Crocodile Monitoring Plan

This approved crocodile monitoring plan provides guidance for staff in the Department of Environment and Science implementing crocodile monitoring and reconnaissance in Queensland. Further information is provided in the Technical Manual, which assists field-based staff.

Queensland Government

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Introduction

Estuarine crocodiles (*Crocodylus porosus*) are found in coastal waterways from Sri Lanka in the west, throughout south-east Asia to the Caroline Islands in the east, and down to northern Australia (Webb and Manolis 1989). The worldwide status of estuarine crocodiles is listed as Low Risk and of Least Concern (2009 IUCN Red List) with large stable populations in Australia, Papua New Guinea, and Indonesia (Webb et al. 2010). This species is considered the most territorial and least tolerant of conspecifics (Lang 1987; Brien et al. 2013), and is responsible for a high number of attacks on humans each year throughout its range with 1305 since 2000, of which 708 were fatal (Caldicott et al. 2005; CrocBITE 2013: accessed June 2018).

In Australia, unregulated hunting for skins in the post-World War II era led to a decline in the population of *C. porosus* and effective commercial extinction resulting in full legal protection by the early 1970's (Western Australia: 1970; Northern Territory: 1971; Queensland 1974; Webb and Manolis 1989).

The species has, however, proved resilient and the population has since recovered in the Northern Territory and Western Australia to pre-hunting levels (Webb et al. 2010) where extensive areas of favourable habitat exist, pressure from agricultural development and human population are small, and there is a sustainable management program that provides economic incentives for the community to tolerate crocodiles. Since protection in 1974, the population in Queensland has been likely to have increased in some areas. However, the results of surveys undertaken between 1979 and 2003 indicate a more modest and patchy recovery compared with the NT and WA which, together with increasing encroachment into crocodile habitat, has increased the frequency of human-crocodile conflict and periodic calls for culling and/or total removal from populated areas (Messel et al, 1981; Taplin, 1988; Read, 1998; Read et al, 2004).

Estuarine crocodile population in Queensland

In Queensland, the estuarine crocodile is spread across both latitudinal and longitudinal gradients around the coastline, from Gladstone on the east coast, through to Cape York Peninsula, and throughout the Gulf of Carpentaria to the Northern Territory border. However, individuals are less frequently seen south of Gladstone in the Mary River and the Great Sandy Strait. Estuarine crocodiles can occur over 100km inland, but are most commonly found in Queensland at elevations of less than about 20m above sea level in tidal reaches of rivers, freshwater lagoons, rivers, and swamps and along beaches throughout their range. They are not uncommon on offshore islands of the Great Barrier Reef and Torres Strait.

The variable physiography, natural environments, man-made environments and climatic conditions are significant and impact on the crocodile population. In addition, very few river systems in Queensland have the heavily vegetated freshwater floodplains and swamps that house a large proportion of the total crocodile population in the Northern Territory. Some of the most extensive swamplands on Cape York Peninsula occur on silica sands of low productivity. Much of Queensland's habitat may prove marginal for crocodiles for reasons such as climate, low availability of good nesting vegetation, or low inherent fertility (Taplin, 1987; Read, 1998, 1999, 2001; Read et al, 2004). Therefore it is not expected that the abundance and biomass of estuarine crocodiles in many Queensland river systems will reach levels found in parts of the Northern Territory.

Along the east coast, south of Cooktown, agricultural development and urbanisation have resulted in numerous habitat changes, including clearing of riparian vegetation, loss of wetlands, and changes to hydrology with the introduction of dams and weirs. Some crocodile populations in northern Queensland occur in areas that have limited human population impact, but there are also areas down the east coast of Queensland south of Cooktown where human populations are large and interactions among crocodiles and humans occur frequently. At the very southern end of their range, south of the Fitzroy River, Rockhampton, estuarine crocodiles are observed infrequently. Departmental staff conducting surveys and patrols are more likely to see tracks and signs, rather than spotlighted animals.

Much of the habitat used for nesting by estuarine crocodiles in Queensland is poorly characterised, despite surveys from as early as 1980 (Magnusson et al, 1980). Surveys since the 1980s have found repeatedly that many waterways are showing rather limited recruitment, as evidenced by nests discovered and numbers of

hatchlings encountered (Taplin, 1988; Taplin & Krieger, 1989; Read, 1998, 1999; 2001; Read et al, 2004). A better understanding of the habitats and vegetation types used for nesting and the focal points of recruitment will improve our understanding considerably and contribute to management decision making.

Current threats to Queensland's crocodile population arise from illegal killing, incidental mortality in fishing nets, crab pots, destruction of nests and nesting habitat by feral pigs (Taplin 1989; Kofron and Smith 2001; Read et al. 2004). However, human encroachment is considered the major threat to the population of estuarine crocodiles in Queensland.

As our population increases and swamplands, mangroves and rivers are encroached upon by industrial, agricultural and residential development, crocodiles are squeezed into smaller spaces. This is most evident along the populated east coast of Queensland (south of Cooktown), where crocodiles share their habitat with some 715,018 people[1] (QGSO 2015).

The Queensland Government has to balance two competing responsibilities in its crocodile management – an obligation to conserve the species and to protect people from harm. The growing human population and apparently growing crocodile population along the east coast of Queensland ultimately means more frequent encounters with crocodiles. Unless the community values crocodiles and their habitats, it will be a challenge to ensure their long-term conservation.

In March 2017, the Queensland Crocodile Management Plan was released in March 2017, which applies across the State and replaced the crocodile management plans for the local government areas of Douglas, Cairns, Cassowary Coast, Hinchinbrook and Townsville – and three Crocodile Urban Management Areas in Mackay, Rockhampton and Gladstone, but maintained existing crocodile management arrangements in the rest of the state- https://www.ehp.qld.gov.au/wildlife/livingwith/pdf/wl-mp-croc-manage-plan.pdf.

Under the Queensland Crocodile Management Plan there are six different crocodile management zones, whereby crocodiles are removed in certain circumstances across different places, in accordance with the level of risk the animals pose to people.

The aims and objectives of the monitoring program are to:

- estimate the size, biomass and distribution of the estuarine crocodile population and reassess its conservation status in Queensland.
- determine relative abundance and size class structure of estuarine crocodiles in Queensland and how this varies between bioregions and over time.
- identify focal points of nesting and recruitment into the crocodile population.
- determine the impact of the government’s crocodile removal programs along the populated east coast.
- better understand the threat posed by crocodiles to people in the populated east coast region and contribute to ongoing management efforts.
- identify, through a systematic surveillance program south of Rockhampton, whether there is any evidence that crocodiles are increasing in numbers or extending their range in south-eastern Queensland.

[1] Estimated residential population from 2013 in regional government areas of Townsville, Cairns, Mackay, Rockhampton and Gladstone.

Conceptual model

Tabulated conceptual model for *Crocodylus porosus* in Queensland

Goals		
Management	To ensure the long term sustainability of the species in Queensland while minimising human-crocodile conflict.	
Population monitoring and surveillance	Knowledge of population size, size class structure, and trends across the whole of crocodile range in Queensland and a sound understanding of the impact of government management programs.	
Potential anthropogenic threats		
Habitat destruction and encroachment	A significant issue in the Populated East Coast (PEC) region as the human population footprint expands. Becoming important in some remote regions as the resident and transient human population increases and encroaches. Remote areas protected by distance and difficult access are becoming less remote and less protective for crocodiles.	Nesting habitat removal and encroachment of urban areas are both collated on an annual basis by the Queensland Government. These threats are occurring primarily on the populated east coast area below Cooktown.
Illegal and incidental killing of crocodiles	There is considerable incidental and some systematic evidence of crocodiles being killed illegally and incidentally, in both the PEC region and remote areas. It is unclear whether the killings are having a significant impact on population growth or conservation status.	Incidental killing through fisheries capture is recorded by fisheries by-catch programs. Illegal killing and recreational fishery impacts have not been recorded over the years but are suspected to have local impacts The department receives regular reports of crocodiles drowning after becoming entangled in crab pots.
Feral pigs and weeds impacting wetlands and floodplains.	Some important nesting areas sites are impacted by feral pigs and weeds, which are widespread and locally abundant in parts of Queensland.	Biosecurity Queensland keep records on feral pig populations. The impact on nests and nesting success is unknown but thought to be low. The impacts of weeds on nests and nesting success are unknown.
Hydrology	Draining and clearing of swamplands for agricultural and other development has reduced or eliminated areas likely to have been important refuges and recruitment sites (e.g. Babinda Swamp, Wyvuri Swamp).The river systems have changed hydrology as a result of dams and weirs	Information is available on draining and clearing and it is estimated that perhaps 10% of the nesting habitat on the Populated East Coast is impacted (Taplin, pers.comm.).
Crocodile removal under approved management	The government is increasingly requested to cull crocodiles in areas visited by people; and attacks or deaths	The highest number of crocodiles taken as a result of government programs in a year was during

actions	lead to calls for culls even in places established for wildlife conservation. To date these have not had significant impact, but pressure on protection regimes is unlikely to decline.	2017, when 84 estuarine crocodiles were removed.
Natural drivers		
Extent of wetlands and floodplains	The extent of favourable habitat and nesting vegetation varies greatly in different regions of Queensland and is likely to affect population growth and recovery.	Analysis of favourable habitat is being conducted, including analysis of clearing of that habitat (Taplin, pers.comm.)
Climate	Climate in the southern Gulf Plains and in south-eastern Queensland is likely to be a significant limiting factor on reproduction, recruitment and ultimate population size.	As part of this monitoring program the extent of crocodile populations in southern areas of Queensland will also be assessed.
Physiography	Catchment size and productivity and habitat suitability for estuarine crocodiles vary greatly across Queensland's regions and will affect carrying capacity.	Limited information is available on productivity of river systems in Queensland but it is anticipated that there will be variability in population numbers in different river systems. No substantial baseline information is currently available, other than monitoring information from the 1970's and 1980's after hunting ceased.
Hydrology	Extensive low-lying plains in the Gulf of Carpentaria are likely to experience significant losses of nests and eggs during flood peaks. This is likely to impact on recruitment, particularly when populations are at a low level. Dams and weirs may impact nesting success through changes in hydrology during substantial releases.	Flood-related losses of crocodile hatchlings are not known in Queensland. The only significant dams in crocodile habitat are the Burdekin and Fitzroy Dams (used for irrigation and water supply), although there are a limited number smaller of dams and weirs which release water periodically
Disease	Disease appears low in estuarine crocodile populations, however there have been a number of specific disease epidemics in other species of crocodiles e.g. Nile Crocodile in the Olifants River in South Africa (Woodborne et al. 2012)	Disease levels are unknown in Queensland but are not anticipated to be significant.
Management actions		
Removal of crocodiles in populated areas according to management plans	The Queensland Crocodile Management Plan (2017) identifies six different zones for the removal of crocodiles based on the location, size and behaviour of individual animals.	300 estuarine crocodiles were removed from the wild in Queensland in the years 2013-2017.

Crocwise education program	A program of education for human behaviour in crocodile country. Targeted at reducing human interactions with crocodiles through building understanding of crocodile behaviour and ecology among residents and tourists, and the adoption of safe behaviours.	The Crocwise program has been in place since 2002. The current program includes: educational talks at schools and clubs; extensive use of permanent and temporary signage; collaboration with key stakeholders; periodic Crocwise stakeholder forums and the use of social media.
Egg collecting	Wild egg collection is currently not legal in Queensland, however a proposed to make it legal under the *Environment Protection and Biodiversity Conservation Act 1999* is currently under consideration.	Some illegal egg collecting may occur but the magnitude is unknown and thought to be very low.
Other threats	At this stage other threats are identified as limited or unknown and are not managed by the State.	

The conceptual model informs the approach to this crocodile monitoring program. The program is dictated by the environment and crocodile population dynamics. A considerable part of the Northern Territory's crocodile population occurs across a narrow latitudinal band on the Arafura coast and in broadly similar physiographic and climatic regimes. In Queensland, crocodile populations are spread across both latitudinal and longitudinal gradients around the coastline. The variable physiography, natural environments, man-made environments and climatic conditions are significant and impact on the crocodile population.

In addition, very few river systems in Queensland have the heavily vegetated freshwater floodplains and swamps that house a large proportion of the total crocodile population in the Northern Territory. Some of the most extensive swamplands on Cape York Peninsula occur on silica sands of low productivity. Much of Queensland's habitat may prove marginal for crocodiles for reasons such as climate, low availability of good nesting vegetation, or low inherent fertility (Taplin, 1987; Read, 1998, 1999, 2001; Read et al, 2004). Therefore it is not expected that the abundance and biomass of estuarine crocodiles in many Qld river systems will reach levels found in parts of the Northern Territory.

Along the east coast, south of Cooktown, agricultural development and urbanisation have resulted in numerous habitat changes, including clearing of riparian vegetation, loss of wetlands, and changes to hydrology with the introduction of dams and weirs. Some crocodile populations in northern Queensland occur in areas that have limited human population impact, but there are also areas down the east coast of Queensland where human populations are large and interactions among crocodiles and humans occur frequently.

Crocodiles are removed for management purposes throughout the state, but removal is higher within designated estuarine crocodile management areas in and around urban areas.

At the very southern end of their range, estuarine crocodiles are observed infrequently. Sightings of crocodiles reported by members of the public in this area exceed recorded sightings by trained personnel. Departmental staff conducting surveys and patrols are more likely to see tracks and signs, rather than spotlighted animals.

Program approach

This monitoring program is divided into three parts: monitoring, reconnaissance, and sightings and management. Monitoring will involve systematic spotlight and helicopter surveys in a selection of river systems throughout the state to assess population trends over time and the level of recruitment, while reconnaissance will involve day and night time surveys to determine the presence or absence of crocodiles and nesting in river systems south of the Fitzroy River, and potentially nesting in the Gulf and Cape. Sightings reported by the public, attacks and problem crocodiles removed have been recorded for many years and will continue to be recorded and used to inform management and the public.

One of the key issues with previous crocodile surveys in Queensland has been the lack of consistency in terms of river transects surveyed, time of year and tides that surveys have been conducted, and data collection and accuracy. These issues have made year on year comparisons and population trend analysis over time challenging. Therefore, consistency and accuracy are critical to this monitoring program and will ensure data is comparable across river systems and between years.

The program has been carefully designed to mirror critical aspects of past survey programs and ensure robust conclusions can be reached. It is informed by intimate knowledge of the areas to be surveyed and the results of previous surveys, the logistical and other challenges to be faced, the conditions that will be encountered in each of the river systems and the peculiar challenges each of them presents. This is essential to conducting an efficient, effective and sustainable program.

The program is geographically extensive because of the great variation in environments across Queensland and the long interval since the last systematic survey program. The variability of population sizes in different river systems means that enough data is required to assess change across the principal systems in all the important regions. It also concentrates in the first three years on gathering data quite extensively within each river system, because the distribution of crocodiles within these systems may have changed over time.

Towards the end of the three-year program, the results will be examined to determine whether a reduced set of transects on a smaller representative set of rivers might be introduced for longer-term monitoring. That review can consider whether transects based on shorter reaches of the mainstream and major tributaries of river systems will provide adequate characterisation of population status and changes in numbers and size distribution.

Monitoring

Population monitoring has been conducted in many of Queensland's river systems, or parts of them, since estuarine crocodile research began in 1979 (Table 1). There are some 87 major and minor waterways along the coastline between the NT border and Cooktown - of which about 45 have had been surveyed on one or more occasions since 1979. Only one of Queensland's 'large' rivers and four of its 'moderate' sized rivers have never been surveyed. This provides a sound basis from which to estimate change in numbers and size class distribution which can then be used to calculate changes in biomass. However, there have been no spotlight surveys of note in any rivers north of Cooktown since 2003 and along the PEC since 2010, and no helicopter surveys north of Cooktown since 1988, and along the PEC since 2003. How the estuarine crocodile population in Queensland has changed since this time is not clear, despite anecdotal reports that numbers are increasing.

Table 1. Number of spotlight surveys of estuarine crocodiles in major and minor river systems in the remote areas of Queensland (1979 - 2016). Note that these counts have not been aggregated consistently between survey years, so that counts for some rivers are high because counts for individual tributaries of some systems have been counted as separate survey units. Spotlight surveys between 1979 and 1989 are largely for the entire navigable portions of whole rivers/systems (excluding Norman R and Port Musgrave where repeat counts on some tributaries are separately recorded). Spotlight surveys from 1990 to the present include some whole rivers/systems but more counts of tributaries and shorter transects on large rivers/systems. Thus the table does not reflect the full extent of survey coverage through time. River systems are listed as they occur along the coastline from the Northern Territory border to Cooktown and allocated to regions defined by Taplin (1987).

Aggregation system	River	1979	1984 - 1989	1990 - 1994	1995 - 1999	2000 - 2003	Total
Southern Gulf Plains							
Nicholson R System	Nicholson R				3		**3**
Nicholson R System	Gregory R				1		**1**
Albert R System	Albert R		2		3		**5**
Leichhardt R System	Leichhardt R		1				**1**
Bynoe R System	Bynoe R		3				**3**
Norman R System	Norman R		12		16		**28**
Smithburne R System	Smithburne R		1				**1**
Duck Ck System	Duck Ck	1	1				**2**
Gilbert R System	Gilbert R	1	1		1		**3**
Northern Gulf Plains							
Staaten R System	Staaten R	1	1		3		**5**
Nassau R System	Nassau R	1	1				**2**
Mitchell R System	Sth Mitchell R		1		2		**3**
Mitchell R System	Mitchell R		1		3	1	**5**
Mitchell R System	Coleman R		1			1	**2**
Chapman R System	Chapman R		1		2	1	**5**
Moonkan Ck System	Moonkan Ck		1		1	1	**3**
Edward R System	Edward R					1	**1**
Edward R System	Balurga Ck					1	**1**
NW Cape York Peninsula							
Archer R System	Little Archer R				1		**1**
Archer R System	Ward R				1		**1**

Albatross Bay System	Hey R		1		3	3	**7**
Albatross Bay System	Embley R		2		6	3	**11**
Albatross Bay System	Mission R		6	2	9	2	**19**
Albatross Bay System	Pine R		3				**3**
Albatross Bay System	Triluck Ck		1				**1**
Pennefather R System	Pennefather R		1				**1**
Port Musgrave System	Ducie R	3	3	1			**7**
Port Musgrave System	Dulcie Ck	1					**1**
Port Musgrave System	Namaleta Ck	1	1				**2**
Port Musgrave System	Palm Ck	1					**1**
Port Musgrave System	Port Musgrave	1	3				**4**
Port Musgrave System	Wenlock R	3	7	2	10	4	**26**
Skardon R System	Skardon R		1		1		**2**
Jackson R System	Jackson R		1				**1**
Jardine R System	Jardine R				1		**1**
Cowal Ck System	Cowal Ck				2		**2**
Eastern Cape York Peninsula							
Escape R - Jackey Jackey Ck	Escape R	1	3			1	**5**
Escape R - Jackey Jackey Ck	Jackey Jackey Ck				1	1	**2**
Harmer Ck System	Harmer Ck					1	**1**
Olive R System	Olive R		1		1	1	**3**
Kangaroo R System	Glennie Inlet					1	**1**
Kangaroo R System	Kangaroo R					1	**1**
Kangaroo R System	Hunter Inlet					1	**1**
Pascoe R System	Pascoe R			1		1	**2**
Claudie R System	Claudie R		1	1		1	**3**
Lockhart R System	Lockhart R		1	2		1	**4**
Nesbit R System	Nesbit R		1				**1**
Stewart R System	Stewart R			1			**1**
Princess Charlotte Bay							
Lakefield - Rinyurru System	Barrow Ck					1	**1**
Lakefield - Rinyurru System	Nth Kennedy R		5	1	10	6	**22**

Lakefield - Rinyurru System	Bizant R		2		2	2	**6**
Lakefield - Rinyurru System	Normanby R		2		2	2	**6**
Lakefield - Rinyurru System	Lakefield Waterholes		2		32	9	**43**
Lakefield - Rinyurru System	Marrett R				2	1	**3**
Eastern Coastal Plains							
McIvor River System	Starcke R		1				**1**
McIvor River System	McIvor R		1				**1**
Total Number of Surveys		**15**	**78**	**11**	**116**	**47**	**267**

The current program will collect monitoring information through repeating the systematic spotlight surveys conducted in 1979 (Messel et al, 1981), from 1984-89 (Taplin, 1988), from 1994-2003 (Read et al, 2004), and helicopter surveys from 1984-1989 (Taplin 1988), and 1994-2003 (Read et al. 2004) leading to directly comparable data. The spotlight surveys will be conducted using the same techniques as those used previously in Queensland and as described by Messel et al. (1981) and Fukuda et al. (2013), though the extent of surveys within individual river systems has varied over time. The helicopter surveys will be conducted using the same techniques as described by Webb et al. (1990). Detailed information on spotlight and helicopter survey technique and protocol are outlined in the *Crocodile Monitoring - Technical Manual*.

All historical data will be compiled and reviewed to ensure that data comparisons between river systems and across time use 'like-for-like' datasets and tightly matched transects. Spotlight survey work in quite a number of the small river systems in the PEC region is made difficult by their small size, heavily vegetated banks, limited navigability and tidal range. Nonetheless, they are still amenable to high quality spotlights surveys and these are treated under this plan in the same way as more remote systems.

Achieving the aims of the crocodile monitoring program is best achieved by repeating spotlight, using the same technique each time, on a selection of river systems that:

(a) have been surveyed historically so as to measure populations changes over time.

(b) are representative of the range of crocodile bioregions in remote Queensland (Taplin, 1987), so as not to skew findings and population estimates in favour of very high or very low density systems.

(c) include known 'hotspots' for recruitment, to provide updated information on where recruitment is now occurring in Queensland and any changes that have taken place.

A comprehensive schedule of survey work encompassing most of the remote river systems first surveyed between 1979 and 1989, and a smaller selection of systems first surveyed in the 1990s, is set out in Table 2. The schedule includes selected rivers on the populated east coast that have been surveyed previously and that are important for management. The rivers in Table 2a are of primary importance to the survey program and will be surveyed in 2017-2018, while those in Table 2b are of secondary importance and will be surveyed in 2018-2019.

Table 2(a): Proposed spotlight and helicopter survey program for river systems of primary importance to the program in Queensland. Table 2(a) includes the most important systems for survey based on their size, location, likely contribution to recruitment in each region, and prior history of survey. All, except those on the Populated East Coast were first surveyed comprehensively in 1979 or during the 1980s. The intention is to survey them during 2017-2019.

River System	Proposed Transect Distance (km)	Proposed Helicopter Transect Distance (km)
Southern Gulf Plains		
Norman River	158	293
Staaten River	52	161
Nassau River	110	229
Northern Gulf Plains		
Mitchell River	91	250
South Mitchell River	57	85
Coleman River	23	66
North-western Cape York Peninsula		
Wenlock River	91	87
Ducie River	77	96
Namaleta Creek	24	18
Eastern Cape York Peninsula		
Escape River	25	38
Escape River Middle Arm	29	23
Jackey Jackey Creek	70	112
Lockhart River	56	101
Lakefield - Rinyurru		
North Kennedy River	69	119
Bizant River	35	64
Normanby River	47	59
Populated East Coast		
Endeavour River	36	58
Daintree River	36	123
Barron River	25	18

Mulgrave River	-[2]	47
Russell River	21	53
Johnstone River	40	49
Hull River	29	27[3]
Bohle River	14	-
Haughton River	23	-
Proserpine River	26	27
Fitzroy River	132	225
Total	**1396**	

Table 2(b): River systems of secondary importance to the program, some of which were first surveyed in 1979 or the 1980s and others only in the 1990s. The intention is to survey these systems in 2018-19. It may be possible to survey all of the secondary river systems in 2018-19, but that will be determined by logistics, resources, and the capacity to have teams operating when survey conditions are suitable.

River System	Proposed Spotlight Transect Distance (km)	Proposed Helicopter Transect Distance (km)
Southern Gulf Plains		
Albert River	106	246
Leichhardt River	90	-
Bynoe River	66	139
Smithburne River	44	-
Gilbert River	37	-
Duck Creek System	72	-
Northern Gulf Plains		
Chapman River	16	-[4]
Moonkan Creek	43	-
Balurga Creek	32	-

[2] The Mulgrave River is not amenable to effective spotlight survey because of extensive shallow waters.
[3] The Hull River proved ill-suited to helicopter survey in 2017 and will not be included in future surveys.
[4] Helicopter survey of four northern Gulf rivers may prove possible as part of the proposed egg-harvest monitoring program at Pormpuraaw, should it be approved.

Edward River	18	-
North-western Cape York Peninsula		
Albatross Bay		21
Mission River	58	95
Embley River	49	62
Hey River	64	98
Pennefather River	33	39
Pine River & Nomenade Creek		94
Skardon River	30	62
Jackson River	20	42
Eastern Cape York Peninsula		
Olive River	21	-
Lakefield - Rinyurru		
Marrett River	37	34
Populated East Coast		
Moresby River	23	32
Murray River	29	37
Herbert River	27	163
Tully River	16	86
Seymour River	20	-
Cattle Creek	25	43
Rocky Dam Creek	20	16
Total	**996**	

Reconnaissance

Estuarine crocodiles reach the southern limit of their distribution in south-east Queensland. Past surveys indicate that the likelihood of spotting crocodiles during night surveys tends to diminish south from Cooktown and is close to zero south of the Fitzroy River at Rockhampton. Efforts to locate animals and nests have generally occurred in response to sighting reports from the public.

In order to establish the presence or absence of crocodiles and nests in these southern rivers, and any trends over time, a structured schedule of reconnaissance surveys, during both the day and night, will occur during the dry season. Night time surveys will be conducted the same way as for monitoring, while daytime surveys will involve searching for animals and the traces they leave on banks (such as slide marks), along with any nest sites. If hatchling crocodiles are found during spotlight surveys, follow-up day reconnaissance may be conducted to identify and describe the nest site. Reconnaissance sites are listed in Table 3.

Table 3: Waterways on the Populated East Coast of Queensland south of the Fitzroy River selected for reconnaissance surveys – both day and night. These systems have low densities of crocodiles and the aim is to determine presence or absence of crocodiles and nesting. Some of these rivers lie in close proximity to urban areas, and so while crocodile sightings are rare, they are of concern to management.

Waterway	Management importance
Boyne River	High
Baffle Creek	Low
Kolan River	Low
Burnett River	Low
Mary River	High
Great Sandy Strait	High

In addition, ad-hoc reconnaissance surveys will be conducted in response to reports of crocodile sightings that require a management response. These ad-hoc surveys do not need to be as rigorous as systematic reconnaissance surveys in terms of the area covered.

Where there is capacity (vessels, helicopter time) for indigenous land and sea ranger program or citizen scientists to assist, reconnaissance surveys, for the purposes of locating and characterising nests and determining the level of recruitment, are also planned for remote areas of the Cape and Gulf. This capacity will be established further through discussions with these groups before annual work plans are developed and prior to the start of each nesting season.

Sightings and management

A disciplined program of recording sightings reported by the public, attacks, and management responses (e.g. removals) throughout Queensland has been in place since the 1980's. The overall purpose of the program has been to ensure details of the distribution and extent of human-crocodile conflict and Departmental responses are publically accessible (via website), and readily available for responding to Departmental enquiries and complaints. The data collected provides heavily biased but nonetheless valuable insights into the occurrence of crocodiles, especially in marginal or uncommon places (e.g. upper freshwater habitat), and extent of human-crocodile conflict, as well as reports of nesting activity and natural deaths or killings in areas that have not warranted dedicated attention from the Department. The program will form an important component of the monitoring program and will be enhanced to complement monitoring and reconnaissance efforts.

Survey planning

Survey planning will need to be conducted a full year ahead and management will need to be aware that there may not be many options for the timing of surveys. In remote areas, population counts on specific rivers may be possible for a few days or weeks in a year - giving just enough time to survey one large system (e.g. Port Musgrave or the Mitchell River system) or two moderate sized systems (e.g. the Staaten River and Duck Creek systems). Information on predicted tidal and lunar conditions for each tidal station in the monitoring zone will be used to identify days that are optimal for spotlight survey. Tidal forecasts will be updated annually and provide guidance for those coordinating and conducting the work. Surveys conducted during 2017 will provide opportunity to test the boundaries of favourable survey conditions once more and determine whether the windows of opportunity for surveys can be widened from those indicated by our planning assumptions.

The most significant constraint on crocodile surveys in Queensland is the challenging tidal regime. Surveying crocodiles on the wrong tide or at times of strong moons (spotlight) can interfere with sightability, particularly where crocodiles are very wary - as has been found in several Queensland river systems. Moderate to high tides tend to conceal crocodiles in fringing vegetation. Strong moonlight allows crocodiles to see more clearly, and can make it more difficult to get close enough to size them correctly during spotlight surveys, and to distinguish *C.porosus* from the Australian freshwater crocodile (*C.johnstoni*).

The time available on any particular night to survey some Queensland river systems can also be short because low tide times can fall at unfavourable hours and fringing vegetation can be such that bank exposure is limited. Thus, reliable survey requires careful pre-planning and precise timing. Spotlight surveys in the 1980s recorded comprehensive details on tide phases, moon phase and brightness, exposed bank, tidal lag with distance upstream, and the time and speed needed to cover each transect. This resource has been used to develop the survey plan and will be used for planning future surveys. More detailed information on survey planning is outlined in the *Crocodile Monitoring - Technical Manual*.

Helicopter surveys to count crocodiles are best done during the winter months and on falling tides during the early morning, as the colder waters encourage crocodiles to bask in early morning sunshine and make them more easily spotted. Even large and wary crocodiles will frequently swim into shallower waters on high tides and allow themselves to rest on the riverbank as the tide falls and the sun rises. This basking behaviour is important for temperature regulation.

Failings of past monitoring surveys

Not all historical survey activities have adopted fully standardised techniques and applied them to the same transects on the same waterways. In many cases, the quality and extent of survey coverage is sufficiently close between years that it does not weaken substantially the conclusions drawn about changes in crocodile population status. However, reliable estimation of change depends on standardisation of methods and survey transects, as planned for this program.

Data quality has been a significant problem at times, in particular for PEC region surveys not conducted by specialist research staff. Problems have arisen from

- inconsistent recording practices and standards,
- insufficient recording of survey metadata,
- failure to consistently record start and end locations and times of survey transects, and
- wrongly recorded or wrongly transcribed GPS locations.

Pro-formas have been developed for formal monitoring and ad-hoc reconnaissance surveys that are designed to reduce errors and avoid these pitfalls.

Quality assurance and Quality control (QA/QC)

QA/QC are very important components of a long-term monitoring program and are critical to ensuring the reliability and accuracy of the data.

Quality assurance (QA) is a design component of a monitoring program which will prevent mistakes and avoiding problems when delivering the data. It results in data of known precision and bias. QA includes staff training programs, calibration processes, written procedures and record keeping. This also includes a quality control program.

Quality control is a designed component of a monitoring program which ensures that the quality of the data is checked to ensure errors are detected.

Below is the table of QA/QC procedures relevant to wildlife monitoring programs, and how they will be applied to the crocodile monitoring program.

Step	Quality assurance	Quality control
Staff are properly trained	Staff are appropriately trained in an induction and provided with field procedures	Supervision of new and retained staff to ensure that they are operating in accordance with the training program
Data collection	Methods are outlined in the technical manual Calibration occurs through replication and duplication of surveys	Confirmation by team leader that methods are being used appropriately. Calibration results checked by regional manager and controls (e.g. retraining or removal from program) are implemented
Record keeping	Record keeping uses a consistent format. Upon completion of a survey the survey team checks that records are fully completed	Data validation – data checked by regional manager after being entered into the database

Spotlight surveys will involve a ‘spotter’ to estimate size and species of crocodiles, a ‘recorder’ that will record the data, and a ‘boat driver’. Staff will be required to complete a training program that will involve both a theoretical and practical component before engagement in the program with a refresher course undertaken annually (refer to the staff training program online). This is critically important to the quality of the program and documents relating to the training program will be collected and filed.

Training and experience in crocodile size estimation (‘spotter’) is especially important because many Queensland waterways may show small or no changes in the numbers of crocodiles sighted, but may show significant increases in the average size of crocodiles. Size distribution changes over time can indicate whether a population is recovering to something like its mature state and size distribution. However, equally, an experienced boat driver is essential for ensuring that surveys are undertaken safely and effectively, especially in remote areas and rivers with significant hazards (e.g. rock bars).

For some river transects, a spotlight survey will be replicated the following night. This replication will occur using the same team in a subsequent night. Comparison between these replicates will enable an understanding of the variability of surveying within a team. In addition, sites will also be duplicated by another team. This duplication will indicate the variability of surveying between teams and will provide quality control between teams. This is particularly important to occur between teams in the northern and southern regional offices to ensure consistency.

A standard approach to replication and duplication would include 5% of surveys. Duplicates and replicates should be scheduled into the annual operational plan.

For routine helicopter surveys, a single spotter (experienced in helicopter and boat spotting operations) is used together with a data recorder. All sightings have GPS locations recorded. Counts using two spotters can be used to better estimate sighting probabilities but are not used routinely as they are more costly. Crocodiles are sized as Small (<6ft), Medium (6-10ft), Large (10-12ft) or Very Large (>12ft) by the spotter. Additional notes recording the estimated size of each animal in standard 1ft size classes are also recorded, but not used for formal comparisons of counts – they are helpful to get informal insights into size distributions.

Some spotters and recorders suited to boat operations are unable to cope adequately with the nausea that can come with airborne operations. Helicopter crew will be selected based on their capacity to cope with the demands of the work.

Poor quality of record keeping, spotting and size calculation will result in further training and potential removal from the program.

Data management

Data will be collected either in paper form (pro-forma) in conjunction with a GPS, or in a computer tablet with a graphic interface designed specifically for crocodile surveys with GPS capability. It will be important that, along with crocodile size estimates, that start and stop times and start and end locations of every segment of the survey are recorded accurately on the data sheet along with environmental conditions (e.g. lunar phase, tide, weather). As soon as possible after a survey, raw data will be inspected by the data collector for any missing data or obvious errors in GPS location or crocodile size.

Ecological data is expensive to collect and irreplaceable. Monitoring data will be managed by a nominated data custodian responsible for collating and assessing data and reporting on crocodile surveys. This data custodian will have management responsibility for staff conducting the surveys and would ideally be the Regional Manager.

The data custodian will confirm the information collected as a result of the survey and assess the quality prior to entry into the database. To do this they will need to check the following:

- All information on the required data sheet is present, particularly information on time (start and finish), location, speed of boat, tide, lunar phase etc.
- Positional data is accurate
- The survey was carried out as identified in this monitoring plan and technical manual
- The information is recorded in the appropriate data format
- Staff who conducted the survey were appropriately trained for their role

It is very important that electronic data is securely stored on a regularly archived site and is supported by metadata that explains where, when and under what conditions it was collected. Therefore, the data custodian will submit monitoring data to WildNet after it has been checked. Data in WildNet should be considered the “point of truth” for crocodile data and any modifications must be justified and submitted to WildNet. This will maintain data integrity and ensure data is not lost.

Analyses and reporting

Spotlight and helicopter survey data will be used to test statistical hypotheses relating to the aims and objectives of the monitoring program. Analyses will essentially focus on assessing temporal changes in population size, density and size class distribution, nesting, and the level of recruitment in each bioregion. Along the PEC, annual changes in the number of attacks, sightings reported and crocodiles removed as part of the management program will also be analysed.

For analyses, the relative index of crocodile density (non-hatchling abundance and/or biomass) from a survey for a particular river transect will be calculated and grouped with historical data for the same transect. Where amenable, the data will be analysed by simple linear regression to test the hypothesis that the slope of the relationship between crocodile density and time is not different from zero. Data will be presented graphically to show trends. In the longer term, data should be reviewed and subject to statistical power analysis to determine whether the data allows detection of changes in crocodile population size in time frames that are useful for management purposes. Data from each biogeographic region should be assessed separately.

The results of the analyses will be presented in two different annual reports. The first will be a technical report containing detailed analyses and presentation of the data. The second will be a report card style report that will be released publicly. The format of this report will be a brief brochure that is able to be read and interpreted by members of the community, along with policy and decision makers, and will be produced in the same format wherever possible each year.

Review and governance

A major program of work, such as this, requires clear identified governance so that individual decisions are not made without considering the success of the overall program, thereby ensuring consistency year-to-year and among regional programs.

This program will be governed by the Director, Wildlife Assessment, Strategic Compliance and Northern Operations (WASCNO) with advice from the Crocodile Monitoring Program Management Team, which will consist of staff responsible for the management of the program. This quorum will comprise of the Director WASCNO, Northern and Southern Regional Managers, and the designated crocodile project officer for the crocodile program.

An operational plan, outlining proposed sites, dates, and teams for monitoring excursions will be developed and approved by the Crocodile Monitoring Program Management Team in April each year in order to be completed for the beginning of the financial year. There will also be an annual review of operations as part of normal project management, and each new plan will be revised according to any recommendations stemming from the review. Coordination of the project plan for the year will be via Regional Managers with linkage among responsible groups provided by the Director WASCNO and the crocodile project officer.

The technical merits of the monitoring program have been endorsed by the International Union for Conservation of Nature (IUCN) Crocodile Specialist Group, which includes many leading international experts in crocodile biology. Technical reports and report cards will also be peer reviewed by scientists with relevant expertise prior to release. In addition, a key advisor engaged by the Department to support the program holds a PhD in crocodile biology and was responsible for delivering rigorous crocodile surveys in far north Queensland dating from the 1980s.

After 3-4 years, or a period of time such that the power analysis reveals the ability to detect change in the population size, the program will be reviewed in light of increased information on threats, abundance and population trends. Monitoring of the impact of management by the Queensland Government, in particular crocodile removal zones, will need to continue.

Change management process

This Plan promotes the value of consistency above all else. However, changes in the physical, ecological and political/financial environment may result in a need to alter the sites visited and/or the timing of these visits. If change is required it must be managed to preserve objectives of this Plan. Any modification must be approved by the Crocodile Monitoring Program Management Team. Proposed changes should be directed to the technical leader for consideration by this group. These will be considered in February each year associated with the project planning process, unless an urgent case for change is apparent and communicated by the proponent.

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