the OIE Pathway (see Chapter 5.2), which was to be overseen by an *Ad hoc* Rinderpest Group answerable to its Scientific Commission. This group made decisions on applications for freedom accreditation, monitored progress and proposed some technical guidelines. The chapters on rinderpest in the *Terrestrial Animal Health Code* (11) and *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* (12) provided guidelines for managing control. Earlier problems with the poor quality of rinderpest vaccines issued for field use were largely overcome by FAO's establishment of the Pan-African Veterinary Vaccine Centre with AU-IBAR (see Chapter 5.6) and the requirement that all vaccines used in rinderpest vaccination campaigns had to be of assured quality (13). These are all basic, and in retrospect rather obvious, issues, but they are essential to consider at the first stages in designing an eradication programme.

Once rinderpest had been eradicated, many offered their opinions to describe the lessons learnt from GREP. Many useful papers based on the experiences of workers who were at the 'coalface' of rinderpest eradication are contained in the proceedings of a symposium held by FAO in 2010 (6); other insightful papers include those by AU-IBAR (14). Yet, when one examines the concepts being applied to the eradication of peste des petits ruminants (PPR), one wonders if the lessons have truly been taken to heart and applied. Despite espousing the epidemiology cause, many people remain obsessed with the practice of mass vaccination, in the sense of pulsed area-wide vaccination campaigns, at the expense of all else. There can be no doubt that, if it were possible to organise saturation vaccination to immunise (not vaccinate) all animals (or at least a very large proportion) for rinderpest or PPR, virus transmission would be halted. However, it is clear to most people with practical experience that pulsed mass vaccination in practice rarely raises herd immunity to a level likely to terminate virus transmission across the whole population. There are a number of reasons why vaccination campaigns can fail to immunise a population adequately, including those linked to the practicalities of vaccination.

First, in rinderpest vaccination campaigns it was found that not all animals received an effective immunising dose of a vaccine; serological studies frequently demonstrated that the herd immunity generated rarely exceeded 70%. The vaccine might not have been fit for purpose, it might have been misapplied or it might have been mishandled during its passage from the production laboratory to the animal and rendered not fully potent. The availability of thermostable vaccines reduced greatly the requirement for an effective cold chain, but retaining vaccine for too long following reconstitution potentially remained a problem.

Second, the logistical and financial requirements needed for an effective vaccination campaign are difficult to sustain; experience in rinderpest control showed that it is not common to achieve vaccine cover exceeding 50% in area-wide campaigns, and in most cases the herd immunity engendered is insufficient to completely interrupt virus transmission in the population. However, transmission within the herd is slowed by this, and it tends to make the disease impact less visible. It has been suggested that such suboptimal levels of herd immunity might even help the virus to persist in certain populations of cattle (5). This leads to the understanding that, pragmatically, the intention must be to identify populations in which the virus is present and then to vaccinate the smallest numbers of livestock, at the greatest intensity possible in the shortest possible time, to achieve immunosterilisation of the high-risk population and thus terminate virus transmission. Of course, infectious agents differ in the characteristics of their maintenance and transmission but there are common elements across the board.

Third, the dynamics of colostral immunity in young stock relative to the timing of vaccination means that a proportion of young animals, already protected passively at the time of vaccination, fail to generate an active immunity and subsequently become susceptible. In cattle this happens by the age of one year. Joined by young animals born after the time of vaccination, they constitute within a short time a substrate vulnerable to infection. This phenomenon confounds eradication programmes and has to be specifically catered for; innovative approaches are called for to overcome the problem.

Notwithstanding these issues, vaccination in the face of an epidemic can contribute significantly to control by rapidly reducing the proportion of susceptible cattle as a result of vaccine–field virus interference and development of active immunity.

Obviously, planning to vaccinate only a relatively small proportion of a population is doomed to failure, yet this is exactly what has resulted on many occasions from a failure to focus vaccination programmes.

DEALING WITH CIVIL UNREST

Several of the countries of great importance in harbouring rinderpest were insecure and lacking in conventional services. However, civil unrest is not necessarily an insuperable impediment as shown by the successful elimination of rinderpest from Ethiopia, Sudan and Iraq, using a mix of conventional and innovative approaches (2, 3, 15 and Chapter 3.9). Even though the situation in the countries that are the bastion of persistence of epidemic diseases is perhaps worse now than it was during most of GREP, there are certainly ways around the constraints posed. Rinderpest was eradicated from southern Sudan through the application of targeted vaccination campaigns in key subpopulations, indicating that civil unrest is not an absolute constraint (15). This is so even if one has to wait for an opportunity to present itself. The lull in fighting between warring parties that took place in Iraq in 1996 and in Sudan in 2001 and 2002 provided such opportunities, as did the amenability of humanitarian aid programmes receptive to including disease control in their mandate, namely Operation Lifeline Sudan in southern Sudan where, by combining such opportunities with engaging community-based vaccine delivery systems, it was possible to achieve remarkable success in rinderpest control (15).

THE VALUE OF RESEARCH

There is a tendency to want to hold off from initiating global programmes until everything is in place, for example epidemiological understanding, vaccine refinement and fine tuning of diagnostics. Laboratory-based research programmes are considered by many to play an overly important role. This is partly because laboratory research scientists and laboratory diagnosticians are very influential in designing disease control programmes. As a result, the need for laboratory-based research programmes to be funded tends to be overplayed; this was true for the rinderpest programme. Undoubtedly molecular characterisation techniques to determine rinderpest phylogeny (16); the thermostable rinderpest vaccine formulation (17) for vaccination in arid areas; the lateral flow immunochromatographic test for detection of rinderpest antigen (18); and the competitive enzyme-linked immunosorbent assay for serosurveillance (19) did make invaluable contributions to the programme. However, in contrast, for example, large amounts of funding over decades for recombinant vaccines never produced anything for use in the field. Arguably, more valuable was the understanding that arose from the development of community animal health and participatory surveillance systems (3, 4) even though these received much less funding. Research is expensive, tends to be long term and does not necessarily yield the rewards expected, and research agendas tend to be self-serving. Pragmatically, once a certain minimal set of tools and understanding are available it is better not to delay embarking on a progressive control programme because much will be learnt, and the requirement for research will be clarified during implementation. Prolonged tinkering with the tools available in the search for perfection will not necessarily yield significant advances. It is not necessary to have the most advanced technology; this is often too expensive and technically demanding for developing countries. A minimal set of tools that are fit for purpose and robust is the baseline required.

FOCUSING AND MAINTAINING MOMENTUM

Linked to the issue of programme design is that of sustaining momentum. This is very difficult to achieve, as enthusiasm for implementing eradication programmes tends to fade away as the disease impact lessens, and at the same time funding is reduced. Nothing is more likely to sustain momentum than demonstrating progress towards the eradication target, and for this to happen the target has to be clearly identified and progress monitored and communicated. All forms of communication are valuable and merit funding – posters, flyers, films and media interviews, for example – but reaching senior decision-makers is difficult to achieve. The OIE assisted greatly in this process by incorporating GREP Secretariat presentations into its regional meetings.

The funds seen to be available for a particular, initially focused, eradication programme are alluring to those with alternative agendas. Thus, a considerable proportion of funding, ostensibly allocated for rinderpest eradication, ended up being spent on, *inter alia,* control of other diseases and privatisation of Veterinary Services. Allowing the focus to widen into additional functions risks diluting the effort and compromising success; funding is always limited and the temptation must be resisted. It has been argued that promoting the privatisation of Veterinary Services was necessary to strengthen them and allow rinderpest eradication to proceed. However, it became clear that in fact it was the focus on rinderpest eradication that encouraged the strengthening of Veterinary Services and provided skills that could then be applied to the control of other diseases. The process of rinderpest eradication has been extremely valuable in generating innovative tools for studying disease epidemiology, for surveillance and for delivering control procedures (3).

WHEN IS IT ALL OVER?

Finally, cessation of circulation of an infectious agent in a population of animals is not the end of an eradication programme. Viruses preserved in the archives of diagnostic and research institutes constitute a threat for reintroduction into the general population. This threat can only be met, and then not completely, by securing national and international sequestration agreements and this takes time and patience (Chapter 8.2 and 20).

KEYS TO SUCCESS

From its inception, there were many issues that needed to be addressed if GREP was to move on from being a routine vaccination campaign to a systematic disease eradication programme. Fundamental to this process was elaborating efficient control strategies and making available to countries technical direction based on epidemiological analysis. Several advances were of special significance:

- establishing the GREP coordination mechanism;
- epidemiological studies that clarified most of the determinants of infection in cattle and the lack of a significant role for wildlife in maintaining infection in the late 20th century;
- provision of vaccine of assured thermostability during transit, together with community-based methods of vaccine delivery;
- improvements in disease surveillance by the use of fit-for-purpose serological tests in serosurveys, combined with participatory epidemiology for the demonstration of freedom from disease.

Undoubtedly it was adopting new understanding and techniques that accelerated the progress of eradication and ensured its ultimate success.

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CHAPTER 8.2

SAFEGUARDING GLOBAL FREEDOM FROM RINDERPEST

S. METWALLY [(1)*], D. ULAETO [(2, 3)], J. LUBROTH [(1)] & T. BRAND [(4)*]

(1) Food and Agriculture Organization of the United Nations, Rome, Italy
(2) Chemical, Biological and Radiological Division, Defence Science and Technology Laboratory, Porton Down, Salisbury SP4 0JQ, United Kingdom
(3) The Pirbright Institute, Pirbright, Surrey GU24 0NF, United Kingdom
(4) World Organisation for Animal Health, 12 rue de Prony, 15017 Paris, France

*Corresponding authors: samia.metwally@fao.org; t.brand@oie.int

SUMMARY

One of the little noticed implications of rinderpest eradication is the demonstration that the earlier eradication of smallpox was not a unique event. The international community can eradicate devastating, widespread infectious diseases. In the post-eradication era, as with smallpox, the most important issues facing rinderpest stakeholders are preventing a re-emergence of this devastating disease and preparedness in case this awful event should occur. These two challenges require stakeholders to assess the advantages of maintaining laboratory stocks of rinderpest virus for emergency preparedness against the risks of unintentional or deliberate virus release. Should rinderpest re-emerge, it would degrade livelihoods, decrease food security and cause substantial economic losses.

Although accidental or deliberate release are considered the greatest risks for rinderpest re-emergence, the possibility of re-emergence from an unrecognised wildlife reservoir cannot be excluded. However, epidemiological and serological studies indicate that rinderpest transmission could only be maintained in cattle, not in wildlife.

The last confirmed case of rinderpest was in 2001, and the continued absence of the disease since eradication builds confidence in the conclusion that there is no unrecognised wildlife reservoir. A further concern is that rinderpest virus might survive in frozen carcasses in permafrost. However, examination of human cadavers from the 1918 influenza pandemic, buried in permafrost, failed to find evidence of viable influenza virus. Taken with the low density of cattle populations in Arctic regions, rinderpest re-emergence from carcasses frozen in permafrost is considered to be highly improbable.

It is clear that continued oversight of rinderpest virus stocks is essential while the stocks remain and that the number of facilities holding stocks should be reduced as much as possible from the current level. It is equally clear that preventing the return of rinderpest is the responsibility of all countries and that raising awareness, rumour tracking, destruction of existing virus stocks, availability of vaccines and national contingency plans are key elements to preventing or if necessary halting an outbreak.

The consequences of rinderpest re-emergence are of global importance and an effective response would require cooperation between multiple stakeholders at the national, continental/

regional, and international levels. The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organisation for Animal Health (OIE) developed the Global Rinderpest Action Plan (GRAP) with collaborating partners, and it is intended to inform and advise a broad range of stakeholders on how to prepare, prevent, detect, respond to and recover from rinderpest if it re-emerges.

KEYWORDS **Global Rinderpest Action Plan – GRAP – Post-eradication – Rinderpest – Rinderpest holding facility – Sequestration – Vaccine.**

INTRODUCTION

Eradicated diseases present the global community with a particular problem – what to do with the remaining stocks of the causative agent. This is not a problem that we are likely to have with bacteria such as *Bacillus anthracis*, the cause of anthrax, that survive or remain dormant in the environment and outside an animal host, or with viruses such as influenza virus that are widespread in many different, free-ranging animal reservoirs. There is no immediate prospect that such diseases will be eradicated. But in certain cases, where a pathogen is unique to a limited number of host species and the tools to institute control measures are available, then true eradication is possible, as demonstrated by the success of the World Health Organization (WHO) smallpox eradication campaign and more recently by the eradication of rinderpest, supported by experts, national veterinary authorities and services, as well by FAO, the OIE and other international and regional organisations.

Even with the global successes of smallpox and rinderpest eradication, once the disease is gone, the virus remains in laboratories in the form of diagnostic samples, virulent isolates and attenuated vaccine strains. After the 2011 declaration of rinderpest eradication, rinderpest virus-containing material (RVCM) was still stored in laboratories in at least 44 institutions in 35 countries (1).

The estimated cost of eradicating rinderpest was over US$610 million (2, 3), but this should more appropriately be described as an investment in livestock production, livelihood and food security; it is estimated that eradication of the disease has resulted in annual economic benefits amounting to US$920 million in Africa alone (3, 4). Viewed in this way, we can see that a re-emergence of this disease, if not dealt with promptly and effectively, would result in losing global freedom from rinderpest, and turn a successful investment into a loss by recreating the social and economic problems caused by the disease and the huge cost of a new eradication campaign.

In this chapter, the international priorities for maintaining global freedom from rinderpest and ways to mitigate the risk posed by the remaining rinderpest virus stocks are discussed.

STATE OF PLAY AFTER ERADICATION

At the historic declaration of rinderpest eradication in 2011, Members directed FAO and the OIE to collaborate on developing and managing a post-eradication strategy to maintain global freedom. A formal definition of material that constitutes RVCM was adopted (4). The management and ultimate fate of the remaining virus stocks is a matter of international concern that requires all nations to be aware of the remaining risk and the role they are expected to play in managing it. Rinderpest remains a threat because of the potential for the escape of virus from diagnostic laboratories, research institutes and vaccine manufacturers, whether unintentional or deliberate. Rinderpest virus has long been recognised as a potential biological weapon because of the ease of its spread among susceptible animal populations and the enormous financial costs caused by outbreaks.

Although accidental or deliberate release are considered the greatest risks for rinderpest re-emergence, the possibility of re-emergence from an unrecognised wildlife reservoir cannot be excluded. However, epidemiological and serological studies indicate that rinderpest transmission could only be maintained in cattle, not in wildlife (5). The last confirmed case of rinderpest was in 2001 (6), and the continued absence of the disease since eradication builds confidence in the conclusion that there is no unrecognised wildlife reservoir. A further concern is that rinderpest virus might survive in frozen carcasses in permafrost. However, examination of human cadavers from the 1918 influenza pandemic, buried in permafrost, failed to find evidence of viable influenza virus (7). Taken with the low density of cattle populations in Arctic regions, rinderpest re-emergence from carcasses frozen in permafrost is considered to be highly improbable.

To mitigate the risk of rinderpest re-emergence, FAO and the OIE established the Joint Rinderpest

Secretariat and the Joint Advisory Committee (JAC) and set the priorities for sustaining global freedom. The JAC was initiated in March 2012, with members appointed in April 2012. The JAC comprised independent experts in the areas of disease management, virology, epidemiology, biorisk, smallpox, and emergency management. The Joint Rinderpest Secretariat coordinates meetings with the JAC to seek advice on matters pertaining to:

- applications by institutes to be designated as a rinderpest holding facility (RHF);
- a virus sequestration policy;
- research proposals using rinderpest virus; and
- an international preparedness plan, referred to as GRAP.

The Joint Rinderpest Secretariat was tasked to coordinate and implement all relevant activities for the post-eradication era.

The joint actions of FAO and the OIE are focused on:

- approval and oversight of applications to be RHFs, including verification of institutional biosafety and biosecurity measures, and supervision of remaining global RVCM stocks and their use in RHFs;
- advocacy and assistance in RVCM destruction and sequestration;
- limiting research activities to those of benefit to maintaining global freedom (policies on research);
- setting international standards for rinderpest vaccines and diagnostics in the post-eradication era;
- rumour tracking and surveillance;
- raising awareness among stakeholders;
- developing a global rinderpest action plan; and
- establishing a rinderpest vaccine reserve.

FAO-OIE RINDERPEST HOLDING FACILITIES

With guidance from the JAC, FAO and the OIE established a rigorous process for the designation of biocontainment facilities applying to become RHFs. The designated facilities were legally bound to the 'FAO and OIE terms and conditions' that state their technical and political mandate to the region and globally in preventing the return of rinderpest.

The established process for the selection of RHFs has four components:

a) a review of the application along with the national rinderpest contingency plan and biosafety manual;
b) a site inspection of the facility by an independent expert team selected by FAO and the OIE to assess the suitability of the facility for safe storage of RVCM;
c) a review of the site inspection report by the JAC for recommendation to FAO and the OIE;
d) approval by the OIE membership through the adoption of a resolution during the OIE General Session and by the Legal Council of FAO to legally bind the institute through an official letter of designation and with notification to Members.

The two categories of RHF are:

- Category A: rinderpest holding facility for storing rinderpest virus-containing material, excluding vaccine stocks; and
- Category B: rinderpest holding facility for storing only manufactured vaccines, vaccine stocks and material solely for vaccine production.

The RHFs must report annually to FAO and the OIE on the inventory of the RVCM stocks. The inventory of the RVCM is monitored regularly through these annual reports.

A network of RHFs was established in 2017 and has been tasked to formulate a biennial workplan aimed at reducing the RVCM inventory. At this time, the network workplan includes full genomic sequencing of rinderpest virus strains/isolates, followed by their destruction; development and validation of non-infectious diagnostic tests; and engagement in the use of a web-based database for reporting and tracking RVCM held at RHFs in real time.

The list of RHFs and their mandate can be found on FAO and OIE rinderpest portals (8, 9).

VIRUS DESTRUCTION AND SEQUESTRATION

Based on the FAO survey done in 2011 (from veterinary authorities, universities, government and private laboratories) and on data collected from countries (from OIE delegates) through the first OIE annual survey on RVCM, in 2013, the number of countries holding RVCM after the declaration of eradication ranged from 23 (OIE survey) to 36 (FAO survey). It became clear that the real number of facilities and countries storing rinderpest virus was most likely being underestimated as a result of several potential sources of under-reporting.

These included but were not limited to:

- lack of information within government authorities, especially when the virus is stored outside such facilities (e.g. universities, vaccine manufacturers, private sector);
- fear of losing capability to conduct diagnostics and produce vaccine, should rinderpest re-emerge.

FAO, the OIE and regional organisations recommended that the remaining stocks of RVCM be destroyed or sequestrated to an RHF of their choice (10, 11). The major reasoning behind the call for destruction was that maintaining the infectious virus would present an unconscionable risk, because its continued presence might result in mistakes or accidents or could conceivably fall into the hands of individuals or groups with malicious intentions who could use it to unleash devastating epidemics in an unvaccinated global population. In addition, as the entire rinderpest virus genome has been sequenced, and more strains continue to be sequenced, future information about the virus can be derived from studies of its genes without the need to use virus strains.

To bolster efforts to safeguard the world's rinderpest-free status, FAO, in collaboration with the OIE and regional partners, organised three outreach regional/international meetings (Sharm el Sheik, August 2015; Rome, January 2016; Kathmandu, June 2017). The core goals of these meetings were to advocate and encourage countries to comply with the international and regional resolutions and affirm their intention to sequester or destroy their remaining RVCM stocks, and to offer FAO assistance in the safe destruction and/or removal of RVCM (12).

In hindsight, these meetings were a success and represented the driving force of the sequestration and destruction efforts. Both during the discussions and after closing the sessions, numerous countries committed to either destroying their holdings or relocating them to an RHF. Additional advocacy was undertaken through personal communication with responsible officials during animal health events and/or through official advocacy letters from international organisations to chief veterinary officers and/or the responsible ministers.

Countries storing the virus were encouraged to:

- destroy remaining stocks on their own or request an FAO expert team mission for assistance;
- transfer a minimum number of valuable samples to a RHF, with FAO assistance if requested; or
- as a last resort, and if such investment is approved at national level, apply to the Joint Secretariat to become a designated RHF; and
- take effective measures to forbid the unapproved manipulation of RVCM in their country, including research with and production and/or synthesis of rinderpest virus.

Standard operating procedures (SOPs) for destruction, shipping and receiving of RVCM and decontamination of facilities were developed and published (12, 13, 14, 15).

FAO and the OIE advocate that the best way to protect a country from an outbreak of rinderpest virus infection is not to have the virus in the country in the first place (16). There would be disastrous social and economic consequences resulting from the release of rinderpest virus, which could be prevented by simply not storing RVCM in a country.

At the time of writing (January 2020), eight countries report storing remaining stocks of rinderpest virus, two countries are ready to destroy their virus stocks, six countries host RHFs and one country is being evaluated to host an RHF (Fig. 1). Additional countries have expressed interest in hosting an RHF and their applications are pending.

POLICIES ON RESEARCH

There is debate in scientific and government circles on the continuing need for active research with rinderpest virus (4, 5). It is widely acknowledged that research with rinderpest virus poses risks of accidental release, and that this risk is borne by all nations, not just those where research is undertaken. Consequently, much effort has been expended on ensuring that, if research with live rinderpest virus must be undertaken, this happens in a transparent manner with internationally agreed safeguards. Rinderpest virus cannot be owned by individuals; it must always be under the ultimate control of a national government. Importantly, FAO and the OIE have made a formal definition of rinderpest virus that includes hybrids between rinderpest and other viruses, and viruses incorporating silent mutations. It has been internationally agreed that research with live rinderpest virus must only take place under the following circumstances:

- It is deemed essential for food security and/or maintaining global freedom from rinderpest.
- It has the prior approval of both FAO and the OIE.
- It takes place at a FAO and OIE-designated RHF.
- It has the prior approval of regulatory authorities in the nation where the research will be undertaken.
- The results of the research are made available to all FAO and OIE Members.

FIG. 1

RINDERPEST VIRUS IN LABORATORIES OF MEMBER COUNTRIES, MARCH 2020

Source: FAO STAT, 2020. Final boundary between the Sudan and South Sudan has not yet been determined. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

INTERNATIONAL STANDARDS FOR RINDERPEST

Prior to the declaration of global freedom from rinderpest in May 2011, the international community concentrated its efforts, over several decades, on cooperative mechanisms to ultimately rid the planet of this deadly cattle disease. One mechanism, referred to as the 'OIE Rinderpest Pathway', was created and launched in 1989, based on OIE standards for the establishment of epidemiological surveillance systems and official recognition of freedom from rinderpest status. In 1994 this pathway was integrated into the Global Rinderpest Eradication Programme (GREP) launched by FAO, which included high-level collaboration with the International Atomic Energy Agency and regional bodies, and involved in-country field work, assay validation and technology transfer.

As a result of eradicating the disease, the *Terrestrial Animal Health Code* chapter 'Infection with rinderpest virus', was subsequently revised to provide measures for the post-eradication era. The revised chapter was adopted by the OIE World Assembly of Delegates during the 81st General Session in 2013. More changes to the *Terrestrial Code* chapter are expected following feedback from countries during the review of the GRAP, particularly on the recovery of freedom from rinderpest in the event of a re-emergence.

In the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals*, the chapter on rinderpest ('Infection with rinderpest virus') includes information about the history of rinderpest, its consequences and clinical signs as well as standards for diagnostic tests and the production of vaccines. Historically, diagnostic tests required RVCM as a positive control, which was recognised as a barrier to ongoing efforts to destroy and/or sequester remaining rinderpest virus stocks. The chapter will continue to be revised with advances in diagnostic tests to remove the need for RVCM.

Ever since the declaration of global freedom, through the approval of OIE Resolution No. 18 (79GS, May 2011) (8) and FAO Resolution 4/2011 (June 2011) (11), FAO and the OIE have overseen post-eradication activities to maintain freedom from the disease and the awareness of the clinical signs of rinderpest, and the consequences and history of the disease. Particular resolutions were issued to support this endeavour (Table I).

TABLE I
OIE RESOLUTIONS TO SUPPORT POST-ERADICATION ACTIVITIES

Number OIE Resolution	General Session/ Year	Title
No. 33	GS80 / 2012	OIE's role in maintaining world freedom from rinderpest (17);
No. 23	GS82 / 2014	Procedure for the designation of facilities holding rinderpest virus-containing material to maintain global freedom from rinderpest (18);
No. 25	GS83 / 2015	Designation of facilities as approved for holding rinderpest virus-containing material (19);
No. 21	GS85 / 2017	Amendments to the annex, 'Guidelines for Rinderpest Virus Sequestration', of Resolution No. 18 of 25 May 2011 (20);
No. 20	GS86 / 2018	Designation of facilities as approved for holding rinderpest virus-containing material (21);
No. 23	GS87 / 2019	Designation of facilities holding rinderpest virus-containing material to maintain global freedom from rinderpest;
No. 24	GS87 / 2019	Extension to the designation of facilities holding rinderpest virus-containing material to maintain global freedom from rinderpest.

RUMOUR TRACKING AND SURVEILLANCE

The absence of disease occurrence or reports of infection is based on the assumption that countries have the capacity to recognise and detect rinderpest, should it appear. There are other infectious and non-infectious causes of stomatitis with and without enteritis and diarrhoea, and other reasons for rapid wasting, dehydration and death that can confuse the less experienced clinician. At the time of writing, rinderpest has not been seen or detected in the wild for over 18 years, and yet other causes of stomatitis, dehydration, fever, explosive diarrhoea, high morbidity, dullness and depression in cattle and other bovids occur on all continents.

It is essential that veterinary systems around the world have the capabilities to immediately follow up on reports or rumours of die-offs in cattle that have clinical signs consistent with a 'stomatitis–enteritis syndrome'. The official regulatory surveillance systems in place must include the participation of cattle owners, ranchers and zoo keepers, private sector veterinary specialists, cross-border agents, and wildlife biologists, so that reporting can be immediate and the appropriate samples taken for an accurate and reliable diagnosis. From the viewpoint of differential diagnosis, the concept that 'the last suspect case of rinderpest was yesterday; the next suspect case will be tomorrow' is a precursor to the notions of early warning, sensitisation of the community, and global preparedness and response.

RAISING AWARENESS AMONG STAKEHOLDERS

With each passing year since the eradication of the disease, the number of people who have had contact with cattle infected with rinderpest or have witnessed rinderpest's consequences for economies and livelihoods is diminishing. Hence, it is crucial to ensure that new generations of veterinarians, animal health professionals, livestock keepers and Veterinary Services are aware of rinderpest's history and its consequences. In addition, diagnostic capacity must be maintained by FAO-OIE Reference Laboratories for rinderpest.

FAO and the OIE supported efforts to maintain community memory of the impact of rinderpest by developing material that described rinderpest facts and figures, clinical signs and findings, and procedures to follow when rinderpest is suspected (9, 22).

A priority action for countries was to raise awareness of rinderpest among stakeholders. Knowing that the next generation of livestock owners and veterinarians has not seen a clinical case of rinderpest, special consideration was given to raising awareness in all communities. Awareness-raising took the form of development and distribution of educational and advocacy tools as a resource for a variety of stakeholders, including:

- farmers, pastoralists and livestock owners;
- veterinarians, paraprofessionals and community animal health workers;
- educators and veterinary students;
- laboratory personnel;
- government officials.

The FAO engaged with national partners to develop methodologies based on the communication for development approach (23), targeting livestock keepers and lay people. A needs assessment field study is the primary step in this participatory approach, conducted through interviews, field observations, *ad hoc* surveys, questionnaires and literature reviews, etc. The study provides insights into farmers' knowledge about rinderpest, their communication systems and how they liaise with veterinarians and central government in the event of an emergency. The needs assessment has been used to develop a communication strategy outlining the tools and media suitable for delivery of the message to the target audience of a given country, including radio, television, flyers, posters, jingles, etc. This approach was used successfully to increase awareness in Africa and Asia.

The OIE developed an overarching communication campaign under the motto 'Never turn back!' that can be implemented at national level by the veterinary authorities or the ministry in charge of livestock and agriculture (22). This campaign targets veterinary students, veterinary practitioners and laboratories, and it makes use of multimedia tools to keep the memory of rinderpest alive among new generations of stakeholders. The campaign is available in six languages (English, French, Spanish, Arabic, Russian and Mandarin) and consists of a set of advocacy tools, such as infographics, posters, leaflets, videos and presentations. A serious game, in which the users play the role of a veterinarian and a laboratory worker to find the source of a rinderpest outbreak and save the world, is also part of this campaign (24). Its ultimate goal is that users understand the role they have to play to safeguard global freedom, by maintaining knowledge of rinderpest to enable surveillance for rapid detection, notification and response, and by guiding laboratories to safely destroy or transfer RVCM.

GLOBAL RINDERPEST ACTION PLAN

The GRAP (25) is the international operational plan that would be activated if rinderpest re-emerged. It complements all other international, continental/regional and national plans for rinderpest re-emergence. The GRAP defines the operational frameworks, the actions to take for rinderpest emergency management, and the assigned responsibility for those actions. The GRAP enables veterinary officials to identify and prioritise gaps, in preparation for a potential re-emergence of rinderpest. The actions recommended within the GRAP will mitigate the risk and strengthen global planning, while providing the necessary confidence for decision-makers to proceed with the destruction of remaining virus stocks.

The GRAP was prepared by the Joint Rinderpest Secretariat in collaboration with experts from regional and international organisations, reference centres and the JAC. The GRAP was further updated in consultation with national and regional authorities, policy-makers of various regions and development partners and during two rinderpest table-top simulation exercises in Africa and Asia.

The purpose of the GRAP was to:

- complement and expand on the rinderpest emergency management guidance (26) in place from FAO, the OIE, continental/regional organisations and countries;
- provide a framework at national, regional and continental, and international levels to reduce the likelihood of rinderpest re-emergence and to facilitate a coordinated response should re-emergence occur;
- identify actions, within a timeframe, beneficial to the five stages of emergency management (prepare, prevent, detect, respond and recover) as they relate to the potential re-emergence of rinderpest; progress towards accomplishing these activities could serve as a means to evaluate the readiness status of a country/region/international organisation and reveal deficiencies that may need additional support or funding.

RINDERPEST VACCINE RESERVES

Dr J.C. Edwards developed the goat-adapted rinderpest vaccine for the active immunisation against rinderpest in 1927. This was the first discovery that vaccination with an attenuated virus confers life-long immunity to rinderpest. More information on vaccines is addressed in this book in Chapter 3.4.

By mid-2018, two of the approved RHFs (category B) had been given the mandate to hold the rinderpest vaccine reserve (RVR). As part of their RHF mandate (OIE Resolution No. 23, GS82, 2014) (18), they are responsible for managing the vaccine stocks and deploying the vaccine in the event of an emergency, when requested by FAO and the OIE.

As of February 2018, there was one RVR of LA-AKO vaccine in the National Institutes of Animal Health, in Tsukuba, Japan, and one RVR of the RBOK vaccine in the African Union Pan African Veterinary Vaccine Centre, in Ethiopia.

The Joint Rinderpest Secretariat developed the Operational Framework of the RVR (OF-RVR), which describes the management considerations, manufacturing policy and vaccine withdrawal mechanism of the RVR hosted by the FAO-OIE-approved RHFs. The OF-RVR defines the formal process for countries to request vaccine through FAO and the OIE. The OF-RVR will be published as an annex of the GRAP (25).

LESSONS LEARNT

In relation to sequestration and destruction of rinderpest virus, it would have been invaluable if a registry had been available at the time of global eradication, recording where rinderpest had been studied (in live animal trials or in tissue samples examined for histopathology and comparative pathology), where the disease had been diagnosed, where vaccines had been produced and where research with the virus had been undertaken. In the absence of such a registry, GREP undertook the first global questionnaire in 2009, which was distributed principally through ministries of agriculture/livestock. As rinderpest virus is often ranked high on lists of potential biological weapons, RVCM may also have been deposited in facilities outside the purview of the veterinary or agriculture authorities, a fact that was not fully addressed in the GREP.

Of additional importance as a risk-reduction measure was the recommendation to suppress all laboratory virus production, genetic manipulation work, and rinderpest research at the time of the global declaration (OIE Resolution No. 18, 79th GS, 2011) (8). In this regard, however, compliant veterinary diagnostic laboratories were limited in the diagnostic platforms that could be used to rule in or rule out rinderpest virus (i.e. clinical investigations or assurance of safe trade of live rinderpest-susceptible hosts). Diagnostic platforms (for whole pathogen or serological detection rather than those based on genetic targets) that do not use infectious material in any of their reagent components was a recognised need towards the end of the eradication efforts, but funding to develop and validate such assays was lacking. Even now, in the post-eradication era, having a diagnostic test that uses non-infectious material to rule out suspect cases and for serological surveillance to regain global freedom should the disease ever recur, remains an outstanding item.

A third retrospective lesson was in relation to the final OIE's official recognition of disease status, which recognises a country's health status for specific diseases. For diseases such as rinderpest that had an official recognition process and was eventually eradicated, it is proposed that the country regulatory officials would need to provide evidence of pathogen destruction from all known facilities and/or the safe transfer to an appropriate biocontainment facility, such as an internationally recognised reference laboratory, before free status could be granted and global eradication could be declared. This is particularly important for future programmes to eradicate other high-consequence transboundary animal diseases.

ACKNOWLEDGEMENTS

The activities that have been undertaken by FAO and the OIE, in implementing their roadmap for maintaining global freedom, were made possible through the generous financial support and/or expertise of partners. Many of the projects related to communications, awareness-building, advocacy meetings, table-top outbreak simulation exercises, sequestration and destruction missions, and approved essential research, along with the development of the RHF web-based database and an updated electronic rinderpest reporting system were financed by Global Affairs Canada's Weapons Threat Reduction Program, the US Defense Threat Reduction Agency, the Government of Japan and the Government of the United Kingdom.

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PART 9
CONCLUSION

CONCLUDING REMARKS

In developing this book, the editors requested that the authors of the various chapters focus on providing the reader with an account of the final stages of the eradication of rinderpest – a period between 1945 (the end of the Second World War) and 2011 (when eradication was announced).

In doing so, we were mindful of the need to provide context for the reader by describing firstly, the nature of the virus, the disease it caused and the extent of its global spread; secondly, the immense amount of work that had been directed to controlling rinderpest prior to this final thrust of eradication; and, lastly, the improved tools, such as vaccines and diagnostics, that were available at the start of eradication in 1945.

Historically, rinderpest was always maintained in two species of domestic animal, cattle and water buffaloes although Asiatic breeds of pig were occasionally involved. The virus was maintained by constant transmission between sick and healthy animals while recovered (and vaccinated) animals developed a lifelong immunity and could not be re-infected. In addition, there was only one serotype which meant that when vaccines became available they immunised against all field strains. Often devastating in its effects, rinderpest generally produced an overt clinical disease so that its whereabouts could be easily reported.

Early in this book rinderpest is identified as a member of the genus Morbillivirus within the family *Paramyxoviridae*. This is discussed along with the fact that rinderpest virus had a close relationship with three other members of this genus; distemper virus in dogs, measles virus in humans, and peste des petits ruminants virus in sheep and goats, a close-knit group of viruses probably diverging from a common ancestor, with bat paramyxoviruses being considered a possible source of this progenitor. One of the chapters illustrates the severe clinical effects rinderpest had on its unfortunate hosts.

Credible clinical accounts place the first European appearance of rinderpest in a period between AD 376 and AD 386 based on the account of a disease which could have been rinderpest, following which historians have been able to chart its continual presence up to the modern era. In the east, Chinese history similarly identified a rinderpest-like disease between AD 75 and 447. And while no 'birthplace' was ever discovered, a fair working assumption was that rinderpest emerged from Central Asia as a lethal infection of domestic ruminants that was subsequently distributed by nomadic movements and by the baggage trains of marauding armies across the whole of the Eurasian landmass and neighbouring islands; thereafter, it persisted as an endemic, sometimes epidemic disease. Rinderpest never became established in the Americas and only had a significant impact in Africa after its introduction in 1878 as a result of a colonial war.

Although we have chosen to consider the end of the Second World War (and coincidentally the launching of the United Nations) as the starting point at which eradication began, much had gone on before that point was reached. The narrative of the book charts the early history of rinderpest in each of the infected regions providing an account of early control initiatives, such as the slaughter and safe disposal of the remains of infected animals and the quarantining of in-contact animals. Such techniques enabled Europe to become free of rinderpest at the turn of the 19th century after enduring the disease for around 1,500 years. The Russian Federation and Central Asia followed suit slightly later. In Southeast Asia rinderpest was endemic in Korea into the early 20th century and in China until 1956. The countries of Indochina had largely controlled rinderpest prior to the Second World War, but final elimination came in the immediate aftermath of that episode. Rinderpest probably reached India at a very early stage in the geographical expansion of the disease, but a positive identification was not forthcoming until 1860. It was known to have invaded Africa in 1878 and to give rise to a massive epidemic.

By the 1920s, several curative and preventative techniques had been explored including the use of immune serum alone or in combination with virulent virus, as also had inactivated vaccines and a promising live virus vaccine attenuated in goats. In the period just after the Second World War further live vaccines followed, including variants attenuated in rabbits and eggs. A 1948 meeting in Nairobi noted that rinderpest killed two million cattle annually and called for international action against it, noting that live attenuated vaccines were sufficiently advanced to be fit for purpose. In those parts of the world where the disease still occurred, zoosanitary controls had given way to the control of rinderpest by the regular use of vaccines in partnership between stock owners and their Veterinary Services, generally funded from the public budget. The Veterinary Services were also responsible for maintaining field staff able to diagnose the disease, a laboratory capable of confirming the disease, and a facility capable of manufacturing and providing quality assured vaccine.

Augmenting and integrating these efforts within an international framework was all that stood between control and eradication. The core of this book documents this process from the national perspective by describing the regional programmes that went on in Africa and South Asia between the early 1960s and the late 1990s in situations where zoosanitary controls were considered difficult to apply and mass vaccination assumed a paramount role.

As success attended these efforts, it became important to devise a means of verifying that rinderpest had indeed been eradicated. This required an understanding that the virus had ceased to circulate, which could only be meaningfully obtained by ending vaccination and then searching, over several years, for clinical evidence of the disease or serological evidence of the virus's presence in the newly susceptible livestock population. Appropriate surveillance techniques and serological techniques were developed. Finally, the evidence that a country was free from rinderpest was registered with the World Organisation for Animal Health (OIE) – a process that continued until all rinderpest-infected counties were so registered. It is important to note that this clinical and serological evidence was not previously available to historians. Now, with the publication of this book it is fully available.

The concluding section of the book exemplifies the roles of the various stakeholders during the struggle to move from a world in which rinderpest was considered under control (although this was not always the situation as epidemics flared) to one in which it no longer occurred. The Veterinary Services were without doubt the most heavily involved group and were constantly buffeted with advice on policies, strategies, new techniques and funding problems while struggling to introduce sufficient vaccine into sufficient animals as to permanently halt virus transmission – and then prove that they had done so. Reintroducing control when epidemics were reported was a role in which the Food and Agriculture Organization of the United Nations (FAO) excelled. Acting as the agency for collecting and distributing reports of the disease was the base role of the OIE, which took on a new perspective through the development of criteria to prove that the virus had been eradicated. In Africa, the African Union Interafrican Bureau for Animal Resources coordinated the efforts of the Veterinary Services. None of this would have been possible, however, without the steadfastness of international funding supplied by the donors, among whom the United States Agency for International Development and the European Union must be singled out for praise.

As eradication became increasingly feasible, the FAO's Global Rinderpest Eradication Programme provided leadership and coordinated the last efforts required, including solving some interesting epidemiological puzzles, to see eradication over the victory line. Since that point was reached much effort has gone into reducing the risk of the disease ever returning by on-going attempts to constrain any remaining virus holdings to a limited number of biocontainment facilities.

Finally, we come to the question of what should be taken away from the production of this book. Firstly, it provides an insight into the length of time it takes to eradicate a disease. Secondly, it reinforces, as with the eradication of smallpox, the concept that epidemiologically informed vaccination can be employed to break transmission chains. Thirdly, it drives home the fact that in order to succeed, all involved parties need to recognise that they are part of the same team. And lastly, success requires dynamic, focused leadership and effective coordination. With the benefit of hindsight, it is clear that national and international trade involving infected livestock did much to undermine control and eradication efforts – a lesson for any future campaigns.

W. Taylor, E. Paul J. Gibbs, Santanu K. Bandyopadhyay, Protus Atang
June 2020

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Note Illustrations are comprehensively referred to from the text. Therefore, significant items in illustrations have usually only been given a page reference in the absence of their concomitant mention in the text referring to that figure.

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RINDERPEST
AND ITS ERADICATION

This book tells the story of rinderpest and its eradication. The focus is on the international coordination that came together after the Second World War in the confident belief that, with vaccines available, the eradication of rinderpest was a practical possibility. In both Africa and South Asia, beginning in the 1960s, there was an initial dramatic success through the coordinated vaccination of cattle across the continents. Unfortunately, follow-up measures could not prevent the return of epidemic rinderpest, albeit to a lesser extent. Chastened by failure, the international community refocused with renewed energy to achieve eradication. The vaccination programmes broadened to reflect a multidisciplinary approach to disease eradication. FAO and the OIE, together with international aid agencies, coordinated policy with the nation states and guided implementation of the eradication programmes until success was achieved.