CHAPTER 13

The Management of Crocodiles in Queensland, Australia

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THIS chapter reviews some current issues in crocodile management in Queensland within the broad perspective of the State's physical and social geography. Attention is directed almost entirely at the management of the estuarine crocodile, *Crocodylus porosus*. The freshwater crocodile, *Crocodylus johnstoni*, does not pose any urgent management problems at present, nor does it generate the same level of public concern as *C. porosus*; it presents no significant threat to people, it is common in many areas of the State and it is locally abundant in many rivers (Limpus and Taplin, unpublished data). There is relatively little interest in the commercial exploitation of *C. johnstoni* at present and this situation seems unlikely to change before successful ranching or farming techniques emerge from experiments underway in the Northern Territory. In contrast, *C. porosus* does not appear to be nearly as abundant as *C. johnstoni*, but its presence in many wetlands close to human habitation produces predictable management problems and periodic calls for harvesting or culling. Farming of *C. porosus* is currently underway in two Queensland farms and interest has been expressed in the establishment of more. There is clearly a more urgent need for considering the management options for *C. porosus*.

Efforts to conserve crocodiles in Queensland effectively began in 1974 with the declaration of the *Queensland Fauna Conservation Act* under which both species were declared totally protected fauna. From the mid-1940's to the early 1970's there was a sizeable industry in crocodile skins and other products, and both species were hunted intensively across virtually the entire north of Australia. The history of crocodile hunting in Queensland broadly follows the pattern in the Northern Territory (see Chapter 11); the Queensland populations of *C. porosus* and, to a lesser extent, *C. johnstoni* were driven to very low levels relative to their earlier abundance. Protection of crocodiles from harvesting was indirectly conferred in 1972 by a Commonwealth Government embargo on exports of crocodile products prior to the *Queensland Fauna Conservation Act*.

Some recovery of both *C. porosus* and *C. johnstoni* populations has undoubtedly taken place since protection. However, the extent of recovery is difficult to determine in the absence of hard data on the populations at the time of protection. Nevertheless, in the context of present day management the problem of estimating pristine, immediate post-protection or present population levels is not necessarily the most rewarding or pressing question to be addressed. While there is no doubt that the historical and biological perspective derived from good estimates of former population densities would be invaluable, it is most unlikely that reliable estimates are attainable. It is more important, therefore, to consider what might be the current carrying capacity and potential productivity of crocodile habitat in Queensland, or northern Australia as a whole, having regard for the extensive changes in land use and population distribution of the post-war era. If commercial utilization of wild populations is to be considered, then estimates of the reproductive potential of crocodile populations and their ability to sustain harvests are essential. Such estimates need to be made in the context of current pressures on crocodile populations and, importantly, with a view to establishing sustainable yield harvesting as a fundamental tenet of the operations.

This chapter reviews our present knowledge of *C. porosus* populations and habitat in Queensland. Information has been drawn from population surveys by Messel *et al.* (1981), aerial surveys of nesting habitat by Magnusson *et al.* (1980), internal Departmental reports, discussions with a wide range of people and from my own personal experiences. Little information is available for most regions of the State, hence my assessments of the "relative conservation value" of various regions are open to revision. My aim has been, however, to present an overview of crocodile conservation issues and a framework for the future development of management and research strategies. Specific management policies,

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many of which are common to the Northern Territory and Queensland and reflect common problems, are discussed within the framework of both short- and long-term objectives with specific reference to Queensland. For a variety of reasons, management strategies appropriate elsewhere, may be inappropriate in Queensland.

THE PHYSICAL AND SOCIAL GEOGRAPHY OF QUEENSLAND

Distribution of Crocodiles

Queensland has a total area of 1.73 million km^2, some 54% of which lies north of the Tropic of Capricorn. *Crocodylus porosus* does not occur in significant breeding populations south of the tropics but is found within a range of over 12.5° of latitude in most major and minor coastal waterways to the north (Fig. 1), occupying over 80% of a coastline estimated to be some 7400 km long (May 1984). Its distribution is near-coastal for the most part, seldom extending more than 40-50 km inland in a direct line from the coast. Some breeding populations can still be found 100 km or more from the sea, while isolated individuals have been recorded as far inland as Julia Creek and Georgetown (Fig. 1).

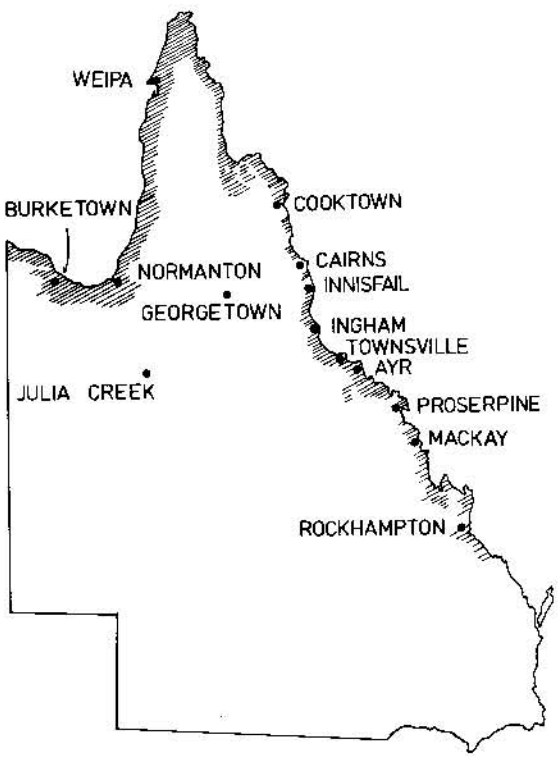

Fig. 1. The approximate distribution of breeding populations of *Crocodylus porosus* in Queensland.

Crocodylus porosus occupies a much wider range of latitude in Queensland than in the Northern Territory (12.5° cf. 6°). Because of the predominant north-south, trend of Queensland's coastline, the State lacks a broad swathe of crocodile habitat within a narrow range of latitude such as occurs along the northern coast of the Northern Territory. It is very important, therefore, to make allowance for the range of climates and habitat types that *C. porosus* occupies when attempting to use data from the Territory's research in formulating management and research strategies for Queensland.

Climate

Crocodylus porosus occupies a range of climatic regimes varying from the dry, hot climate of the southwestern Gulf of Carpentaria to a uniformly moist region near Cairns and a moist temperate zone between Proserpine and Rockhampton (Fig. 2). The southern limit of *C. porosus* in Queensland probably reflects primarily the relatively cool climate and correspondingly low winter water temperatures of inland waterways — typically 16-18°C. Average minimum and maximum air temperatures in the Rockhampton-Mackay region during July (winter) are around 8-10°C and 21-23°C respectively, compared to averages of 15-21°C and 29-31°C for much of the Northern Territory coastline (Plumb 1977). Comparable January (summer) averages are 21-24°C minimum and 30-31°C maximum for

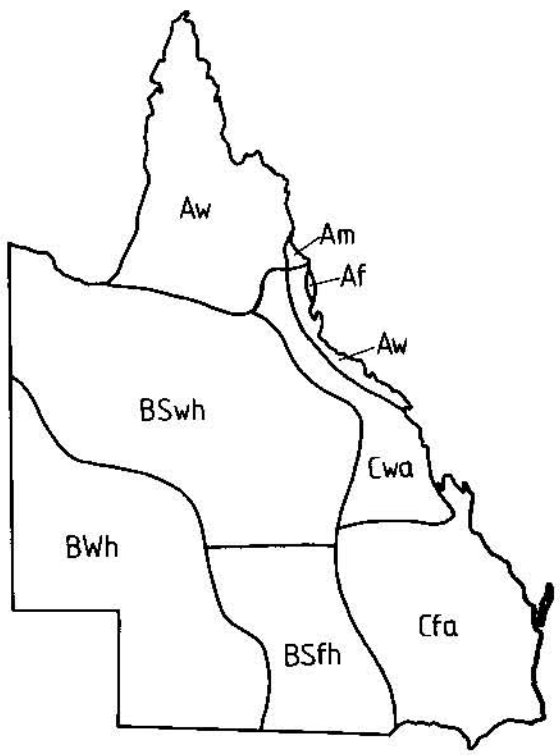

Fig. 2. Climatic zones of Queensland according to the Köppen classification system (after Plumb 1977). A, hot moist climates (Af, uniformly moist; Am, short dry season; Aw, marked winter dry season); BS, dry hot to warm climates (BSfh, hot with uniform rainfall; BSwh, hot with winter drier than summer); BW, very dry, hot to warm climates (BWh, hot); C, temperate moist climates (Cfa, uniform rainfall with a long hot summer and mild winter; Cwa, long, hot moist summer with a mild dry winter).

Rockhampton-Mackay; 24-25°C and 32-34°C for the Northern Territory. The cold winters of these southernmost latitudes appear likely to limit the growing season and reproductive opportunities for *C. porosus*.

Average annual rainfall ranges from 3000-4000 mm near Innisfail (see Fig. 1 for localities) to only 700-1000 mm in the southwestern Gulf. Winter rainfall is highest in the coastal strip between Ingham and Cooktown and lowest in the Gulf and western Cape York — in fact lower here than in the southwestern deserts (Fig. 3). Summer rainfall is again very high on the eastern coast (Fig. 3) with a localized area of low rainfall, persistent through the winter, around Townsville. The most arid area within the range of *C. porosus* lies in the southern Gulf. It is noteworthy that virtually nothing is known of the physiological or ecological adaptations of *C. porosus* to the climatic gradients it encounters in Australia.

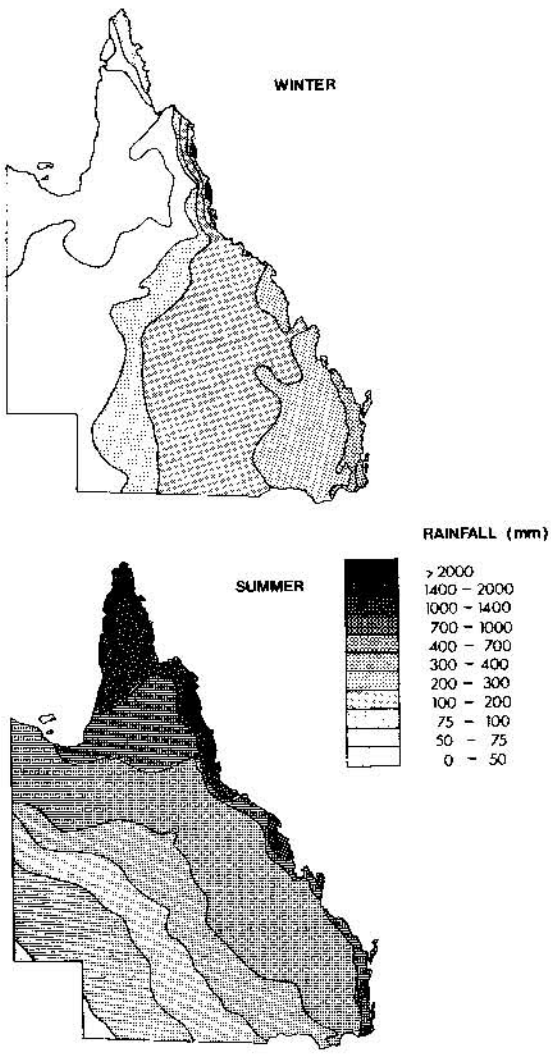

Fig. 3. Average winter rainfall (*upper*; May to October inclusive) and summer rainfall (*lower*; November to April inclusive) in Queensland (after May 1983).

Physiography

The most distinctive topographic features of tropical Queensland are the Gulf Plains and the Eastern Highlands (Fig. 4). The Gulf Plains comprise an enormous area of riverine plains of low to extremely low relief encompassing the catchments of the majority of tropical Queensland's major river systems (Fig. 8). The headwaters of some of these rivers extend to within a few tens of kilometres of the east coast. The Eastern Highlands, on the other hand, are comprised of ranges and plateaus of moderate to high relief extending from central Cape York south to Rockhampton and beyond. The coastal plain is very narrow or non-existent over much of the east coast and is traversed by large numbers of small rivers with very small catchments. The only major drainage system on the east coast north of the climatically marginal Burdekin and Fitzroy River systems lies in Princess Charlotte Bay and includes the North Kennedy, Bizant, Normanby and Marriott Rivers (Fig. 8). Apart from these major physiographic units, some smaller regions can be identified, including the more elevated and dissected plains of the Weipa Plateau and Bamaga-Shelburne Lowlands in northwestern Cape York and the narrow coastal plains east of the Central Uplands in the central Cape (Fig. 4).

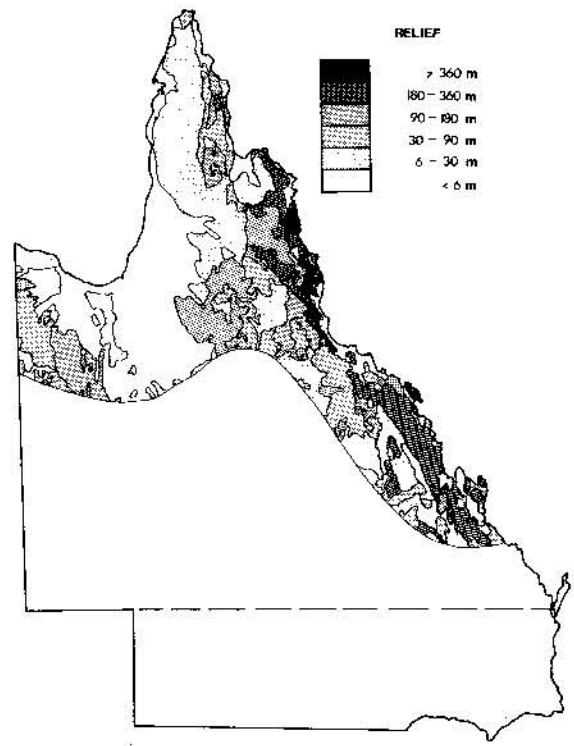

Fig. 4. Relief map of *Crocodylus porosus* habitats in tropical Queensland (after Grant *et al.* 1984).

Population and agriculture development

Queensland has a population of some 2.5 million people (2.35 million at the 1981 census and growing at an annual rate of 2-3%). Of these, the vast majority live in the eastern coastal regions with major concentrations in the range of *C. porosus* near Rockhampton, Mackay and the coastal plains from Ayr to Cooktown (Fig. 5). Population density across the majority of tropical coastal Queensland is extremely low, averaging only 1-10 people per 100 km^2 with very few communities of any size close to the coast. The major coastal population centres of Cape York and the Gulf are Weipa, Normanton/Karumba and Burketown with populations of 2400, 1600 and 250 respectively.

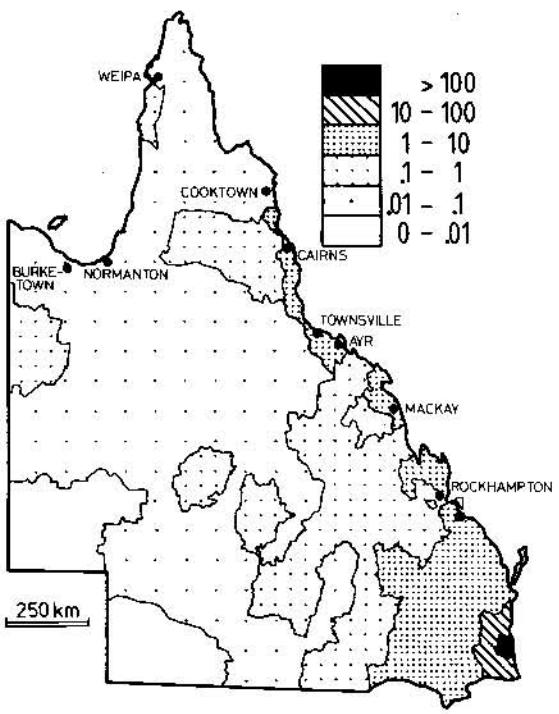

Fig. 5. Average population densities (km^{-2}) of Local Government Authority regions in Queensland as of the 30th June 1982 (from May 1983).

Coastal urban developments on the east coast impose severe pressure on wetlands through reclamation of mangroves and swamplands, heavy recreational usage of waterways for water sports, fishing and boating, and erosion of river bank vegetation by boat wakes. These negative impacts on wetlands are coupled with direct disturbance of crocodiles and periodic calls for removal of crocodiles from populated areas.

Intensive agricultural development of the tropical coast is similarly concentrated in the eastern coastal plains south of Cooktown (Fig. 6). Farming of sugar cane, rice, tropical fruits and vegetables has resulted in extensive clearing of fresh water wetlands, draining and reclamation of former swamps, clearing of

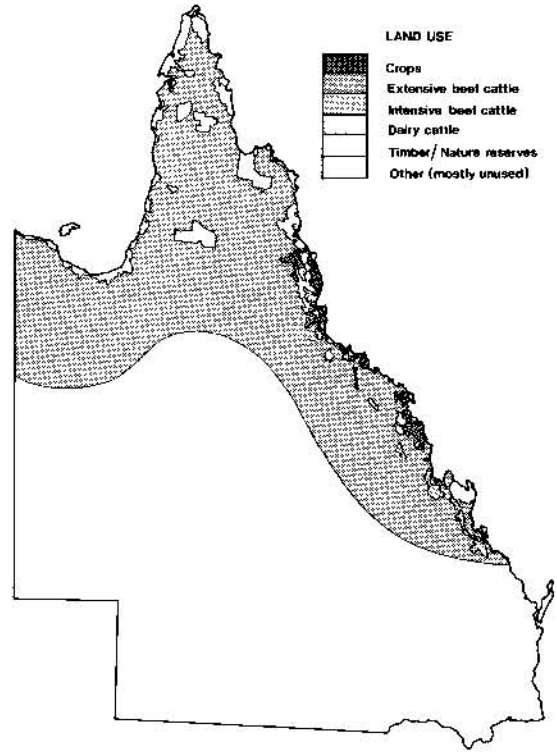

Fig. 6. Principal land uses within the range of *Crocodylus porosus* in tropical coastal Queensland (from Plumb 1977).

fringing riverside vegetation and invasion of waterways by weeds such as Para Grass (*Brachiaria muticans*). Elsewhere in the range of *C. porosus* the principal land use is beef cattle grazing at low stocking rates. The major impacts in these areas are caused by concentrations of livestock, damage to potential nesting areas on fresh water lagoons and swamplands, and the siltation of water courses through increased soil erosion and changes in water flow regimes.

Gill netting and river closures

Commercial gill netting may be a major cause of mortality of mature *C. porosus* in Queensland. Few hard data are available, but information from commercial fishermen suggests that the "take" is large among the 300-400 licensed commercial fishermen, involved primarily in gill netting between Rockhampton and the Northern Territory border (derived from Williams 1980). Gill netting is not allowed in any permanent fresh waters in Queensland but is permitted from February 1st to October 31st in all tidal waters of the majority of tropical coastal rivers. Several rivers are closed to gill netting for part or all of the year, thus providing some protection for their crocodile populations. These closures are listed in a series of Schedules to the *Queensland Fisheries Act* (1976). Many of them affect eastern coastal streams of relatively limited value as crocodile habitat (see below). However, some significant closures are in effect on Cape York

rivers, usually associated with Aboriginal Reserves. The most important of these is the closure of virtually all tidal waters in the Mission/Pine/Embley/Hey river system near Weipa, encompassing some of the best *C. porosus* habitat identified in the State so far.

National Parks and other Reserves

Numerous National Parks in Queensland support significant areas of suitable habitat for *C. porosus* (Table 1; Fig. 7). In addition, many Aboriginal Reserves act as habitat reserves because population density is localized and low, agricultural and pastoral development is usually minimal, access for non-Aboriginal people is strictly limited and the local community exercises considerable control over land use. Commercial gill netting is allowed in rivers on Aboriginal Reserves but many rivers are closed. Aboriginals are allowed to take crocodiles and their eggs as traditional food but there is no evidence to suggest any significant take of either in recent years. A large military reserve in the Shoalwater Bay area near Rockhampton (Fig. 7) is reputed to harbour some *C. porosus*, but few hard data are available.

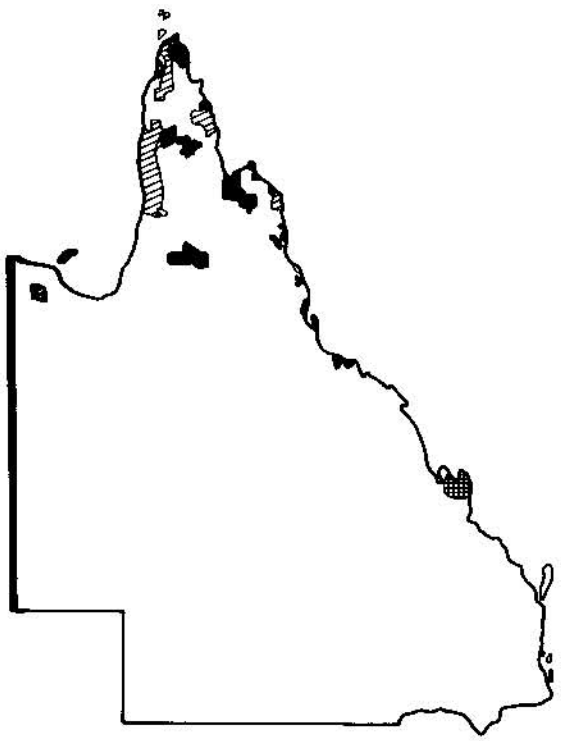

Fig. 7. National Parks (solid), Aboriginal Reserves (hatched) and Military Reserves (cross-hatched) contributing significantly to the conservation of *Crocodylus porosus* in Queensland.

THE "CONSERVATION VALUE" OF *C. POROSUS* HABITAT IN QUEENSLAND

For convenience, I have defined six regions which incorporate blocks of *C. porosus* habitat, but which differ considerably in conservation value and, to a lesser extent, pose different management problems (Fig. 8). Their boundaries are defined largely by the drainage divides of various major and minor river systems with further divisions based on changes in physiography, land use and population density. They are as follows:

1. Gulf of Carpentaria Plains — subdivided into
   - 1a Massacre Inlet
   - 1b Albert/Leichhardt drainage
   - 1c Norman/Flinders drainage
   - 1d Mitchell/Gilbert drainage
2. North-west Cape York
3. North-east Cape York
4. Princess Charlotte Bay
5. Eastern Coastal Plains — subdivided into
   - 5a Cape Melville to Cooktown
   - 5b Cooktown to Ayr
   - 5c Ayr to Rockhampton
6. Burdekin/Fitzroy Region — subdivided into
   - 6a Burdekin catchment
   - 6b Fitzroy catchment

My assessment of the conservation value of each of these six regions is summarized in Table 2. Those for National Parks, other reserves and netting closures

Table 1. Major National Parks in Queensland supporting significant areas of *Crocodylus porosus* habitat and an indication of their conservation value — "*"=lowest, "***"=highest.

Latitude (°S)	Name	Area (ha)	Conservation Value
11-12	Jardine River	235,000	***
12-13	Iron Range	34,600	**
14-15	Cape Melville	39,000	*
15-16	Lakefield	537,000	***
15-16	Endeavour River	2334	*
16-17	Cape Tribulation	59,096	*
17-18	Russell/Mulgrave Rivers	2930	*
17-18	Eubenangee Swamp	1520	**
17-18	Clump Point	1103	*
17-18	Hull River	546	**
18-19	Edmund Kennedy	6200	**
18-19	Hinchinbrook Island	46,192	**
19-20	Cape Bowling Green	55,300	*

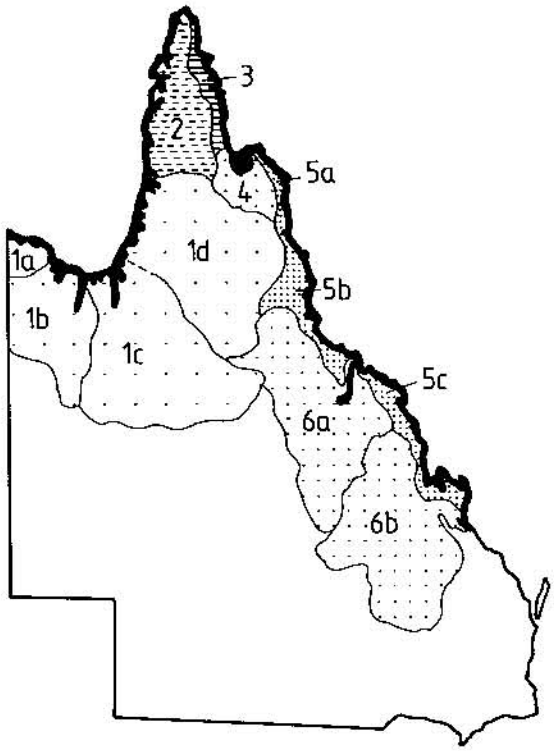

Fig. 8. Land units of *Crocodylus porosus* habitat in Queensland (as defined in the text): 1, Gulf Plains (1a, Massacre Inlet; 1b, Albert-Leichhardt drainage; 1c, Norman-Flinders drainage; 1d, Mitchell-Gilbert drainage); 2, North-west Cape York; 3, North-east Cape York; 4, Princess Charlotte Bay; 5, Eastern Coastal Plains (5a, Cape Melville to Cooktown; 5b, Cooktown to Ayr; 5c, Ayr to Rockhampton); 6, Burdekin-Fitzroy Region (6a, Burdekin catchment; 6b, Fitzroy catchment). The areas shaded black represents the principal areas occupied by *C. porosus*.

are based on the area and quality of the habitat they protect. Thus, closures of large sections of rivers in areas of relatively degraded habitat score only a moderate value. Similarly, Aboriginal Reserves in the Cooktown-Ayr section of the Eastern Coastal Plains (Region 5b, on Fig. 8) score a low value because they incorporate very little suitable crocodile habitat. Quality of nesting habitat has been considered separately from crocodile habitat *per se*. Some large areas of Queensland may lack significant areas of good nesting habitat but could well support substantial populations of immigrants from adjoining regions of high nesting intensity. Each region is considered in turn below:

1. *Gulf Plains (1 on Fig. 8)*

The Gulf Plains encompass the catchments of most of the major river systems of tropical Queensland, but they lie in a relatively arid region. Virtually all of the rivers stop flowing above ground during the dry season in most years, receding to strings of waterholes upstream of their tidal reaches. *Crocodylus porosus* habitat is largely restricted to the tidal and immediately supratidal reaches, but occasional sightings have been reported from permanent waterholes far inland.

There is much suitable crocodile habitat in the coastal Gulf Plains but nesting habitat is poor overall (Magnusson *et al.* 1980; Taplin, unpubl. obs.). The topography of the plains does not favour the development of perennial spring-fed swamps and many of the riverside nesting areas are susceptible to severe flooding. The estuarine reaches of many

Table 2 Assessments of the impact and conservation value of various negative and positive influences on *C. porosus* populations in Queensland and the overall conservation value of various regions of the State as defined in Fig. 8.

	Population Impact	Agricultural Impact	Quality of *C. porosus* Habitat	Quality of Nesting Habitat	Value of National Parks	Value of Aboriginal and other Reserves	Value of Netting Closures	Overall Conservation Value
Gulf Plains	Low localized	Low coastal Moderate inland	High	Low Unknown-coastal dune swamps	Nil	High	Low	Low
North west Cape York	Low overall Moderate Weipa region	Low	High	High	Nil	High	High	High
North-east Cape York	Low	Low	High Unknown — coastal dune swamps	Unknown	High	High	Low	Moderate
Princess Charlotte Bay	Low	Moderate	High	Moderate but degraded	High	Nil	Nil	Moderate
Eastern Coastal Plains								
Cape Melville to Cooktown	Low	Low	Moderate	Moderate Unknown-coastal dune swamps	Moderate	High	Low	Moderate
Cooktown to Ayr	High	High	High but degraded	High but degraded	High	Low	Moderate	Low
Ayr to Rockhampton	High	High	Moderate	Moderate but degraded	Moderate	Moderate	Moderate	Low
Burdekin/Fitzroy Rivers	Moderate	Moderate	Low	Low	Nil	Nil	Nil	Low

rivers are likely to hypersaline (salinity greater than sea water) during the winter because of the low rainfall and lack of dry season flow from upstream; these rivers are unlikely to support any good nesting habitat. The major unknown quantities at present are the extensive flood plain lagoons around some of the major rivers of the southern Gulf and the numerous swamps of the coastal sand dune fringe which extends from the Northern Territory border to near the tip of Cape York. These dune swale swamps are apparently not used for nesting in the Edward River region (Magnusson *et al.* 1980) but require more detailed investigation. Messel *et al.* (1981) observed densities of 0.43 non-hatchling *C. porosus* per km over 360 km of tidal waterway (subregion 1d on Fig. 8) surveyed during April 1979. Only four hatchlings were seen. Spotlight surveys of the Albert, Leichhardt, Bynoe and Norman Rivers in 1985 revealed only 127 *C. porosus* in 515 km of river, of which 26 were hatchlings (LET, unpublished data).

Pressure from human populations is low except near Burketown and Normanton/Karumba in the southern Gulf. There are no Aboriginal Reserves, National Parks or netting closures of any consequence anywhere along the coast south of the Mitchell River Mission (Lat. 15.5°S) on the western Cape. However, the entire coast north of the mission is afforded considerable protection by Aboriginal Reserves (Fig. 7). Agricultural development is largely restricted to beef cattle grazing. Stock damage to potential nesting habitat around flood plain lagoons is often severe but its overall impact is unknown. Stock pressure on coastal dune swamps appears to be relatively low. Substantial incidental catches of *C. porosus* during commercial netting operations in the southern Gulf have been reported by local fishermen and residents.

2. *North-west Cape York (2 on Fig. 8)*

The northwestern region of Cape York is characterized by the higher relief of the Weipa Plateau, rising to 100-200 m very close to the coastline near Aurukun and Weipa, and by considerably higher summer and winter rainfall than the southern Gulf Plains. Some of the major rivers such as the Mission and the Wenlock are perennial, and permanent fresh water swamps are common in near-coastal areas. In consequence there are large areas of good nesting habitat in areas less prone to flooding than in the Gulf Plains. Suitable habitat for *C. porosus* extends well inland despite the relatively limited extent of the coastal plains proper. Spotlight surveys of the Wenlock and Ducie River systems in 1979 revealed relatively large numbers of crocodiles and substantial recruitment of hatchlings (1.76 non-hatchlings per km and 112 hatchlings in 241 km of waterway) (Messel *et al.* 1981). A second survey in 1985 showed a 60% increase in the relative density of crocodiles sighted and further evidence of regular and substantial recruitment (Taplin, unpublished data). A total of 588 *C. porosus*, including 185 hatchlings, were counted in 145 km of waterway.

Population pressure is very low for the most part except near Weipa where a sizeable population of *C. porosus* and much good nesting habitat occur very close to the township. A significant river closure is in effect on almost the entire Mission/Embley/Hey River system at Weipa. Agricultural pressure is low with very few cattle stations in the coastal area. There are no coastal National Parks in this region. Extensive bauxite mining around Weipa appears to have little direct impact on *C. porosus* habitat but the impact of mining and subsequent reafforestation on the aquifers draining into fresh water swamps should be examined. Aquifer draw down and subsequent saline intrusion into swamplands could result in significant losses of crocodile nesting habitat.

Overall the Weipa Plateau undoubtedly contains the best *C. porosus* habitat and the largest breeding population known in the State.

3. *North-east Cape York (3 on Fig. 8)*

This region is very largely an unknown quantity. There are no settlements of any size and very few roads to the coast. Areas of good crocodile habitat are known in sizeable mangrove swamps around the Escape and Lockhart Rivers and at Temple Bay, some of which are protected by National Park or Aboriginal Reserve status. The majority of rivers are very short because of the narrow coastal plain east of the Central Uplands. The high relief and relatively high summer and winter rainfall lend themselves to the development of small but permanent coastal swamps of potential value as nesting habitat. Extensive wind-blown sand dunes in the vicinity of Orford Ness, Shelburne Bay and Cape Grenville may harbour significant numbers of *C. porosus* (Limpus, unpublished data). Messel *et al.* (1981) surveyed the Escape River system in 1979 and sighted 0.67 non-hatchlings per km and 3 hatchlings in 42 km of waterway. The total area of crocodile habitat in the region is relatively small but is afforded considerable protection from many negative influences and may be rated more highly on further investigation.

4. *Princess Charlotte Bay (4 on Fig. 8)*

This region encompasses the catchments of four substantial rivers and includes an extensive area of temporary and permanent lagoons and swamplands, much of which is incorporated into Lakefield National Park. No perennial, spring-fed swamplands likely to support high densities of *C. porosus* nests have been identified to date (LET, unpublished data). Much of the coastal wetland in the region is low-lying and prone to severe flooding, including the small areas of marginal quality nesting habitat

upstream on the North Kennedy and Normanby Rivers. The Bizant River lies wholly within Lakefield National Park but is hypersaline during the dry season and supports little or no nesting habitat. *Crocodylus porosus* numbers within the Park are low but some recruitment is occurring (LET, unpublished data.). Feral pig damage to swampland nesting habitat is severe and may be limiting population recovery.

Human population pressures in the region are low, and derive mostly from several thousand tourists visiting the National Park each year. Their impact is primarily on upstream lagoonal and riverine habitats of the Normanby and North Kennedy Rivers and results in some pressure to remove large *C. porosus* from camping areas. Tourists appear to have little impact on the tidal reaches of rivers. However, all rivers in the area (including those within the National Park) are open to commercial net fishing to the limit of tidal influence. Twenty fishermen are currently licensed to operate within the Park. Pastoral activities have little impact on the tidal flats and salt meadows but fresh water lagoons outside the Park are often heavily affected by stock. Overall the area is of moderate value for conservation at present and could be capable of supporting a substantial population of *C. porosus*.

5. *Eastern Coastal Plains (5 on Fig. 8)*

a) Cape Melville to Cooktown

This region is largely uninhabited and includes numerous small rivers, their estuarine wetlands, and 600 km^2 of sand dunes and blackwater dune lakes near Cape Flattery. Though limited in area by the narrow coastal plain, many of the riverine systems are likely to support good nesting habitat because of the elevated topography and high annual rainfall. Preliminary surveys of the McIvor and Starcke Rivers and the Cape Flattery dune lakes in 1985 suggest that the area does not support a dense crocodile population. However, the total area of wetlands is very large and the absolute numbers of crocodiles in the region could be substantial. We do not know at present which vegetation types are used for nesting in the dunefield swamps. Nests and hatchlings have been reported but not yet located.

Population and agricultural/pastoral impacts in the region as a whole are low. A large Aboriginal Reserve and two National Parks protect parts of the coastal plain including the Cape Flattery dunefields. This region may well include the best nesting habitat for *C. porosus* remaining on the east coast.

b) Cooktown to Ayr

This region of very high summer and relatively high winter rainfall is characterized by many short, perennial rivers draining from the high coastal ranges. The major deltaic plain wetlands around Cairns, Ingham and Ayr are largely devoted to agriculture and much of their formerly extensive swamplands have been reclaimed. The majority of the rivers are utilized heavily for recreational and commercial fishing, boating and water sports. However, some significant areas of protected and inaccessible habitat remain in small coastal National Parks and Aboriginal Reserves and several rivers are closed to commercial netting.

Small numbers of *C. porosus* occur in many of the coastal rivers but no large aggregations are known or suspected at present. It appears that a substantial fraction of the population is to be found in quiet backwaters and isolated lagoons rather than in the mainstreams. Small numbers of successful nests are laid down in most years and some recruitment occurs. However, there are few rivers or swamplands more than a few kilometres from townships and it is unlikely that any substantial increase in the local crocodile population would be tolerated by the communities. Subadult and mature crocodiles are removed regularly to farms and zoos in the interests of public safety. If estuarine crocodile populations are to persist on the populated east coast, then strategies for maintaining recruitment while removing potentially dangerous adults will have to be developed. Research into the reproductive status of small crocodiles in these depleted populations is currently underway.

c) Ayr to Rockhampton

Little is known about the crocodile resources of this climatically marginal section of coastline. As in the Cooktown-Ayr region, the vast majority of the arable riverine plains are now settled or under cultivation. The low frequency of reported crocodile sightings makes it unlikely that any large breeding populations remain in the area. Overall the region has little conservation value as *C. porosus* habitat but is of considerable scientific interest because of its marginal climate and the dearth of information on physiological and ecological responses of crocodiles to extremes of climate.

6. *Burdekin and Fitzroy River Catchments (6 on Fig. 8)*

Small populations of *C. porosus* are known from both these river systems, as far as 200 km inland by river. Populations are low in both rivers but nesting and recruitment still occur (J. Lever and L. Taplin, unpublished data). Both the Fitzroy and Burdekin populations are of considerable scientific interest as here *C. porosus* are inhabiting unusually harsh country, which is relatively cold and dry, in addition to them being effectively land-locked in permanent fresh water.

Population and agricultural/pastoral impacts have been assessed as moderate but really little is known of the Fitzroy River population. The Burdekin

population appears to have survived to date largely because of the inaccessibility and low agricultural value of the area. Recreational activity on the more accessible parts of the river is quite intense but consists largely of camping and fishing where road access is possible. Establishment of the Burdekin River dam with its attendant changes in flow regimes and recreational opportunities appears likely to lead to the disappearance of the colony downstream of the dam. Agricultural impacts in the Burdekin catchment include some increased siltation of rivers such as the Bowen and damage to lagoonal nesting habitat by feral pigs and domestic stock. Like the coastal plain between Ayr and Rockhampton, The Burdekin/Fitzroy region is of little conservation value but considerable scientific interest.

SHORT-TERM ISSUES IN CROCODILE MANAGEMENT

The variable quality of *C. porosus* habitat in Queensland and the limited extent of good nesting habitat suggest a research effort should be aimed at refining the assessments presented here and identifying more precisely the priority areas of crocodile conservation in Queensland. The initial aim should presumably be to locate prime breeding sites, both in areas comparable to those studied intensively in the Northern Territory (e.g. the Weipa region) and in poorly known but extensive habitats such as the coastal dune swamps of the Gulf and eastern Cape. Such a survey would identify the most important geographic areas in which to concentrate future efforts and would be an essential prerequisite to any management strategy incorporating the commercial utilization of wild populations.

The large area of interaction between crocodiles and people along the east coast poses several management problems. Formal reports of crocodiles are common; 122 reported from the Townsville-Cooktown region in 24 months from 1984 to 1986. Fifty-three per cent of these involved crocodiles over 2.5 m long and required investigation by the Service. Many complaints were accompanied by newspaper articles or radio announcements reporting exaggerated claims by laymen of enormous numbers of crocodiles in east coast rivers. These claims do not stand up to rigorous examination. Surveys by Service personnel reveal only low densities of crocodiles on the coastal streams examined to date. Even allowing for the limitations of the survey techniques, it is hard to reconcile the claims with the hard data. Nevertheless, the east coast rivers are, in effect, the "frontline" of our crocodile conservation efforts in the short-term and deserve a higher priority than their low conservation value would otherwise suggest. Intensive research in the region is precluded by the small numbers of crocodiles available and continual disturbance on the rivers. The present research effort is aimed at determining the status of *C. porosus* populations in river systems throughout the east coast and at locating nest sites and important foci of recruitment.

One must also consider the strategy to be adopted in dealing with "problem" crocodiles in this region. Given the low conservation value of the populated east coast and the damage to conservation efforts that has followed two recent crocodile attacks, a policy of removing any problem crocodile might appear reasonable. It is important, however, to look beyond the immediate impact of management efforts to their long-term aims. The population of north Queensland is growing rapidly and there is a corresponding increase in the numbers of tourists visiting remote areas in Cape York and the Gulf of Carpentaria. This trend is unlikely to change in the the foreseeable future. If the long-term effect of this development is not to be the gradual exclusion of *C. porosus* from all but the most inaccessible regions of the north, then two important components of a long-term conservation strategy must be:

1. to provide crocodiles with some significant value in the eyes of the public; and,
2. to educate the community to the view that "living with crocodiles" is not a totally unacceptable proposition.

Progress in this area is unlikely to be easy. *Crocodylus porosus* have not had a prominent place in the consciousness of the average north Queenslander for some decades. Many long-term residents in formerly good crocodile habitats on the east coast remember them only from stories of occasional animals shot by parents or grandparents. They have seldom had to concern themselves with the potential dangers of swimming in coastal lagoons and rivers. Such concerns are now widespread in the community and, not suprisingly, calls for a return to the *status quo* are increasing.

The Queensland National Parks and Wildlife Service has not undertaken to maintain any areas "crocodile-free". Such areas do exist, in effect, in many populated areas where *C. porosus* of any size are removed as a matter of course. However, the expense and difficulty of removing *all* crocodiles from the coast between Cooktown and Rockhampton cannot be justified. For operational purposes, *C. porosus* less than 2 m long are not regarded as problems, except in particularly sensitive areas, for example near swimming holes, caravan parks and schools. Larger crocodiles are dealt with on a case-by-case basis. An important part of the rationale for this policy is that the removal of all crocodiles from populated areas further removes them from the consciousness of both residents and tourists. This does little to enhance public safety and is detrimental to the long-term aim of changing

public attitudes towards crocodiles. Part of the cost of crocodile control is defrayed by allowing registered farms and zoos to catch specified animals. There is, however, only a limited capacity to house these animals, which cannot enter commercial trade under present domestic and international restrictions. Continued management along these lines will depend on rational development of the crocodile farming industry and/or the development of nationally and internationally acceptable schemes for wild harvests.

Management problems with crocodiles also occur on National Parks and pose a different set of problems. Parks along the populated east coast may harbour small breeding populations from which juveniles and subadults disperse into surrounding areas. Mature crocodiles are likely to move in and out of parks, particularly during the summer breeding season. In many cases, parks are located very close to townships and tourist resorts. Under these circumstances, it is difficult to sustain the argument that all crocodiles in National Parks should be totally protected unless they pose real and immediate danger to people. There are cases where the removal of individual crocodiles is necessary to avoid compromising longer-term objectives. In the case of remote National Parks, however, opportunities for the public to see crocodiles in the wild can be incorporated in Park interpretation programmes and tourist activities, forming part of the overall National Park/outback experience. Here, greater weight is given to controlling activities of park visitors, so as to minimize or eliminate the need to remove animals. Once again, a broad perspective on the crocodile resources of the State as a whole is needed to provide a framework for decision making, within which the benefits and risks of specific strategies can be evaluated.

LONG-TERM ISSUES IN CROCODILE MANAGEMENT

There are two major options, not mutually exclusive, which might be pursued in the long-term management of *C. porosus* in Queensland. One is the protection of wild populations from commercial harvesting, the gradual development of a crocodile farming industry based on captive breeding, and the development of a system of reserves and netting closures aimed at protecting important breeding sites. The second option is to follow the Northern Territory's lead by trying to develop the commercial potential of wild populations and give crocodiles some economic value to the landholders on whose property they live and to the community as a whole.

The present management regime in Queensland is cautious and does not allow any harvesting of wild populations. It does support the development of a crocodile farming industry and makes provision for problem crocodiles to be taken from the wild for breeding stock. Crocodile farming in Queensland is still in its infancy. There are currently two established farms, one at Edward River on western Cape York and the other at Rockhampton. The Edward River farm is a Commonwealth Government-funded operation aimed at establishing the viability of crocodile farming as a source of employment and income for Aboriginal communities. Established in 1969, it has a current stock of some 3400 *C. porosus*, including about 300 breeders of which 80% are female. Some 50-60 nests per year have been laid down over the past 3-4 years and about 1200 hatchlings per year raised. Initial sales of skins from farm-bred stock began in 1984, as these skins satisfied the requirements for trade under Appendix 1 of CITES. A second, private farm at Rockhampton has stocks of approximately 110 *C. porosus* and 150 *C. johnstoni*. This farm was established in 1982 and is still not in full operation. At the time of writing, attempts to breed *C. johnstoni* had limited success but *C. porosus* nesting is well underway with 16 nests in the 1985/86 season. The Northern Territory experience suggests that farming of *C. johnstoni* is unlikely to prove economically viable using current strategies and further development of the skin industry for this species may depend on ranching (captive rearing of eggs or juvenile crocodiles taken from the wild).

Present Queensland policy favours the establishment of more crocodile farms based on captive breeding of *C. porosus*. Very limited breeding stock is available from the wild in the form of problem crocodiles from the populated east coast and near more remote townships. Costs of capture and transport for those available are often prohibitive as relatively few of the east coast animals are adult and a high proportion are very difficult to catch. Present policy does not allow for the establishment of further farms based on wild-caught stock until information on population status is available. Purchase or leasing of stock from other crocodile farms is encouraged. The Edward River farm is currently investigating the feasibility of establishing "rearing stations" which will allow farm-bred stock to be reared at other locations on a profit-sharing basis.

Expansion of the crocodile farming industry in the Northern Territory is made easier because the major population and trade centre, Darwin, is flanked by numerous rivers with large crocodile populations. Breeding stock is readily available at relatively low cost and farms can be located close to tourist routes, which give potential markets for by-products. Farms in Queensland will have to balance their dependence on tourism and local markets, largely restricted to the east coast, against the costs and delays involved in establishing adequate breeding stocks from the limited numbers of mature crocodiles available there.

If commercial utilization of crocodiles is to be pursued in Queensland, with a view to giving crocodiles some economic value, the development of ranching schemes is most likely to succeed in melding preservation and utilization. Despite the reservation of large tracts of land in National Parks, the vast majority of crocodile habitat lies on freehold or leasehold property. Apart from a few tourist-orientated cattle stations that use crocodiles as a drawcard, there is little incentive at present for any landholder to conserve crocodiles on his property. In the case of *C. porosus* there can be definite disincentives in the form of stock losses and potential danger. It is not uncommon for landholders to destroy crocodile nests and large crocodiles thought responsible for stock losses. There can be obvious benefits, therefore, in pursuing a strategy which allows landholders to profit from maintaining crocodiles on their properties through the harvest of eggs or juveniles for rearing in commercial farms.

Ranching operations involving the collection of eggs from areas prone to flooding are unlikely to be economical in Queensland; eggs are difficult to handle without killing the embryos and there are few areas of concentrated nesting activity close to present crocodile farms. Economically viable harvesting will probably depend on collection of hatchlings or juveniles from major breeding sites in remote areas, relying on air transport back to farms or ranches on the east coast. Our present policy is to await the results of the Northern Territory's experiments on ranching of *C. porosus* and *C. johnstoni* before proceeding along similar lines. However, if this management strategy is to be retained as a long-term option, the identification of populations capable of sustaining a harvest and the development of an experimental harvest programme are seen as very high priorities for research in the short-term.

There is need for caution, nevertheless, in pursuing a strategy which argues for the conservation of crocodiles entirely on the basis of their commercial value. This is undoubtedly likely to be the most effective argument in favour of conserving crocodiles should commercial utilization prove successful. It is unwise, however, to rely entirely or primarily on this argument before the crocodile farming industry is solidly established. Public education programmes in Queensland will also emphasize the value of crocodiles as important components of aquatic ecosystems and the tropical wetlands which support fish and game; scientifically interesting animals with a long history of veneration and abhorrence by man; members of an ancient group of animals in danger of extinction throughout much of the world. Complementary to these arguments will be development of the theme that crocodiles do not represent a major threat to life and limb in Australia relative to other causes of injury such as snakes, spiders, box jellyfish and sharks; a reality that the community tends to lose sight of.

Regardless of whether or not ranching schemes develop as part of the the QNPWS Rural Nature Conservation programme, the reservation or protection of important breeding sites is likely to remain an integral part of our crocodile management programme. There is no doubt that many of Queensland's coastal National Parks are too small to support viable *C. porosus* populations in the long-term. Some of the larger ones on Cape York may be large enough; we have too little information on the population biology of *C. porosus* to judge at present. It is certainly too early to decide whether a programme of establishing further large reserves specifically or primarily for the protection of crocodiles is the best or most appropriate conservation strategy. Our research effort will aim, *inter alia*, to evaluate the role of reservations and netting closures in crocodile management and to determine the optimum balance between ranching and reservation as complementary options.

SUMMARY

1. Peculiarities of Queensland's physical and social geography create management problems different from those experienced in the Northern Territory. Queensland's immediate management problems are less severe than those of the Northern Territory but have the potential to be much greater because of our larger population and greater area of interaction between crocodiles and people.

2. The remoteness and marginal quality of much of the *C. porosus* habitat in the State limit opportunities to develop farming and ranching schemes.

3. There is little evidence yet that Queensland supports large populations of *C. porosus* in isolated areas, such as occur in the Northern Territory and provide the species with an important buffer against overexploitation there.

4. Development of biologically sound schemes of harvesting will depend on a substantial effort in basic research. The range of crocodile habitats found in Queensland limits the extent to which research results from the Territory can be translated directly into a local context.

5. Encouragement of ranching operations aimed at making crocodiles valuable to the man on the land is seen as the most effective long-term conservation strategy. Progress in this direction will depend greatly on the identification and protection of major breeding sites able to sustain recruitment into exploited and protected populations.

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