3

Ecologically or Biologically Significant Marine Areas (EBSAs)

Special places in the world's oceans

SOUTHERN INDIAN OCEAN

Areas described as meeting the EBSA criteria at the CBD Southern Indian Ocean Regional Workshop in Flic en Flac, Mauritius, 31 July to 3 August 2012

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Convention on Biological Diversity

Japan Biodiversity Fund

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Eastern Cape. Photo © D.King.

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Bumphead parrotfish. Photo © David Obura.

FOREWORD

Activities related to ecologically or biologically significant marine areas (or EBSAs) have been an important part of the CBD's programme of work on marine and coastal biodiversity since 2008. This work has significantly contributed to global, regional and national efforts to expand scientific knowledge on marine biodiversity and improve conservation and sustainable use in support of the achievement of the Aichi Biodiversity Targets in marine and coastal areas.

The CBD's work on EBSAs began with the development of the EBSA criteria, which were adopted in 2008 at the ninth meeting of the Conference of the Parties (COP) to the CBD. At this meeting, the COP urged Parties, and invited other Governments and relevant organizations to apply, as appropriate, the EBSA criteria to identify ecologically or biologically significant marine areas, with a view to assist the relevant processes within the United Nations General Assembly and further enhance conservation and management measures, in accordance with international law, including the United Nations Convention on the Law of the Sea.

At its tenth meeting, in 2010, COP requested the CBD Secretariat to convene a series of regional workshops to facilitate the description of EBSAs. Since then, the CBD Secretariat has embarked on a remarkable collaborative effort, working with many global, regional and national partners around the world, to describe areas meeting the CBD's scientific criteria for EBSAs (decision XI/20, annex 1) through a series of regional EBSA workshops that started in the Western South Pacific region in November 2011.

The regional EBSA workshop process has facilitated the sharing of scientific information and the networking of experts across disciplines at the regional scale, and has enhanced collaboration between various initiatives for marine conservation and sustainable use by providing a global platform for scientific assessment of the ecological or biological significance of marine areas.

The reports of the regional EBSA workshops are the product of expert scientific discussions, and therefore, often contain very detailed and technical descriptions of various features of the marine ecosystems and species. This booklet, which was produced with the kind support of the European Commission, is part of a series of booklets that aims to present the information compiled at each regional EBSA workshop in a concise, engaging and easily understandable way. The purpose of this publication is to expand the recognition and understanding of these important marine areas across a broad range of stakeholders and the general public.

I encourage you to read this booklet and gain a greater appreciation of the breadth, depth and complexity of the unique features of the marine environment and their important role in a healthy functioning planet.

Braulio Ferreira de Souza Dias
Executive Secretary, Convention on Biological Diversity

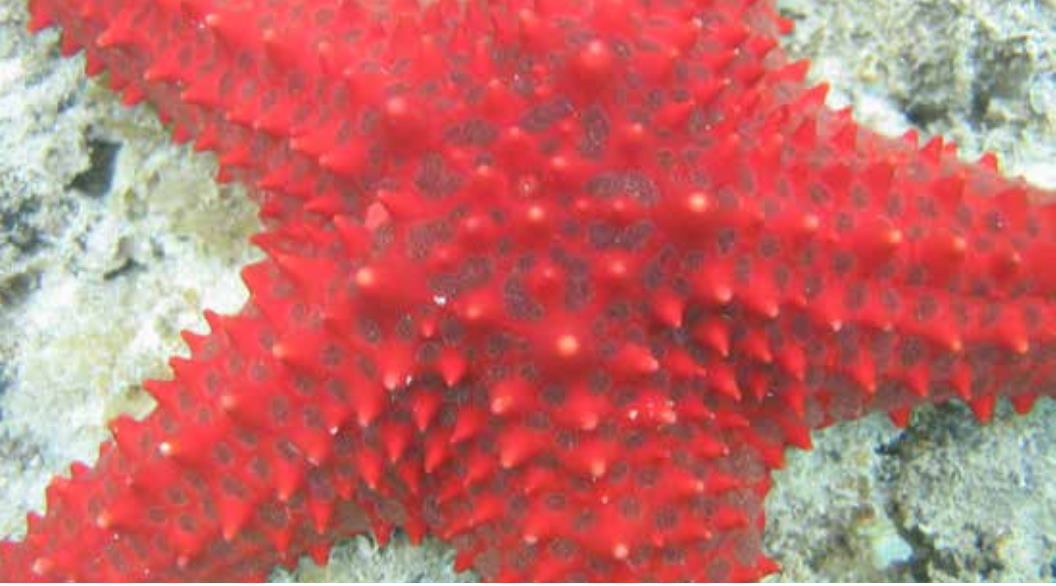
Cape gannet. Photo © Lloyd Edwards.

EBSAs: AN INTRODUCTION

The ocean encompasses 71 per cent of the planet's surface and a large portion of its habitable space. Whereas life on land is almost exclusively contained within a thin strip of breathable atmosphere overhead, in the ocean it is found from the waves that wash against the shore to the deepest canyons that plunge thousands of metres beneath the sea floor.

Life is found throughout the ocean, from coastal zones to the open sea, from coral reefs to kelp beds, in forms as varied as algae that cling to the underside of polar ice floes, humpback whales that migrate from the Antarctic to the equator and back, and multitudes of marine viruses that, if laid end to end, would span farther than the nearest 60 galaxies.[1]

But the distribution of life in the ocean is varied. Whether caressed by currents, sheltered by the shore, nurtured by nutrients, or heated by hydrothermal vents on the sea floor, some areas boast life that is more plentiful, diverse or unique than others. For example, scientists with the Census of Marine Life found that white sharks congregate in an area off Hawaii that they dubbed the "white shark café", and that several species



Starfish, Tanga, Tanzania. Photo © Matthew Richmond.

of whales, turtles, seabirds, seals and sharks all congregate at "hotspots", such as the California Current.

The top 100 metres (m) of the open ocean hosts the great majority of the sea life with which we are more familiar—turtles, fish and marine mammals—as well as the microscopic plankton that form an integral part of the ocean food web and provide so much of the oxygen that we breathe. Far below the surface, in the dark depths, seamounts—underwater mountains that rise 1,000 m or more from the ocean floor—provide habitat for rich and diverse communities. Hydrothermal vents and cold-water seeps form the basis of unique ecosystems and species that might seem to belong more comfortably in a science fiction movie than the real world.

Yet, much of this unique and special biodiversity is facing major threats related to such factors as habitat destruction, overfishing, pollution and climate change. The global community has recognized the need to address these threats and to take measures to support the health and well-being of marine and coastal biodiversity.

In 2010, at its tenth meeting, the Conference of Parties to the Convention on Biological Diversity (CBD) adopted a new 10-year Strategic Plan for Biodiversity, including 20 "Aichi Biodiversity Targets". A number of these targets focus specifically on marine and coastal biodiversity, including targets to achieve sustainable fisheries and protect at least 10 per cent of the world's marine and coastal areas by 2020.[2]

But in order to protect and preserve marine biodiversity effectively, we need to know where to focus and prioritize conservation and management. We must have a good understanding of the many different types of marine ecosystems in different regions, including which areas are the richest in life, which boast the greatest diversity and abundance of species, and which possess the rarest species and the most unique communities of marine flora and fauna.

It is in this respect that the CBD's work on ecologically or biologically significant marine areas (EBSAs) plays a key role. In 2008, the Parties to the CBD adopted a set of seven scientific criteria to be used in identifying EBSAs. The EBSA criteria are as follows:

1	Uniqueness or rarity
2	Special importance for life history stages of species
3	Importance for threatened, endangered or declining species and/or habitats
4	Vulnerability, fragility, sensitivity, or slow recovery
5	Biological productivity
6	Biological diversity
7	Naturalness

These criteria provide guidance on the key types of features to be considered when identifying areas that are critically important to the functioning of marine ecosystems.

In 2010, the Parties to the CBD requested the CBD Secretariat to collaborate with Parties, other Governments and a range of partners in different regions in convening regional workshops to facilitate the description of EBSAs using the EBSA criteria. Through an inclusive and science-driven process involving experts from all over the world and an enormous amount of scientific data, these regional EBSA workshops have described the areas of the oceans that are the most crucial to the healthy functioning of the global marine ecosystem.

EBSAs can be as varied as the life within them. They can address large ocean areas or individual features. They can be static or move with seasonal variations in certain oceanographic features. But they all, in one way or another, have been described as important in the context of one or more of the seven EBSA criteria.

Furthermore, there are many different types of measures that can be used in regard to the EBSAs. These include, but are not limited to, marine protected areas and other area-based management tools, impact assessments and fisheries management measures.

The description of an area as meeting the EBSA criteria is a scientific exercise aimed at supporting the prioritization of management efforts of governments and relevant authorities. It does not necessarily mean that new management measures will be put in place, and it does not prescribe what types of management measures should be used.

These booklets, one of which is being produced for each region in which an EBSA workshop has taken place, provide snapshot summaries of the pages upon pages of data compiled by participating experts, to provide a detailed guide to some of the most ecologically or biologically significant ocean areas in the world.

This booklet, the third in the series (see also Volume 1: Western South Pacific, **www.cbd.int/marine/ebsa/booklet-01-wsp-en.pdf** and Volume 2: Wider Caribbean and Western Mid-Atlantic, **www.cbd.int/marine/ebsa/booklet-02-wcar-en.pdf**), provides summaries of the areas described during the Southern Indian Ocean Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas, which took place in Flic en Flac, Mauritius, from 31 July to 3 August 2012. The workshop was organized in collaboration with the Secretariat of the Nairobi Convention and the United Nations Food and Agriculture Organization and hosted by the Government of Mauritius, with financial support from the Government of Japan, through the Japan Biodiversity Fund, and from the Government of Australia, through the Commonwealth Scientific and Industrial Research Organisation, for scientific and technical support. To find out more about this and other EBSA workshops, see www.cbd.int/ebsa. The full report of this workshop is available at **www.cbd.int/doc/meetings/mar/ebsa-sio-01/official/ebsa-sio-01-04-en.pdf**.

This booklet is available online at: **www.cbd.int/marine/ebsa/booklet-03-sio-en.pdf**

Stony sponge and soft corals, sea bottom, southern Madagascar. Photo © Pierre Laboute, La Planète Revisitée/MNHN-PNI.

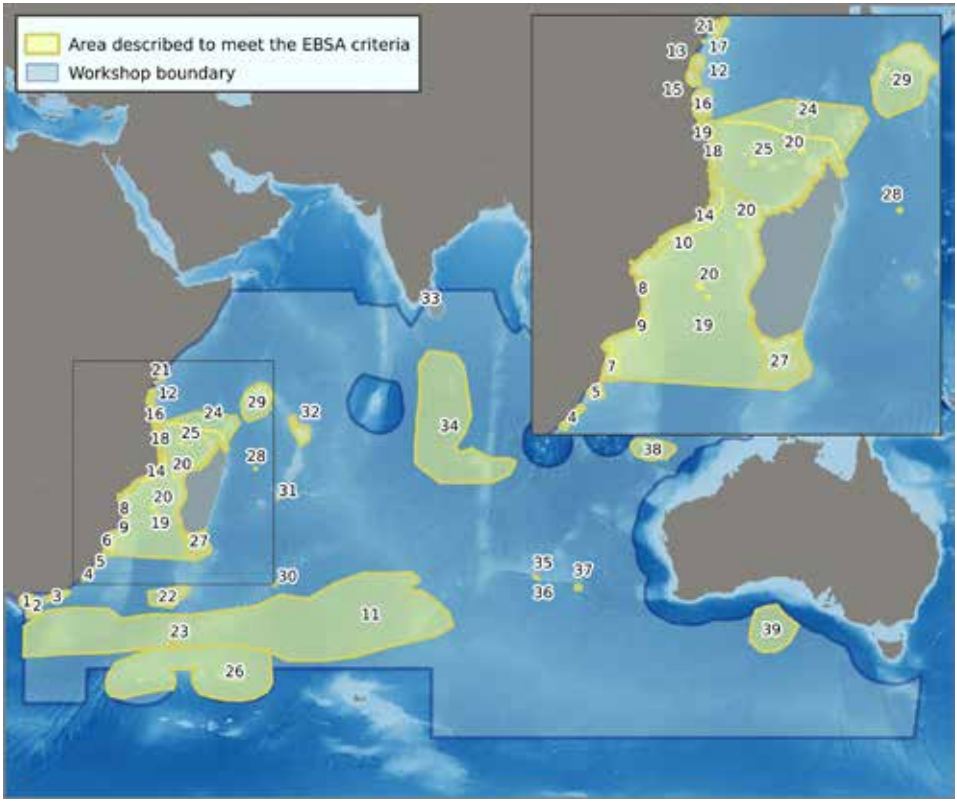
SOUTHERN INDIAN OCEAN

Were it not for the waters of the Southern Indian Ocean, it is possible that none of us would be here today, that the human story as we know it would never have unfolded, that ours might have been just another species consigned to nature's recycle bin. As it is, echoes of human history, and of its intersection with the ocean, reverberate through the ages: the caves on the tip of South Africa where our ancestors huddled, surviving off shellfish that allowed humanity to survive an ice age before spreading northward to conquer the world; the pearl fishery on the Sri Lankan coast that has existed for thousands of years and was praised by the Roman historian Pliny the Elder; the scattered tern bones that mark the final stand of shipwrecked slaves, abandoned to their fate in 1776 on a tiny island far east of Madagascar; the mountainous sea floor off western Australia, revealed in greater detail through tragedy, as the result of the search for a commercial airliner that disappeared in 2014.

This region encompasses the coastal areas of Sri Lanka; Madagascar and Mauritius; the Seychelles; the Comoros Islands, much of Somalia; southern and eastern South Africa, Mozambique, Tanzania and Kenya: all of them

rich in human experience. But it also covers great swathes of ocean, as far south as the fringes of the Antarctic, where humans have never dwelt and surely never will. It includes surface waters where an annual “sardine run” attracts thousands of visitors, and the cold, dark lairs of the mysterious coelacanth, a species whose existence was unknown to science before 1938. It features seagrass beds that nurture dugongs, and reefs that attract huge aggregations of sharks. Seabirds fly thousands of kilometres to feed in the middle of the ocean, taking advantage of seasonal phytoplankton blooms; elsewhere, the lifetime migrations of some fish may be no more extensive than from seagrass beds to adjacent coral reefs.

There are 39 areas described as meeting the EBSA criteria in this region, featuring habitats as distinct as mangroves and seamounts, from subtropical islands to the abyssal plain, a rich and varied tapestry.



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The eddy and the plankton. Photo © NASA Earth Observatory.

AGULHAS BANK NURSERY AREA

This area, located within the approximately 800 km long Agulhas Bank along the southern tip of Africa, includes both benthic and pelagic features, ranging in depth from 30 to 250 m below the ocean surface. Key benthic features include critically endangered mud habitats, deep reefs and rare gravels. This area is the centre of abundance of numerous warm temperate species, some of which are threatened or overexploited; the deep reef habitats are considered important for the recovery of overexploited deep reef fish species.

Black musselcracker. Photo © Dennis King.

The waters and coastline in this area have been, in the literal sense of the word, vital to the history of our species. In the words of one archaeologist, it was here that the sea "saved humanity."[1]

Between 195,000 and 123,000 years ago, the planet was locked in a deep ice age. Much of Africa was arid and cool, rendering it unsuitable for the plants and animals on which the continent's population of human beings mostly relied. The human population plummeted, to the extent that it is possible that everyone who is alive today is a descendant of just one group that was able to survive the climate crisis by eking out a living on Africa's southern tip – where, archaeological evidence suggests, as far back as far back as 164,000 years ago, they were foraging for protein from the coastal ocean in the form of sea snails and brown mussels.[2] Ultimately, the ice caps receded, sea levels rose, temperatures increased and the people of the continent's southern tip "eventually pushed out of their refuge, filled up the African continent and went on to conquer the world."[3]

One of the reasons for the region's high productivity is that the clash of the cold waters from the Benguela upwelling and the warm Agulhas Current created a mix of warm and cold eddies along the coast, nurturing diverse and dense beds of shellfish.[4] That is as true now as it was 164,000 years ago, even as the ice has receded and the water has risen to cover many of the areas that our common ancestors would have patrolled in search

Dageraad. Photo © Dennis King.

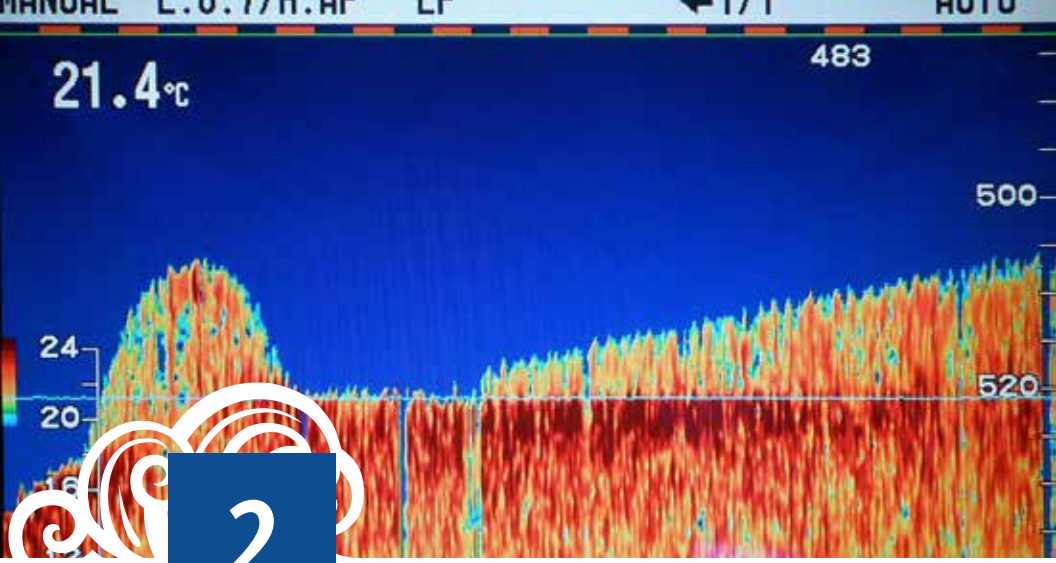
Red steenbras. Photo © Peter Southwood.

of seafood. Today, the seabed under the zone of convergence between the Atlantic and Indian oceans is known as the Agulhas Bank; it wraps around the southern coast of Africa for approximately 800 km, at depths of between 35 and 200 m below the surface until, on its southern edge, it drops deeply to more than 1,000 m.[5]

Within the bank are a number of habitat types, composed of sands, muds, gravels and deep reefs, including some that are either rare or threatened, or both.[6] Some of these habitats are of vital importance to fish species that are themselves endangered or threatened, particularly linefish such as the endangered dageraad and vulnerable black musselcracker.[7]

The bank supports numerous commercial fisheries, particularly trawl, trap and longline fisheries, and is a vital nursery area for species that spawn on the narrow shelf further north, including shad and geelbeck. Squid also spawn in this area, and the paralarvae that hatch from the benthic eggs are dispersed across the bank, feeding on a dense layer of copepods that occur close to the seabed.[8]

Silver kob. Photo © Dennis King.



2

Coral mound. Image courtesy of Kerry Sink.

AGULHAS SLOPE AND SEAMOUNTS

The outer margin along the southern tip of the Agulhas Bank – on the edge of the continental shelf off southern Africa – is a diverse, productive and dynamic region. This is where the Agulhas and southern Benguela ecoregions meet, and where sporadic shelf-edge upwelling enhances productivity throughout the area. Four pelagic habitat types and 10 benthic habitats occur in this area. Descending from depths of 200 m to 1,800 m, this area contains outer shelf, shelf edge, slope and seamount habitats, and is important for spawning of sardine, anchovy, horse mackerel and hake.

As the Agulhas Bank stretches away from the South African coastline, it slopes downward and then plunges, far below the surface to depths as great as 1,800 metres. Rising up through the cold, dark water are two seamounts, known as Shackleton and Mallory, after explorers of some repute; they comprise half of the Davie Seamount Cluster, and while they have not been well studied, it seems probable that they host a number of unique species.[9] Seamounts often have complex surfaces of terraces, pinnacles, ridges, crevices and craters, and their presence diverts and alters the currents that swirl about them; for these and other reasons, these undersea mountains frequently act as "biological hotspots", and studies have suggested that as many as one-third of the species found on and around seamounts could be endemic.[10]

Further up the slope, but still at depths beyond the reach of sunlight, surveys of the seafloor have found a number of soft corals, gorgonians, sea pens and ascidians, many of which are considered endemic to the bioregion.[11] The area's pelagic waters are considered important spawning grounds for sardines, horse mackerel and hake, as well as for anchovies, which spawn intensively in an area around the 200 m depth contour and then move inshore ahead of the warm Agulhas Current.[12] Eddies in the area, produced by the meeting of the Benguela upwelling and the Agulhas Current, help recirculate water inshore and link spawning habitat on the shelf edge with important nursery sites. Upwelling along the shelf edge creates areas of high productivity, making this an important foraging area for seabirds;[13] those upwellings are driven inshore by the Agulhas Current, ensuring cool, productive water is carried onto the shelf.[14]

Horse mackerel. Photo © Dennis King.

3

African penguins, St. Croix Island, Algoa Bay. Photo © Lorien Pichegru.

OFFSHORE OF PORT ELIZABETH

This area, from the South African coast of Port Elizabeth to the upper continental shelf, includes a wide array of habitats, such as submarine canyons, deep reefs, shelf-edge gravels and deep cold-water corals. It is a foraging and breeding area for a number of seabirds, including the endangered African penguin, and is also used by endangered leatherback turtles.

Although penguins are commonly associated with the southern polar realm, only two penguin species are exclusively Antarctic in nature, and only five in total live in the region. The other 12 are distributed throughout the Southern Hemisphere, as far south as New Zealand and as far north as the Galapagos; the very first penguins to be

seen and described by Europeans were on the coast of Africa. In 1497, a member of Vasco de Gama's expedition described "birds as big as ducks, but they cannot fly … ."[15]

Because of those purportedly donkey-like vocalizations, the penguins that live in what are now South Africa and Namibia were long referred to as jackass penguins; they are also sometimes called black-footed penguins but are today named after the continent on which they are the only surviving penguin species. African penguins breed primarily on offshore islands, one of which – St. Croix Island – lies in Algoa Bay, just off the town of Port Elizabeth. With approximately 8,000 breeding pairs, it is the second-largest breeding colony of the species, whose overall numbers are plummeting – by more than 60 per cent since 1980, or three generations.[16]

But there are multiple other aspects of this region that mark it as worthy of special consideration. It is an important area for the vulnerable Cape gannett, as well as for Damara terns, kelp gulls and Roseate terns and is used by critically endangered leatherback turtles,[17] and the number of endemic coastal fishes in southern Africa peaks in this region around Port Elizabeth.[18] Indo-Pacific humpback dolphins – a coastal species that does not appear to be abundant anywhere – are regularly seen in Algoa

Gannets, Bird Island (Algoa Bay). Photo © Pierre Pistorius.

Bay where they are typically found in the vicinity of rocky reefs within 400 m of the shore. Surveys conducted during the 1990s recorded some 470 animals here, yet concern has been expressed over the continued survival of the species in South Africa, particularly in Kwa-Zulu Natal waters further north.[19] [20] [21]

The area's boundaries contain no fewer than four pelagic and 16 benthic habitat types, ranging from a sandy inner shelf to a submarine canyon that slices through the seabed.[22] Nearshore, it is considered an area of crucial importance for eggs and larvae spawned upstream, en route to their arrival at the Agulhas Bank nursery area.[23] And far offshore, in the area's coldest depths, lie deep sea corals, growing slowly in the darkness.

Unlike the more familiar warm-water corals, deep sea corals cannot photo-synthesize, because sunlight does not reach far enough for them to do so. Instead, they feed on the detritus that falls slowly from the sea surface. In the cold, dark conditions, they grow slowly, and accordingly are highly vulnerable to damage from human activities.[24] Although specimens of two species have been found in this area, in-site surveys have not yet been conducted to assess the extent of the sensitivity of their habitat.[25]

4

Sardines. Photo © Dennis King.

PROTEA BANKS AND SARDINE ROUTE

Containing a unique deep-sea reef system known as the Protea Banks, this area – which extends outward from an area of coastline between the South African coastal towns of Port Edward and Pennington – constitutes a site of fish spawning aggregations and is home to an abundance of soft corals, algae and molluscs, many of which are endemic. It is perhaps most notable for being a key component of the migration path of several fish species, colloquially known as the “sardine run”. The area also contains four submarine canyons.

"The sky was white with gannets and filled with their manic chatter. Wings folded to their sides, they plummeted into the sea like feathered missiles, leaving green bubble trails in their wakes. They were hunting sardines, and the water boiled with fish. It was as if this patch of sea off the eastern coast of South Africa had been turned into a pot of bouillabaisse – and everyone was falling to the feast. Scores of circling dolphins harried the sardine shoal into an ever tightening mass. Panicked sardines threw themselves into the air and splashed back into the melee. A pale pink dorsal fin sliced through the midst. Then another. "Copper sharks!" said Mark Addison, our boat skipper. "Fantastic! Look – three, four, five of them." Tails lashing, they lunged and rolled in an orgy of feeding."

—Kennedy Warne, *National Geographic Magazine,* August 2002[26]

Every year, generally beginning between late May and mid-June, and continuing until late July or on occasion even into September, South African coastal waters from the eastern edge of the Agulhas Bank to the coast of KwaZulu-Natal host a natural phenomenon that has become "part of the cultural heritage of the South African nation."[27] A combination of environmental factors, including the presence of cooler coastal waters and the development of eddies and pulses, enable shoals of a genetically distinct subpopulation of sardine to travel north en masse on their annual reproductive migration; because the warm offshore Agulhas Current acts as a barrier for the sardines, which prefer colder water, this "sardine run" frequently occurs close to the coast, where it creates a feeding frenzy for predatory marine life and excited human spectators alike.[28] Cape gannets, African penguins, humpback and Bryde's whales, common and bottlenose dolphins, and Cape fur seals are among the most frequently sighted species to take advantage of the available smorgasbord, but researchers have counted a total of 23 species of seabird and marine mammal feasting on the temporary bounty.[29]

The sardine run is not the only natural feature to attract human visitors. The Protea Banks – a 6 km long, 800 m wide reef that lies at a depth of 27 to 40 m – is widely regarded as the "shark diving Mecca" of South Africa and one of the best shark diving sites in the world, because of a

preponderance of bull, scalloped hammerhead and tiger sharks, among other species.[30] In addition to being a spawning aggregation site for many fish species, Protea Bank appears to be unique in the region; although deep reefs are poorly studied and little known, no similar features have been found at the same depth range along the KwaZulu-Natal coast.[31] Certainly, the species it hosts include several that have not been identified elsewhere, including two species of red algae and an entirely new genus and species of electric ray, with one of the most elaborate and ornate colour patterns ever seen on rays of its kind.[32] [33]

Top: Gannets diving for a ball of schooling sardines. Photo © Lloyd Edwards.
Bottom: Protea Bank. Photo © Dennis King.

5

Aliwal Shoal. Photo © Dennis King.

NATAL BIGHT

In this area, located off the east coast of South Africa, cool water driven toward the shore by upwellings meets freshwater from the Thukela River, and the resultant turbid, nutrient-rich conditions create important breeding, nursery and feeding areas for crustaceans, demersal fish, migratory fish, turtles and sharks, including some threatened species. Potential vulnerable ecosystems include submarine canyons and cold-water corals.

The Thukela River rises as a stream more than 3,000 metres above sea level on the Mont-aux-Sources plateau, hurtles through a series of waterfalls for a drop of over 900 m and eventually, after a journey of some 500 km, slowly eases its way into the Indian Ocean, where it

Porcupine stingray, Cape Vidal. Photo © Mike Fraser.

deposits the sediments it has picked up along the way in a series of alluvial banks.[34] [35] The sediment provides habitat for benthic organisms, eggs and larvae, while the combination of a clockwise eddy that occurs within the Bight area, some upwelling, and enhanced phytoplankton levels in the northern extremity of the Bight, provide ideal conditions to enhance the survival chances of early larvae and juveniles.[36] [37] Additionally, the eddy and upwellings, as well as periodic northward intrusions by the Agulhas Current, help to keep larvae and juveniles in the area, and as a result the turbid, nutrient-rich waters of the Natal Bight are important for multiple life-history stages for a number of species.

Sand tiger shark, Aliwal Shoal. Photo © Dennis King.

The Bight is home to rare or endemic species, such as the spotted legskate, porcupine stingray and bearded goby;[38] a spawning and migration route for sardines; a nursery area for endangered scalloped hammerhead sharks and for slinger seabream and black musselcracker; a spawning area for bull sharks, sand tiger sharks and king mackerel; a feeding area for critically endangered leatherback turtles; and provides a migration corridor for geelbek, white stumpnose, shad, vulnerable dusky kob and Garrick.

6

Indo-Pacific bottlenose and Indian Ocean humpback dolphins. Photo © Sal Cerchio. Opposite: Dugong. Photo © Fergus Kennedy.

INCOMATI RIVER TO PONTA DO OURO (SOUTHERN MOZAMBIQUE)

This area includes much of Maputo Bay, on the coast of Mozambique. This shallow bay, with five river inlets, is diverse and harbours important habitats such as extensive mangroves and seagrass beds and the largest, southernmost coral reefs in sub-equatorial Africa. For such a relatively small area, it hosts extremely high biodiversity in various taxa. Maputo Bay is also the second-most important fishing ground in Mozambique, especially for shrimp. The area is home to more than 20 artisanal fish-landing areas that provide high catch rates.

Right whales were so called because, to early whalers, they were the "right" whales to shoot: they swam slowly and close to shore, and contained long baleen plates and large amounts of blubber, which

made them valuable targets that were easy to retrieve once they had been killed because they floated at the surface.[39] The North Atlantic species, the first to be targeted by commercial whalers, and the North Pacific species are today the rarest large whale species in the world.[40] By 1920, the entire Southern Hemisphere right whale population was estimated to have declined to 300 individuals, and although the 20th century saw recoveries in some of the putative pre-exploitation breeding stocks (including South Africa), many others showed little recovery or were presumed extirpated.[41] Among the stocks thought to have been eliminated was the stock believed to live in Mozambique waters; however, recent sightings – centred on an area just south of Maputo Bay – have led to suggestions that southern right whales have returned, at least seasonally, to the area.[42]

Despite the small size of this area – Maputo Bay measures 1,280 km^2 – right whales, if they do indeed spend time here, would be just one of perhaps half-a-dozen marine mammal species to be found here, including dugongs, bottlenose dolphins and a small population of Indo-Pacific humpback dolphins.[43] [44] Mangroves cover an area of about 138 km^2 around the bay, and seagrasses cover an area of about 38 km^2, mainly in the inlets surrounding Inhaca, a small island (42 km^2) located on the eastern side of the bay.[45] [46]

The waters around Inhaca in particular present a stunning display of marine diversity: about 26 classes of invertebrates, including 232 families and 965 species, some 490 fish species; and at least 160 species of reef-building coral, representing approximately one-third of the total number throughout the Indian Ocean, have been identified. Notably, the island's coastal waters provide habitat for four species of commercially important lobsters, the aforementioned dugongs, four species of sea turtles and two species of giant clams.[47]

Inhaca also provides permanent or transitory habitat for a profuse number of bird species. Almost 300 species have been recorded here, representing 33 per cent of all birds occurring in southern Africa.[48] The island's beaches and intertidal areas support thousands of shorebirds (e.g., waders and terns): as many as 8,500 individuals have been recorded during direct counts.[49] Vagrants (e.g., albatrosses and petrels) and migrants (e.g., whimbrel, sanderling) make up 60 per cent of the island's recorded avifauna, underscoring its importance for Palearctic migratory birds and rare visitors.[50]

7

Delgoa shelf edge and canyon. Photo © Peter Timm.

DELAGOA SHELF EDGE, CANYONS AND SLOPE

This area lies within the waters of South Africa and Mozambique. It extends south, north and offshore of the existing Maputaland and St. Lucia marine protected areas in the iSimangaliso Wetland Park, a World Heritage Site, and also encompasses the Ponta do Ouro Partial Marine Reserve, to capture the full extent of offshore benthic and pelagic habitat types, providing for coastal and offshore connectivity and covering the important offshore habitats of endangered leatherback turtles. Potential vulnerable marine ecosystems include numerous submarine canyons, palaeo-shorelines and deep reefs, and hard shelf edge with reef-building cold-water corals at depths of more than 900 m.

Bull shark. Photo © Mike Fraser.

On December 22, 1938, Captain Hendrik Goossen and the crew of the trawler *Nerine* put into the South African port of East London and unloaded its usual mixed haul of sharks, rattails, redfishes and others. In among the catch, however, was a peculiar specimen, about a metre and a half in length, which was unlike anything any of the trawlermen had seen before. The deckhands called it a "great sea lizard". It was a coelacanth, a fish that been believed extinct for 70 million years (see area 12 for photo .[51]

Over subsequent decades, more coelacanths were found, but all of them in the immediate vicinity of Grande Comore and Anjouan in the Comoros archipelago, so that as recently as 1991, a popular history of the species noted that "it is the consensus among ichthyologists" that this was their sole location and that the South African specimen found in 1938 was a "stray".[52] But since then, a second species has been identified in the waters of Indonesia, and coelacanths have been discovered in waters elsewhere in southeast Africa – including in 2000, in Sodwana Bay in the iSimangaliso Wetland Park. Taking advantage of the fact that each coelacanth has individual spot markings, scientists have developed a photographic database of South African coelacanths that, as of June 2013, had reached 32 individuals, eight of them in iSimingaliso Wetland Park.[53]

New species of coffin fish, Delagoa Bight. Photo © African Coelacanth Ecosystem Program.

King mackerel. Photo © Mike Fraser.

The deep-sea environment in this area is especially conducive to coelacanths, nocturnal benthic feeders that spend the daytime in caves several hundred metres deep. In this area, they are found primarily in a series of submarine canyons. Although they have not been well studied, it is believed that submarine canyons are frequently hot spots of biodiversity, perhaps because of the unusual oceanographic patterns that form within them, such as accelerated currents and dense-water cascades, which transport organic matter from coastal zones to the deepest parts of the ocean.[54] Indeed, one study has shown particularly high levels of richness of some sponge communities in the submarine canyons in this area, although such richness is not confined to the canyons, showing numerous spikes throughout the shelf slope.[55]

This area extends outward from existing protected areas within the iSimangaliso Wetland Park, ensuring protection for a wide range of benthic and pelagic habitats, providing connectivity between coastal and offshore environments, and covering offshore habitats of endangered leatherback turtles.

It also includes a key migratory route for humpback whales, a nursery area for bull sharks, spawning areas for fish (especially endemic sparids) and sharks and includes habitat of other threatened species, including marine mammals and sharks. Whale sharks feed in this area in summer.

8

Save River estuary. Photo © Jay Roode/Skyhawk Photography.
Opposite: Marlin. Photo © Peter Timm.

SAVE RIVER TO SAN SEBASTIAN (CENTRAL MOZAMBIQUE)

At the heart of this area is the Bazaruto Archipelago, which lies approximately 20 km off the Mozambique coast and is home to the most viable dugong population in East Africa. The archipelago boasts varied habitats such as sand dunes, rocky and sandy shores, coral reefs, seagrasses and mangrove forests; in addition to dugongs, the archipelago is home to megafauna such as turtles, dolphins and marlins. Whale sharks and manta rays occasionally visit the area.

On January 9, 1493, Christopher Columbus reported encountering three mermaids while sailing near the Dominican Republic in the Caribbean. They were, he recorded with disappointment, "not half as beautiful as have been painted."[56] Unsurprisingly so, because Columbus almost certainly saw manatees, which, along with dugongs, are commonly considered a source of the mermaid myth. Such confusion must surely have been a consequence of sailors spending too long at sea; a more typical modern description of a dugong, for example, is of an animal that "looks something like a cross between a rotund porpoise and a walrus."[57]

There are three extant species of manatees in the Atlantic and Caribbean, and one species of its close dugong relative, which historically occurred in almost all coastal areas from southern Mozambique in the west to Australia in the east, including many of the island States in the Indian and Pacific oceans.[58] [59] However, the dugong today is largely represented by relict populations, including in the African region of the Western Indian Ocean, where aggregations in Kenya, Tanzania, Madagascar and the Seychelles may comprise as few as three individuals.[60] By far the largest population in the entire Western Indian Ocean is in the waters of Mozambique's Bazaruto Archipelago.

Surveys have suggested that there are two core areas of dugong distribution in the area: one near the mouth of the Save River and the other aligned with shallow sandbanks off Santa Carolina Island in the Bazaruto Archipelago. Dugong densities in the area are substantially lower than in the Arabian Gulf or Australia, but the approximately 250 animals likely constitute the only viable population remaining in the Western Indian Ocean.[61]

Dugongs are the only truly herbivorous marine mammals in the world, and their distribution in this area appears closely correlated to the presence of seagrass meadows of the type particularly favoured by dugongs because they occur at the ideal depth (1-5 m), have high amounts of nutrients and are easy to digest because they contain low levels of fibre and phenols.[62] Many seagrass beds contain several species, and all are enormously productive, providing nutrients and shelter that support a rich marine fauna. A total of 153 invertebrate species have been identified in the seagrass meadows of the area, including six species of gastropods that are believed to be endemic to the Bazaruto Archipelago.[63]

Sting rays, Bazaruto Marine Reserve. Photo © Jay Roode/Skyhawk Photography.

The region also contains three types of reefs – submerged sandstone reefs, submerged fringing reefs and patch reefs – and although most coral species found here appear to be Indo-Pacific in distribution, a new soft coral species (*Cladiella kashmani*) was found in the Bazaruto Archipelago, which appears to be limited in its distribution to East Africa.[64] Some of the reefs provide spectacular diving opportunities, particularly the outer reef areas where larger fish are encountered, and the fringing reef tops, where an abundance of staghorn corals, a diversity of other corals, and colourful reef fish occur.[65] The reefs also break the energy of the wind and waves, increasing protection for the sand flats along the seaward edge of the islands.[66]

9

Whale shark. Photo © Quest Overseas/Marine Photobank.

MORRUMBENE TO ZAVORA BAY (SOUTHERN MOZAMBIQUE)

This area has abundant megafauna, notably the world's largest populations of reef manta ray, giant manta ray and whale shark. Centered around Inhambane Bay, about 400 km northeast of Maputo, the area also has dugongs and five species of sea turtles, as well as coral reefs, mangrove forests and extensive seagrass beds.

There are two recognized species of manta rays in the world, both of which are found in tropical and subtropical waters throughout the ocean, although both may occasionally venture into temperate waters as far north as North Carolina and as far south as New Zealand. The giant manta is likely migratory, traveling with ocean currents to areas where upwellings of nutrient-rich water increase prey concentrations; while the reef manta, though undertaking migrations on both a daily and

longer-term basis, tends to be more localized in nearshore waters.[67] [68] [69] Both species, however, are found in this area off southern Mozambique, in two principal areas: the appropriately named Manta Reef, with 250 m^2 of rocky reef, and Giants Castle, a narrow, reef plateau. [70] [71]

One of the factors that appears to attract the rays is the presence of what are known as "cleaning stations" on the reefs: areas where "cleaner" fish remove parasites, mucus and dead and diseased tissue and scales from rays and sharks.[72] But this is not the only phenomenon at play. The principal reason why this area also boasts a high concentration of whale sharks is likely the presence of an abundant food source.[73]

Reaching up 20 m in length, whale sharks are filter feeders, and like other large planktivorous animals, such as baleen whales, they tend to aggregate on a seasonal basis, to take advantage of seasonally abundant, high-density patches of zooplankton.[9] In the tropics and subtropics, these usually revolve around fish or crab spawning driven by oceanographic and climatic processes.[75] This area is unique, however, in that whale sharks are present in relatively large numbers – approximately 700 animals, with a mean monthly density of roughly 30 sharks per 100 km^2 – year-round. The cause appears to be a unique confluence of several different local upwellings that bring cool, nutrient-rich water to the surface and promote the growth and distribution of phytoplankton on which these filter feeders subsist, creating an almost constant buffet that sustains one of the largest single aggregations of the largest species of fish in the world.[76]

Manta ray. Photo © David Obura.

10

Mangroves of the Zambezi River Delta, dominated by Sonneratia alba.
Photo © Salomao Bandeira.

QUELIMANE TO ZUNI RIVER (ZAMBEZI RIVER DELTA)

This area stretches along some 200 km of the mangrove-lined coastline of the Zambezi River delta of Mozambique (between the Bons Sinais River at the city of Quelimane and the Zuni River) and extends out into the Mozambique Channel to include a large section of the wide, shallow shelf known as the Sofala Bank.
The area is characterized by its remarkable productivity, largely fueled by nutrient input from the Zambezi River and the most extensive mangrove system on Africa's east coast.

Africa contains approximately 20 per cent of the world's mangrove forests, and within Africa, the second-largest mangrove system – and the largest on the east side of the continent – is located in this part of Mozambique.[77] Globally, Mozambique ranks 13th in total mangrove coverage, containing approximately 2.3 per cent of all mangroves on Earth;[78] and the Zambezi River delta, which stretches almost 200 km along the coast and as far as 50 km inland, accounts for roughly 30 per cent of that total.[79] [80]

The physical complexity of mangrove forests provides a wide diversity of ecological niches suitable for breeding, spawning and hatching of many estuarine and marine species. Particularly important in this region is the critical nursery habitat provided by mangroves for the fish and shrimp that, upon maturity, head out to the adjacent shallow shelf and rich fishing grounds known as the Sofala Bank.[81]

More than 340 fish species, primarily demersal, have been recorded from the Zambezi River delta and Sofala Bank;[82] the region's productivity attracts a range of migratory wildlife, such as sea turtles – in particular green and loggerhead, but also olive ridley, hawksbill and leatherback – and wintering humpback whales.[83] [84] The region also supports vast

Quelimane fish farms. Photo © Jay Roode/Skyhawk Photography.

Zambezi River estuary. Photo © Jay Roode/Skyhawk Photography.

numbers of shallow-water shrimp, notably commercial prawns (Indian, giant tiger, western king, green tiger) and shrimp (speckled and Karuma).[85]

Sofala Bank is one of Mozambique's most productive shelf regions and is the country's largest fishing ground,[86] [87] supporting numerous small-scale and industrial fisheries.[88] Of particular value are the region's shrimp fisheries, which provide an important source of export income,[89] though like much in this area they are ultimately dependent upon the nutrient-rich waters of the Zambezi River and the nurturing shelter of the mangroves ringing the coast.

11

Wandering albatross. Photo © Phil Whittington.

AGULHAS FRONT

The Agulhas Front is the eastward extension of the Agulhas Current, which connects water from south-western Africa to the subtropical and sub-Antarctic waters as far east as the French overseas territories of Amsterdam and Saint-Paul islands. A region of high productivity, the area supports a large number of species, including a high diversity of seabird species, pinnipeds, extensive areas of southern bluefin tuna and, historically, large numbers of southern right whales.

Totalling a mere 55 km^2 in area, Amsterdam Island is a subantarctic volcanic island sitting in the Southern Indian Ocean alongside its tiny, seven km^2 neighbour Saint-Paul Island, some 80 km to the south. Located approximately at mid-distance between the tips of South Africa and Australia, the islands are more than 3,000 km away from the nearest continent. Amsterdam Island is home to the endemic and critically endangered Amsterdam albatross, the global population of which consists of an estimated 170 individuals, including about 100 mature birds, which breed biennially on the island's central plateau and feed in the vast waters of this region.[90]

A small relict population of another seabird endemic to the islands, the little-known Macgillivray's prion, apparently only survives on an islet just offshore of Saint-Paul.[91] Large numbers of the endangered northern rockhopper penguin can be found breeding on both Amsterdam and Saint-Paul – around 25,000 pairs at the former and 9,000 at the latter – though are much reduced from past decades on Amsterdam.[92] [93] Also found breeding here are the flesh-footed shearwater, Indian yellow-nosed albatross and soft-plumaged petrel, among various others.[94] [95]

Along with the Amsterdam albatross, the Agulhas Front region is also a "globally significant feeding area" for the endangered Barau's petrel, endangered Indian yellow-nosed albatross, endangered sooty albatross, and the vulnerable wandering albatross. Antarctic terns, white-chinned petrels, white-bellied storm-petrels and both northern and southern giant petrels also forage here, and as tracking studies continue it is likely that the importance of the region for other seabirds will be revealed.[96] [97] [98] [99] The attraction to seabirds is courtesy of the Agulhas Front, formed by warm water that extends east from the Agulhas Current, generally shadowing and occasionally diverging from the Subtropical Convergence, spinning off eddies and intensifying the clash between warmer waters to the north and cooler seas to the south, creating a highly productive mix and a layer of water that is high in chlorophyll.[100] As a consequence, the area is visited by large numbers of seabirds that travel here from colonies in sub-Antarctic, tropical and temperate areas, both within and beyond the Indian Ocean.

Northern rockhopper penguin. Photo © Rémi Bigonneau.

A variety of other species make use of this region as well: the critically endangered southern bluefin tuna;[101] foraging southern elephant seals;[102] and southern right whales, which are gradually re-occupying areas they historically used before being greatly reduced by commercial whaling in the 19th century.[103] About 50,000 sub-Antarctic fur seals breed on Amsterdam Island, whence they undergo foraging trips extending as far as some 1,800 km from the colony.[104]

12

Coelacanth. Photo © Peter Timm.

TANGA COELACANTH MARINE PARK

Tanga Coelacanth Marine Park covers an area of 552 km^2, of which 80 km^2 are terrestrial. It covers the northern and southern boundaries of the Zambezi River delta down to the coastal shelf of the Sofala Bank. About 13 submerged and tidal reef formations, including stretches of intertidal fringing reef, are also located within the park. The principal reason for the park being established as a marine protected area is the high number of coelacanths recorded in this area in recent years. Scientific research and the use of remotely operated videos in the area have shown coelacanths living in caves at depths between 150 and 200 metres.

The extent of mangrove forest cover in this area is the third largest in Tanzania. The Tanga region features 407 km of coastline, along which are found a total of 376 km of reef edge: fringing reefs occur along the coast, shallow patch reefs are found in the inshore waters, and offshore there are deeper reefs near the drop-offs, containing a total of 47 coral genera. There are three species of marine turtles, occasional sightings of dugongs and 380 recorded marine fish species.

However, it is the presence of one fish species in particular that has prompted the establishment of this park: the coelacanth.

The first recorded catch in Tanzania of coelacanth, one of the world's rarest and most enigmatic deep-water fishes, occurred in September 2003; word of the catch spread rapidly through scientific circles and just two days later it was announced to the World Parks Congress by noted oceanographer and explorer Dr Sylvia Earle.

By September 2005, 25 coelacanths had been caught in Tanzania, 19 in a six-month period: the greatest number of coelacanths caught in the shortest time anywhere in the world. The vast majority of fish were caught off the Tanga-Kigombe coast. The catches have continued since then, along the Tanzanian coast, with the total now reaching 52; as of January 2011, 37 of those catches were within the boundaries of the park.

The sudden increase in coelacanth catches was the result of diminishing fisheries yields, resulting in shark nets being set in deeper and deeper water, until they encroached on the coelacanths' deep sea realm. The catches have also led to increased attention being paid to the coelacanth population in the region, which has led to a number of unexpected discoveries.

It is possible, for example, that at least some coelacanths off the Tanga-Kigombe coast may live at shallower depths than their relatives elsewhere. Coelacanths are known to spend most of their time below 200 m, with larger individuals venturing below 400 m and as deep as 698 m.

Genomic studies suggest that the Tanzanian population is genetically distinct from those off South Africa or Comoros – and is, in fact, the most distinct of all three populations. Despite the fact that the coelacanths of

Tanga-Kigombe and those of Comoros are a mere 1,000 km apart, they may as well be in parallel universes, as the nature of ocean currents in the region is such that it effectively keeps the populations separate. Those currents likely caused the Tanzanian population to diverge from the South African and Comoros populations some 200,000 years ago, since when they have largely existed in isolation from the others, presumably unseen by the humans that slowly populated the coasts over subsequent millennia, until that September day in 2003.

Coral, Tanga, Tanzania. Photo © Matthew Richmond.

13

Spinner dolphin. Photo © Sal Cerchio.

PEMBA-SHIMONI-KISITE

Pemba-Kisite-Mpunguti is a transboundary area located at the border of Tanzania and Kenya. The Pemba Channel has a high fish diversity comprising pelagics, turtles, dolphins, dugongs and occasional whales. The Kisite-Mpunguti area, located in the Shimoni area on the southern coast of Kenya, incorporates the Kisite Marine Park, the largest no-take area in Kenya (28 km²), and the adjacent Mpunguti Marine Reserve, Kenya's smallest reserve (11 km²). The area covers shallow waters and supports a high diversity of marine life, including corals, reef fish and sea turtles, and plays an essential role in the life cycle of the coconut crab.

Straddling the boundary between Kenya and Tanzania, this area comprises Kisite-Mpunguti, a marine area consisting of four islands surrounded by coral reefs that lies off the south coast of Kenya; and Pemba Island off Tanzania, which is an oceanic island surrounded on all sides by deep water reaching a maximum depth of 1,092 m. In these deeper waters are seamounts, which form part of a ridge perpendicular to the current, creating massive upwellings and prolific fisheries biomass.

The shallow waters of Kisite-Mpunguti boast a diverse assemblage of habitats, including coral reefs, seagrass meadows and mangrove forests. Kisite is recognized as an Important Bird and Biodiversity Area (IBA) for migratory seabirds, and particularly for a globally significant breeding population of approximately 1,000 pairs of roseate terns.[105] Lower Mpunguti Island is the westernmost redoubt of the coconut crab; although a terrestrial island species during most of its life cycle, coconut crabs are born at sea, undergoing a planktonic stage for three to four weeks and an additional three to eight weeks occupying empty gastropod shells on the sea floor, before migrating on to land..[106]

Pemba Island contains the only oceanic reefs in the Eastern African Marine Eco-region (EAME), with high diversity and coral communities ranging from those in shallow waters down to reefs extending as deep as 64 m, and possibly the deepest seagrass beds for this ecoregion as well. Pemba Island is thought to be a unique example of a diverse, deep-water coral

Roseate terns. Photo © GVI Kenya.

Moray eel. Photo © David Obura.

Coconut crab. Photo © GVI Kenya.

community on a granitic island with spectacular underwater scenery that has been considered for World Heritage listing. The 1,100 km of reefs around the island represent 50 per cent of the coral reefs in Tanzania and support a high diversity of coral genera, fish and more than 40 species of sponges.[107] There are 12,000 ha of mangrove forests on Pemba (out of a total of 20,000 throughout the Zanzibar Archipelago), comprising 10 of the 11 species found in Tanzania.[108]

The diversity of environments found here is reflected in its diversity of fish species. The North Pemba Channel, with its steep drop and associated upwelling, supports considerable concentrations of sailfish, black marlin and tuna. The Pemba Banks, together with the North Kenya Banks and waters around Latham Island, are host to globally important congregations of black marlin.[109] Of the five species of marine turtles in the Western Indian Ocean, four – green, hawksbill, leatherback and loggerhead – have been recorded on Pemba; and the island is considered a significant nesting area on account of its numbers of nesting green and hawksbill.[110] The area is also considered regionally important for dolphins, with Indo-Pacific bottlenose, Indo-Pacific humpback and spinner dolphins being the most frequently encountered in Zanzibar coastal waters.[111]

There are significant numbers of whales in the inshore waters on the west side of Fundo Island, while humpback whales and sperm whales are regularly sighted in the Pemba Channel.[112] The area is also home to one of two population "hotspots" of dugongs in the region.[113]

14

Aerial view of Baixo do Pinda. Photo © Nuarro Lodge.

BAIXO PINDA – PEBANE (PRIMEIRAS AND SEGUNDAS ISLANDS)

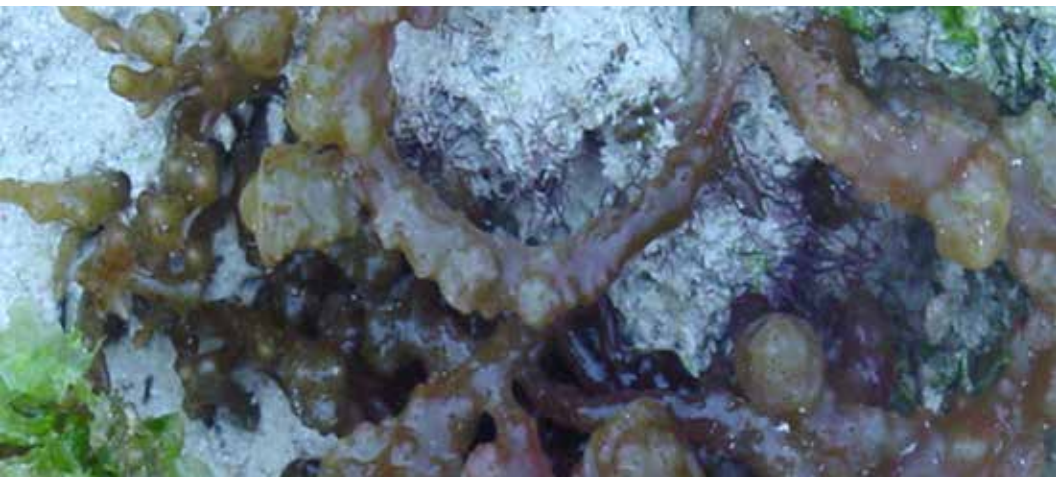
Located at the northern boundary of the Sofala Bank, this area has two strings of islands running from the south (the Primeiras) to the north (the Segundos) that boast among the most pristine coral reefs in Mozambique. It also covers the bank of São Lázaro, which is probably the third most productive area in Mozambican fisheries. Baixo Pinda is the best representative of a unique coastal region in Mozambique, with complex lagoons and intertidal areas.

Encountered by Europeans for the first time on 5 February 1498, during Vasco da Gama's first voyage toward India, the Primeiras and Segundas Archipelago consists of 10 corraline islands, fringed by reefs that have repeatedly been described by researchers in ways that, by scientific standards, border on the breathless. A 2007 report described them as "the best reefs in Mozambique, not only in terms of diversity, but also their conservation status,"[114] while another study that same year described them as "remarkable."[115] Scientists have identified 43 genera of stony coral and 15 genera of soft coral around the islands with the coral coverage in places as high as 71 per cent, supporting as many as 194 fish species from 42 families.[116] [117]

The islands are nesting sites for loggerhead, green and hawksbill turtles – and indeed, have been identified as an area of high nesting concentrations for green turtles since 1971.[118] Concerns over the possible impact of turtle and egg poaching has resulted in the establishment of a partnership between local communities, with the support of WWF, which includes the funding of rangers to protect nests and promoting conservation awareness among fishers and other local people.[119] This initiative had proven so successful that, by 2007, according to WWF, "compared to the 1990s, the number of marine turtles in the region of Primeiras and Segundas has registered an increase of about 85 per cent."[120]

One net result of these efforts has been the establishment by the Government of Mozambique of a marine reserve around the islands, offering protection not only to turtles but also to the coral cover as well as the extensive seagrass beds and mangrove forests[121] along the coasts and the deep underwater canyons[122] on the seabed. Covering more than 10,000 km^2, it is the largest marine protected area in Africa.[123]

Red algae, Kapaphyccus alkveresii, *endemic to this area. Photo © S. Bandeira.*



15

Furry pin cushion, Zanzibar. Photo © Matthew Richmond.

ZANZIBAR (UNGUJA) – SAADANI

Unguja is a limestone island on the continental shelf off the northern coast of Tanzania. It is the largest island in the Zanzibar archipelago. Coral reefs, mangroves and seagrasses are notable along the coast, and the waters are home to sharks, dolphins and sea turtles, among other species.

Nestled on the eastern coast of Unguja, Chwaka Bay is a hotspot of seagrass diversity. Eleven species are found in the embayment – almost all of the 14 species known to occur in the Western Indian Ocean region – distributed in an "extraordinarily complex" manner and supporting "highly diverse" communities of fish.[124] The diversity of that fish life is enhanced because the embayment is a seagrass-mangrove-coral reef continuum, in which species may migrate between the different, adjacent systems on a daily basis or from life stage to life stage: adult

Anthias and coral. Photo © Matthew Richmond.

Mangrove, Zanzibar. Photo © Matthew Richmond.

fish live on the coral reefs, where they reproduce; after hatching, larval fish may be transported over long distances by ocean currents, after which they settle in seagrass beds and/or mangrove forests, where they spend their juvenile life stage, during which time they may interchange and migrate between the two; and finally, as they approach maturity, sub-adults migrate back to the coral reefs, and the cycle begins again.[125]

Along with Chwaka Bay are similar stretches of seagrasses, mangroves and reefs around Unguja, and in locales such as Mbegani Bay on the mainland side of this area.[126]

The waters surrounding Unguja, including the Zanzibar Channel, which separates it from the mainland, are home to several dolphin species, including Indo-Pacific bottlenose, spinner, Risso's, the near-threatened Indo-Pacific humpback, rough-toothed, pantropical spotted, and common bottlenose. Recent genetic analysis suggests that humpback dolphins along the coast of east Africa may belong to genetically distinct populations: Tanzanian dolphins, for example, are apparently genetically isolated from those further south in Mozambique and further north in Oman.[127]

The waters around Unguja have recently been documented as part of a larger wintering ground for humpback whales in East Africa[128] and may still harbour some dugongs, although none have been reported for several years.[129] Small numbers of green and hawksbill turtles nest in the region, and immature turtles from both species concentrate on the east of the island.[130]

16

Green turtle at Mafia Island Marine Park. Photo © David von Helldorff.

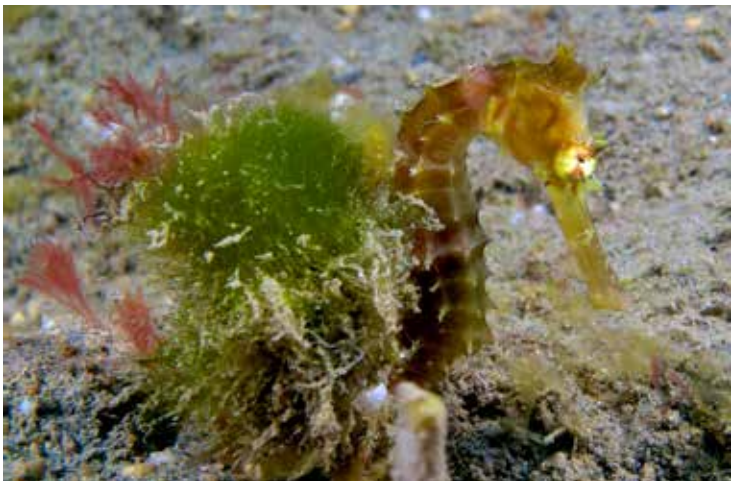
RUFIJI-MAFIA-KILWA

South and east of the Rufiji River delta on the Tanzanian coast, where the continental shelf widens, the shallow waters of the Mafia and Songo Songo archipelagos support luxurious coral reefs. A fringing outer reef runs down the eastern side of both archipelagos to meet the mainland south of Kilwa Masoko, and from there it continues south to the Mozambique border – broken in places by deep water channels, river outlets and bays. This area contains a variety of endangered marine species, such as dugongs and sea turtles, and the largest continuous mangrove area in East Africa.

Formed by the confluence of the Kilombero and Luwego rivers, the Rufiji River splits before reaching the coast and forms the Rufiji Delta. The total delta area is about 72,000 hectares, of which approximately 54,000 hectares are mangroves, forming the largest continuous mangrove area in eastern Africa. Offshore, but separated from the mainland by water that is never more than 50 m deep, sits Mafia Island. On the southeastern portion of the island lies Mafia Island Marine Park, much of which is fringed by mangroves. The park also includes a large, shallow and sheltered bay (Chole Bay) and a complex mosaic of seagrass beds and coral reefs.

South of Mafia Island is Songo Songo Island, at 4.5 km the largest in the Songo Songo Archipelago, which is a conglomeration of islands and atolls, 50 km long and 30 km wide, comprising an extensive coastal reef and numerous smaller patch reefs.

Extensive seagrass beds off the southern Rufiji Delta are reported by local residents to be important feeding grounds for green turtles. On Mafia Island, immature and adult green and hawksbill turtles are seen regularly by recreational divers in Chole Bay and along the east coast of Juani Island where seagrass and corals occur. Off Ras Kisimani on the west coast of Mafia, green turtles have been observed digging pits in the sand at a depth of 10-15 m, where they appear to rest.[131] These seagrass beds and sheltered bays also appear to be the most important dugong area



Juvenile thorny seahorse. Photo © Nic Hobgood.

in Tanzania, although it is likely that few animals remain.[132] The delta is also used by globally significant numbers of coastal waterbirds: curlew sandpiper, crab plover, Terek sandpiper, greater and lesser sandplovers, common gull-billed tern, lesser crested tern and Saunder's tern.[133]

There are five species of seahorses occurring along the east African coast, all of which are found in Tanzania. Two of these, the Réunion seahorse and the thorny seahorse, are particularly abundant in the Mafia Island area.[134] There is also a high diversity of reef fishes in Mafia Island Marine Park: Three hundred and ninety-four species belonging to 56 families have been documented in the 822 square kilometre park, with others likely yet to follow. More than 30 coral genera are frequently sighted.[135]

The waters of Mafia island are also an aggregation site for whale sharks – a species long assumed to aggregate solely on a seasonal basis while spending most of their time dispersed in unknown locales. However, acoustic monitoring around Mafia has revealed that the sharks are, in fact, present year-round and simply spend much of the year farther offshore and swimming deeper, presumably in pursuit of prey. It remains to be determined whether this is exceptional, or in fact typical of apparently seasonal whale shark aggregations elsewhere.[136]

Ray fish at Mafia Island Marine Park. Photo © David von Helldorff.

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Indo-Pacific bottlenose dolphins. Photo © Sal Cerchio.

WATAMU AREA

Watamu is located on the north coast of Kenya near Malindi town, about 100 km north-east of the city of Mombasa. The area includes the Watamu/Malindi Marine Parks and Reserve (WMMPR), itself divided into two marine parks: Malindi in the north, and Watamu in the south. This amounts to approximately 30 km of coastline, with a fringing reef along its entirety, as well as numerous patch reefs. The fringing reef forms several lagoons, some of which are rich in coral and fish species. The parks and reserves provide an important residing and feeding habitat for sea turtles, while the 5 km beach within Watamu Marine Park is a key turtle nesting ground.

Brown noddy. Photo © Sal Cerchio.

This area comprises a complex of marine and tidal habitats on Kenya's north coast, stretching from just south of Malindi town southwards to beyond the entrance to Mida Creek. Habitats include inter-tidal rock, sand and mud; fringing reefs and coral gardens; seagrass beds; coral cliffs, platforms and islets; sandy beaches; and mangrove forests. Whale Island and the coastline to the north and south of Mida Creek support significant feeding, roosting and nesting populations of terns. Roseate terns nest on Whale Island between June and October every two to three years, with counts reaching 1,500 pairs,[137] but of particular interest is the sudden increase in the brown noddy population.

Until 2006 one or two pairs of brown noddy were found on the island during the roseate breeding season, and it is possible that they attempted to breed while there; the following year, however, numbers leaped to 1,000, remaining at similar numbers for several more years until, in 2011, the African Bird Club reported that more than 3,000 had been spotted in May of that year.[138] [139]

Giant grouper. Photo © IRD–Serge Andrefouët.

Diversity and biomass are high throughout the area: one study reported 291 species of molluscs in the Mida Creek area,[140] while 385 species of fish have been documented so far in Watamu National Park. One study documented 55 fish species from 22 families in the low tide rocky intertidal zone alone, which the authors considered to be of "high richness" at the family level when compared to other intertidal areas in the Indian Ocean.[141]

Sea turtles are widely distributed, particularly greens, hawksbills, olive ridleys and leatherbacks;[142] all are closely associated with seagrasses and coral reefs, which they use as foraging grounds, and greens, hawksbills and olive ridleys are also reported to nest in the Watamu area. The area provides foraging grounds for several species of cetaceans, including humpback and bottlenose dolphins, and for whale sharks and giant groupers. The northern part towards the Malindi area is a muddy high-nutrient bay with sudden drop-off, providing a nursery for sharks and globally important feeding area for sailfish, marlin and swordfish.

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Quirimbas Archipelago. Photo © Jay Roode/Skyhawk Photography.

PEMBA BAY – MTWARA (PART OF THE MOZAMBIQUE CHANNEL)

The Quirimbas Archipelago is a string of coastal islands extending from Pemba Bay in northern Mozambique, 400 km to the Ruvuma estuary and the Mtwara-Mnazi Bay reef system in southern Tanzania. The archipelago, which comprises 28 islands and the offshore Lazarus Bank, has the highest diversity of corals recorded in the Western Indian Ocean (along with northern Mozambique), with almost 300

Plating and bubble corals, Pemba Bay. Photo © David Obura.

species in 60 genera. The Quirimbas National Park protects a portion of the south-central part of the archipelago and mainland, including approximately 6,000 km^2 of mainland and 1,500 km^2 of marine and island habitats.

The rich human history of this region extends back beyond the 10th century, when the islands of the Quirimbas Archipelago were known as the Lazurus Islands and were the site of fishing settlements and Arab trading posts. At the northern end of this region, the East Africa Coastal Current flows north throughout the year, forming a one-way conveyor for marine larvae dispersed northwards to Tanzania and Kenya. At the southern end of this region, upwelling and the Zambezi delta system influence marine habitats, and past the constriction in the Mozambique Channel at 17°S, flow is predominantly southwards. Between these two points, clockwise and anticlockwise eddies may push water in any direction, and

Seagrass, Mnazi Bay. Photo © Matthew Richmond.

the consistent marine climate results in the highest diversity in coral reef species west of the Andaman islands in the Indian Ocean.[143]

In total, scientists have identified almost 300 species of corals, from 60 genera, in the region;[144] at Vamizi Island alone, in the north of the archipelago, researchers documented 146 species from 46 genera and 14 families, as well as an associated community of 400 species of reef fish.[145] The richness of the waters around Vamizi was underlined by scientists' description of one site that they were able to examine only superficially, because of the presence of strong and unpredictable currents.

Here there were large aggregations of 100+ gray reef sharks (*Carcharhinus amblyrhyncos*) and many species of grouper, snapper and emporer (angelfish). Snappers and emporers were present in large schools too abundant to attempt to estimate numbers. Trevallies were seen in abundance, together with individuals of other top predators such as dogtooth tuna (*Gymnosarda unicolor*). The large aggregations of piscivores attract significant attention for diving purposes, albeit for experienced divers only, and have been the cause of two newspaper articles by a well-known diving journalist and writer claiming it to be "one of the healthiest underwater landscapes I have ever seen."[146] The area includes more than the coral islands of the Quirimbas Archipelago. Mnazi Bay is enclosed by sandy shores to the west and the Ruvula-Msimbati spit and string of rock islands

Blue trevally, Mnazi Bay. Photo © Matthew Richmond.

and reefs to the east. The underwater topography is characterized by a series of deep, east-west running channels, beginning at depths greater than 1000 m, cutting between the islands before petering out in sand flats or seagrass beds to the west of the main line of islands.[147] Rising from the seafloor about 70 nautical miles east of the northern Mozambique coast, the Lazurus Bank is a shallow seamount overgrown with corals on its surface and with a steep topography that drops abruptly from between six and 60 metres below the surface to more than 2,000 m deep. It is hit in the north by the powerful Mozambique current, creating eddies and a circulation system that may contribute to the retention of pelagic eggs and larvae on the platform. Its "unique physical and biological characteristics" make it "a very peculiar place on Earth, a biodiversity hotspot, and a paradise for both the organisms living there and those having the possibility to study them."[148]

Three species of marine turtles — olive ridley, green and hawksbill — feed and nest in the region. The green turtles of Vamizi Island are the most important nesting population in Mozambique, and the density of hawksbill nests on the island is the highest known in the country.[149] Dugong are known to reside in the Quirimbas National Park area, but are scarce and their actual numbers are unknown. Dolphins, whales (namely the humpback whale), sharks, including bull sharks, white tip sharks, whale sharks and large populations of manta rays are known to frequent the islands.[150]

Sooty tern. Photo © Sal Cerchio.

19 MOZAMBIQUE CHANNEL

The Mozambique Channel is considered one of the most turbulent areas of ocean in the world. Its particular geographic shape and location lead to a complex system of mesoscale eddies that interact with each other and with the continental shelf to create a dynamic and highly productive system.[151] Because water flows in all directions as a result of the eddies, genetic connectivity throughout the Mozambique Channel is likely very high, resulting in high retention and recruitment of larvae in pelagic and shallow marine ecosystems; the eddies' rotation also causes down- and up-welling of water, transferring nutrients across through the water column.[152]

The Mozambique Channel is bordered by the coast of Mozambique in the west and Madagascar to the east. It is limited by the Comoros archipelago to the north and is connected to the greater Agulhas Current system to the south. This description is delineated by a line from Mtwara in southern Tanzania to the north-eastern corner of Madagascar, southwards to the south-eastern tip of Madagascar and St Lucia Lighthouse in South Africa.

The tropical seabird community in the channel has been described as "exceptionally abundant and diversified", while the southern part of the channel in particular is also an important overwintering area for many sub-Antarctic seabird species, including endangered albatrosses and petrels.[153] In total, more than 3 million pairs of seabirds from 16 species are estimated to breed on the islands of the channel;[154] the dominant seabird species in the region is the sooty tern, with other frequently observed species including the red-footed booby, the great frigatebird and the flesh-footed shearwater.[155]

The area is also an important migratory path for tunas and swordfish, and contains the highest diversity of fish species in the Western Indian Ocean. It is a notable nesting site for green and hawksbill turtles and foraging ground for olive ridleys, loggerheads and leatherbacks. An important nursing zone for humpback whales,[156] it contains a superlative reef shark site between Vamizi and Metundo islands.[157]

Flesh-footed shearwater. Photo © Ross Wanless.

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Aerial view, Iles Éparses. Photo © IRD–Pascale Chabanet.

THE ILES ÉPARSES (PART OF THE MOZAMBIQUE CHANNEL)

Four of the five "Scattered islands" — Europa, Bassas da india, Juan de Nova and Glorieuses — stretch down the length of the Mozambique Channel, between the east coast of Africa and Madagascar. (The fifth, Tromelin, is on the other side of Madagascar, and is not addressed here). These islands are remote and largely still intact; they have no permanent human habitation, experience little human disturbance, and have been protected since 1972.

When attempting to assess the state of an ecosystem — be it marine or otherwise — scientists must first establish a baseline against which the present status may adequately be judged. But that baseline may itself be compromised because, by the time observations are recorded, the area may already have been substantially affected by human activity. It is extremely rare in the 21st century to find an area that presents something close to a pristine environment that can be used as a "measuring stick" for similar systems, but that is what exists in the Iles Éparses.

It has been argued that the islands that make up this area prove that "isolated coralline formations, even of small size, can be endowed with a high biodiversity." The fish biomass here has been described as "exceptional", and valued "up to approximately three times higher than the highest value currently recorded in the Indian Ocean." The total amount of biomass calculated to exist for the islands – 3,500 kilograms per hectare – "represents a reference value for coral reefs with no fishing pressure for over 60 years."[158]

Although there is no permanent human settlement, meteorological and military personnel are sporadically present on these islands – with the exception of the submerged Bassas da India – and visitors are few. Scientists have been able to document the life on the islands, however, and while any conclusions should be considered preliminary, the indications are that the Isles Éparses are special indeed.

Three hundred and sixteen species of seaweed — two new to science and 27 possibly endemic — have been discovered on Europa, Glorieuses and Juan de Nova combined[159]; the three islands between them boast at least 98 species of echinoderms,[160] with 60 — including two that are

Iles Éparses. Photo © IRD–Pascale Chabanet.

critically endangered — on Juan de Nova.[161] There are at least 157 crustacean species, including six that are terrestrial, on the Glorieuses and 112 at Juan de Nova.[162] [163] The coastal waters of Europa contain at least 389 species of fish,[164] and there are at least 299 reef fish species alone at Juan de Nova — a quite remarkable number for an island of only five square kilometres.[165]

Also remarkable is the number of bird species on Europa, which is only 30 square kilometres: 50 in all, including eight breeding species of seabirds.[166] Among those seabirds, Europa boasts some of the last remaining colonies of great and lesser frigatebirds, red-footed boobies and red-tailed tropicbirds in the Western Indian Ocean, and between 750,000 and a million sooty terns; Juan de Nova, however, holds the largest breeding population of sooty terns in the entire Indian Ocean, with some two million birds — 65 per cent of the total number.[167]

Recent research has indicated that the green turtles in the Southwest Indian Ocean are divided into two distinct genetic stocks, preliminary genetic analysis of which suggests may each be further divided into two sub-stocks, including one each for the turtles of Juan de Nova and Europa. While the fewer than 150 green turtles that nest on Juan de Nova may not seem an enormous amount, their distinct genetic profile should make them a priority target for conservation.[168] Meanwhile, the 7,000-10,000 green turtles that nest annually on Europa make the island the most important site for the species in the Indian Ocean; 1,500-2,500 turtles — mostly greens, but also a few hawksbills — also nest on les Glorieuses.[169]

Greater frigatebird. Photo © Sal Cerchio.

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Mangroves in the Lamu area. Photo © Peter Prokosch. www.grida.no/photolib/detail/mangroves-in-the-lamu-area-indian-ocean-coast-of-kenya_92e6

LAMU-KIUNGA AREA

The mangrove and tidal flat habitats in the area of Lamu on the Indian Ocean coast of north-eastern Kenya, close to the Somali border, are known as some of the most extensive and species-rich along the entire coast of East Africa. Seventy per cent of Kenya's mangroves are located within this area.

Approximately 850 km in length, the Tana River is the longest in Kenya; rising in the Aberdare Mountains, it discharges into the ocean about halfway between Lamu and Malindi, into Ungwana Bay. Before it does so, however, it gives off a branch about 30 km upstream that leads to the complex of tidal creeks, flood plains, coastal lakes and mangrove swamps known as the Tana Delta.[170] The Delta covers some 1,300 square kilometres behind a 50 m high sand dune system and includes some of the mangrove cover for which this area is famous. There are approximately 53,000 hectares of mangroves along the Kenyan coast,

70 per cent of which are found in Lamu, where barrier islands protect the shoreline.[171] Perhaps the most productive mangrove forests in the country are found in the Kiunga Marine Protected Area, where near-pristine forests with 80 per cent stand density and mean stand heights greater than 10 metres still occur.[172]

The area has high biodiversity importance due to nesting activities of marine turtles — mostly greens, although olive ridleys and hawksbills nest here also[173] — and migratory birds (including a globally important population of roseate terns on the outer islands off the Kiunga Marine National Reserve[174]); the presence of whales; and a series of patch and fringing coral reefs around the barrier islands and on the offshore rocky reef. Some of the coral and reef fish species found in this area have clear affinities with those from the Red Sea and Gulf of Aden, likely due to the waters from that region sweeping south, bringing with them larvae that become established in the area, and converging with northward currents off the coast.[175]

Ungwana Bay is a pupping ground for the endangered scalloped hammerhead shark;[176] this region is one of the few remaining areas in which the critically endangered longtooth sawfish is still extant;[177] and the 11 species of seagrass along the coast provide support for multiple species, including a small number of dugongs.[178]

Mangroves in the Lamu area. Photo © Peter Prokosch.
www.grida.no/photolib/detail/mangroves-in-the-lamu-area-indian-ocean-coast-of-kenya_654a#

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Hatchetfish (Argyropelecus acuelatus). *Photo © Sarah Gotheil, IUCN.*

WALTERS SHOALS

Walters Shoals are an isolated series of seamounts reaching to within 18 m of the surface, located about 400 nautical miles south of Madagascar and 600 nautical miles east of South Africa. The shoals are cone-shaped with flat tops that are covered by coral reefs of broken and jagged relief. They are the only known habitat of the recently described giant species of spiny lobster, *Palinurus barbarae*. Some 30 to 40 per cent of the shallow water fish fauna of Walters Shoals is endemic to some part of the local West Wind chain of islands and seamounts.

When fisheries officials in Durban, South Africa, examined a catch of spiny lobsters that had been brought to shore on board a Spanish fishing vessel in September 2005, they were concerned that it was illegal. The huge lobsters, which weighed up to 4 kg each, did not appear to match the species on the accompanying export permit. But after they called in specialists to look more closely, they realized

Palinurus barbarae. *Photo © John Groeneveld.*

it would have been impossible for these lobsters to have been on the vessel's fishing permit, because this particular species of spiny lobster had never been seen before.[179] Now named *Palinurus barbarae* it is the sixth known extant species of spiny lobster and the only one documented on submerged seamounts: specifically, Walters Shoals, about 400 nautical miles south of Madagascar.[180]

It is not, however, the only apparently endemic species to have been discovered on Walters Shoals. The discovery of a new species of grenadier — one of 22 grenadier species found there to date, was announced in 2004.[181] An endemic species of snapping shrimp was described in 1969, an endemic isopod six years later and a new species of crab in 1992.[182] [183] [184] Seamounts, partly because of their relative isolation on the seabed, frequently boast high levels of endemism,[185] and Walters Shoals follows that pattern: between 30 and 40 per cent of the shallow water fish species in the area, for example, are believed to be endemic to some part of the region.[186]

A large number of taxa have been documented on, over and around the shoals and include, for example, a variety of mysids (shrimp-like crustaceans), euphausiids (krill), decapod crustaceans, and some 50 species of cephalopod.[187] [188] As is also the case with many other seamounts, the waters around the shoals also appear to be important feeding and staging areas for numerous migratory species — for example, the red-tailed tropicbird and the endangered Barau's petrel[189] — while humpback whales from the southwest Indian Ocean have been tracked passing through this area on their way to Antarctic waters.[190]

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Brisingid photographed using a remotely operated vehicle from the James Cook expedition. Photo © IUCN/NERC.

CORAL SEAMOUNT AND FRACTURE ZONE FEATURE

Rising from the surface of the seabed in an area beyond national jurisdiction far to the southeast of South Africa, the Coral Seamount is overlain by a layer of cold, productive sub-Antarctic water. Its peak stands approximately 300 metres beneath the surface, and its topography drops a further 4,900 metres to the bottom of a deep-sea trench/fracture zone structure. Recent research expeditions have found a number of species that are new to science and may be endemic to the seamount, as well as the first recorded instance of reef-building soft corals in sub-Antarctic waters of the Southern Indian Ocean.

Paragorgia photographed using a remotely operated vehicle from the James Cook expedition. Photo © IUCN/NERC.

Seamounts, underwater mountains rising from the ocean floor, are found in all oceans of the world, and are known to be hotspots of biological diversity and production. Their varied topography provides substrate for corals and other habitats; their sharp ascension from the flat seabed diverts currents into nutrient-rich upwellings; and they act as oases for a multitude of species from migratory fishes to marine mammals and seabirds.[191]

But, due in large part to the relative inaccessibility of seamounts, knowledge about them can be fragmentary. To address this lack of knowledge, the IUCN Seamounts Project, with the support of the United Nations Development Programme, launched an expedition in 2011 on board the RRS *James Cook*, which focused particularly on the benthic realm of seamounts along the South West Indian Ridge.[192] Focusing on five seamounts on the ridge, the expedition first visited the Coral Seamount.[193]

Deploying a remotely operated vehicle (ROV), scientists on board the *James Cook* confirmed the presence of coral gardens on the summit and upper flanks of the seamount, comprising scleractinian hard corals but also thickets of soft octocorals: the first known example of reef-forming cold-water corals in sub-Antarctic waters of the Indian Ocean.[194] Farther

Gorgonocephalus photographed using a remotely operated vehicle from the James Cook expedition. Photo © IUCN/NERC.

down the seamount's slopes, at depths of around 1,000 metres, they recorded stony cold-water coral reefs with high densities of associated species, including tube worms, sea stars and brittle stars, and invertebrates such as squat lobsters and octopi.[195] Glass sponges occurred at high density. Shark or ray eggs were visible in areas attached to coral. The associated fish community boasted particularly high concentrations of pelagic grenadiers.

Although detailed taxonomical analysis of the corals and their associated species is ongoing, preliminary evidence suggests that up to 50 per cent of the brittle star species found by the *James Cook* are new to science.[196] So, too, are at least three species of shrimp [197] [198]and a species of sea cucumber.[199] In one particularly fascinating study, the team on board the *James Cook* retrieved small packages of wood and whale bone; those packages had been deployed two years earlier to mimic natural "falls" (ecosystems that form around wood detritus and whale carcasses that have fallen to the seafloor) to see what species they attracted. They tallied a total of 4,284 specimens of boring worms, shrimps, crustaceans and others, 49 species in all, from the whale bones, and 1,208 individuals representing 38 species from the wood: in total, 13 species had not previously been recorded.[200]

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Mayotte. Photo © David Obura.

NORTHERN MOZAMBIQUE CHANNEL

The Northern Mozambique Channel has the highest concentration of biodiversity in this portion of the Western Indian Ocean. This area includes the southern part of Tanzania, from Mtwara southwards; northern Mozambique; the northwest and northeast part of Madagascar; the Comoros archipelago; the southern Seychelles, including the Aldabra group; Providence plateau and Farquhar; and the French overseas territories Mayotte and Glorieuses.

When the crew of the *Nerine* caught the first known coelacanth off South Africa in 1938, the species' existence had been unknown to scientists, who assumed coelacanths had been extinct for 70 million years. But as early research expeditions spread out in search of more specimens, they came across an area of the Indian Ocean where at least some residents were familiar with it: the islands of Comoros. There, locals had a name for it — *gombessa* or *ngombessa* — and would accidentally catch two or more a year. They would not keep the fish because it had no value as food, but some did use the scales as sandpaper to roughen up the inner tubes of bicycle tires when they had to apply a patch.[201] The waters of the Comoros would provide so many coelacanth specimens over the ensuing decades that as recently as 1991, one author concluded incorrectly that the islands were the coelacanth's sole locale, and occasional sightings elsewhere were of errant individuals. [202] The species has since been confirmed to live off Mozambique, Kenya, Tanzania, Madagascar and Indonesia, but the largest known population is indeed off Grand Comore.[203] Studies of that population have estimated the population size at a mere 300-400 individuals, each of which may live 100 years or more; interestingly, however, it appears to comprise solely adults, leaving unsolved for now the question of where the juveniles and sub-adults are to be found.[204]

The waters of the Comoros archipelago also appear to be important for a number of cetacean species: 12 were recorded during a survey between 2000 and 2003, although by far the most frequently seen were spinner dolphins and, especially, humpback whales, the latter accounting for 72 per cent of sightings. Mother-calf pairs were the most commonly

Omura mom and calf. Photo © Sal Cerchio.

sighted humpback social grouping, indicating that the Comoros archipelago is an important nursery area for the species.[205]

This area can also boast what is believed to be the first genetically confirmed identification of living Omura's whales – which had historically been confused with Bryde's whales, to which they are closely related, and was only recognized as a separate species in 2003 – a population of which has been identified off the coast of northwestern Madagascar.[206]

The Northern Mozambique Channel contains a variety of seascapes and environments – ranging, for example, from the world's second-largest raised coralline atoll by land area in Aldabra in the Seychelles to the mangrove-lined embayments and offshore reefs of northwestern Madagascar.[207] In addition, a complex series of gyres and eddies creates water flow in a multitude of directions within the channel, likely contributing to high retention and recruitment of larvae in pelagic and shallow marine ecosystems, and thus high resilience of communities and populations.

The net result is a riot of diversity and abundance. There are, for example, 11 species of seagrass, 39 species of sharks and rays, and some 390 fish species off the island of Mayotte alone. Aldabra is home to between 3,000 and 5,225 nesting green turtles annually, while more than 5,000 greens nest on just five beaches on Moheli Island in the Comoros; the total nesting population on this island is the largest in the Western Indian Ocean. Aldabra is home to the largest breeding population of frigatebirds in the Indian Ocean. The Seychelles atoll of Cosmoledo alone is home to 20 per cent of sooty terns, 25 per cent of red-footed boobies, and more than half the masked boobies in the world.

Opposite page:
Top: Barracuda, Aldabra.
Middle: turtle, Mayotte.
Bottom left: Coral, Aldabra.
Bottom right: Eagle rays, Aldabra.
All photos © David Obura

Right: this small Euphausiid (krill) is a food base for large vertebrates, such as Omura's whales, mobula rays and manta rays, off the northwestern Madagascan island of Nosy Be. Photo © Sal Cerchio

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Humpback whale. Photo © Sal Cerchio.

MOHELI MARINE PARK

The Comoros archipelago is located in the Indian Ocean at the northern entrance to the Mozambique Channel, equidistant (approximately 300 km) from Madagascar and the east coast of Africa. It comprises four islands, separated from each other by about 80 km: Grande Comore, Moheli, Anjouan and Mayotte. Moheli is the smallest of the four islands of the archipelago. A national park was established on Moheli in 2001. It features the first nesting site in the archipelago for the green turtle, an important breeding area for humpback whales and a refuge for the conservation of dugongs.

Named after the layer of green fat beneath their carapaces, green turtles are among the largest sea turtle species and the only one that is truly herbivorous. Like other marine turtles, after hatching, they set out to sea for many years, swimming thousands of kilometres, before returning to mate, the females ultimately clambering out on to the very same beach from which they first emerged to lay their eggs. Among the many beaches where this cycle repeats itself every year are those of the Moheli Marine Park in the Comoros. Just five beaches along a 1.5 km section of coast support approximately 5,000 nesting females, which lay throughout their year but particularly during the peak, dry, season between May and August.[208]

Green turtles (and less frequently hawksbills) feed on the seagrass beds in the park area, which are also vital for the survival of a remnant population of dugongs. Although seen regularly, dugong numbers here are small: surveys conducted in 2004, 2009 and 2010 among fishers in the area of the marine park yielded a count of 9, 13 and 13 respectively.[209]

The marine park is the only part of Moheli in which mangrove forests occur, covering an area of 91 hectares in the bay on the island's south coast. Several species of terns intersect in the park area; a guano-covered island off Itsamia harbours a population of about 200 masked boobies and more than a thousand brown noddies. The waters of the island are inhabited by more than a dozen species of cetacean and are particularly important for humpback whales, which are present in large numbers during the July to November mating and calving season, following a long migration from the polar waters around Antarctica.[210]

Photo courtesy of Ahmed Youssouf/Moheli Marine Park.

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King penguins. Photo © Phil Whittington.

PRINCE EDWARD ISLANDS, DEL CANO RISE AND CROZET ISLANDS

This pristine area includes four islands within the Crozet Archipelago (îlot des Apôtres, Cochons, Pingouins and l'Est islands) and two within the Prince Edward Islands (Marion and Prince Edward). They have a high level of endemism, breeding and foraging habitat, and are critical for various life history phases of albatrosses, penguins, other seabirds and marine mammals, some of which are globally threatened. It lies in sub-Antarctic waters approximately 2000 km southeast of South Africa.

Lying on the edge of the Antarctic, in the zone where the Subtropical Front gives way to the Subantarctic Front, which in turn yields to the Antarctic Polar Front, where warm waters clash with cold, this is an area of transition and extremely high productivity.[211] The islands support substantial colonies of seabirds and seals, colonies that for several species are of global importance. For example, the Crozet and Prince Edward Islands together host all of the world's Crozet shags, about 70 per cent of wandering albatrosses, 54 per cent of king penguins, 33 per cent of Indian yellow-nosed albatrosses, 27 per cent of sooty albatrosses and 21 per cent of the world's southern rockhopper penguins.[212] [213] [214] [215] Recent research concludes, however, that gentoo penguins and the Crozet shag should be considered endangered and critically endangered respectively under South Africa's Red List of threatened species.[216]

Île de l'Est in the Crozet Islands holds the most diverse community of seabirds in the world: 32 species, of which 19 are burrow-nesting petrels. Many are believed to number in the tens of thousands of pairs. Particularly abundant are the South Georgian and common diving petrels and Salvin's prion; estimates of the population sizes of each are of several million pairs, which, in the case of Salvin's prion, represents 80 per cent of its global numbers. The Île aux Cochons Important Bird Area (IBA) holds the world's largest rookery of king penguins and the largest colony of wandering albatross in the Indian Ocean.[217] [218]

Indian yellow-nosed albatross. Photo © Rémi Bigonneau.

Meanwhile, the Prince Edward Islands seasonally accommodate up to five million seabirds and seals, attract at least ten species of whales and dolphins to its productive feeding grounds, and support a diverse (approximately 550 species) and biomass-rich benthic community.[219] [220] [221] Eighty species of fish in the vicinity of the islands have been documented, though this is considered to be a conservative estimate.[222]

Although orcas had been observed on several occasions around Marion Island, their presence at neighbouring Prince Edward Island had been limited to one recorded observation – until a 2012 study reported several observations, all of which involved orcas hunting juvenile fur seals.[223]

There is considerable habitat heterogeneity with potentially sensitive habitats and vulnerable species, including reef-forming cold-water corals. Habitats include many seamounts, transform fault ridges and deep trenches, hydrothermal vents, shallow abyssal plains and several pelagic habitat types. The abyssal plain features species that have been described only in this region, including several species (and a new genus) of sea cucumbers.[224] [225] [226]

Subantarctic fur seal. Photo © Rémi Bigonneau.

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Bridled tern. Photo © Ben Lascelles.

SOUTHERN MADAGASCAR (PART OF THE MOZAMBIQUE CHANNEL)

The highly productive waters of Madagascar's "Deep South" are critical feeding grounds for highly migratory species, including seabirds and cetaceans.

Extending south from Madagascar for a distance of nearly 1000 km, an extensive underwater plateau rises and falls from about 1000 m to 2500 m deep until, at its southern end, it forms a shallow platform 100 m below the surface. The platform was formed by basaltic extrusion from the Marion hotspot during the Cretaceous, as Antarctica and Madagascar moved apart. The interaction of the plateau with the strong East Madagascar Current produces a complex oceanography, resulting in strong coastal and offshore upwelling, eddies and turbulence. These promote the formation of the large phytoplankton bloom that occurs during the austral summer and fertilizes waters downstream and into the southern Mozambique Channel.

Because of its productivity, the plateau is an important foraging ground for multiple marine species, including seabirds, large fish and marine mammals.[227] [228] [229] In the summer, it is primary habitat for the pygmy blue whale, which occurs here in its highest abundances within the Southern Indian Ocean.[230] Humpback and Bryde's whales also migrate through the area,[231] [232] [233] and it is likely being used by some southern right whales.[234]

Tracking data suggest that the area is a seabird hotspot: Barau's petrel and red-tailed tropicbird forage here and farther south during their breeding season;[235] and there are roseate, sooty and bridled tern colonies on small islands off the coast.[236]

At least some whale sharks appear to move across the channel from Mozambique and then south of Madagascar before heading up that country's east coast.[237]

A recent expedition involving 64 scientists from 15 countries, the Atimo Vatae (see photos below), intensively sampled the algae and invertebrates of the shallow and upper-slope fauna; it found 766 species of crustaceans and between 800 and 900 species of molluscs (with an anticipated 700 or so more to come), of which perhaps a quarter are endemic, as well as kelp beds and more than 500 species of seaweed, more than the country's tropical algal flora.[238] Some of those macroalgae species were new to science,[239] as were some species of chitons,[240] rock snails[241] and sea squirts.[242]

Above: Endemic sea snail (Lyria patbaili) *Photo © Bob Abela /La Planète Revisitée/MNHN-PNI.*
Opposite top: Aerial view of "Pointe Evatra", extreme south of Fort Dauphin, south-eastern Madagascar.
Photo © Xavier Desmier/La Planète Revisitée/MNHN-PNI.
Opposite bottom: Porcelain crab (Petrolisthes moluccensis). *Photo © Tin-Yam Chan/La Planète Revisitée/MNHN-PNI;*

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Red-footed boobies. Photo © J Bourjea.

TROMELIN ISLAND

Tromelin is an isolated small sand caye (less than 1 square kilometre in area) located approximately 440 km east of Madagascar and 580 km north of la Réunion. It is one of the most important nesting sites for green turtles in the Western Indian Ocean and the site of both rare and genetically isolated coral populations.

For 15 years in the second half of the 18th century, Tromelin became the unwitting home to some 200 Malagasy slaves and their French captors, following a shipwreck on the island.[243]

Almost 250 years later, Tromelin has long been uninhabited, save for four workers involved in maintaining a weather station that was erected in 1953. At high tide, rough seas wash onto its beaches, and low tide exposes fringing coral reefs, a combination that adds to its inaccessibility and has helped make Tromelin a *de facto* protected area.[244]

The coral composition of the caye is of particular interest. An area of flat paving composed of two species of faviid corals is one of the few examples in the western Indian Ocean region,[245] [246] while recent genetic studies on three coral species of the *Pocillopora* genus have shown that their populations at Tromelin are different from those at Réunion and Europa islands, suggesting geographical isolation at Tromelin.[247]

The islet is a major nesting site for green turtles: a recent study estimated 1,500 nesting females laying 481,000 eggs that yielded 289,000 hatchlings in a single season, a figure similar to earlier observations and thus suggestive of a relatively stable population.[248]

Like many tropical islands, Tromelin – and in particular its seabird populations – suffered from the unintentional introduction of Norway rats from on board sailing ships; since a rat eradication programme in 2005-2006, two species of seabirds – red-footed and masked boobies – increased their reproductive success by 22 to 23 per cent a year; the white tern was recorded breeding on the island for the first time since 1856, and the brown booby for the first time in history.[249] The rat eradication effort was not successful in eliminating house mice from Tromelin; however, it is interesting to note that the island is the site of what may be the first recorded instance of seabird predation on an invasive mammal, when a masked booby was observed pursuing, killing and swallowing a house mouse.[250]

Brown booby. Photo © Ray Pierce.

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Whale shark, Mafia Island Marine Park. Photo © David von Helldorff.

MAHE, ALPHONSE AND AMIRANTES PLATEAU

The Mahe, Alphonse and Amirantes Plateau consist of two areas within the Republic of Seychelles. These include the inner island group, which make up the Mahe Plateau, and the Amirantes group of islands to the south of the Mahe Plateau. The area is an important feeding site for killer whales, and an important feeding, nesting and reproduction site for seabirds, as well as one of the most significant nesting sites for green and hawksbill turtles in the world.

Amirantes reef scene, Seychelles. Photo © National Geographic Pristine Seas.

The 115 islands of the Seychelles are divided up into two principal groups: the 40 granite rock Inner Islands of the Mahe group in the country's northeast, and the approximately 65 low-lying coralline Outer Islands spread out over a large area to the Mahe islands' southwest. The Outer Islands are themselves divided into five groups, and one of them – the Amirantes Islands – combine with the Inner Islands to their northeast to make up this area.[251] [252]

Boasting a diversity of habitats from granite cliffs to corals to seagrasses and extensive mangroves, this area includes some of the highest biological productivity in the Western Indian Ocean and is a vital refuge for numerous species of marine fauna.

Uninhabited Aride Island, in the Mahe group, hosts more than one million seabirds belonging to 10 different species, including the world's largest colonies of lesser noddy and tropical shearwater, the largest roseate tern colony in the Seychelles and the only woodland colony of sooty terns.[253] To the southwest, St. Joseph Atoll in the Amirantes group hosts the third-largest breeding colony of wedge-tailed shearwaters in the Western Indian Ocean.[254]

Islands within this group are also important turtle-nesting sites for both hawksbill and green turtles, and the Mahe plateau is the

Aerial view of Alphonse. Photo © GIS Office, Seychelles.

third-most-important site in the world for hawksbill turtle nesting, while the Amirantes Plateau is the fourth-most important site for green turtle nesting.[255] The hawksbill population numbers between 1,000 and 2,000 nesting females annually — the largest national population in the Western Indian Ocean[256]. Recent studies are encouraging: despite centuries of hunting, the population appears to have maintained a surprisingly high level of genetic variability, meaning that its "effective population size" (the point above which it is at risk of losing that diversity) is relatively large and that the population should therefore be in a good position to adapt to environmental change.[257] Meanwhile, the green turtles that nest in the Amirantes appear to be a distinct sub-population, one of two in the northern part of the Southwest Indian Ocean.[258]

Although they do not breed here, loggerhead and leatherback turtles have also been known for some time to frequent the area, with olive ridleys recently identified in the Seychelles for the first time.[259] The area may be important for orcas (i.e., killer whales), and is clearly so for sperm whales, as groups of females and calves (typically around 16 individuals in a group) have been documented, apparently feeding and resting.[260]

Whale sharks – which have been recorded off the Seychelles since at least 1756[261] – also aggregate in this area; the waters off Mahe are one of just 11 known aggregation sites for the species globally. Unlike with sperm whales, these aggregations generally involve juvenile males, are seasonal rather than short-term, and involve many of the same individuals in successive years: 27 per cent of individuals identified in 2001 were seen again in 2009.[262] And the sicklefin lemon shark, which has undergone range reductions and even disappeared in certain areas, remains a regular visitor to this area, appearing annually in the lagoon of St. Joseph's Atoll.[263]

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*Sea urchin (*Dermechinus horridus*) photographed using a remotely operated vehicle from the James Cook expedition, 2011. Photo © IUCN/NERC.*

ATLANTIS SEAMOUNT

Located in subtropical waters beyond national jurisdiction to the east of South Africa, this is an actively tectonic seamount. The seamount hosts diverse coral gardens and complex sea-cliff deep-sea communities characterized by large anemones, armchair-sized sponges, and octocorals.

The flat summit of the Atlantis seamount appears to be covered in sandy ripples of the kind common on exposed beaches. But these beaches are fossilized, lithified in limestone millions of years ago as they sank beneath the ocean. Unlike most flat-topped seamounts, the Atlantis seamount is not volcanic in nature, but tectonic: rather than providing an opening to Earth's mantle, it is part of the mantle itself, thrust up through the planet's crust until, about 9.5 million years ago, it formed an island with a surface area of approximately 25 square kilometres. Subsequently, however, it subsided slowly into deep waters and now lies 700 m below the sea's surface.[264] Its past is betrayed by the fossil

beaches on the summit, as well as by fossilized clams, gastropods and other marine animals encrusted in its surface.[265]

The seamount's flat summit is generally a flat pavement of carbonate thinly draped in sediment with steep outcrops of bedrock colonized by various corals, some of which are themselves colonized by sea urchins. The spines of these urchins form red mats around the bases of the outcroppings and mix with coral rubble to provide a rich habitat for species such as anemones.[266] Solitary corals that dot the seamount's summit are of an as-yet-unidentified species; also yet to be identified is the small, fast-moving species of shark that swims in the peak's waters.[267]

From its summit at 700 m to depths of around 4,000 m, the seamount hosts a diverse deep-sea fauna, from rich benthic communities of large, armchair-sized sponges, glass sponges, anemones and sea spider predators on its western slope to fish species including crow shark, Gilchrist's orange roughy and big-eye dory.[268] Its fish assemblage contains pelagic armourhead in numbers that do not appear to occur anywhere else along the South West Indian Ridge.

A 2011 expedition on board the research vessel *James Cook* found numerous species that had not only previously been unrecorded on the seamount but were new to science, including two species of sea cucumbers and a species of squat lobster, among others;[269] [270] researchers are even now continuing to pore through the samples that were collected, and the total number of new and possibly endemic species seems certain to rise considerably as they do so.

*Glass sponge (*Euplectella*) photographed using a remotely operated vehicle from the James Cook expedition, 2011. Photo © IUCN/NERC.*

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Montipora aequituberculata. *Photo © Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping and Outer Islands, Mauritius.*

BLUE BAY MARINE PARK, MAURITIUS

Blue Bay Marine Park was proclaimed a national park in October 1997, and then declared a marine protected area and designated as a marine park in 2000 under the Fisheries and Marine Resources Act 1998. The second Wetland of International Importance (Ramsar Site) for Mauritius, it is located in the south-east of the island and extends over an area of 353 hectares (3.5 square kilometres). Blue Bay Marine Park is known for its diverse and rich fauna and flora; its coral, including extensive brain coral, is particularly notable.

Acropora muricata *colony. Photo © Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping and Outer Islands, Mauritius.*

A popular tourist spot and the most popular beach in southern Mauritius, Blue Bay plays host, it is estimated, to more than one hundred thousand visitors, Mauritian and foreign nationals alike, every year – attracted in part by the park's diverse and rich fauna and flora. It is especially notable for its coral, including brain coral measuring 6 to 7 metres in diameter; in total, 108 species of coral, from 33 genera, have been documented in the park. Indeed, despite measuring only 3.5 square kilometres, Blue Bay Marine Park is notable for an abundance of species, including 233 species of fish and 201 types of mollusc.[271]

Two types of reefs are found in the park: fringing reefs and patch reefs. The overall length of the fringing reef is about 3 km, with a narrow (10 m) reef flat composed of dead corals and coral rubble and a fore reef slope that is characterized by several grooves consisting of basaltic rocks and boulders.

The patch reef of the park is spectacular, ranking among the best in the world because of its luxuriant coral growth. Dense growths of table corals, cactus corals, stag-horn corals, brain corals and fire corals alternate and compete for space. The patch reef is the only location in Mauritius where convoluted *Montipora aequituberculata,* a species of stony coral, has been recorded. The coral species diversity is high, representing 28 genera and 15 families on the patch reef alone. Surveys carried out so far have revealed the presence of 72 fish species representing 41 genera and 31 families.[272]

*Lobed brain coral (*Lobophyllia hemprichii). *Photo © Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping and Outer Islands, Mauritius.*

Other marine fauna present in the park include seven species of echinoderms, four species of crustaceans, four species of sponges, two species of nudibranchs, four species of holothurians and one species of turtle. Marine flora include four species of seagrass; 31 species of algae representing 26 genera and three families have also been recorded. Two species of mangroves are found scattered along the inter-tidal region of the south-western part of the park.[273]

Acropora muricata. *Photo © Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping and Outer Islands, Mauritius.*

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*Seagrass (*Thalassodendron ciliatum).
Photo © Khaled bin Sultan Living Oceans Foundation.

SAYA DE MALHA BANK

The Saya de Malha Bank is the largest of three shallow banks forming the Mascarene Plateau, located in the Western Indian Ocean along the underwater Mascarene Ridge that spans the distance between the Seychelles and Mauritius. The largest single bank in the Indian Ocean, it covers an area of approximately 40,000 square kilometres, and is believed to boast the largest contiguous seagrass beds in the world. The waters over the bank are, in effect, a globally unique mid-ocean shallow sea.

Between 20 and 40 million years ago, volcanic activity threw up islands that, perhaps as recently as 18,000-6,000 years ago, settled beneath the waves and are now known as the Saya de Malha Bank.[274] From above, its structure, with a curved lagoon carved into its top, is ostensibly typical of atolls;[275] but in fact corals cover only around 10 to 20 per cent

of its surface.[276] Potentially much of its approximately 40,000 square kilometre surface area is covered by seagrasses, making it perhaps the most extensive seagrass area in the world, and an unusual seagrass hotspot in the open ocean.[277]

At its shallowest, the water above the Saya de Malha Bank is no more than seven metres; as such the bank has been widely regarded primarily as a navigational hazard, and as a consequence, relatively little mapping or scientific research had been conducted there prior to a major expedition in 2002.[278] However, that expedition and subsequent research have shed considerable light on "one of the largest shallow tropical marine ecosystems on Earth."[279]

Because of the rich supply of nutrients and plankton delivered to the banks from adjacent deep waters, the area is an oasis of high productivity; and since a large part of the seagrass organic production is swept by the currents into deep waters, where some of it is buried in deep sediments, the Bank serves as a significant sink of atmospheric carbon dioxide and a source of oxygen.[280]

The shallow-water ecosystems of Saya de Malha Bank provide feeding areas for the green turtle, as well as breeding grounds for pygmy blue whales, a subspecies that is resident particularly in the Indian Ocean.[281] Spotted and spinner dolphins, pilot whales and beaked whales also make use of the area.[282] A Russian research expedition during the mid-1980s tallied 142 species of molluscs, 11 of which were previously unknown, and including apparent endemics.[283] [284] And partly because Saya de Malha has been subjected to close scientific investigation only relatively recently, research efforts are continuing to uncover new species. For example, an endemic gastropod, *Conus gordyi*, was described in 2000,[285] another sea snail, *Antillophos usquamaris*, in 2005,[286] two new species of sand lance — named for their ability to dive into sand to escape predation and to rest — were described in 2014,[287] and a new species of scorpionfish one year later.[288]

The ecological importance of Saya de Malha may extend to providing a potentially important stepping stone in the migration of shallow-water species across the Indian Ocean. It may have played a critical role in the colonization of the shores of East Africa and Western Indian Ocean islands by species originating from the Coral Triangle to the east.[289]

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Blue whale. Photo © Asha de Vos.

SRI LANKAN SIDE OF GULF OF MANNAR

The Gulf of Mannar separates the southeastern tip of India from the island of Sri Lanka. This area is a site for endangered species of marine mammals such as dugongs and blue whales, as well as for some turtle species. It also boasts a substantial diversity of fin fish, sharks, rays, shrimp, spiny lobsters, slipper lobsters, conch shells, sea cucumbers and reef fishes. Traditionally important natural pearl beds are also located in this area.

The pearl fishery of the Gulf of Mannar has been renowned since antiquity. Three thousand years ago, the Tamil kings of Southern India reckoned it one of their principal sources of revenue, considering

it of such import that the main pearling centre was second in importance only to Madurai, the capital, and was the residence of the heir apparent. A millennium later, Mannar's pearls continued to be prized far and wide: they commanded a high price in Ancient Rome, where the famous chronicler Pliny the Elder dubbed them the most productive pearls in the world.[290] Today, the fishery may not bring quite the riches to Sri Lanka as in times far past, but the pearl beds remain, as do many other signs of a nutrient-rich environment supporting a diverse marine fauna.

Each year, humid winds blocked by the central mountains of Sri Lanka produce heavy rain in the coastal areas. Three rivers, swollen with rainfall, discharge water to the 70-km-long coastline of this area, enriching the continental shelf with nutrients. Lagoons and estuaries situated along the coastline provide habitats for a large number of aquatic animals that migrate between lagoon and sea, and shelter a large number of migratory bird species.[291] The Gulf of Mannar is considered an important gateway for some migratory birds entering the country from the Indian mainland.[292]

Harbouring coral reefs, seagrass beds, lagoons and estuaries bordered by mangroves, the Gulf of Mannar is an important nursery and reproduction area for multiple marine species, such as penaeid shrimps, spiny lobsters, slipper lobsters, crabs, conch and sea cucumbers. It also provides protective habitats for nesting sea turtles, and acts as a migratory route for the hawksbill turtle population living in South Asia. Dolphins, dugongs and endangered whale sharks have also been observed in the area.[293]

The Gulf of Mannar is known for its pearl banks of Pinctada radiata *and* Pinctada fucata. *Photo © Philippe Bourjon/Wikimedia Commons.*

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Wedge-tailed shearwater. Photo ©Ben Lascelles.

CENTRAL INDIAN OCEAN BASIN

Lying south and east of Sri Lanka and the Maldives, over the mid-Indian Ocean basin and parts of the Ninety East Ridge, this area is known to be a key feeding site for at least four species of seabirds that nest on islands in the Western Indian Ocean, with birds migrating more than 3,000 km to feed here during a pronounced seasonal phytoplankton bloom during the austral winter.

Watch a red-tailed tropicbird attempt to move across land and you would be forgiven for thinking it had been seriously injured: its tiny legs struggle to propel it forward as it topples onto its belly in a series of drunken lurches.[294] Those same small feet also render it incapable of swimming strongly; but once in the air, the red-tailed tropicbird is in its element, a beautiful, graceful streamlined bird that glides

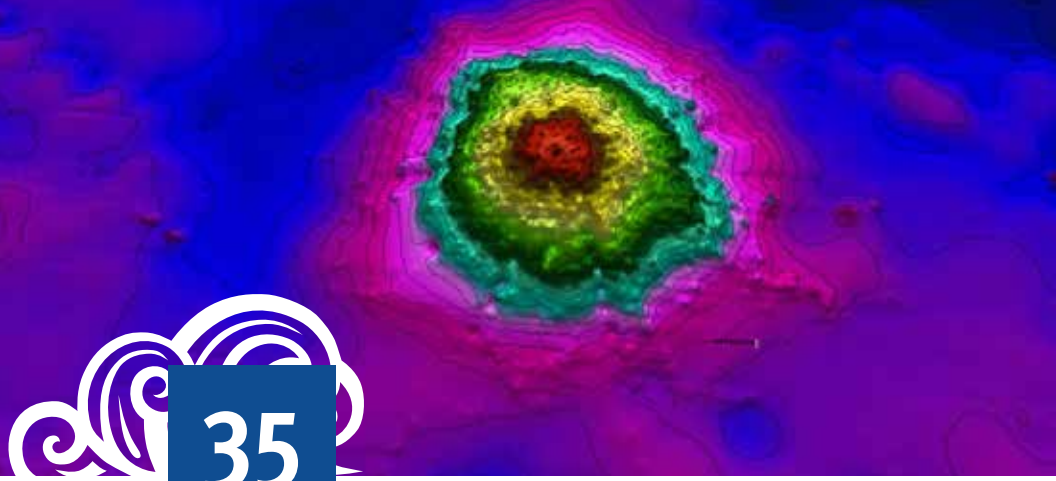
across the sky as it searches for prey. Like other tropical seabirds, it feeds by surface seizing and plunge diving; because its prey is located within the top 50 metres of the water column and because it can dive no more than a few metres, the red-tailed tropicbird and other tropical seabirds can only feed when that prey is driven toward the surface by predators such as tunas and dolphins.[295] This interaction is so important for tropical seabirds that it has been termed a "near-obligate commensalism" between seabirds and marine top predators.[296]

Able to disperse widely across the Indian Ocean by following the south-easterly trade winds,[297] the red-tailed tropicbird is one of four species that migrate as much as 3,000 km to feed in this area. In fact, this area can easily be divided into two sub-areas. One, a relatively restricted zone about 1,200 km south of Sri Lanka and located at the surface of a seamount in the Ceylon Abyssal Plain, is important for wedge-tailed shearwaters from D'Arros, Cousin and Aride in Seychelles and from Reunion Island, and for white-tailed tropicbirds in the Seychelles.[298] The second, a much larger area straddling the Ninety East Ridge, is used primarily by endangered Barau's petrels from Reunion Island and red-tailed tropicbirds from Nosy Be in Madagascar and from Europa Island.[299]

The presence of the seamount and the Ninety East Ridge is presumably significant: the upwellings that they produce may play an important role in the development of phytoplankton blooms that occur during the austral winter in the central Indian Ocean.

White-tailed tropicbird. Photo © Ross Wanless.

Red-tailed tropicbird. Photo © Ross Wanless.



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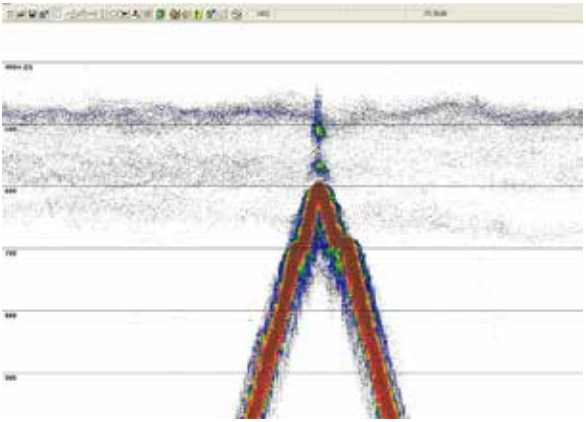
Bathymetric projection of Rusky knoll.[302]

RUSKY

"Rusky" is the name given to a knoll on the Broken Ridge Plateau, which lies due west of Australia and south of western Indonesia. It is the only knoll located in the middle part of Broken Ridge and the only place along the ridge known to host black coral.

The tragic disappearance in March 2014 of Malaysian Airlines Flight MH370 focused international attention on what was considered a "priority" search area at the bottom of the Southern Indian Ocean, due west of Australia. Using sidescan sonar, an international team scoured the area for clues, and although they did not find wreckage of the aircraft, the maps they developed provided enhanced imagery of the region around what is known as the Broken Ridge Plateau.[300]

Stretching approximately 1,200 km across the Southern Indian Ocean toward the southwestern tip of Australia, Broken Ridge is up to 400 km wide.[301] A 1997 survey by the University of Hawaii Mapping Group found that most of the ridge is continuous and overlain with sand and sediments, but that local areas of rocky, coral garden and knoll/bank habitat exist. All

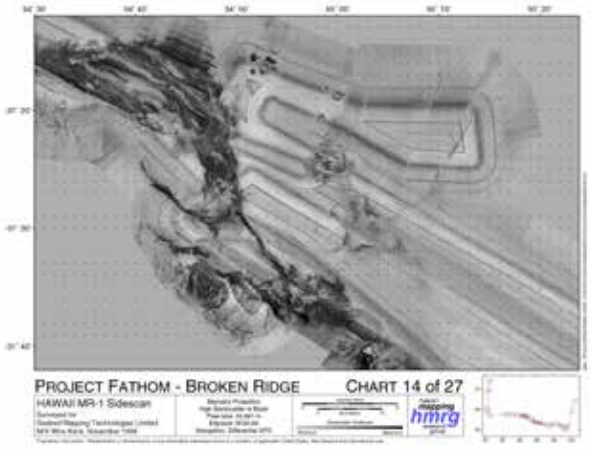


Echogram showing small schools of alfonsino and armourhead on the top and ledges around Rusky knoll. Image © G. Patchell.[302]

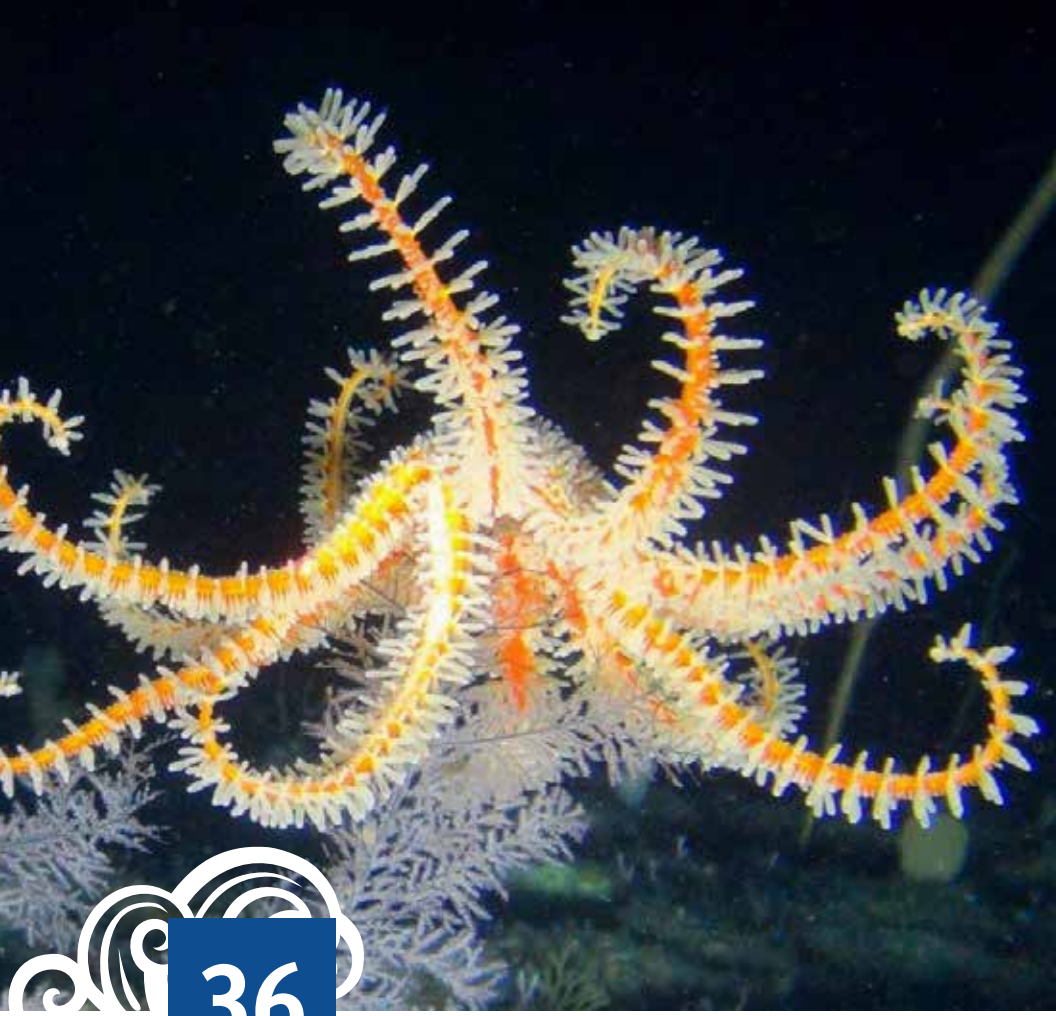
of the knolls are found around the edges of the plateau, except one, called "Rusky", which is located 24 km from the edge, covers an area of roughly 17 km^2 and rises from a depth of 1,200 m to 580 m below the sea surface.

Fish species such as small alfonsino and armourhead are found on the knoll, and so too is an extensive cover of black coral, which was first identified when brought up in trawl nets.[302] Rusky is the only knoll on the ridge known to have any black coral cover.

Primarily deep-water species, black coral are generally long-lived — the record known age for one species is 4,265 years[303] — and accordingly very slow to grow and reach maturity. The presence of black coral was among the considerations that prompted the Southern Indian Ocean Deepwater Fishers' Association to include Rusky in the world's first-ever voluntary deep-water trawl fishery closure in 2006,[304] codified in the Southern Indian Ocean Deepsea Fishers' Association (SIODFA) list of Benthic Protected Areas in the Southern Indian Ocean.[305]



Sidescan image of Rusky and Fools' Flat (area no. 36). © Hawaii Mapping Research Group and Sealord Group.



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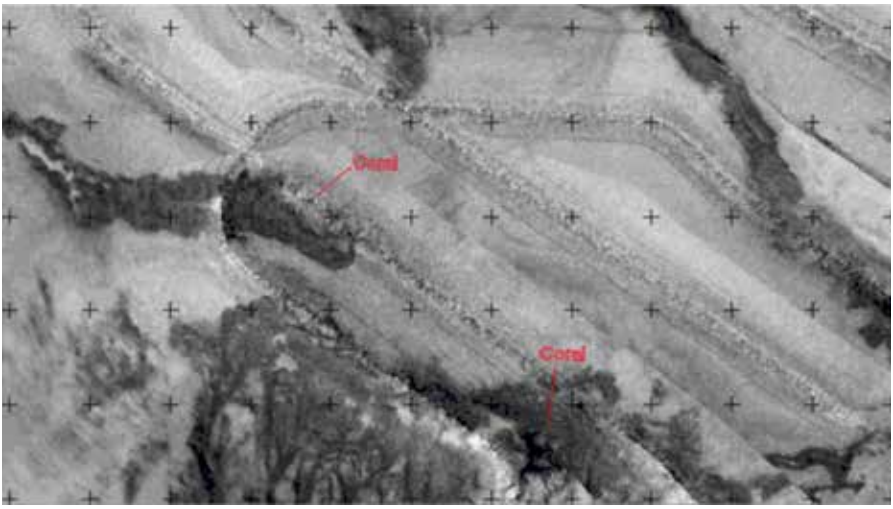
Deep water brisingid seastar. Photo © Peter Timm.

FOOLS' FLAT

Located on the southern side of the Broken Ridge Plateau, due south of western Indonesia and west of western Australia, Fools' Flat is the only area along the ridge that shows substantial coral reef formations.



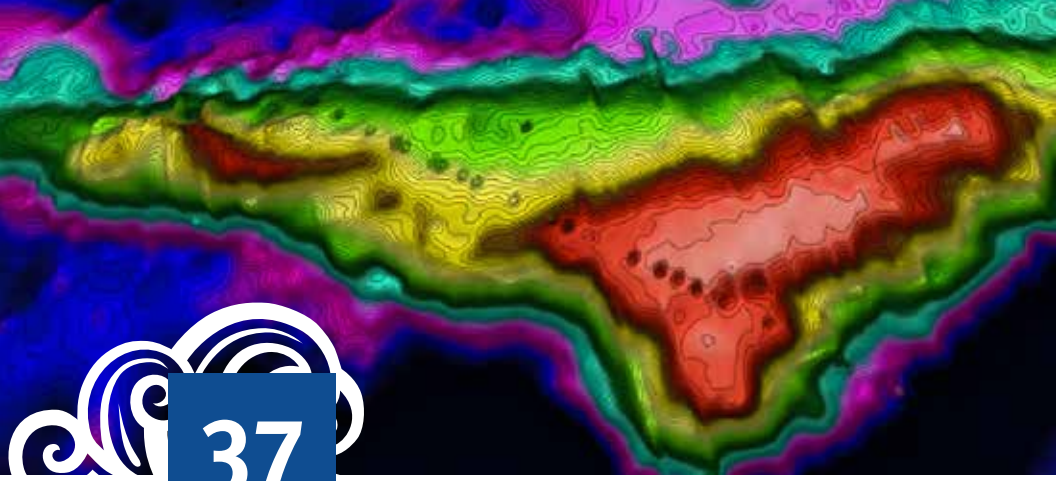
Sidescan sonar image of cold-water coral beds on Fools' Flat.[302]

At first glance, a curious fishing vessel might find this area worthy of investigation. Echo-sounders reveal what appear to be aggregations of fish; but minimal further investigation reveals that that those putative fish are not moving, and sidescan sonar unveils the echoes as, in fact, outcrops of deep sea coral. It is in recognition of such possible disappointment that this EBSA is dubbed "Fools' Flat."[306]

Along the southern edge of Broken Ridge, at a depth of about 990 m, before the sides plunge rapidly down to a depth of almost 4,000 m, lies the only part of the entire plateau that is home to substantial coral reefs.[307] These reefs stand 20 to 30 m high and were positively identified as coral rather than rocky knolls in 1997, when one trawl brought up dead brain coral that had ripped its nets. The extent of the reef cover appears to be in excess of 2.5 km^2, and comprises primarily the colonial coral *Solenosmilia variabilis*.

Upwellings from the southwest corner of the ridge likely have resulted in favourable conditions for the growth of deepwater corals, and for the fish and other fauna that can reasonably be expected to take advantage of the coral habitat.[308]

Fools' Flat is listed among the Southern Indian Ocean Deepsea Fishers' Association (SIODFA) Benthic Protected Areas in the Southern Indian Ocean.[309]



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Bathymetry of guyot to the east of Broken Ridge.[302]

EAST BROKEN RIDGE GUYOT

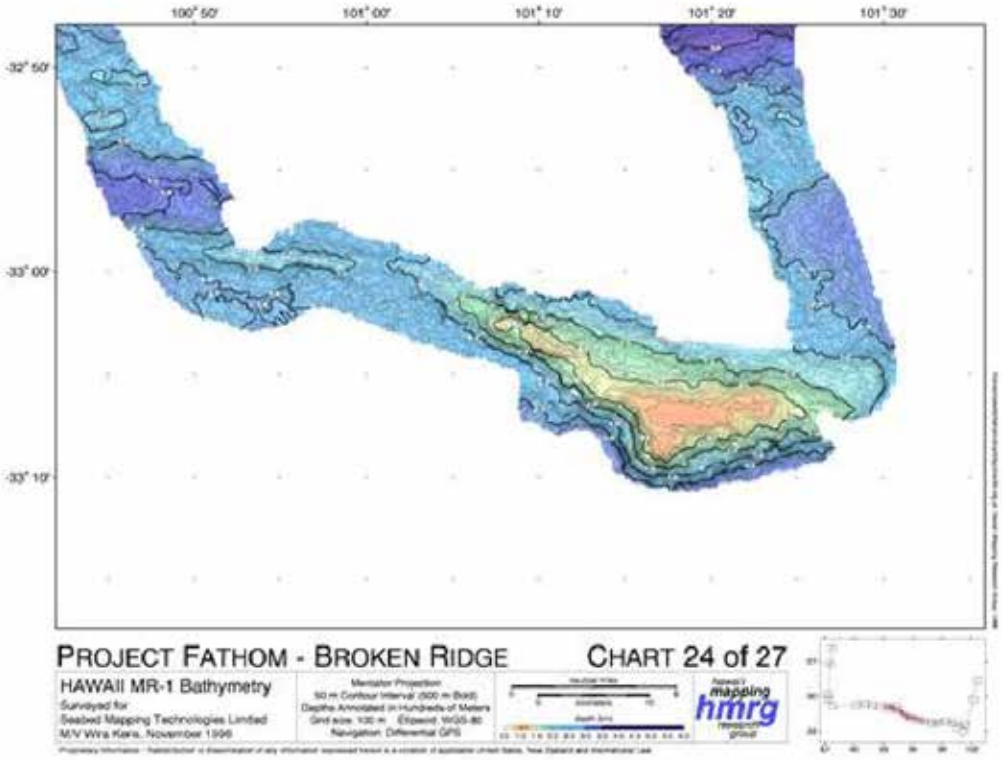
Located toward the eastern end of Broken Ridge, this guyot is separated from the ridge itself by deep water and rises from 3,000 m to 1,060 m deep. It is believed to be biologically pristine.

Seamounts are widely recognized as hotspots of marine biological diversity, and although the precise reasons are unconfirmed and likely vary to some extent among individual seamounts, the likely causes include their providing substrate for benthic habitat, which in turn supports additional organisms, and the fact that their sharp relief from the surrounding seafloor alters currents and generates nutrient upwellings.[310]

Little is known about seamounts – including their whereabouts: a new topographic map of the ocean floor, released in 2014, revealed 15,000 more than had previously been recognized.[311] We do know, however, that they are "hotspots", hosting life that is frequently long-lived, slow-to-reproduce, endemic, or some combination of all the above. Such is the case with the East Broken Ridge Guyot.

This guyot – the name given to a flat-topped seamount – rises from 3,000 m deep at its base to 1,060 m below the surface at its top. It is characterized by numerous slips and canyons extending down its sides, and appears to be severely eroded.[312] Very little is known about the fauna it supports: exploration for fish aggregations has been undertaken, but only for one day.[313] However, the seamount appears to have suitable environmental conditions for the deepwater species of fish that typically occur in the area; is believed to be biologically pristine.[314]

This guyot is included among the Benthic Protected Areas of the Southern Indian Ocean that have been declared off-limits to trawling by the Southern Indian Ocean Deepwater Fishers' Association (SIODFA).[315]



Sidescan imagery of the East Broken Ridge. © Hawaii Mapping Research Group and Sealord Group.

38

Southern bluefin tuna. Photo © CSIRO.

SOUTH OF JAVA ISLAND

This area extends south of Java Island outside the Indonesian exclusive economic zone toward Cocos Island and Christmas Island. An area of high seasonal productivity, it is especially notable as the only known spawning area for the critically endangered southern bluefin tuna.

A meeting place of multiple current systems from west and south, creating upwellings of warm, nutrient-rich waters, this is an area of high seasonal productivity and, as a result, the host of a multitude of marine species. The genetically distinct eastern Indian Ocean subpopulation of Bryde's whales is found in these waters;[316] whale sharks – presumably foraging – traverse the region;[317] and the Regional Management Units of five different sea turtle species overlap to varying extents with this area.[318]

But the main reason for this area's importance is the presence of one species in particular: the southern bluefin tuna. Warm-blooded and long-lived (they have been known to reach 42 years of age), the bluefin is a

fish unlike any other.[319] In an eloquent profile in 2008, after noting that the bluefin can reach a weight close to three quarters of a tonne and a length of four metres, writer Richard Ellis described the species as:

> "... a massive hunk of superheated muscle that cleaves the water by flicking its scimitar-shaped tail ... The bluefin is also among the fastest of all fishes, capable of speeds up to 80 kilometers per hour and able to migrate across entire oceans. It is such a marvelous swimmer that when scientists in the 1990s endeavored to build a mechanical fish, they used the species as a model."[320]

Much about the southern bluefin remains unclear, however, particularly with regards to its early life history, when mortality is substantially higher than at any other stage of a bluefin's life and when larvae are believed to be highly susceptible to changes in environmental conditions.[321]

This is the only area in the world where southern bluefin are known to spawn, and it appears that there are a number of convergent conditions that makes it an especially favorable location. The sea surface temperature is consistently at or above the minimum desired threshold of 24˚C; the majority of the spawning ground is a region of low eddy activity, allowing larvae to grow without being dispersed before they are ready; and although the area is one of high seasonal productivity, levels of chlorophyll *a* are in general relatively low, which makes it less attractive to potential larval tuna predators.[322] All of these factors combine to make this region necessary for the survival of one of the world's most iconic and endangered fishes.

Aerial view of southern bluefin tuna. Photo © Jim Dell CSIRO.

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Wandering albatross. Photo © Rémi Bigonneau.

DUE SOUTH OF GREAT AUSTRALIAN BIGHT

The Great Australian Bight is a large bight off the central and western portions of the southern coastline of mainland Australia. It extends south until it meets the South Australia Basin, and it is the waters over that basin that comprise this area. These deep, pelagic waters are crucial feeding areas for several species of threatened seabird, including the sooty and wandering albatross.

For sailors in the frequently forbidding waters of the Southern Ocean, the presence of an albatross is traditionally considered good luck. In 'The Rime of the Ancient Mariner', by Samuel Taylor Coleridge, the arrival of one presages fair sailing for a ship that has been blown off

course by Antarctic storms — until the titular hero shoots it, prompting a sequence of tragic events that culminates in the deaths of all his crew mates. It has been speculated that early mariners considered albatrosses good luck because their presence indicated the proximity of land, even though, as later mariners would have suspected and scientists have confirmed, the relationship between albatrosses and land is an occasional one at best.[324]

At length did cross an Albatross,
Through the fog it came;
As if it had been a Christian soul,
We hailed it in God's name.
...
'God save thee, ancient Mariner!
From the fiends, that plague thee thus!—
Why look'st thou so?'—With my cross-bow
I shot the ALBATROSS. [323]

Wandering albatrosses, for example, breed on islands in the Sub Antarctic, from South Georgia in the west to Macquarie Island, southwest of New Zealand, in the east. Upon fledging, they take to the air, where they may remain for more than five years, spreading their 3 m wingspans (the largest on Earth) and riding thermals as they travel thousands of kilometres at a stretch without ever touching land.[325] Satellite tagging showed that one newly fledged bird covered 6,590 km in a mere 28 days after leaving its colony.[326] Upon breeding, they take flight once more, not returning until it is time to breed again, two years later.[327]

While at sea, wandering albatrosses feed by surface-seizing: diving down to snatch fish, cephalopods, crustaceans and carrion. Satellite tracking of juvenile birds that breed on Crozet Island in the Indian Ocean southeast of South Africa shows that the waters south of the Great Australian Bight are a vital feeding area for wandering albatrosses during these formative juvenile years at sea.[328] Similarly, tagging and tracking of sooty albatrosses from Amsterdam Island has revealed that this endangered species frequents the same waters during its non-breeding season.[329]

Critically endangered southern bluefin tuna also migrate across this area from the Tasman Sea to the Indian Ocean,[330] and studies have suggested that the right whales that winter at the head of the bight likely comprise a single population, which migrate through these waters to the Antarctic and back again.[331] For these species and others, often engaged in long migrations and extensive travels, the waters south of the Great Australian Bight serve as a welcome oasis, a vital source of sustenance during weeks, months and even years spent at sea.

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