CSIRO PUBLISHING
www.publish.csiro.au/journals/wr *Wildlife Research*, 2004, **31**, 527–534

The distribution and abundance of the estuarine crocodile, *Crocodylus porosus*, in Queensland

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Abstract. A total of 6444 *Crocodylus porosus* (4303 non-hatchlings and 2141 hatchlings) were recorded during 196 vessel-based surveys of 103 waterways to determine the distribution and abundance of *Crocodylus porosus* in Queensland. The surveys, conducted from January 1994 to December 2000, covered 4174.3 km of waterway. Population structure was biased towards immature crocodiles, with 91% of all animals sighted being less than the minimum breeding size for individuals in the Northern Territory. The mean relative density of non-hatchling *C. porosus* was highest in waterways of north-western Cape York Peninsula and Lakefield National Park, and lowest for waterways along the populated east coast of Queensland. The highest numbers of hatchlings were recorded from waterways of north-western Cape York Peninsula, where nearly 74% of all hatchlings were recorded during the seven-year survey period. The *C. porosus* population in northern Queensland appears to be undergoing a limited recovery, with marginal increases in the mean relative density of non-hatchlings in seven of the eight crocodile biogeographic regions. On the basis of the distribution and abundance of hatchling and non-hatchling crocodiles, the north-western Cape York Peninsula region contains the best habitat for *C. porosus* in Queensland, particularly in the Wenlock River and Tentpole Creek area.

Introduction

The estuarine crocodile, *Crocodylus porosus*, is a semi-aquatic, oviparous reptile that inhabits reefal, coastal and inland waterways in Queensland from Gladstone on the east coast, throughout Cape York Peninsula and west to the Queensland–Northern Territory border (Limpus 1980; Taplin 1987; Cogger 1992; Miller and Bell 1997). The species is usually restricted to coastal waterways and floodplain wetlands below major geographical obstacles, but populations may be encountered hundreds of kilometres upstream, such as in the Fitzroy River and waterways of the southern Gulf of Carpentaria (Taplin 1987). The distribution and habitat of *C. porosus* in Queensland has been described in detail by Limpus (1980), Magnusson *et al*. (1980), Messel *et al*. (1981), Taplin (1987), Miller (1994) and Miller and Bell (1997).

Intensive harvesting of wild crocodiles in Queensland began after the return of soldiers from the Second World War in 1945/46 (Taplin 1987). In Queensland, the majority of these crocodile hunters were land based, and over the years thousands of skins were exported and many juvenile crocodiles were hand-caught to supply the ‘stuffer’ trade (Roff 1966). The intensive harvest severely depleted the population of wild *C. porosus* in Queensland and raised concerns about the long-term viability of the population (Taplin 1987). The species was fully protected under the *Fauna Conservation Act 1974* and a monitoring program to determine the distribution and abundance of the species in Queensland was initiated in the early 1980s (Taplin 1987).

Following extensive vessel-based and aerial surveillance of *C. porosus* populations and habitat in Queensland, Taplin (1987) defined eight crocodile biogeographic regions based largely on major drainage divides, changes in physiography, land use and human population density (Fig. 1). These biogeographic regions differ considerably in available habitat and population abundance of *C. porosus*, thus providing a general structure by which to describe the estuarine crocodile population in Queensland. One of the key points of Taplin’s (1987) synopsis was that the distribution of crocodile habitat and estuarine crocodiles in Queensland was spatially variable and markedly different from that described in the Northern Territory. These differences necessitated the development of a specific management plan for the conservation and management of the species in Queensland (Taplin 1987, 1990).

A management program for *C. porosus* (QDEH 1995) defined a series of research objectives, including (1) to determine the population status and distribution of *C. porosus* in Queensland, (2) to locate areas of high population and/or nesting density where intensive research on population dynamics and experimental manipulations can be conducted, and (3) to identify and monitor current and potential threatening processes. In order to achieve these objectives, a series of standard vessel-based surveys were conducted in waterways throughout Queensland between January 1994 and December 2000. This paper describes the distribution, abundance and population structure of

 10.1071/WR02025 1035-3712/04/050527

C. porosus in Queensland and it represents the first major summary for the species since 1995 (QDEH 1995).

Methods

A total of 196 vessel-based surveys of 103 waterways were conducted in Queensland from January 1994 to December 2000 (Fig. 1, Table 1). All efforts were made to obtain a representative subsample of waterways between Gladstone and the Northern Territory border on an annual basis, but logistical constraints dictated that not all biogeographical regions could be sampled equally (Table 2). All vessel-based surveys were conducted in the dry season or early wet (July–November) and surveys within each biogeographic region were conducted at the same time each year to minimise variability in counts. The overall survey effort, in terms of both the number of surveys conducted and the number of kilometres covered per biogeographic region, concentrated on waterways of the East Coast Plains (ECP; 30.1% surveys, 25.4% km), Lakefield National Park (LNP; 24.5% surveys, 18.1% km) and those of north-west Cape York Peninsula (NWCYP; 17.9% surveys, 21.8% km) (Table 1). In total, 4174.3 km of waterway were surveyed (Table 1).

The techniques used to conduct vessel-based surveys to determine the distribution and abundance of *C. porosus* in Queensland followed those defined previously by Messel *et al*. (1981) and Bayliss (1987). Briefly, crocodiles (or evidence of crocodiles such as eyeshines and fresh slides) were counted at night from a 4-m outboard-powered vessel. All attempts were made to cover all habitats represented within each waterway, with most surveys extending upstream into the freshwater and non-tidal sections. Surveys were timed to coincide with the dark phases of the lunar cycle and falling tides, preferably spring low tides. The waters, exposed banks and riparian vegetation of selected waterways were scanned with a 100-W hand-held spotlight. Crocodiles were identified to species and their total length estimated (using feet and inches) by two observers. Where size estimates could not be made, sightings were classed as 'eyes only' (EO). Once a crocodile was sighted and its size estimated, the position of the animal was recorded using a global positioning system (GPS: Garmin™ 12XL. Garmin Corporation, Olathe, Kansas 66062, USA). The distances covered during each survey were calculated using the GPS's 'trip-meter' function or estimated using the ARCVIEW™ GIS program's scale function overlaid on georeferenced topographical maps (AUSLIG 1 : 100 000 series maps). Relative density of *C. porosus* is expressed as the number of non-hatchlings (>70 cm total length or >1 year old) (Webb *et al*. 1991) counted per kilometre of waterway surveyed. Given that hatchling crocodiles rarely flee when detected during spotlight surveys (Webb and Messel 1979), 'eyes only' sightings were assumed to represent animals >1 year old and are therefore included in calculations of relative density.

To enable comparison of our results with those of other researchers, data were grouped into size-class categories as used by researchers in the Northern Territory and Western Australia. Changes in the population structure of *C. porosus* in Queensland were then analysed using three different techniques. First, a Kruskal–Wallis non-parametric ANOVA was used to determine whether there was a significant difference in the median number of hatchling *C. porosus* sighted during surveys of the eight Queensland crocodile biogeographic regions between 1994 and 2000. Second, changes in the proportional representation of three different size classes of non-hatchling *C. porosus* (2–4 ft, 4–6 ft, >6 ft + EO: Webb *et al*. 2000) were analysed using a Chi-square homogeneity test and trends in these size classes were examined using regression analysis. In addition, changes in the relative density of non-hatchling *C. porosus* in waterways from each crocodile biogeographic region were examined using analysis of variance. Statistical analyses were performed using the SigmaStat™ computer statistics package. Means are provided ± one standard deviation. Proportional data were transformed using arcsine ($\sqrt{P}$) to improve normality and variance homogeneity.

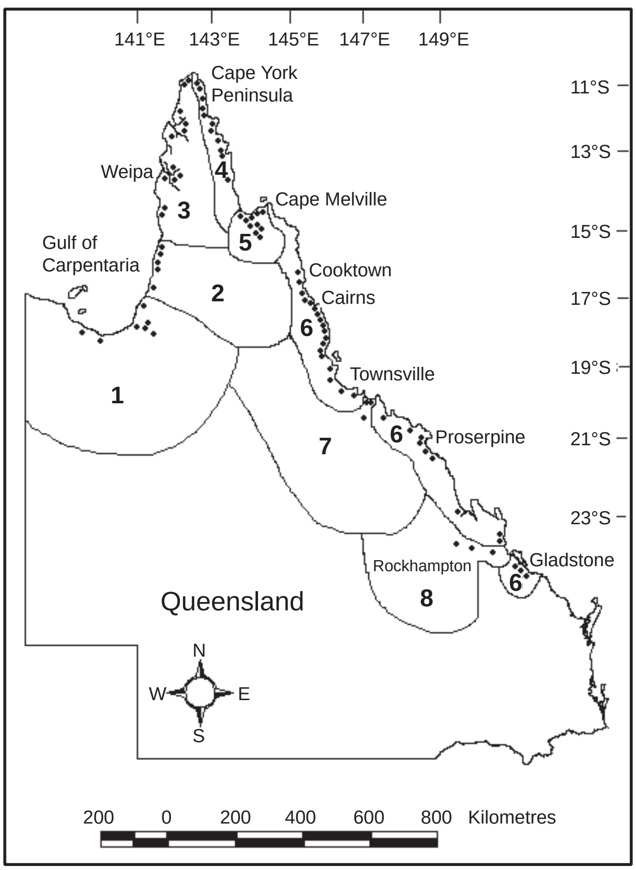

Fig. 1. Geographic distribution of vessel-based surveys conducted in Queensland from January 1994 to December 2000. Crocodile biogeographic regions in Queensland are after Taplin (1987) and are as follows: (1) Southern Gulf Plains; (2) Northern Gulf Plains; (3) North-west Cape York Peninsula; (4) North-east Cape York Peninsula; (5) Lakefield National Park; (6) East Coast Plains; (7) Burdekin River catchment; (8) Fitzroy River catchment.

Results

Distribution of C. porosus *in Queensland*

During the seven-year survey period 6444 sightings of *C. porosus* were recorded (Tables 1, 2). These sightings were broken down into 33.2% hatchlings and 66.8% non-hatchling *C. porosus* (including eyes-only sightings). There were marked differences in the distribution of non-hatchling *C. porosus* encountered between crocodile biogeographic regions. Over half of all crocodiles sighted during the survey period were recorded from waterways of the NWCYP (53.8%, $n = 3467$), followed by LNP (21.2%, $n = 1368$) and the ECP (9.1%, $n = 584$). This overall pattern was consistent throughout the survey period, with higher relative densities of non-hatchling *C. porosus* counted annually during surveys of the NWCYP and LNP regions (Table 2). Very few non-hatchling *C. porosus* were encountered in either the

Table 1. Summary information on vessel-based spotlight surveys conducted in Queensland during the period January 1994 to December 2000

Crocodile biogeographical region (after Taplin 1987)	Surveys conducted	Kilometres surveyed	Non-hatchling crocodiles sighted
Southern Gulf Plains	20 (10.2%)	550.4 (13.2%)	296 (6.9%)
Northern Gulf Plains	11 (5.6%)	267.3 (6.4%)	271 (6.3%)
North-West Cape York Peninsula	35 (17.9%)	910.8 (21.8%)	1884 (43.8%)
North-East Cape York Peninsula	17 (8.7%)	413.5 (10%)	247 (5.7%)
Lakefield National Park	48 (24.5%)	757.2 (18.1%)	1148 (26.7%)
East Coast Plains	59 (30.1%)	1058.8 (25.4%)	434 (10.1%)
Burdekin River Catchment	4 (2.0%)	57.3 (1.4%)	6 (0.1%)
Fitzroy River Catchment	2 (1.0%)	159.0 (3.8%)	17 (0.4%)
Total	196	4174.3	4303

Burdekin River Catchment (BRC) or the Fitzroy River Catchment (FRC) (Table 2).

During the survey period 2141 hatchling *C. porosus* were recorded, with 73.9% (n = 1583) of all hatchlings being recorded from waterways of the NWCYP region, followed by waterways of LNP (10.3%, n = 220) and the ECP (7.0%, n = 150) (Table 2). There were significant differences in the relative density of hatchling *C. porosus* between each crocodile biogeographic region (Fig. 2), with significantly higher densities recorded from waterways of the NWCYP

Table 2. Summary information on vessel-based spotlight surveys conducted in Queensland during the period January 1994 and December 2000

Crocodile biogeographical region	Survey year	n	Kilometres surveyed	Hatchlings sighted	Non-hatchling 2–4 ft	Non-hatchling 4–6 ft	Non-hatchling >6 ft + EO	Mean relative density[A] (± s.d.)
Southern Gulf Plains	1996	3	46.0	2	5	0	9	0.3 ± 0.3
	1997	6	239.1	68	29	9	77	0.6 ± 0.3
	1998	6	134.9	5	50	12	34	1.4 ± 1.1
	1999	5	130.4	9	24	10	37	0.8 ± 0.5
Northern Gulf Plains	1997	4	93.6	6	29	13	71	1.2 ± 0.4
	1998	4	90.8	4	28	11	46	1.1 ± 0.4
	1999	3	82.9	2	19	6	48	0.8 ± 0.3
North-western Cape York Peninsula	1994	4	180.5	337	113	51	62	2.0 ± 1.4
	1995	2	64.0	309	236	40	100	5.3 ± 1.8
	1996	6	183.5	229	160	30	64	2.1 ± 3.5
	1997	10	168.4	118	214	56	149	2.7 ± 3.3
	1998	6	104.9	101	121	16	82	2.4 ± 2.5
	1999	4	144.7	209	104	29	79	1.4 ± 1.0
	2000	3	64.8	280	74	26	78	2.2 ± 1.3
North-eastern Cape York Peninsula	1994	4	163.2	9	26	34	49	1.2 ± 0.6
	1996	1	15.0	0	10	3	3	1.1
	1999	1	77.7	20	14	5	12	0.4
	2000	11	157.6	56	23	10	58	0.6 ± 0.3
Lakefield National Park	1997	5	135.1	45	58	39	151	0.7 ± 0.4
	1998	16	202.0	69	132	50	139	1.6 ± 1.8
	1999	18	243.0	45	101	45	183	2.7 ± 2.4
	2000	9	177.1	61	104	37	109	1.9 ± 1.3
East Coast Plains	1994	2	18.5	5	10	2	16	1.5 ± 0.8
	1995	6	32.0	3	4	1	6	0.3 ± 0.1
	1996	5	87.0	11	6	3	6	0.2 ± 0.2
	1997	14	374.4	42	60	13	43	0.4 ± 0.4
	1998	8	148.3	54	38	6	24	0.4 ± 0.6
	1999	12	130.6	5	54	8	13	0.5 ± 1.2
	2000	12	268.0	30	47	9	65	0.6 ± 0.6
Burdekin River Catchment	1996	1	8.5	0	0	0	0	0
	1999	2	27.5	0	0	0	4	0.2 ± 0.2
	2000	1	21.3	0	0	0	2	0.1
Fitzroy River Catchment	1998	1	91.3	7	0	0	8	0.1
	1999	1	67.7	0	2	2	5	0.1

[A]The number of non-hatchlings (>1 year old) per kilometre of waterway.

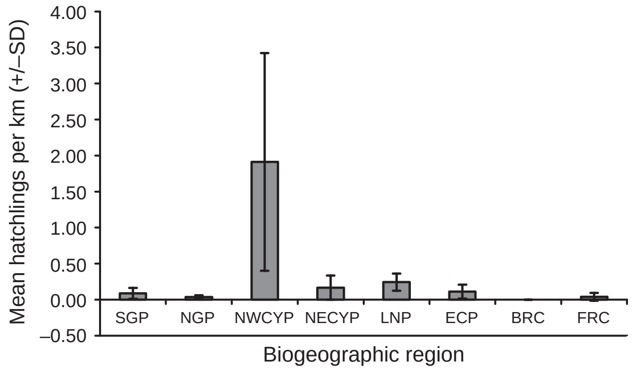

Fig. 2. Mean (±1 s.d.) numbers of hatchling *C. porosus* sighted per kilometre of waterway during surveys conducted between 1994 and 2000 in the eight crocodile biogeographic regions of Queensland.

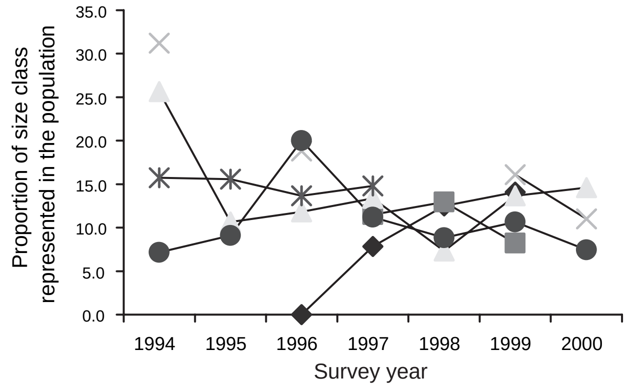

Fig. 4. Annual changes in the proportion of the *C. porosus* population represented by animals in the 4–6-ft size class.

region (Kruskal–Wallis non-parametric ANOVA: $\chi^2 = 24.7$, d.f. = 7, $P < 0.001$). This general pattern was consistent throughout the survey period, with high numbers of hatchlings being sighted annually in waterways of the NWCYP, LNP and ECP regions (Table 2).

Population structure of C. porosus *in Queensland*

The population structure of *C. porosus* in waterways of Queensland is strongly biased towards immature animals, with an average of 91.1 ± 4.6% of all animals sighted per survey year (excluding 'eyes only' sightings) being less than the minimum breeding size for individuals from wild populations in the Northern Territory (= 2.3 m total length: Webb and Manolis 1989) (Table 2). If it is assumed that 'eyes-only' sightings represent mature crocodiles, then the proportion of the population represented by immature *C. porosus* changed to an average of 75.4 ± 8.6% per survey year.

There were significant differences in the population structure of non-hatchling *C. porosus* between each crocodile biogeographic region. Using survey data collected for the years 1997–99 (when surveys were conducted in most biogeographic zones), there were significant differences in the proportion of the population represented by crocodiles in the 2–4-ft sizeclass ($\chi^2 = 114.5$, d.f. = 10, $P < 0.001$), 4–6-ft size class ($\chi^2 = 124.9$, d.f. = 10, $P < 0.001$) and >6-ft + EO size class ($\chi^2 = 58.6$, d.f. = 10, $P < 0.001$) between crocodile biogeographical regions. Waterways of the ECP region had the highest proportion of the population represented by crocodiles in the 2–4-ft size class, while waterways of the NGP, SGP and LNP had the highest proportion of larger crocodiles in the >6-ft + EO size class (Table 2). The population structure of *C. porosus* in waterways of northern Cape York Peninsula (comprising the NWCYP and NECYP crocodile biogeographic regions) was very similar (Table 2).

There were no discernible trends in the data describing changes to *C. porosus* population structure over the duration of the survey period. There were considerable fluctuations in the proportion of the population represented by crocodiles in the 2–4-ft, 4–6-ft, and >6-ft + EO size class (Figs 3–5), with a significant increase through time in the number of crocodiles in the larger size classes for three of the biogeographical regions (Table 3).

Relative density of C. porosus *in Queensland*

There were marked differences in the relative density of non-hatchling *C. porosus* between crocodile biogeographic

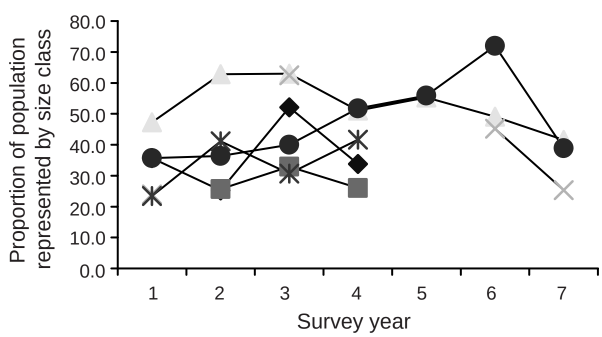

Fig. 3. Annual changes in the proportion of the *C. porosus* population represented by animals in the 2–4-ft size class.

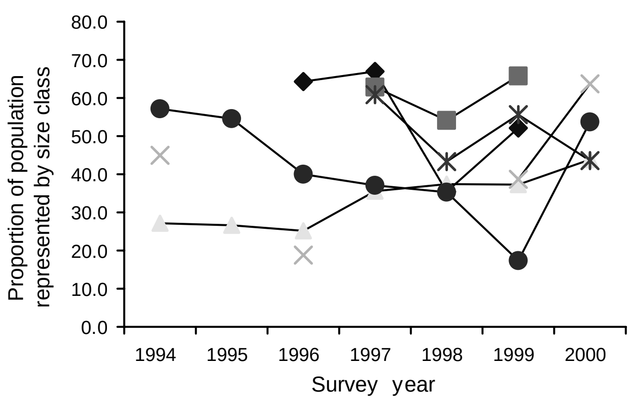

Fig. 5. Annual changes in the proportion of the *C. porosus* population represented by animals in the >6-ft+EO size class.

Table 3. Details of regression analysis describing changes in population structure for three size classes of *Crocodylus porosus* in Queensland from January 1994 to December 2000

Crocodile biogeographic region	Size class 2–4 ft *F*	*P*	4–6 ft *F*	*P*	>6 ft + EO *F*	*P*
SGP	0.12	0.76	22.60	0.04	1.19	0.34
NGP	0.002	0.97	0.85	0.52	0.06	0.84
NWCYP	1.70	0.25	1.10	0.34	26.30	0.004
NECYP	0.02	0.91	19.10	0.05	0.79	0.47
LNP	1.46	0.35	1.42	0.36	1.01	0.42
ECP	2.22	0.20	0.08	0.79	1.55	0.27

regions (Table 2). There were significantly higher densities of non-hatchling *C. porosus* recorded from waterways of the NWCYP and LNP regions than from waterways surveyed in the SGP, NGP, NECYP and the ECP (Table 4). As evidenced by the high standard deviations for the mean relative density of non-hatchling *C. porosus* for each crocodile biogeographic region (Table 4), there was considerable variation in relative density between waterways surveyed within each crocodile biogeographic region.

Discussion

These vessel-based surveys provide the baseline information to assess the current distribution and abundance of the *C. porosus* population in Queensland and are crucial for the long-term management of the species. The results of these surveys illustrate important differences between the Northern Territory and Queensland in terms of their *C. porosus* populations and the suitability of remaining habitat.

The spatial distribution of *C. porosus* in waterways of Queensland is variable, with considerable differences both within and between each crocodile biogeographical region. As determined previously (Magnusson *et al*. 1980; Messel *et al*. 1981; Taplin 1987; Miller 1994), waterways of the NWCYP biogeographical region provide the best habitat in Queensland for *C. porosus*. Nearly three-quarters of all hatchlings, and over half of all non-hatchlings recorded during our surveys were from this region, with most of those sightings (89.1%) recorded from the Wenlock River and its main tributary, Tentpole Creek. On the eastern side of Cape York Peninsula the situation is quite different, with low relative densities of crocodiles recorded from waterways of the NECYP region. Low population densities were recorded in areas with apparently suitable habitat, such as the substantial mangrove swamps near Lockhart River, Temple Bay and Shelburne Bay (Taplin 1987). On the basis of the low numbers of hatchlings sighted in the waterways of the NECYP region, it appears that the extent of suitable nesting habitat may be too limited to support any substantial increase in this region's crocodile population from recruitment.

The population density of *C. porosus* was relatively low in the ECP, BRC and FRC biogeographic regions. Due to sub-optimal ambient temperature conditions, these regions have always represented marginal habitat for *C. porosus* (Taplin 1987). Several anthropogenic influences may also contribute to lower densities in these regions. All three regions occur on the eastern coast of Queensland and have been intensively developed to support the highest human population in northern Australia (Taplin 1987; Cook *et al*. 1997). Consequently, these regions have undergone considerable modification to provide for agricultural, pastoral and urban expansion (Kofron and Smith 2001). This expansion has resulted in the loss of important nesting habitat for *C. porosus*, via reclamation of lowland floodplains by draining of wetland habitats and clearing of riparian vegetation corridors (QDEH 1995). Kofron and Smith (2001), who conducted a series of vessel-based surveys in waterways of the ECP, also recorded low densities of *C. porosus* at an overall mean relative density of 0.34 non-hatchlings km^{-1}. There has also been a considerable effort to reduce the potential for dangerous human–crocodile interactions in this region, with ~180 crocodiles being removed from this area during 1985–92 under approved management programs (QPWS, unpublished data). 'Problem' crocodiles, usually longer than 2m, are removed from these three regions on a 'case-by-case' basis (QDEH 1995; Kofron and Smith 2001), and the continuous, selective removal of medium to large animals has presumably had an impact on the *C. porosus* population there.

The population structure of *C. porosus* in Queensland is biased towards immature animals, with over 75% of all animals sighted during the survey period (including 'eyes only' sightings) being smaller than the minimum breeding size for wild *C. porosus* in the Northern Territory (Webb and Manolis 1989). Overall, the structure of the *C. porosus* population in Queensland is markedly different from that of the

Table 4. Analysis of variance on the relative density of non-hatchling *Crocodylus porosus* (non-hatchlings km^{-1}) between six crocodile biogeographic regions in Queensland

Survey year	d.f.	*F*	*P*	SGP *n*	Mean	s.d.	NGP *n*	Mean	s.d.	NWCYP *n*	Mean	s.d.	NECYP *n*	Mean	s.d.	LNP *n*	Mean	s.d.	ECP *n*	Mean	s.d.
1997	4,38	3.0	<0.05	6	0.56	0.3	4	1.15	0.4	10	2.71	3.3	Not surveyed			5	0.70	0.4	14	0.40	0.4
1998	4,39	1.4	0.25	6	1.40	1.1	4	1.13	0.4	6	2.35	2.5	Not surveyed			16	1.56	1.8	8	0.40	0.6
1999	4,44	4.2	<0.05	5	0.76	0.5	3	0.84	0.3	7	1.44	1.0	Not surveyed			18	2.65	2.0	12	0.55	1.2
2000	3,33	8.0	<0.005	Not surveyed			Not surveyed			3	2.22	1.3	10	0.61	0.28	9	2.03	1.3	12	0.58	0.6

Northern Territory (Webb *et al*. 1994, Webb *et al*. 2000). Pristine populations of crocodiles, which typically have a high rate of juvenile mortality (Webb and Manolis 1989), should contain a higher proportion of reproductively mature animals and fewer immature animals (Cott 1961; Graham 1968). The structure of the *C. porosus* population in Queensland, with a large proportion of immature animals and few adults, resembles the Northern Territory *C. porosus* population as it was during the mid-1980s, when the population recovery was taking place (Webb *et al*. 2000), and the Nile crocodile (*C. niloticus*) populations that were hunted intensively in Uganda and Zimbabwe (Cott 1961). Spotlight surveys conducted in the Northern Territory between 1994 and 1998 indicated that ~65% of the population was represented by animals larger than 6 ft (including 'eyes only' sightings) (Webb *et al*. 2000). In Queensland over the same period the proportion of the population represented by animals >6 ft (including 'eyes only' sightings) was only 36.6 ± 22.5%. The skewed population structure found in Queensland indicates that the population may still be recovering from hunting or that larger animals are still being removed from the population.

The mean relative density of non-hatchling *C. porosus* in the eight crocodile biogeographic regions in Queensland is much lower than for most waterways surveyed in the Northern Territory. Webb *et al*. (1994) surveyed a series of 24 waterways in the Northern Territory and recorded a mean relative density of 7.14 non-hatchlings km^{-1}. This exceeds any relative density recorded in Queensland, where the highest mean relative density recorded to date was only 2.7 non-hatchlings km^{-1}. Overall, because of the comparatively large areas of suitable nesting habitat in the Northern Territory (Magnusson *et al*. 1978; Webb *et al*. 1987), and a small human population relative to that of the populated eastern coast of Queensland (Taplin 1987), the *C. porosus* population in the Northern Territory is larger, and, on the basis of the reported size-class distribution (Webb *et al*. 2000), more representative of a stable age-class distribution (Cott 1961; Graham 1968) than the Queensland population.

Apart from waterways of the NGP region, the mean relative density of non-hatchling *C. porosus* has increased marginally in all crocodile biogeographical regions since the previous summary of their distribution and abundance was completed (QDEH 1995), indicating that a limited population recovery is taking place. Too few surveys have been conducted in the BRC and FRC regions for trends in the population status of *C. porosus* in these areas to be determined, and further surveys are required to build on the current database. To better understand the status of *C. porosus* in Queensland, increased survey effort in the NECYP, BRC and FCR biogeographic regions is needed.

There appear to be several factors that are limiting the recovery of *C. porosus* populations in Queensland. The primary limitation is a lack of suitable nesting habitat. Most available nesting habitat in coastal regions south of 13°S has been described as 'marginal' or 'poor' (Magnusson *et al*. 1980; Taplin 1987), with limited opportunities for successful nesting by female *C. porosus*. The limited availability of suitable nesting habitat is a by-product of the geography and topography of northern Queensland, which is markedly different from that of the Northern Territory (Webb *et al*. 1987; Webb and Manolis 1989). Hatchling numbers are limited by the absence of suitable freshwater swamps or ox-bow lake habitats that support high-density nesting in the Northern Territory (Webb and Manolis 1989; Webb *et al*. 2000). Most of the waterways that flow through the SGP and NGP regions have limited geographical relief, which means that many nests laid by *C. porosus* in this region are inundated during the monsoonal wet season, drowning the developing embryos (Magnusson *et al*. 1980; Taplin 1987). During a typical survey of waterways between the Northern Territory border and Weipa 50–150 hatchlings are usually recorded. However, during the 1998 survey only 2 hatchlings were sighted, indicating a remarkably poor year for hatchling production. This poor hatchling production can be attributed directly to the large wet season experienced during 1997–98.

The spatial distribution of successful nesting habitat for *C. porosus* in Queensland is also highly variable. Using the presence of hatchlings as an indicator of successful nesting habitat (Webb and Messel 1978; Da Silveira *et al*. 1997), good nesting habitat appears to be distributed throughout the NWCYP and LNP regions. The vessel-based surveys have provided important information on the nesting biology of *C. porosus* in LNP, where high numbers of hatchlings indicate active breeding; the data also indicate that most successful breeding occurs in the upper reaches of the tidal waterways and in permanent and semi-permanent inland waterholes. Limited nesting does occur in the FRC, but this is low density only. A high proportion of all hatchlings sighted during the seven-year study were recorded from waterways of the NWCYP region, and ~85% of these hatchlings were recorded from a single system, the Wenlock River. Nesting is successful in the Wenlock River system because this area has a relatively high geographic relief provided by the Weipa Plateau (Taplin 1987) and nests have a low incidence of flooding. This combination of factors is unique in Queensland.

There is considerable commercial netting for fish in waterways in northern Queensland (Taplin 1987; QFMA 1998), and, although formal reports are rarely lodged, anecdotal and observational data indicate that several medium-to-large *C. porosus* are caught and drowned annually, as has been demonstrated in the Northern Territory (Webb *et al*. 1984). Given that spotlight surveys indicate that many of these waterways support low numbers of large animals, it is possible that the incidental capture of medium-to-large *C. porosus* in mesh nets set for barramundi and other commercially important species is one of several factors having an impact on the recovery of estuarine crocodile populations in waterways of the SGP, NGP and LNP. Obtaining access to information that documents this incidental mortality is essential for future management of the species in Queensland.

Detailed knowledge of the spatial distribution of crocodiles in Queensland has important implications for successful management of the species, as wildlife management agencies need to balance the biological needs of estuarine crocodiles with the necessity of minimising potentially dangerous human–crocodile interactions. A monitoring program to determine changes in the population status of *C. porosus* in Queensland must contain a representative series of waterways from all crocodile biogeographic regions and should be conducted annually to provide sufficient statistical power to detect trends in the population (Stirrat *et al*. 2001). The importance of the Wenlock River and Tentpole Creek sites as crucial habitat for the continued maintenance of *C. porosus* in Queensland has been highlighted previously (Messel *et al*. 1981; Taplin 1987; Miller 1994), and effort needs to be expended to ensure that this area is afforded protected-area status from any potentially negative anthropogenic impact, such as netting for commercially important finfish species.

The distribution and abundance of the *C. porosus* population in Queensland is spatially variable and related to the availability of suitable nesting habitat. The number of crocodiles is highest for the waterways of the NWCYP region, because this area supports some of the best nesting habitat in Queensland. The population of *C. porosus* in Queensland is biased towards immature crocodiles with very few large animals sighted. It is suggested that population growth is restricted by a combination of factors, including a lack of suitable nesting habitat, incidental capture of large animals in nets set for commercial finfish species, habitat degradation and modification and the selective removal of large 'problem' crocodiles under approved management plans. On the basis of this combination of factors, it is suggested that large numbers of large *C. porosus* will be supported only in remote areas on Cape York Peninsula and the Gulf of Carpentaria.

Acknowledgments

The Queensland Environmental Protection Agency provided funding and infrastructure support to conduct research and monitoring on *C. porosus* in Queensland over the period January 1994 to December 2000. Many Departmental staff and volunteers donated their time and energy to make these surveys possible, with special mention to Dean Brake, Mark Burnham, Wayne Coleman, Mike Delaney, Dr Nancy FitzSimmons, Dr Chris Kofron, Philip Koloi and Rusty Smith. Drafts of this manuscript were reviewed by Dr Kirstin Dobbs, Professor Gordon Grigg and Dr Martin Cohen.

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Manuscript received 15 April 2002, accepted 3 March 2004