CHAPTER 11

Crocodile Management in the Northern Territory of Australia

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IN the Northern Territory, the endemic Australian freshwater crocodile, *Crocodylus johnstoni* Krefft, and the saltwater or estuarine crocodile, *Crocodylus porosus* Schneider, were both hunted commercially before protection in 1964 and 1971 respectively. At that time both species had become "rare" in areas where they had once been "common", and this change in density can be attributed almost exclusively to hunting. Habitat degradation, although a problem in some areas, appears to have played a minor role in reducing crocodile densities in the Northern Territory.

Protection proved an effective management strategy for both species. It was introduced to increase densities and that aim was achieved. For example, *C. porosus* was hunted commercially for 26 years (1945/46 to 1971), and during that period about 140,000 animals were killed. The population at the time of protection is unknown, but was very much a remnant. After 13 years of protection (1984) the population is about 40,000 individuals, and this represents some 30% to 50% of the estimated population before commercial hunting started (Webb *et al.* 1984b). With *C. johnstoni* an equivalent if not greater recovery seems to have taken place (Webb *et al.* 1983a); they were hunted intensively for only five years (1959 to 1964) and have now (1984) been protected for 20 years.

The formulation of management plans more complex than blanket protection was a response to the changed status of both species. A passive management strategy based chiefly on legal protection may have proved an adequate conservation strategy in the short-term, but a more active programme, that generates interest in the conservation of crocodile habitats, is needed for long-term protection. Our immediate objective of establishing a sustainable industry based on a renewable and valuable wildlife resource, is seen as a positive conservation goal, consistent with the aims of both the World Conservation Strategy (IUCN 1980), the Australian Conservation Strategy (Myers 1983), and with recommedations of the U.S. National Research Council (NRC 1983).

This chapter reviews the history of crocodile hunting and management within the Northern Territory and discusses the ranching programmes proposed and operating for both species.

HISTORICAL PERSPECTIVE

Crocodile meat and eggs were used as a food source by Aboriginal people for some 20,000 to 40,000 years prior to European contact (McBryde 1979; Flood 1983). The impact of this harvesting on "pristine" populations is unknown, but should not be lightly dismissed. Aboriginals are very skilled hunters and they are especially adept at locating nests of both species (Webb *et al.* 1977; Magnusson 1982). Aboriginal hunting may be related to geographic variation in "wariness" of *C. johnstoni*, which affects the suitability of hatchlings (even if collected as eggs) for raising in captivity. In areas where Aboriginals rarely, if ever, ventured, *C. johnstoni* are not wary (Webb 1984b), whereas in areas heavily occupied by Aboriginals in the past, where the crocodiles become isolated in small pools during the dry season, they are most wary.

There are scattered references to *C. porosus* from the time of exploration and early settlement (1818-1900), but virtually no mention of *C. johnstoni*. This is perhaps not surprising, as much of the early exploration and settlement was coastal and *C. porosus* represented a dramatic and noteworthy animal to record in diaries, log books, memoirs and adventure books. Even so, when attempting to research the history of crocodiles in the Northern Territory one is struck by just how few times *either* species is mentioned.

The literature on *C. porosus* is consistent with a very "patchy" distribution, both within and between rivers (Webb *et al.* 1984b). *Crocodylus porosus* never appear to have been evenly distributed, on

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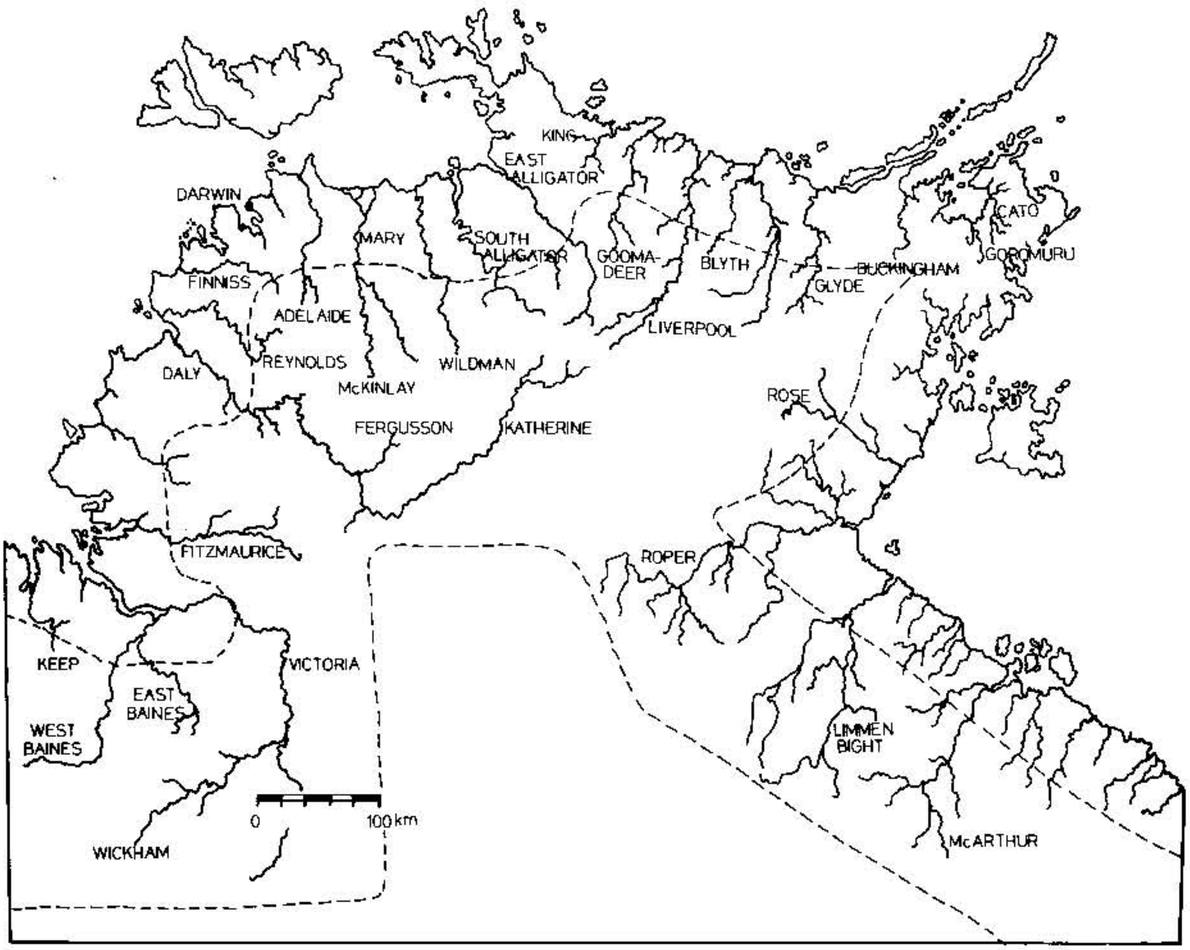

Fig. 1. The distribution of *Crocodylus porosus* (within coastal line) and *Crocodylus johnstoni* (between the lines) in the Northern Territory. In some rivers *C. johnstoni* extend into the *C. porosus* area.

both banks of a river, along its complete length, even in areas where they were generally "abundant". The highest numbers appear to have been in the Adelaide, Roper, Daly and Alligator Rivers (King 1827; Stokes 1837; Herbert 1870; Scott 1873; Sowden 1882; Searcy 1905, 1907, 1911; Anon 1906; Lee 1925; Dahl 1926; Christie 1946) (Fig. 1). During this early period of settlement crocodiles were killed as vermin or for sport, and in 1874 some preserved hatchlings were sold on an experimental basis (Anon 1874). However, there is no evidence of any commercial scale hunting, as for example occurred with *Alligator mississippiensis* during the American Civil War (see Joanen Chapter 4).

During the 1920's there were trial shipments of crocodile skins and experiments with a minor curio industry, but neither was to develop. Commercial crocodile hunting in the Northern Territory began in 1945 and was directed solely at *C. porosus*. The population at that time has been estimated as being no more than 100,000 individuals (Webb *et al.* 1984b), and unevenly distributed around the coast and associated freshwater swamps. On the basis of interviews with people who hunted during the 1940's, the following statement reflects accurately what the 1945 hunters found:

"Do not imagine that all the Northern Territory rivers and tidal creeks are thus swarming with the estuarine crocodile. Although in occasional localities along the length of the Territory coast crocodiles are numerous, in most waterways they are not nearly so plentiful". (Idress 1946).

Between 1945 and 1971 the number of Northern Territory *C. porosus* skins traded has been liberally estimated as 113,000; 87,000 between 1945 and 1958 and 26,000 between 1959 and 1971 (Webb *et al.* 1984b).

Crocodylus johnstoni was largely ignored between 1945 and 1958. Their skin was inferior to that of *C. porosus*, because it had relatively large belly scales and some skins contained sub-dermal deposits of bone that the tanning technology of the period was unable to remove without blemishing the final product. Increased demand for skins and advances in tanning technology were to change this situation, and in 1959 a market for *C. johnstoni* skins was established. According to hunters, the majority of skins came from the billabongs and upstream freshwater sections of the Mary, McKinlay, Victoria, Daly, Roper and Alligator Rivers. No precise data on the total numbers taken are available, but a preliminary analysis similar to that carried out for *C. porosus* (Webb *et al.* 1984b) indicates about 60,000 hides were traded. *Crocodylus johnstoni* was protected in 1964, five years after hunting started and seven years before *C. porosus* was protected.

In neighbouring Queensland, neither species of crocodile was protected until after a total export ban was imposed by the Commonwealth Government in 1972. This asynchrony in legislation meant that *C. johnstoni* was protected and recovering in the Northern Territory (since 1964) and in Western Australia (since 1962), but skins could still be sold and exported through Queensland. A significant but illegal interstate traffic in *C. johnstoni* skins is known to have existed (Bustard 1970, 1971; Webb *et al.* 1984b), but its extent is difficult to quantify. On the basis of interviews with Queensland buyers operating at the time, it may have been as high as 20,000 skins since 1964. If so, the total Northern Territory harvest (pre- and post-protection) of *C. johnstoni* would have been about 80,000 animals.

Mounted specimens of both *C. porosus* and *C. johnstoni* were sold into a local curio market, although again the extent of the industry cannot be reliably quantified. Our estimate of 20,000 young *C. porosus* (Webb *et al.* 1984b) is probably an overestimate.

The structure of the populations at the time of protection is better known for *C. porosus* than for *C. johnstoni*. When the hunting of *C. porosus* ceased in 1971, most populations contained a nucleus of wary adults. In intensively harvested areas most other age classes were scarce, but in remote areas, where intense hunting occurred irregularly, there was often a large complement of unharvested one and two year old animals (Webb *et al.* 1984b). Larger juveniles, especially those between one and two metres long, were rarely sighted. With *C. johnstoni* a similar situation is thought to have existed although there appear to have been more subadult survivors. In the McKinlay River area, where *C. johnstoni* was heavily hunted between 1959 and 1964, the 1978/79 age structure contained a significant complement of animals that would have been subadults when the legal hunting period finished (Webb and Smith 1984; Webb *et al.* 1983a).

Most of the published research into crocodile biology stems from studies initiated after protection. A considerable body of information about crocodile biology had been accumulated by the hunters, but little of it was ever published. The University of Sydney initiated a programme of research into the basic biology of *C. porosus*, especially in tidal habitats, which was to generate a considerable amount of basic information (Drane *et al.* 1977; Grigg 1978, 1981; Grigg and Alchin 1976; Grigg and Cairncross 1980; Grigg *et al.* 1980; Magnusson 1979a-c, 1980a,b, 1981, 1982; Magnusson and Taylor 1980, 1981; Magnusson *et al.* 1978a,b; Messel 1977; Taplin 1984a,b; Taplin and Grigg 1981; Taplin *et al.* 1982; Taylor 1979; Taylor *et al.* 1978; Webb 1977a,b; Webb and Messel 1977a,b, 1978a,b, 1979; Webb *et al.* 1977, 1978a,b). In addition, they surveyed and re-surveyed crocodile numbers across the Northern Territory coastline, providing a unique data base on population recovery (Messel 1977; Messel *et al.* 1979a-g, 1980a-f, 1981a-c, 1982, 1984). The Conservation Commission of the Northern Territory (then the Territory Parks and Wildlife Commission) initiated a programme of research into the biology and management of *C. johnstoni* (Edwards 1983; Ferguson 1985; Smith and Webb 1985; Webb 1982, 1985, 1986; Webb and Gans 1982; Webb and Manolis 1983; Webb and Smith 1984; Webb *et al.* 1982, 1983a-d,f,g, 1984a) and addressed specific management problems with *C. porosus* (Bennett *et al.* 1985; Ferguson 1985; Seymour *et al.* 1985; Webb *et al.* 1983e,g,h). More recently they conducted a wide ranging survey of *C. johnstoni* recruitment (Webb and Smith 1984) and *C. porosus* population densities (Bayliss *et al.* 1986; Webb *et al.* 1984b). The Australian National Parks and Wildlife Service have surveyed *C. porosus* populations within the Alligator Rivers region over a number of years (Jenkins 1979; Jenkins and Forbes 1984).

The recovery of *C. johnstoni* populations that occurred with protection went largely unnoticed by the public. The habitats occupied by the species tend to be away from population centres, there is no legal commercial fishing in the inland freshwater areas (and thus no opportunity for interaction with net fishermen), and the species does not attack people, cattle or horses. In contrast, the post-protection recovery of *C. porosus* was marred by a series of interactions between crocodiles and people.

The recovery of *C. porosus* must be viewed in the correct context. They had been hunted and kept at low densities for many years before protection in 1971. In areas where few if any crocodiles had been sighted in "years", crocodiles began to appear regularly. Professional fishermen operating in the coastal estuaries began to encounter crocodiles more frequently in their nets. As elsewhere in the world, the interaction is of economic importance. Nets are damaged and need repair, nets are often tangled reducing their effectiveness, netted fish are often eaten or damaged in the nets, and to remove crocodiles from nets entails a risk of personal injury. Amateur fishermen were also affected by increasing numbers of *C. porosus*. In the past, isolated billabongs and creeks could be fished from the water's edge or from small boats with little chance of even seeing a crocodile or worrying about what to do if one appeared. When crocodiles began to appear more regularly, this freedom was infringed. Swimming in coastal areas and underwater construction in and around the jetties and wharfs of Darwin, were similarly affected.

A crocodile "problem" was developing, and it reached a peak in the late 1970's when: a tourist who was swimming was killed by a crocodile; a woman washing at the edge of a billabong was killed by a crocodile; a large crocodile began attacking boats in a popular fishing hole; a safari operator was taken and badly mauled by a crocodile; and, a veterinary officer had his leg mauled by a crocodile when he was walking at the edge of a swamp.

Public attitude to *C. porosus* polarized rather quickly. On the one hand, residents who had arrived in Darwin as far back as the mid-1950's were seeing more crocodiles than they had ever seen before, and were experiencing a restriction on the freedom they had enjoyed in wetlands for the last twenty years. On the other hand, preservationists were claiming no recovery had taken place and that the *C. porosus* population was in danger of extinction. The Australian *C. porosus* population was shifted from Appendix II to Appendix I of CITES at this time, even though the Northern Territory Government objected on the grounds that it was both inappropriate and unnecessary.

At this stage, four developments set crocodile management on its current path:

1. Public safety demanded increased awareness of crocodiles: the positive effects of protection needed to be clearly stated, and advice given on how crocodile-people interactions could be reduced. This led to a *public education programme*.
2. The probability of crocodile-people interactions was greatest in the heavily populated areas. On the basis that it could be reduced by removing crocodiles from those areas, a *problem crocodile programme* was initiated.
3. Permission was given for the first crocodile farm to be started, which would serve as a centre for public education, an additional tourist facility and a place to house problem animals. A commitment was thus made to a *crocodile farming programme*.
4. After considering the situation that may exist in twenty or thirty years time, it was decided that public support for the conservation of both species of crocodile and their habitats would be greatly enhanced if there was a financial incentive to have crocodiles present in large numbers in the wild. This development complemented a growing need for the Northern Territory to develop sources of primary production that were well suited to the "wet-dry" tropics, and was consistent with the crocodile farming programme already initiated. Research into a *sustainable harvest programme* was initiated for both species.

DISTRIBUTION AND HABITATS

When assessing the distribution and abundance of both species of crocodile within the Northern Territory, it is important to recognize that we are dealing with a land mass that is essentially arid. Permanent wetlands are scarce relative to those in countries such as Papua New Guinea, the southern U.S. and Venezuela, and our crocodilian populations in the wild will never be as large as in those countries. As in the Venezuelan Llanos, crocodile habitats in the Northern Territory are dominated by a "wet-dry" season dichotomy which is superimposed on a "warm-cool" temperature regime. In terms of crocodile biology, this gives three significant seasons (Table 1) which can be referred to generally as "wet-warm", "dry-cool" and "dry-warm" (Webb 1986).

Table 1. Meteorological data from Middle Point, 50 km south-east of Darwin (over 15 years).

Month	Temperature (°C)			Rainfall		Relative Humidity
	Daily max.	Daily min.	9 a.m.	Mean (mm)	No. of raindays	9 a.m. (%)
Jan.	32.8	23.9	27.6	323	20	84
Feb.	31.7	23.9	26.8	281	20	87
Mar.	31.9	23.7	27.0	262	18	85
April	33.0	22.1	26.8	87	7	77
May	32.0	19.4	24.8	24	3	71
June	31.1	17.0	22.8	4	0	67
July	30.9	15.1	21.5	0	0	61
Aug.	33.0	17.7	24.3	1	0	67
Sept.	34.7	20.3	26.9	10	2	65
Oct.	35.5	22.9	28.5	54	6	68
Nov.	35.5	23.8	29.1	116	12	70
Dec.	33.7	23.9	28.2	245	16	79

The wet season rains usually begin in November, when ambient temperatures are high. The peak of rainfall, with widespread flooding of low-lying areas, is in January- February. Rains usually abate in March-April and thus the period November to April is usually considered the wet season. As ambient temperatures are high during most of this period, we can refer to it as a "wet-warm" season. From April-May through to the start of August, rains cease and ambient conditions are appreciably cooler than either before or later (Table 1); this can be considered a "dry-cool" season. During and after August, ambient temperatures steadily increase, although there is little if any rain until November. This period can be referred to as the "dry-warm" season, and as wetlands are steadily receding, it is a period of maximum concentration of crocodiles.

The general distributions of *C. porosus* and *C. johnstoni* within the Northern Territory are shown on Figure 1, and the types of wetlands they occupy are diagramatically represented in Figure 2.

The majority of *C. porosus* occur in tidal rivers (B, C, D on Fig. 2), coastal floodplain channels, billabongs and swamps (E, F, G respectively on Fig. 2), or

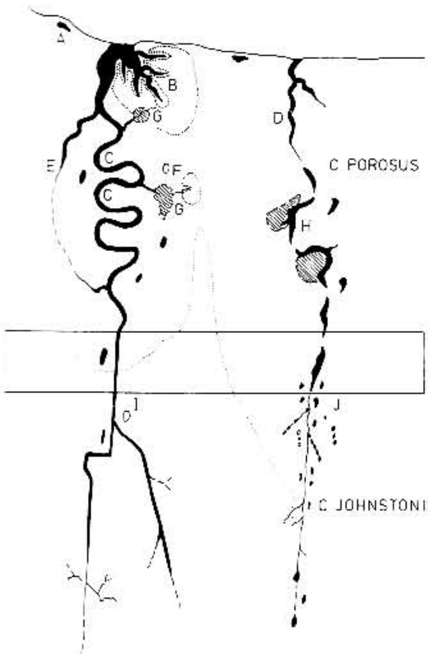

Fig. 2. A schematic representation of Northern Territory wetlands occupied by crocodiles. Dots mark elevated land and cross-hatched areas are freshwater swamplands. A, freshwater billabongs behind beachlines; B, a tidal river penetrating into elevated land; C, a tidal river meandering over a floodplain; D, remnant of a meandering tidal river which has become silted; E, tidal floodplain creek with no freshwater input during the dry season; F, isolated floodplain billabongs; G, spring-fed freshwater swamp adjacent to a tidal river; H, isolated sections of an old meandering river no longer open to the sea and containing freshwater and often floating rafts of vegetation; I, non-tidal upper reaches of a river draining rocky escarpment; J, a seasonally flowing mainstream channel which has numerous freshwater billabongs associated with it.

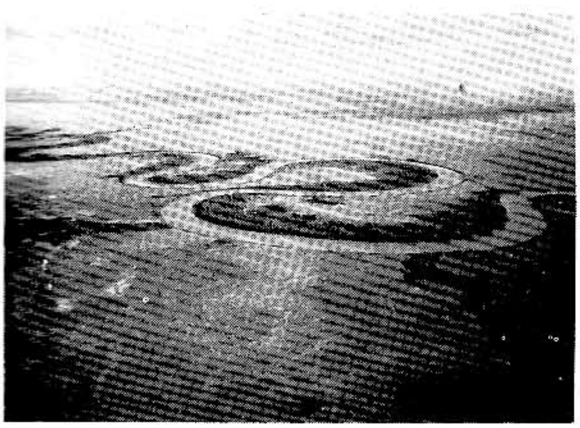

Fig. 3. A meandering tidal river bordered with mangroves and floodplain grasses (Adelaide River, N.T.).

are in silted river channels (H on Fig. 2) which were once meandering tidal rivers, but which now contain fresh water. In waterways under tidal influence (B, C, D on Fig. 2) the banks are muddy and lined with mangrove or floodplain sedges and grasses (Fig. 3). Where tidal rivers terminate in elevated land (B on Fig. 2) or are isolated branches of a mainstream (E, F on Fig. 2) continual evaporation during the dry season can result in salinities up to 70‰ (sea water is usually about 32‰). In contrast, the salinity within long meandering mainstream channels (C on Fig. 2; Fig. 3) usually decreases with increasing distance upstream because there is an upstream input of fresh water for at least part of the dry season. Nevertheless, a salt wedge moves progressively upstream from the coast, increasing salinities as the dry season progresses (Messel *et al.* 1981b).

Fig. 4. Crocodylus porosus nest in a freshwater swamp draining into a tidal river (Adelaide River, N.T.).

Where permanent springs are associated with elevated land beside tidal rivers (G on Fig. 2) there are often isolated patches of freshwater swamp, which are favoured sites for *C. porosus* nesting (Fig. 4). These sites are not subject to inundation by saline water during spring tides and tend to be above the general level of flooding on the adjacent plains.

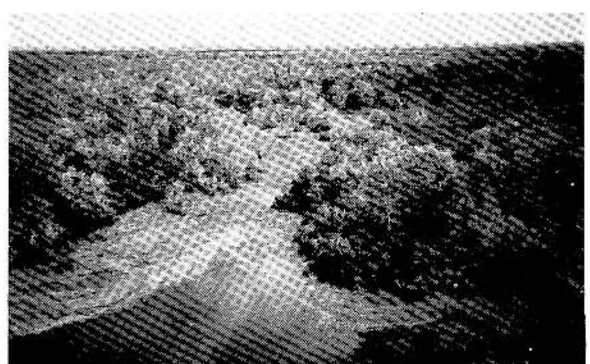

Fig. 5. Floating rafts of vegetation covering one arm of a freshwater billabong. *Crocodylus porosus* nest on these rafts (Finniss River, N.T.).

Where a meandering tidal river has silted, there typically remains a short tidal segment (D on Fig. 2) and a series of isolated non-tidal billabongs (H on Fig. 2) which in reality are the separated meanders of an original tidal river (C on Fig. 2). These contain fresh water throughout the year although it does not usually flow during the dry season. Where undisturbed by feral and domestic stock, extensive floating rafts of vegetation may extend from the shoreline out over the water (Fig. 5). These rafts are important *C. porosus* nesting sites.

Fig. 6. The upstream, freshwater reaches of most Northern Territory rivers contain exclusively *Crocodylus johnstoni* (Mann River, N.T.).

The wetlands upstream of those described above are occupied mainly by *C. johnstoni*. They contain non-tidal fresh water which may or may not flow during the dry season. Upstream river channels may be situated in rocky escarpments or plateaus (I on Fig. 2; Fig. 6), or they may traverse floodplains (J on Fig. 2). In either case, secondary creek lines contract into isolated permanent and semi-permanent billabongs where *C. johnstoni* congregate in the dry season. Substrates vary but are typically sand rather than the mud of tidal downstream areas. During the wet season there is widespread flooding of these upstream habitats and particularly high water levels occur where rivers pass through rocky gorges.

As indicated on Figure 2, the distribution of *C. johnstoni* and *C. porosus* overlap in many river systems, giving recognizable zones of sympatry. In addition, individuals of one species are sometimes found in areas dominated by the other, either well upstream or downstream of the sympatric zone. Recent evidence (Webb *et al.* 1983g) suggests that *C. johnstoni* may be excluded from downstream areas as numbers of the larger and more recently protected *C. porosus* increase.

ABUNDANCE

The density of *C. porosus* varies greatly between different habitats, some of which are relatively "easy" to survey from boats or helicopters and some of which are extremely difficult to survey. *Crocodylus porosus* reach their highest densities in vegetated floodplain billabongs and swamps. Densities of up to 35 *C. porosus* per kilometre of channel have been recorded from spotlight counts and the mean value from some 135 kilometres of channel examined was 5.6 crocodiles sighted per kilometre (Webb *et al.* 1984b), Given that the vegetation in such swamps shields many crocodiles from the spotlight, the real densities are appreciably greater than those recorded.

In tidal channels, a much higher proportion of the total population of *C. porosus* are seen during spotlight surveys. However, densities both within and between rivers depend partly on proximity to successful nesting areas. In tidal channels associated with successful nesting areas some 3.2 crocodiles were sighted per kilometre of channel, whereas in those with minimal or no associated breeding areas 0.7 were sighted per kilometre (Webb *et al.* 1984b).

To obtain an estimate for the total *C. porosus* population, the amount of habitat available was quantified approximately, multiplied by the densities sighted in samples of those habitats surveyed and then multiplied again by size-specific corrections between relative and absolute densities derived in tidal areas (Bayliss *et al.* 1986). A very conservative minimum estimate was 30,000 individuals and the real population is thought to be at least 40,000 and up to 50,000 (Webb *et al.* 1984b).

With *C. johnstoni*, absolute densities are equally variable between different habitats. In rocky Arnhem Land plateau channels (Fig. 6), densities are about 5 to 15 per kilometre where there is permanent water (Webb 1985). In floodplain areas such as the McKinlay River, *C. johnstoni* congregate in the deep billabongs that will contain water throughout the dry season (Webb *et al.* 1983f) and densities can be very high in short "lengths" of pool; for example one hundred animals caught in a pool seventy metres long. In larger river channels, such as the Daly, Mary, Victoria and Baines, mean spotlight count relative densities range from 15 to 25 per kilometre. We have not quantified the availability of *C. johnstoni* habitat in a form similar to that done for *C. porosus*, but on the basis of some crude estimates place the current population within the range of 30,000 to 60,000 individuals.

ECOLOGY AND POPULATION DYNAMICS

Although a substantial amount of information on the ecology of both *C. johnstoni* and *C. porosus* is now available, we here review only those aspects that are fundamental to assessment of population dynamics, and which accordingly have direct application to the management of both species.

Reproduction

Information on *C. johnstoni* reproduction is in Compton (1981), Smith and Webb (1985), Webb and Smith (1984) and Webb *et al.* (1983d). Information on *C. porosus* reproduction within Australia is in Magnusson (1979a-c, 1980a,b, 1981, 1982), Magnusson and Taylor (1980, 1981), Magnusson *et al.* (1978a,b), Messel *et al.* (1981b) and Webb *et al.* (1977, 1983e,h, 1984a,b).

1. *Crocodylus johnstoni*

Within the McKinlay River area, females mature at 74-78 cm snout-vent length (SVL) and 11-14 years of age; males mature at about 87 cm SVL and 16-17 years of age. Reproductive senescence appears to be about 40-45 years of age and there are probably a few years between senescence and death. In an average year, an estimated 84% of females greater than 11 years of age and 8% of females less than 11 years of age will nest. However, total nesting effort was reduced by about 30%, and the time of nesting delayed by two weeks in a year in which the previous wet season was particularly late and dry season conditions were unusually cool (1983).

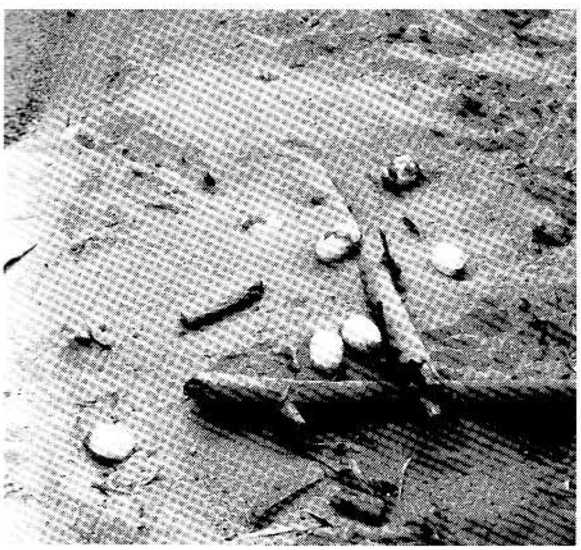

Fig. 7. A *Crocodylus johnstoni* nest excavated by another nesting female.

Nesting is a dry season activity and usually occurs in August-September. Mating appears to occur some six weeks prior to nesting. *Crocodylus johnstoni* is a hole-nesting species and can be considered a "pulse" nester; all females nest in a contracted period of about three weeks. Females lay their eggs in sand or other friable substrates close to water and typically excavate down to a distinct moisture band into which the eggs are deposited. Large females with bigger clutches of large eggs tend to nest before small females, which have smaller clutches of small eggs. Mean clutch size is 13 eggs, mean egg weight 68 g and mean hatchling weight 42 g.

Incubation times vary between about 65 and 95 days, although most are between 75 and 85 days. Females do not attend their nests during this period and do not appear to defend them against predators. Around late October, females show renewed activity on the nesting banks which coincides with imminent hatching. They excavate nests from which young are calling but ignore sites with dead eggs, or where eggs have been taken by predators. At least some females carry their hatchlings to the water, and 0.4% of a large sample of hatchlings examined (N = 4573) had puncture marks attributed to this behaviour (unpublished data). Hatchlings congregate in creches among fallen trees or semi-emergent vegetation, and adult females often remain with them. On occasion these females will threaten investigators interfering with the hatchlings.

This pattern of nesting shows slight geographic variation. Nesting tends to be slightly later in the Victoria and Roper River regions and female and clutch sizes appear to be smaller there than elsewhere. In the McKinlay River area friable sand banks are often restricted to small patches associated with any particular pool and nests are often made next to each other. This same "colonial" nesting occurs in other areas, but where there are extensive sand banks, nests are usually well separated from each other.

2. *Crocodylus porosus*

Females can mature when about 105 cm SVL, but most are about 120 cm SVL and about 12 years of age. Males mature at about 165 cm SVL and 16 years of age. Age at reproductive senescence and the maximum age are unknown, although one large male had bone rings indicating 65+ years of age (unpublished data). The proportion of mature females that nest each year is unknown, but circumstantial evidence indicates it is probably 80-90%. However, nesting effort was reduced by 30 to 50% in a year in which wet season rains were delayed until February (1982/83 wet season).

Nesting is a wet season activity. Courtship and mating occur 4-6 weeks before nesting and may continue throughout the wet season. Females typically select nest sites in areas of tall vegetation (>1 m) close to permanent water and build a large mound into which the eggs are deposited. Egg-laying begins in November, reaches a peak in January/February and may continue until May. Circumstantial evidence indicates that a small proportion of females may nest twice in a wet season. Mean clutch size is 52 eggs, mean egg weight 113 g and mean hatchling weight 72 g.

Incubation times vary between about 65 and 114 days, but most take 85 to 95 days. Females usually attend their nests during this period and will often defend the nest against potential predators. In

Fig. 8. A female *Crocodylus porosus* beside her nest on a floating raft of vegetation.

response to hatchling calls, attendant females excavate the nest and probably carry the young to the water. Here the hatchlings usually form a creche, and the female may remain with it for more than two months. In cases where females do not attend nests, hatchlings can sometimes burrow out of the nests, but in muddy nests, where the exterior has baked hard in the sun, excavation may be essential.

This pattern of nesting shows little geographic variation, although there are differences in the time of nesting between different habitats. These are poorly understood, but within any one river system the peak of nesting in freshwater swamps does not necessarily coincide with the peak of nesting on the banks of tidal rivers. Similarly, nesting in freshwater swamps associated with some rivers peaks at least a month before nesting in the freshwater swamps associated with other rivers.

Sex Ratios

Both *C. johnstoni* and *C. porosus* embryos have their sex determined by the incubation environment of the egg, and thus the potential is present for primary and secondary sex ratios to deviate markedly from 0.50 (expressed as the proportion of males) (Webb and Smith 1984). In the McKinlay River population of *C. johnstoni*, there exists a very significant female bias; the sex ratio of immature animals is 0.36, whereas that of mature animals is 0.17. In areas outside the McKinlay River, the mean sex ratio of hatchlings from 13 rivers was 0.35, again indicating a significant female bias. Equivalent data for *C. porosus* are not available, but a sample of 302 juveniles caught in a tidal river had a sex ratio of 0.51, which was not significantly different from 0.50. It would seem likely that there is considerable variation in the sex ratio of *C. porosus* recruits from different areas, as for example in two freshwater swamp areas in which nesting was examined, mean nest temperatures during the early stages of incubation were significantly higher in one (33.0 ± 1.4 SD, N = 18) than the other (30.5 ± 1.5; N = 11) (Webb *et al.* 1983b).

Survivorship

1. *Crocodylus johnstoni*

Crocodylus johnstoni eggs fail to develop for a number of reasons. Predation by varanid lizards is particularly important and in one study accounted for 58% of eggs laid. Other losses occur because of inundation, overheating, infertility, trampling by feral stock, predation by pigs and excavation of nests by other nesting females. Taken together, average egg survivorship has been estimated as 30% of eggs laid (Smith and Webb 1985).

Survivorship between hatching and one-year of age has been estimated as 12%, and most losses occur within the first six months after hatching. Between one and ten years of age, annual survivorship is about 85% per year (Smith and Webb 1985; Webb and Smith 1984). Annual survivorship between 10 years of age and reproductive senescence is unknown, but if the population dynamics are simulated with 85% survivorship, the numbers of older animals in the population are greatly underestimated. Accordingly, survivorship after ten years of age is thought to be appreciably greater than 85% per year.

2. *Crocodylus porosus*

Inundation by rising water levels during the wet season is the major source of *C. porosus* egg mortality. In river bank nests it can account for 100% of eggs laid in some years, in some areas. Other reasons for eggs failing to develop are: infertility, overheating, predation and unexplained development failures. Mean egg survivorship has been estimated as about 25% of eggs laid (Webb *et al.* 1984b).

Survivorship between hatching and three or four months of age is about 70%, and annual survivorship between hatching and one year of age has been estimated as 54% in tidal areas. There are no primary data on survivorship in older *C. porosus* and the problem is confounded by an apparent relationship between the survivorship of 2 and 3 year old crocodiles and the number of larger crocodiles in the population. If losses due to movement are excluded, data in Messel *et al.* (1981b) and Webb *et al.* (1984b) indicate about 70% survivorship from 1 to 2 years of age and 66% survivorship from 2 to 3 and 3 to 4 years of age. Survivorship among older *C. porosus* is unknown.

Population Dynamics

1. *Crocodylus johnstoni*

The population dynamics of *C. johnstoni* are characterized by low egg and hatchling survivorship, with less than 5% of eggs laid being represented by one year olds a year later (Smith and Webb 1985; Webb and Smith 1984). In contrast, survivorship among subadults is reasonably high, with about 85% of year classes between one and ten being represented in the population a year later. The annual rate of increase of the population is about 1.5% per year and there is a steady trend towards increasing proportions of adults; the annual rate of increase of adult females is 3.1% per year (Smith and Webb 1985). The population age structure is not stable, even though hunting ceased 20 years ago.

2. *Crocodylus porosus*

The population dynamics of *C. porosus* are characterized by low egg survivorship (25%) but greater hatchling survivorship than *C. johnstoni*. About 14% of eggs laid can be expected to be represented by one year old survivors in the population a year later. Survivorship among subadults is lower than in *C. johnstoni* and appears to range between 60% and 70% for the first few years; it also appears to be a function of the number of larger crocodiles in the population. In a sample of river populations first surveyed in 1975-78 and resurveyed in 1984 (Webb *et al.* 1984b), the mean annual rate of population increase was 2-3%. However, the rate of increase of animals less than 2 m long was marginal, whereas that of animals greater than 2 m long was about 10% per year. The population age structure is unstable after 13 years of protection.

THE MANAGEMENT FRAMEWORK

Legislation

Within the Northern Territory, *C. johnstoni* and *C. porosus* are both protected under the *Territory Parks and Wildlife Conservation Act*, which was assented to on 1 April 1980. The Act prohibits the killing of both species and makes it an offence to possess the animals or parts of them without an appropriate permit. The maximum penalty is $2000 and/or six months imprisonment, with an additional fine of up to $100 per animal or part thereof involved in the offence.

Export from Australia of *C. johnstoni* and *C. porosus*, or parts of them, is prohibited under the Federal *Wildlife Protection (Regulation of Exports and Imports) Act* 1982, which came into effect in May 1984. The Act is the enabling legislation for Australia's commitments under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and contains provision for the Federal Minister to approve the export of products derived from management plans also approved by him.

Crocodylus johnstoni is listed on Appendix II of CITES. *Crocodylus porosus* was on Appendix II, but it was moved to Appendix I (1979), and the Australian population has now been moved back to Appendix II (1985).

National Parks and Protected Areas

The existing National Parks and Wildlife Sanctuaries (Fig. 9) include the Alligator Rivers region, which contains the largest known population of *C. porosus* in Australia, and a significant but unsurveyed population of *C. johnstoni*. A major part of the range of both species lies within Aboriginal Lands, which are equated with Category VII of the IUCN List of National Parks and Protected Areas. In these areas access to non-Aboriginal people is by permit only and activities likely to affect habitats, or which would be detrimental to the long-term conservation of crocodiles, are controlled by the local communities.

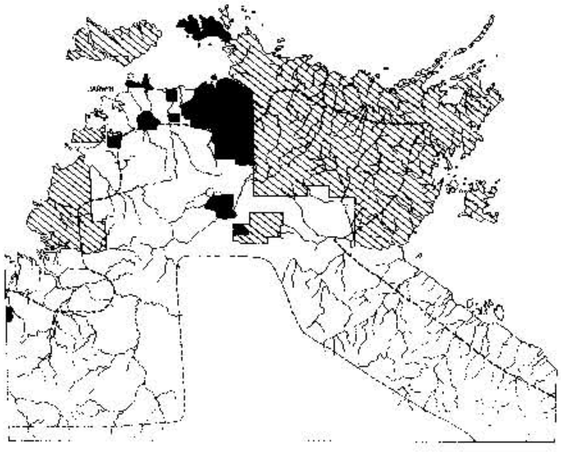

Fig. 9. The distribution of crocodiles in the Northern Territory relative to National Parks (black) and Aboriginal Lands (hatched).

Problem Animals

Problem animals are broadly defined as those within settled areas or areas of priority recreational use, where it is considered that public safety is compromised by having *C. porosus* present. Decisions on problem animals are made case by case by the Conservation Commission of the Northern Territory. *Crocodylus johnstoni* have been considered problem animals on the few occasions that they have ventured into areas where *C. porosus* are considered a problem. It is often difficult to identify species and the presence of any crocodile in some areas constitutes a problem.

Every effort is made to capture problem animals alive and relocate them to crocodile farms. This policy was adopted in preference to destroying them because it was consistent with the central theme of the education programme; "Living with Crocodiles". Animals relocated in the wild have demonstrated a homing ability (Fig. 11).

A

B

Fig. 10. A: Holes in a fishing boat overturned by a 5 m *Crocodylus porosus*. B: the stomach contents of a 5.5 m *C. porosus* containing fishing net and a float, a plastic bottle and a cattle ear tag.

Fig. 11. A relocated *Crocodylus porosus* burnt in a grass fire while travelling overland towards its original capture site.

The numbers and locations of crocodiles removed from the wild up to 1984 are on Figure 12; they include 52 *C. porosus* removed from the Daly River as establishment stock for crocodile farms.

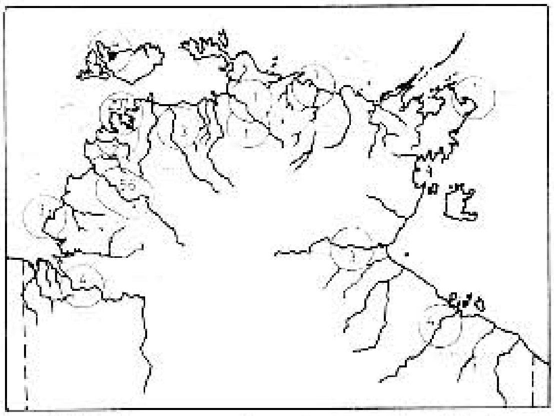

Fig. 12. The locations and numbers of *Crocodylus porosus* removed from the wild by the Conservation Commission of the Northern Territory up to 1984.

Accidental Capture and Feral Animals

All non-tidal freshwater habitats and most tidal habitats are closed to commercial fishing. However, some 12% of the available tidal habitats of *C. porosus* are commercial fishing grounds and some *C. porosus* mortality results. A survey carried out in 1980 indicated that about 350 *C. porosus* were caught annually, of which about 30% were released alive. Although reason for concern, the losses have not prevented a substantial recovery taking place, and can be expected to decrease in the future. In accordance with government policy, the commercial barramundi industry is being actively scaled down in favour of a recreational fishery more oriented to tourism. A license "buy-back" scheme and legislation reducing net lengths have been introduced.

Fig. 13. Feral water buffalo (*Bubalus bubalis*) in a freshwater swamp.

Feral stock, especially buffalo (Fig. 13), have had a significant impact on the quality of wetland habitats within some parts of the Northern Territory (Letts *et al.* 1979; Fogarty 1982; Hill and Webb 1982). The major areas of concern are a reduction of nesting habitat for both *C. johnstoni* and *C. porosus*, and the general effects of wetland degradation (increased drainage, reduction in aquatic vegetation, siltation). The extent to which these changes have influenced recovery is unclear, as the most affected areas are also those with some of the highest populations of both species. An eradication programme for wild buffalo herds throughout the Northern Territory is underway (for bovine disease control). Experiments being conducted in the Alligator Rivers area by CSIRO indicate that habitat rehabilitation occurs remarkably quickly after buffalo have been eliminated, even though they may have been present in high densities, for long periods of time.

Public Education

Educating the public about crocodiles, and gaining public support for crocodile conservation within the Northern Territory, have both been major management aims. As the populations of *C. porosus* began to recover, it was considered important that the public be fully informed about what was happening, why it was happening and what the future held. This programme is discussed more fully by Harry Butler (Chapter 22) but includes: encouragement of media coverage of crocodiles; talk-back programmes on radio; school talks by Wildlife Rangers, often with young crocodiles for children to see and touch; brochures; a "no-swimming" sign featuring a crocodile, which is placed at creek crossings and billabongs where it is considered unwise to swim (the same sign is available for purchase, and a replica of it was produced as a "sticker" that could be widely and cheaply distributed); crocodile posters; and, a television commercial which "sells" crocodiles as an important part of Northern Territory life and an asset to the tourist industry, while reminding people that saltwater crocodiles are dangerous and swimming should be restricted to safe areas.

Aboriginal Attitudes to Crocodile Management

Within the Northern Territory, the attitudes of Aboriginal people to crocodile conservation and management vary in different regions. In some areas crocodiles are regarded as pests and threats to public safety, and the Conservation Commission receives numerous requests to kill or remove animals from Aboriginal lands. In other areas, crocodiles have totemic significance to specific groups of people, and disturbance of animals, particularly large ones, is viewed with concern. Attitudes to the commercial utilization of crocodiles are equally diverse. Aboriginals in many areas hunted crocodiles commercially during the 1945 to 1971 period, and soon after protection some Aboriginal groups expressed an interest in re-establishing a commercial crocodile industry in one form or another.

As the attitudes of the majority of Aboriginals have not been sought, no plans for the commercial utilization of either species of crocodile on Aboriginal lands have been made. An active working group on crocodile management has been established between the Conservation Commission and both the Tiwi and Northern Land Councils to investigate generally the direction Aboriginal people would prefer to follow.

UTILIZATION

Although programmes are underway to utilize both *C. johnstoni* and *C. porosus*, they are still in the development phase. No products have yet been sold and with *C. porosus* a change in the CITES classification was an essential prerequisite to developing a harvest strategy. At this stage, the proposed utilization with both species involves raising animals within crocodile farms, although in the longer term other options may be pursued.

Crocodile Farms

Three crocodile farms have been established in the Northern Territory. Two of these are privately financed with additional funding through the Development Corporation (NTDC; low interest loans and repayment schedules which allow for cash flow delays inherent in establishing a primary industry). The third is integrated with a sound pastoral enterprise and utilizes land, equipment and capital provided through it. Total capital investment in Northern Territory crocodile farms to 1984 exceeds AUS$1.80 million.

The first farm [Crocodile Farms (N.T.) Pty. Limited] was started in 1980, and is the only farm open for tourism. The farm is a mixed farming/ranching venture. Both *C. porosus* and *C. johnstoni* are now breeding in captivity and animals hatched from these eggs are being raised on the farm. In addition, the farm is given permits for the collection of up to 2000 *C. johnstoni* hatchlings per year from the Daly River region. A small proportion of these are collected as eggs.

The second farm [Janamba Crocodile Farm Pty. Limited] was established in 1982 and was primarily a ranching venture based on raising *C. johnstoni* hatchlings collected from the wild in the Victoria River region. A small nucleus of *C. porosus* breeding stock is gradually being obtained from problem animals. In the future these will supply a significant number of farm bred animals for raising. On an experimental basis, some *C. porosus* hatched from wild caught eggs are being raised. The farm's future direction is currently under review.

The third farm [Letaba Crocodile Farm] was also established in 1982 and is an exclusively ranching venture, with both *C. johnstoni* and *C. porosus*. *Crocodylus johnstoni* eggs are collected within parts of the Finniss and Reynolds Rivers that are located on the cattle station on which the farm is situated. Additional *C. johnstoni* hatchlings are collected from parts of the Victoria River system. On a trial basis, *C. porosus* eggs have been collected from flood prone nesting sites within the cattle station, on the condition that attempts be made to control the feral buffalo around the floating vegetation rafts on which the crocodiles nest. The numbers of crocodiles housed on the three farms as of 30 June 1985 is in Table 2.

Table 2. Crocodiles held on Northern Territory crocodile farms as of 30 June, 1985.

Farm	*C. johnstoni*	*C. porosus*	Totals
Crocodile Farms (N.T.)	3257	1484	4741
Janamba	1929	913	2842
Letaba	2700	452	3152
Totals	7886	2849	10,735

Captive breeding is now well established, and 19 *C. porosus* nests and 14 *C. johnstoni* nests were laid in captivity during the 1983/84 wet season and 1984 dry seasons respectively. All farms are equipped with incubation facilities and have now gained sufficient experience to maximize incubation success. From fresh clutches of fertile eggs, over 90% hatching success is achieved, although overall success rates vary between different batches of eggs.

Initial efforts at raising were confounded by a number of unforseen problems, but the majority of these have been solved satisfactorily. As a consequence, raising success has been greatly improved and with a planned injection of research support over the next five years is expected to continue in that direction. The major problems which have been encountered to date are:

1. At one farm, a fungal infection causing severe skin lesions and increased mortality of *C. johnstoni* hatchlings occurred in two consecutive years. The pathogen proved difficult to control within the low-cost low-maintenance pens, and these pens are now being overhauled to remove earthern banks and increase water flow. The disease has not appeared at the other two farms, even though when it was thought the disease was controlled, some animals were transferred from the infected farm to one of the others.
2. Predation by birds and the escape of juveniles from the more open style of pen have both resulted in significant losses. These problems have been largely overcome by using wire netting to enclose the pens containing young animals.
3. Failure of hatchlings to begin feeding on dead food was an initial problem with *C. johnstoni* and *C. porosus* hatchlings. It was largely overcome by changing the pen design to give more cover, generally restricting disturbance to hatchlings, and supplying heat during the "cool-dry" season. The problem is confounded by a geographic trend; hatchlings from some areas appear to start feeding readily whereas those from other areas are more difficult to get feeding.

Utilization of Crocodylus johnstoni

1. *Background*

Egg and hatchling mortality in *C. johnstoni* are both substantial, and thus the effects of removing a large proportion of either eggs or hatchlings could be expected to be minor relative to a harvest of adults or subadults. When population dynamics were simulated with a deterministic model (Smith and Webb 1985), the results indicated that the population could be harvested without affecting the population size or recovery rate if 2.6% of eggs collected or 8.7% of hatchlings collected were returned to the wild after being raised to two years of age. These predictions did not account for any compensatory mechanisms that may operate on hatchling survival, and were of course taken as a broad "guide" to what could be expected. Field tests indicated no significant difference in survivorship in the field between wild and released, raised animals of the same age (Smith and Webb 1985).

2. *Field Trials*

Numerous field trials have now been carried out with egg and hatchling harvests, and the strategy currently being employed combines both approaches. Because of the contracted dry season laying period of *C. johnstoni*, an egg harvest has a number of advantages over a hatchling harvest: the period of egg-laying is about three weeks in duration whereas that of hatching is nearer six weeks; the mortality which occurs in the egg stage can be largely avoided, increasing the harvest from any given area; the number of eggs available for collection is more predictable than the number of hatchlings because variation in incubation success is negated; the harvest can be carried out in the dry season, when access to *C. johnstoni* habitats is not affected by wet conditions; and, incubation conditions can be controlled to produce hatchlings of known sex and known size (relative to egg size).

However, hatchling harvests have a number of advantages over egg harvests: eggs are more fragile than hatchlings; eggs must be incubated through to hatching; a proportion of eggs are damaged when locating them; a concentrated effort is needed to collect eggs within the first day or two after laying; and, perhaps most important, nests are difficult to locate in areas where nesting habitat is abundant and nest sites are widely separated from each other, whereas hatchlings in such areas can be located readily.

To date, all harvests carried out have been considered experimental and each team operating in the field has been accompanied by a Conservation Commission Ranger. During the first commercial scale harvest (a hatchling harvest in November/December 1982) many areas were visited in order to locate populations that were logistically accessible and which had significant breeding populations. Landowners were contacted and involved in the trial, because in the long-term hatchling collection may be carried out by them. Altogether 4573 hatchlings were collected from sections of 13 rivers. Each was measured, sexed and aged (from the condition of the umbilical scar) in order to quantify geographic variation in hatchling size and times of hatching (Webb and Smith 1984).

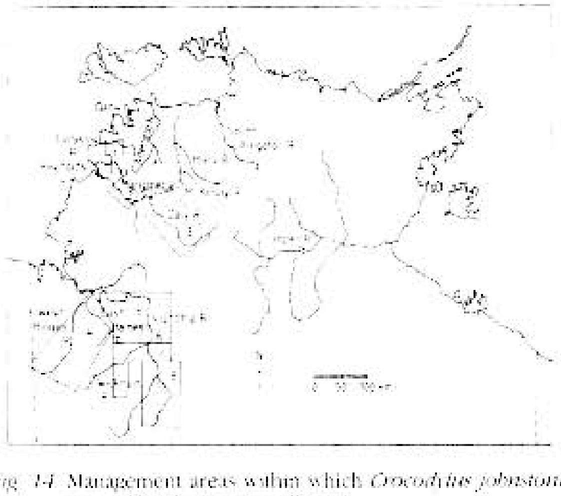

Fig. 14. Management areas within which *Crocodylus johnstoni* eggs and hatchlings are collected.

On the basis of these data, management areas were defined (Fig. 14) and assigned to the farms. Liaison and assistance by landowners was subject to agreement between the landowners and crocodile farmers. Under current legislation, Northern Territory wildlife is not the property of landowners; they can assist crocodile farmers, but cannot collect and sell crocodiles independently.

The first commercial egg harvest was carried out within the defined management areas in August/September 1983. Detailed records were kept of all eggs collected and these were used to assess the commercial viability relative to hatchling collection. It was a viable strategy in one area (Finniss River) and part of another (Daly River), but was impractical in the other areas due to an abundance of nesting habitat, lack of colonial nesting and disturbance of the fresh tracks of nesting females by cattle and wallabies.

Although some spotlight counts were made during the 1982 trial harvest, detailed monitoring was not commenced until the management areas were defined. The approach taken has been annual spotlight counts in the accessible areas where hatchlings and eggs are collected, and these are carried out in the dry season each year.

3. Harvesting Hatchlings

Hatchlings are collected by hand at night after creches are located with a spotlight. Adults are often present with creches, but usually dive when approached. Hatchlings are placed in plastic crates (Fig. 15) with tight fitting lids. Inside dimensions of the crates are 56 × 32 × 8 cm high, and each has a piece of hessian bag on the bottom to act as an evaporative cooler. Forty hatchlings can be stored in one crate.

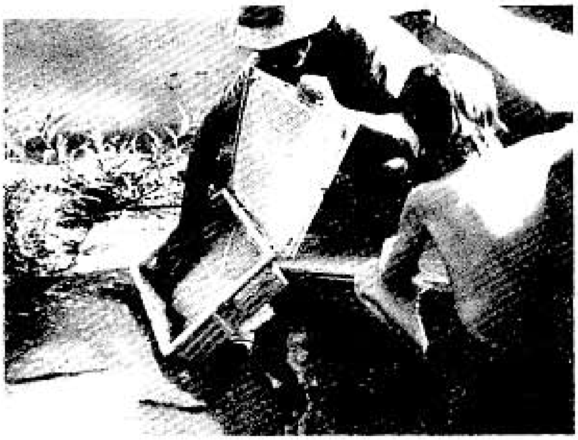

Fig. 15. The plastic crates used for transporting *Crocodylus johnstoni* hatchlings and *C. porosus* eggs.

Hatchlings proved much more robust than expected, and if kept out of direct sunlight in the crates could be kept for at least four days in the field without apparent ill effects. Of the 4573 hatchlings collected in 1982, three died the night they were collected and five died in transit between the field and the crocodile farms.

During that harvest, some areas were patrolled regularly in order to quantify the time of hatching, reduce immediate mortality and maximize the harvest. However, the costs involved in keeping teams in the field for long periods mitigated against this approach. In addition, some teams became isolated by early wet season rains. In 1983 and 1984 hatchling harvests have been more rapid, concentrating on the peak of hatching when maximum numbers can be obtained for minimum effort.

4. Harvesting Eggs

One farm does not collect eggs, and another carries out a minor harvest from one area in which eggs are collected after the peak of nesting. The third farm carries out a major egg harvest, which requires a concentrated effort by two people for two to three weeks. Routine checks are made when the females begin to make trial nests, and when the first eggs are laid the nesting banks are patrolled each day or two days. The fresh tracks of nesting females often allow the approximate site of the nest to be located rapidly, and the exact position of the clutch (which is relatively small compared to the clutch of larger hole-nesting crocodiles such as *Crocodylus niloticus*) is located by gently probing the sand with a spring steel rod, 3 mm in diameter and 1 m long.

The upper surface of each egg is marked with a felt pen and the eggs are removed and packed horizontally in small polystyrene boxes filled with nest sand. After transportation back to the incubators eggs are repacked and incubated in a horizontal position. All incubation is carried out with the eggs positioned on racks. They are incubated within water-jacketed incubators, or in one case in a closed wooden field incubator constructed so that warm spring water flows continually through it. The optimal incubation temperatures are about 31-32°C.

About half way through incubation, after the opaque band has started spreading to both ends of the egg, all eggs are checked. Any that appear not to be developing are opened and the dead embryos examined. The results of the 1984 egg harvest are in Table 3.

Table 3. The success rates for three batches of *Crocodylus johnstoni* eggs incubated during the 1984 season. Wild collected eggs were either collected within 0-7 days of laying (fresh), or after the majority of clutches had been laid (old).

	Wild fresh	Wild old	Captive fresh
Total number located	1873	318	150
Probed	41	15	0
Obviously dead at collection	3	20	0
Infertile	50	65	30
Possibly viable eggs	1779	218	120
Hatched	1623	179	105
% of viable eggs hatched	91	82	88

Table 4. Numbers of *Crocodylus johnstoni* eggs and hatchlings collected from the wild by crocodile farms.

Year	Hatchlings	Eggs	Total
1982	4573	0	4573
1983	2269	1563	3832
1984	1953	2191	4144
Totals	8795	3754	12,549

5. *The Extent and Impact of the Harvests*

The numbers of hatchlings and eggs collected up to 1984 are in Table 4. During the first trial harvest, only three areas were surveyed both before and after the harvest (Table 5); the two counts yielded an overall decrease of 44 animals after a total harvest of 310 hatchlings. In the second harvest, different areas were surveyed before and after collection and these included areas from which 78% of the harvest was taken. The results showed a decrease of 230 animals sighted following a total harvest of 2971 eggs and hatchlings. This decrease was almost entirely attributed to the Finniss-Reynolds River area where 304 animals sighted in 1983 was reduced to 108 sighted in 1984. Water levels were high during the resurvey. In fact, 150 nests were subsequently collected from the area where 108 crocodiles were sighted in 1984!

Table 5. Numbers of *Crocodylus johnstoni* counted before and after egg and hatchling harvests in selected monitoring areas. A reduced and slightly different area was surveyed before and after the first harvest (1982). The decrease in 1983/84 reflects mainly a drop of 196 animals in two areas resurveyed when water levels were high (see text).

Year	Number sighted before	Eggs and Hatchlings Harvested	Number sighted following year
1982/83	581	310	537
1983/84	2282	2971	2052

These results are very much preliminary and additional data are clearly required. Nevertheless, they do indicate that no catastrophic change in numbers is occurring as a result of the harvests. In overview, some 8813 hatchlings and 3754 eggs have been removed over three years from areas where spotlight counts yield around 3000 animals sighted.

Utilization of Crocodylus porosus

1. *Background*

Up to 1984 the Australian population of *C. porosus* was on Appendix I of CITES, however it is now (since 1985) on Appendix II, which allows "ranching". The programme proposed for *C. porosus* is similar to that implemented with *C. johnstoni* in its underlying strategy, but methods will differ. It should be emphasized that only a broad approach to the problem of how to implement an egg harvest programme with *C. porosus* has been formulated, as the research needed to work out the details and study nesting from the point of view of harvesting eggs could not be justified until the Appendix II categorization was in place.

Crocodylus porosus egg mortality is similar to that of *C. johnstoni* at around 75%, but hatchling mortality, in tidal areas at least, is appreciably less. Whereas approximately 12% of successfully hatched *C. johnstoni* eggs could be expected to survive to juveniles of one year of age, about 54% of hatched *C. porosus* eggs could be expected to survive to one year of age. Accordingly, the impact (if any) of an egg harvest on the population should be less than that of a hatchling harvest.

Crocodylus porosus nest over an extended period (November to May) and hatch over an even greater period (February to September). Nests tend to be well separated from each other, although nesting within any one area is often concentrated into a specific section of river or patch of swamp. In addition, nesting occurs during the wet season, when vehicular access to areas is greatly restricted. A further problem occurs as a result of females defending their nests.

2. Egg Harvest Programme

Like many crocodilians, *C. porosus* tend to use specific nesting areas repeatedly, so there is a high probability of finding nests annually once a site has been identified. As demonstrated by Magnusson *et al.* (1978b, 1980), potential nesting areas can be efficiently identified from light aircraft, and in some habitat types (especially river bank nesting sites) a reasonable index of the number of nests present in an area can be obtained. Helicopters offer an even better vehicle for locating *C. porosus* nests, and have the added advantage of being able to land beside many nests (Fig. 16). Because of the "wet season" nesting time, collecting *C. porosus* eggs can involve logistic difficulties, but again helicopters fitted with floats have worked extremely well for us. If used wisely, our experience indicates hatchling *C. porosus*, from wild eggs, could be introduced to the farms for less than AUS$5.00 each, if collected with helicopters.

Fig. 16. *Crocodylus porosus* eggs can be collected efficiently in the wet season using a helicopter.

During preliminary trials, the upper surface of each egg was marked and the eggs were placed horizontally amongst nest vegetation in either the *C. johnstoni* hatchling crates (Fig. 15) or in domestic styrofoam or plastic "eskies". One egg from each clutch is opened to approximately age the nest and predict hatching dates. Incubation can be quite satisfactorily carried out in the same incubators used for *C. johnstoni* eggs, using the same techniques (Fig. 17). As in *C. johnstoni*, eggs lacking an opaque band when others in the clutch are banded, and those that are banded when others in the clutch are uniformly opaque, are almost invariably dead.

Fig. 17. *Crocodylus porosus* eggs hatching after incubation in controlled conditions.

Because of the long nesting period, the efficiency of a commercial egg collection will depend partly on being able to predict when peak nesting occurs. Nesting has thus been monitored in one area since 1980, and sporadic data from other areas can be related to this "standard". Mortality within nests is now being studied in depth. In some tidal river systems "early" nests are generally flooded whereas "late" nests survive. In floating mat situations many "late" nests are flooded, because as ambient temperatures start to decline, the adults bask on the nest, submerging the eggs in the process. The optimum time for egg collection will probably vary both within and between rivers and at this stage is difficult to quantify. During the initial trials, egg collection will be carried out in the January-February period, as although more nests are available later in the season, many embryos have already been killed by flooding.

3. The Extent and Impact of Harvests

When a commercial harvest of *C. porosus* is introduced, it will aim at 4000 eggs per year, the majority of which will come from the Adelaide and Finniss-Reynolds Rivers areas, or from any areas where landowners express an interest in becoming involved.

The populations within harvested areas have been surveyed and will be monitored annually by either spotlight counts, as done for *C. johnstoni*, or helicopter survey methods which are currently being developed (Bayliss *et al.* 1986). Permit conditions will stipulate that 5% of the eggs collected will need to be returned to the Conservation Commission as raised three-year olds, should they be required to restock any harvested areas. Such restocking will be implemented only if an impact of the harvests occurs, as a mandatory release programme could well be cosmetic rather than effective.

4. *"Problem"* C. porosus *and a Trial Harvest of Juveniles*

Many of the problem animals captured and placed in the farms have been subadult males, which are not required for captive breeding programmes. Up to 100 of these animals will be made available for commercial utilization per year.

A trial harvest of subadults (up to 200 individuals), may be conducted to quantify the impact of such a harvest on wild populations. The data available at present indicate that a very high proportion of subadults die in the field and it is possible that this type of harvest may be both biologically sound and economically feasible in the future.

Supervision

All collecting of both species of crocodile from the wild has been carried out under the supervision of Conservation Commission Rangers. When the programme reaches the stage of exporting skins, specific permits will be issued for the number of animals being killed and each skin will be tagged with a non-reuseable tag (Webb *et al.* 1984b).

CONCLUSIONS

Management programmes for crocodiles in the Northern Territory have developed gradually over the last decade. There was an initial research effort directed at obtaining basic biological data from the wild populations, and with these data as a starting point, attention was given to harvest programmes designed to achieve a sustainable yield.

The programmes involve ranching, with eggs or hatchlings being collected from the wild and subsequently raised in crocodile farms. Harvested populations are monitored annually and if necessary, can be restocked with a proportion of the animals collected.

The programmes are broadly aimed at making both species of crocodile and their habitats "important", while establishing a small but viable industry based on the maintenance of wetlands in their natural state.

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