



FAUNA *of* AUSTRALIA



41. NATURAL HISTORY OF THE CROCODYLIA

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Pl. 9.2. *Crocodylus porosus* (Crocodylidae): when feeding in the water, this species lifts the tail to counter balance the head; see also Pls 9.1 & 9.3. [G. Grigg]

Although the following is a discussion of the natural history of crocodylians in general, the Australian crocodiles, *Crocodylus porosus* and *C. johnstoni*, are used to illustrate examples whenever possible. A good introductory work based on Australian crocodiles is that of Webb & Manolis (1989).

LIFE HISTORY

Reproductive Strategies

The age and size at sexual maturity in crocodylians is variable, even among different populations of the same species (Cott 1961; Graham 1968; Staton & Dixon 1977; Gorzula 1978; Hutton 1984; Joanen & McNease 1987; Cooper-Preston 1992). Females of *Crocodylus johnstoni* mature at approximately 0.75 m snout-vent length and 12 years old in river systems such as the McKinlay River, Northern Territory (Webb, Buckworth & Manolis 1983a). In contrast, females as small as 0.55 m snout-vent length are mature in the upper Liverpool River in Arnhem Land where growth rates are low, at an estimated age of 20 years (Webb 1979b; Cooper-Preston 1992). Differences in age and size at sexual maturity probably reflect both genetic and environmental factors (Joaanen & McNease 1981; Ferguson 1985) and may be adaptations to environments with differing food resources. Reproduction can be maximised by attaining a large size before maturity in suitable habitats. However, marginal areas can be populated by compromising growth for a reduced, yet sustainable, reproductive effort.

In part both social and environmental factors, along with the number of potential breeding females, determine the nesting effort during a given year in a particular population (Hines & Abercrombie 1987; Joanen & McNease 1987). It appears that the proportion of sexually mature *C. johnstoni* that nest annually varies greatly, but in certain populations the nesting effort is consistently lower than that in other populations (Smith & Webb 1985; Cooper-Preston 1992).

Young and very old females may not contribute much to recruitment. High rates of infertility in eggs and small clutch sizes have been attributed to small or young females of *C. johnstoni* (Dunn 1981; Smith 1987; Webb unpub. data) and *C. porosus* (Webb unpub. data).

Crocodylians are polygynous and a lack of males rarely, if ever, limits reproduction in *C. johnstoni* (Webb Webb, Buckworth & Manolis 1983a) and probably in other crocodylians. Although no studies have been conducted on *C. porosus* in the wild, in captivity only the larger males in multiple animal enclosures breed with the available females (Mengden pers. comm.).

Clutch Characteristics and Hatching

Average clutch size, mass and egg dimensions vary inter- and intraspecifically. The size, age and diet of the female affect clutch size. In *C. johnstoni*, the average clutch size varies from four to six eggs along the upper Liverpool River (Banks pers. comm.) to 12 to 13 eggs on the McKinlay River (Webb *et al.* 1983a; Smith 1987). The average clutch size for *C. porosus* is 53 in the Northern Territory (Webb & Manolis 1989) and 59 in Papua New Guinea (Cox 1985). Mean clutch mass is similar, suggesting that the Northern Territory and Papua New Guinean females are of similar average size (Cox 1985; Webb & Manolis 1989), since clutch mass appears to be the best clutch characteristic for predicting individual female size in crocodylians (Smith 1987; Webb unpub. data). Grigg & Gans (Chapter 40) record a range of clutch sizes from four to 21 for *C. johnstoni* and 50 to 60 in *C. porosus*. The average egg dimensions for

C. porosus in the Northern Territory are 80 mm by 50 mm (Webb & Manolis 1989) and those of *C. johnstoni* are approximately 66 mm by 42 mm (Webb *et al.* 1983a).

Egg mortality may result from predation, inundation, desiccation, and excavation by other females. The extent varies between years and populations. In *C. johnstoni*, up to 60 to 70% of the eggs at the McKinlay River are lost each year, mostly as a result of predation by varanids (Webb *et al.* 1983a). Mortality appears to be much lower in areas such as the Katherine River region, perhaps because of the lower nesting effort and therefore the absence of communal nesting banks. Flooding is the major cause of egg mortality in *C. porosus*, and up to 90% of nests in the Northern Territory may be inundated in some areas (Webb & Manolis 1989).

Incubation periods range from 40 to 120 days for crocodylians (Ferguson 1985). The incubation periods for *C. johnstoni* and *C. porosus* are from 63 to 98 days (Webb *et al.* 1983a) and 70 to 98 days (Webb, Sack, Buckworth & Manolis 1983b), respectively. The period varies with nest temperature because of its effect on embryonic developmental rates (Webb & Smith 1984).

Hatchling size is determined principally by egg size (Webb & Manolis 1989), but is also affected by incubation temperature (Hutton 1987b; Manolis pers. comm.). *Crocodylus johnstoni* hatchlings are approximately 240 mm long and weigh 42 g and those of *C. porosus* are 290 mm long and 72 g in weight (Webb & Manolis 1989; Cooper-Preston 1992).

In many, if not all crocodylians, the female excavates the nest upon hearing the calls of the hatchlings and assists them to the water (see also Chapter 40). Experiments with *C. johnstoni* have shown that the hatchlings will die in the nest if not assisted by a female (Fig. 41.1; Limpus pers. comm.). This is probably true for all hole-nesters. Experimental manipulation of *C. johnstoni* nests showed that females other than the mother will also open nests in response to hatchling calls (Smith 1987). In *Caiman crocodylus fuscus* both parents assist in releasing the hatchlings (Alvarez del Toro 1974).

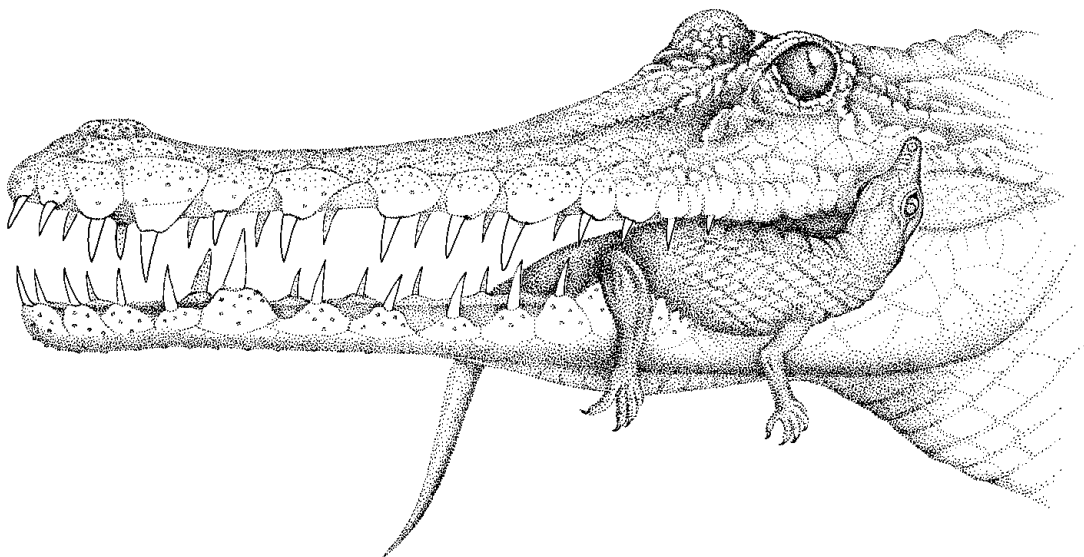


Figure 41.1 After excavating the nest, a female *Crocodylus johnstoni* picks up hatchlings and carries them to the water. (After ABC 1988) [T. Wright]

Primary Sex Ratio

The sex of crocodylians is determined during the first third of embryonic development by incubation temperature which acts either directly or indirectly by influencing the embryonic developmental rate and release of hormones (Ferguson & Joanen 1982, 1983; Webb & Smith 1984; Ferguson 1985; Hutton 1987b; Lang 1987; Smith 1987; Webb, Beal, Manolis & Dempsey 1987; Yamakoshi, Magnusson & Hero 1987; Lang, Andrews & Whitaker 1989; Webb & Cooper-Preston 1989; Deeming 1990; Magnusson, Lima, Hero, Sanaiotti & Yamakoshi 1990). Temperature-dependent sex determination tends to produce males in the conditions most conducive to high chances of survival and good post-hatching growth (Webb & Cooper-Preston 1989). Under constant laboratory temperatures, female *C. johnstoni* are produced at all temperatures (28° to 34°C) and males only between 31° to 33°C (Webb & Smith 1984). The highest percentage of males produced in laboratory trials was 31% (Webb, Beal, Manolis & Dempsey 1987). However, the results of experiments using constant incubation temperature should be viewed cautiously (see Chapter 40).

Field nests have produced 100% males after an incubation period of 72 to 74 days, corresponding to incubation time at 32° to 33°C in the laboratory (Webb & Smith 1984). In *C. porosus*, males are also produced between 31° to 33°C. The proportion of males can be higher than in *C. johnstoni*, however, and at 32°C, up to 91% of the hatchlings are males (Webb *et al.* 1987). Clutches producing only females at high incubation temperature have not been documented for *C. porosus* because of high percentages of death and abnormality above about 34°C (Webb pers. comm.). Other crocodylians also tend to produce females at low temperatures and males at high temperatures (Ferguson & Joanen 1982, 1983; Hutton 1984, 1987b; Lang 1987). Not surprisingly, primary sex ratios vary among populations of the same species and from season to season within a population. However, a female-biased sex ratio is the norm for several species, including *C. johnstoni* (Webb *et al.* 1983a; Cooper-Preston 1992).

Longevity

Although it is well-known that crocodylians live for a long time, the maximum age and the age at senility can only be guessed. *Crocodylus porosus* are known to live for over 70 years and may even reach 100 years, whereas *C. johnstoni* are not as long-lived, and animals of 50 years are considered old (Webb & Manolis 1988a, 1988b).

ECOLOGY

Environmental Relations

Crocodylians are ectothermic, and exploit the external environment to regulate their body temperature by such thermophilic and thermophobic behaviours as basking, movement in and out of water, and mouth gaping. Physiological mechanisms of temperature control are described in Chapter 40.

Temperate species are more thermophilic than tropical ones (Mazzotti 1989). The American alligator, *Alligator mississippiensis*, typically spends the morning basking, moves into shallow water in the afternoon but keeps its back exposed, and retreats into deeper water as the air temperature drops at night (Mazzotti 1989). However, the estuarine crocodile, *Crocodylus porosus*, avoids heat by remaining in the water during the day and comes up on the banks at night, often burying itself in the mud of tidal areas (Lang 1987). Basking in both *C. porosus* and *C. johnstoni* is most evident during the winter months of June and July, especially in the mornings. A basking *C. porosus* aligns itself with the sun for

maximum heat exchange; as its body temperature rises it faces the sun with mouth agape thereby reducing the impact of heat on the brain (Webb & Manolis 1989).

Mouth gaping increases the area for evaporative cooling which affects internal temperature. Many species gape and, although Spotila, Terpin & Dodson (1977) confirmed some thermoregulatory role, the habit remains puzzling. Since the water loss is related to body temperature, thermoregulatory behaviour also affects osmoregulation (Mazzotti 1989).

Preferred body temperature is influenced by many factors, including climate and social conditions, size, age, feeding activity, health, and incubation temperature of the embryo (Lang 1987). Preferred body temperatures are the same in adults and older hatchlings, and thermophily in newly hatched crocodilians aids in the quick digestion of yolk (Lang 1987). Thermophily also increases the rate of digestion after eating, and is more prevalent in alligators than in tropical crocodilians (Mazzotti 1989). Lang (1987) found that *A. mississippiensis* will create a 'behavioural' fever that combats infection (see Chapter 40). This may be true also of other species of crocodilian.

Seasonal variation in climate may cause dramatic changes in gross behaviour in some species. No crocodilian is known to hibernate; however *Alligator mississippiensis* will position itself in shallow water with only its nostrils exposed during severe cold spells (Mazzotti 1989). *Crocodylus johnstoni* has been known to aestivate at the end of the dry season (September to November) in underground refugia along a dry creek bed in the Northern Territory (Christian pers. comm.). This behaviour may be widespread.

Crocodilians respond behaviourally to changes in environmental salinity. They do not drink saline water and move to fresh water after feeding in saline water (Mazzotti 1989; Grigg *et al.* 1998).

Diet

Crocodilians tend to be opportunistic feeders. Their diet reflects both the local availability and vulnerability of prey species and size-related shifts in dietary preferences (Graham 1968; McNease & Joanen 1981; Webb, Manolis & Buckworth 1982). Many crocodilians feed primarily at the water's edge, including *Crocodylus johnstoni* (Webb, Manolis & Buckworth 1982; Cooper-Preston 1992) and *C. porosus* (Fig. 41.2; Taylor 1979). The slender-snouted *Gavialis gangeticus* and *C. johnstoni* are adapted to feeding on mobile prey such as fishes, which form a high proportion of the diet of these predators (Pooley & Gans 1976; Webb *et al.* 1982; Whitaker & Basu 1983). A slender snout can snap sideways more effectively because it meets less water resistance. In contrast, *Caiman latirostris* uses its broad snout to scoop molluscs from the river bottom (Diefenbach 1979).

Diets change with increasing size and with age (Cott 1961; Fogarty & Albury 1967; Dodson 1975; McNease & Joanen 1981; Webb *et al.* 1982; Magnusson, da Silva & Lima 1987). Insects constitute the major food items of juveniles, and adults take larger prey (Corbet 1959, 1960; Cott 1961; Dodson 1975; Staton & Dixon 1975; Gorzula 1978; Seijas & Ramos 1980; McNease & Joanen 1981; Hutton 1984; Magnusson *et al.* 1987). In some larger species of crocodilians, such as *C. porosus* (Taylor 1979), *Alligator mississippiensis* (Giles & Childs 1949; Dodson 1975; McNease & Joanen 1977), and *C. niloticus* (Cott 1961; Blomberg 1977), the diet includes an increasing proportion of terrestrial prey as body size increases. *Crocodylus johnstoni* feeds on smaller prey than other crocodilians of comparable body size, and tends to eat insects throughout its life, although the proportion in the diet diminishes (Webb *et al.* 1982; Magnusson *et al.* 1987).

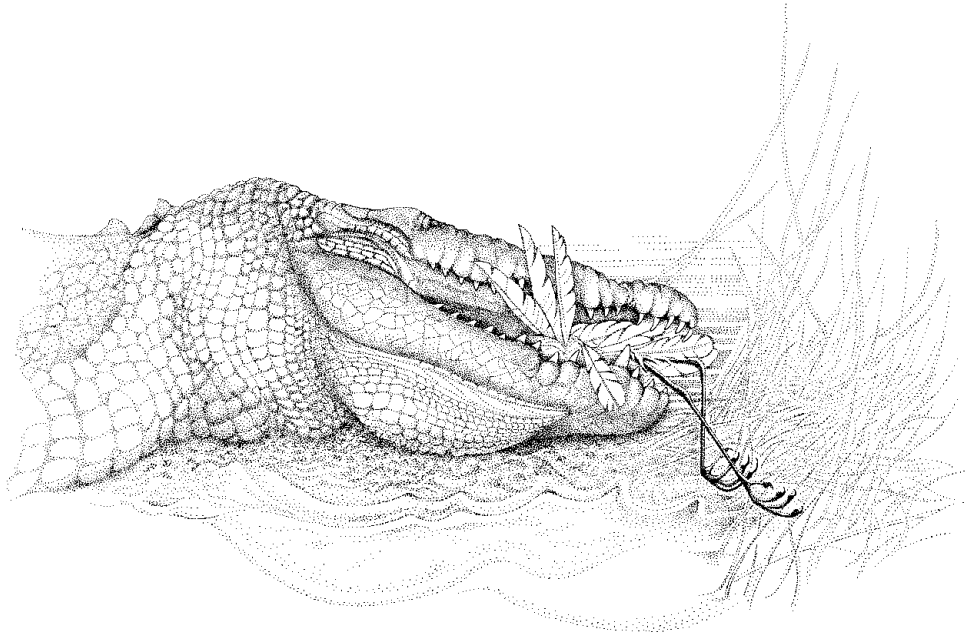


Figure 41.2 Typically *Crocodylus porosus* turns its head to one side when taking prey from land. (After photo by G. Grigg) [T. Wright]

Visual cues, chemoreception and tactile stimuli are important in detecting prey both in and out of the water (Whitaker & Basu 1983; Weldon, Swenson, Olson & Brinkmeier 1990; Cooper-Preston 1992); sensory pits along the side of the jaws may detect movement of prey (see Chapter 40; Webb & Manolis 1989).

Feeding behaviour is specialised in many species. *Caiman crocodilus* feeds mainly on floating semi-aquatic prey such as insects and frogs and avoids actively swimming prey (Gorzula 1978). *Paleosuchus trigonatus* is often found away from the water and consumes more terrestrial vertebrates than any other Amazonian crocodylian (Magnusson *et al.* 1987). Some species will extend the snout out of the water to catch insects in flight. Juvenile *Caiman latirostris* use this approach to feed on flying carabids (Diefenbach 1988), as do small *Crocodylus niloticus* when feeding on dragonflies at dusk in Uganda (Corbet 1959). *Crocodylus porosus* will leap partially out of the water for food. Like other crocodylians they adopt sit-and-wait tactics, and rely on swift attack from the water to seize and immobilise terrestrial prey before it is swallowed. Whilst stalking prey, crocodiles move silently and surreptitiously, often with only the nostrils, eyes and the top of the skull platform visible at the surface (Fig. 41.3; see Chapter 40).

Seasonal differences in diet reflect food availability and activity patterns of crocodiles and their prey (Gorzula 1978; Webb *et al.* 1982; Diefenbach 1988). Evidence of seasonal changes in the quantity of food eaten has been reported for some species of alligators and caimans (Fogarty & Albury 1967; Dodson 1975; McNease & Joanen 1981; Gorzula 1978; Diefenbach 1988) and in some populations of crocodiles (Hutton 1984, 1987a). Taylor (1979). Webb, Hollis & Manolis (1991) found no seasonal variation in the amount of food in stomachs of *C. porosus*, although the type of food changed from predominantly crustaceans in the dry season to a high proportion of insects in the wet season.

Stones, or gastroliths, are often found in crocodile stomachs and their presence has stimulated lively discussions on their function. Some authors have proposed that stones are ingested incidentally, and serve no function, or that they maintain stomach size and stimulate gastric juices. Others suggest that stones have an important role in buoyancy (see Chapter 40), or that a digestive function for the stones is the most plausible hypothesis (Bakker 1986; Cooper-Preston 1992).

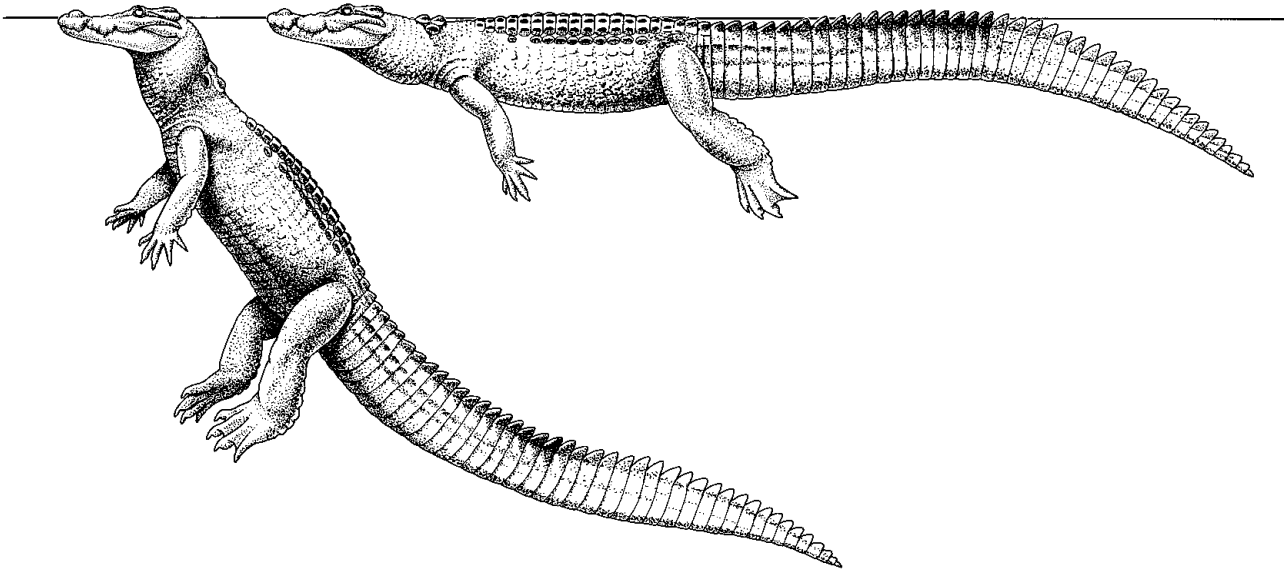


Figure 41.3 Fine-tuned buoyancy control enables *Crocodylus porosus* to approach very close to prey without detection. Although denser than water they inflate the lungs appropriately to achieve neutral buoyancy. Crocodilians using shallow breathing can float at the water surface for long periods, and maintain the eye constantly within a couple of millimetres above the water level. [D. Kirshner]

Home Range and Movement

Home range may be defined as the area where an animal spends the majority of its time. Home ranges include centres where certain activities are concentrated such as basking or feeding (McNease & Joanen 1974). Few data are available for Australian crocodiles. However, home ranges of *Alligator mississippiensis* and *Crocodylus niloticus* differ between age groups and vary seasonally (Joanen & McNease 1972a, 1972b; Hutton 1984).

Movements among crocodilians are usually seasonal or size-specific. In some areas, male and female *C. niloticus* migrate to breeding grounds where courtship and nesting occurs (Magnusson, Vliet, Pooley & Whitaker 1989). During the breeding season females of *A. mississippiensis* leave protected marsh areas for open waters inhabited by males, and retreat back to the marshes to lay their eggs (Joanen & McNease 1980).

Annual inundation during the wet season is a major factor in dispersal of *Crocodylus porosus* in Australia (Webb & Messel 1978; Jenkins pers. comm.). During mark-recapture work on *C. porosus* in the Liverpool River area most movement was via the main streams with more males travelling downstream than females (Webb & Messel 1978). Flooding is a major factor in the dispersal of *C. johnstoni* (Webb, Buckworth & Manolis 1983c; Cooper-Preston 1992).

BEHAVIOUR

Nesting

Nesting in crocodilians takes place over either a protracted period, as in *C. porosus*, or a short 'pulse' of several weeks, as in *C. johnstoni*. The time of nesting depends on factors such as air and water temperatures, rainfall, water level and photoperiod (Joanen & McNease 1979). *Crocodylus porosus* nests during the wet season in northern Australia (November to April) and egg laying

usually peaks during January (Webb & Manolis 1989). The nesting season of *C. johnstoni* is restricted to several weeks from the end of August through to the beginning of September (see also Chapter 40).

Crocodylians construct either a mound nest, mostly of vegetation (Fig. 41.4), or dig a hole nest in sand or other friable substrate (see Chapter 40). Only *Crocodylus acutus* is known to construct both types of nests (Mazzotti, Kushlan & Dunbar-Cooper 1988). *Crocodylus johnstoni* nests communally, as other hole-nesters do, except where breeding numbers are low in relation to potential nesting sites (Cooper-Preston 1992). Larger females tend to nest earlier than smaller animals (Smith 1987; Webb pers. comm.). Site selection is random (Smith 1987; Cooper-Preston 1992). In contrast, female *C. porosus* select nesting sites on the basis of access to permanent water, a refuge, suitable vegetation and a basking area (Webb, Sack, Buckworth & Manolis 1983b). Factors influencing the time of nesting are difficult to identify, because of the extended nesting period (November to May); rainfall and water level may play an important role, whereas air and water temperatures are unlikely to affect timing (Webb unpub. data).

The extent of nest defence against predators and humans is variable, and ranges from non-existent in most *C. johnstoni* to direct attacks on intruders by female *C. porosus*. Caimans are more likely to defend their nests early in incubation when nests are easier to detect (Magnusson, Vliet, Pooley & Whitaker 1989). Nesting is the only period when *Gavialis gangeticus* shows any aggression towards humans (Magnusson *et al.* 1989).

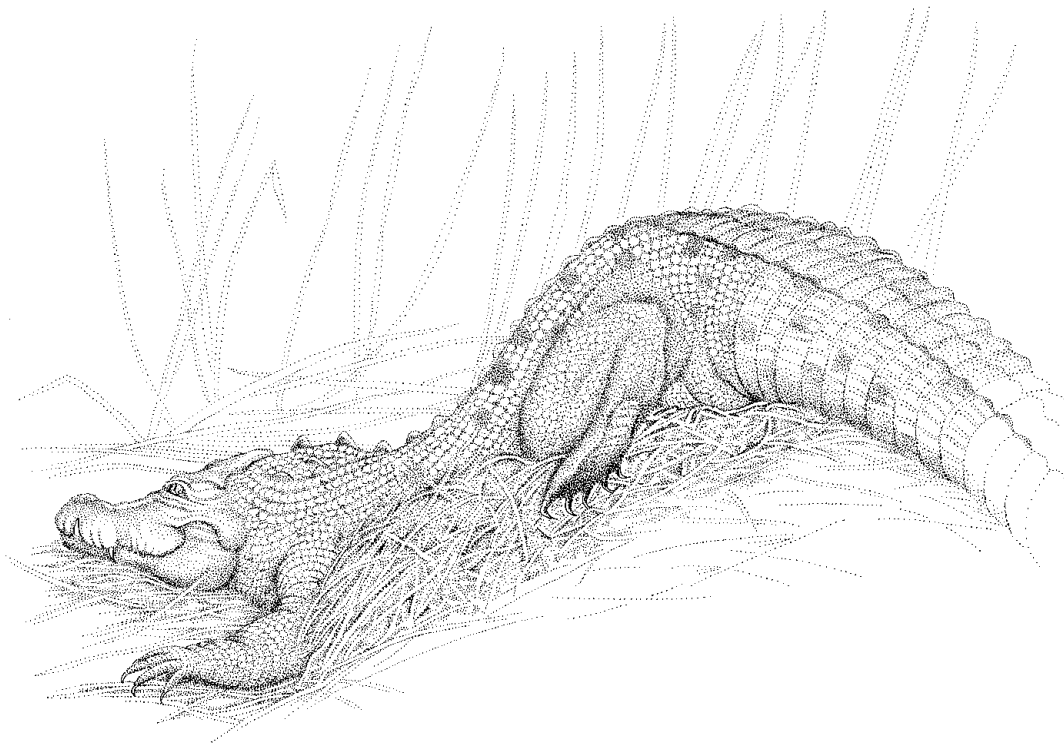


Figure 41.4 In *Crocodylus porosus* the female constructs her nest from vegetation raked together with her hind feet to form a mound in which the eggs are laid.

[T. Wright]

Social Behaviour

Crocodylians exhibit quite complex social behaviours associated with individual recognition, group living and courtship. Such behaviours may be stereotyped or flexible and can incorporate vocal, acoustic, visual, tactile and chemosensory communication. Certain general behaviour patterns are found throughout the order, while components of patterns are usually specific to species or even populations.

Communication begins in the egg with tapping sounds about two weeks before hatching, which may help to synchronise hatching (Lang 1989). Hatchlings vocalise (at pipping), and alert the female who usually opens the nest and assists the young to the water. Contact calls keep the pod together and distress calls usually elicit a response from the mother and often from other adults and juveniles. *Crocodylus porosus* often growl when under threat and during courtship, especially in captivity (Webb & Manolis 1989). *Crocodylus johnstoni* may respond to a threat with a low-pitched growl or grunt (Webb & Manolis 1989).

Vocalisation among adults tends to be species- and population-specific; *Alligator mississippiensis* is the most vocal crocodylian (Lang 1989). Species living in marshes and swamps tend to be more vocal than those in open water and rivers (Lang 1989), presumably because visual cues are less effective in heavily vegetated areas.

Other acoustic behaviour also varies between species. All but *Gavialis gangeticus* perform a variation of the headslap which signals an individual's presence. The head is lifted out of the water with mouth opened and then slapped against the water, creating a loud clap as the jaws come together, and a splash as the head hits the water. This may be followed by bubble blowing, roaring and thrashing of the tail. Some species, including *C. johnstoni*, vibrate their trunk muscles, creating bubbles and low frequency waves around the body (Lang 1989; Webb & Manolis 1989). This is a threat display in *C. johnstoni* (Webb & Manolis 1989), but is also used during courtship in other species (Lang 1989). Another acoustic signal consists of exhalations from the throat and nasal passage in and above water.

Visual signals used in individual recognition include body posturing with the head, back and tail high out of the water in dominant individuals (Pl. 9.2), and snout lifting for submissive crocodiles. Snout lifting is also used in courtship in many species. Tail thrashing in the water and also on land indicates aggression in crocodylians (Lang 1989).

Other forms of communication involve tactile receptors on the head and secretory glands under the chin and in the cloaca (see Chapter 40). The importance and exact function of these has yet to be determined (Lang 1989). Other reptiles use chemosensory mechanisms for identifying individuals, marking territories and indicating reproductive status.

Studies conducted in captivity suggest that territoriality and dominance hierarchies are species-specific and density-dependent (Lang 1989). The dominant male is usually large and aggressive and exposes a large proportion of his dorsal body above the water when swimming, and submissive animals tend to submerge and retreat in his presence. Physical combat is rare in most species. However, *C. porosus* can be quite violent, especially during the breeding season, and serious injury or death can result. Males bite each other, and roll and thrash about until the subordinate one swims away (Webb & Manolis 1989). Similarly, dominant females attack other females.

Courtship displays are similar in all crocodylians. The female usually initiates courtship by approaching the male in a submissive posture (Compton 1981; Lang 1989; Magnusson *et al.* 1989; Webb & Manolis 1989). The pair will rub

their snouts together lifting them out of the water. Head and body rubbing is common with both male and female mounting each other in turn. Vocalisations and exhalations can be quite noisy. The animals circle, submerge and re-emerge. Copulation takes place with the male mounting the female and positioning his tail under the base of the female's. Usually the pair then submerges. Copulation may last from a few minutes in some species to 30 minutes in *Gavialis gangeticus* (Magnusson *et al.* 1989). The actual sequence of courtship may be stereotyped as in *C. acutus* or flexible as in *A. mississippiensis*. Pre-copulatory behaviours permit assessment of potential mates and may synchronise reproductive activity (Lang 1989). Apparently they do not prevent interbreeding which occurs in captivity and may also occur in the wild (Hollands pers. comm.).

ECONOMIC SIGNIFICANCE

The commercial exploitation of crocodiles has varied according to the value of their skins on the international market. Some species such as *C. porosus* and *C. niloticus* were hunted intensively for their highly prized skins. *Crocodylus porosus* was virtually eliminated from many parts of its range in mainland South-East Asia, and its numbers in Australia were severely depleted as a result of unregulated hunting. Although the skin of *C. johnstoni* is less valuable, this species was hunted after it became unprofitable to exploit the dwindling populations of the saltwater crocodile. Numbers of *C. johnstoni* had not declined to the same extent as those of *C. porosus* when governments enacted legislation to prohibit hunting.

Legislation and CITES

The responsibility for conservation and management of native wildlife in Australia lies principally with the State and Territory Governments. *Crocodylus johnstoni* first received protection in Western Australia in 1961, followed by the Northern Territory in 1964. *Crocodylus porosus* became legally protected in Western Australia in 1969 and in the Northern Territory in 1971, and Queensland's Fauna Conservation Act extended legal protection to both species in 1974. Protection of Australian crocodiles was not provided, however, until it was apparent that both species had been seriously depleted.

The failure of State and Territory Governments to apply uniform legislation simultaneously to protect crocodiles left avenues by which skins could be traded, thus undermining the efforts of States to protect the wild resource. Crocodile skins were taken illegally from Western Australia or the Northern Territory, moved into Queensland, where neither species was protected, and used within that State or exported from Australia. The Commonwealth Government moved in 1972 to ban the export of crocodiles or their products by listing both species as prohibited exports under the *Customs Act*.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was established in 1973 to regulate international trade in certain species of wild animals and plants and to ensure that such trade is conducted at sustainable levels. Australia became a Party to CITES in 1976 following the introduction of the 'Customs (Endangered Species) Regulations' under the Customs Act.

The two Australian crocodile species were listed initially in Appendix II of CITES, which includes species that may become threatened with extinction unless international trade is strictly regulated. However, concern was raised later about the conservation status of *C. porosus* when the results of the studies conducted by the University of Sydney (Messel, Green, Wells, Vorlicek, Onley *et al.* 1979–1987) were taken to indicate that the northern Australian population

was critically endangered. As a result the Australian population of *C. porosus* was transferred to Appendix I of CITES, in which species are considered to be threatened with imminent extinction and are banned from commercial trade. Since the 1973 Washington Conference, no crocodylian species has been removed from the Appendices.

The Convention provides for commercial trade in specimens of Appendix I species that have been derived from closed-system captive breeding operations, on the basis that such trade can be conducted with minimal impact on the wild population. This management prescription has removed pressure from the wild resource and enhanced its potential for recovery. Appendix I species, such as *C. porosus*, have become the focus of research to provide a firm basis for their management as a renewable resource.

Farming and Ranching

The Edward River Crocodile Farm, located on the west coast of Cape York Peninsula in Queensland, was the first operation to experiment with the captive production of *C. porosus* skins for export. The farm established in 1972 by Applied Ecology Pty Ltd, was funded by the Commonwealth Department of Aboriginal Affairs, to provide an industry by which the local Aboriginal community could derive economic independence. After more than 10 years of research on the requirements for breeding *C. porosus* in captivity, the Edward River Crocodile Farm finally received approval to export skins derived from its operation in 1984.

Importantly, this farm and others enhanced the recovery of the *C. porosus* population by promoting both public awareness of crocodiles and government attention to effective management of wild crocodiles.

As a conservation strategy, ranching was established in 1981, after the decision by Parties to CITES that some species of wildlife could benefit from management for commerce. This enabled Appendix I species (or populations thereof) to be transferred to Appendix II and managed by 'ranching'. This involves cropping the 'natural surfeit' of eggs and hatchlings of the wild population for use in commercial farming operations (Fig. 41.5). In effect, this surfeit comprises the portion of the annual reproductive output that would fail to survive, as a result of predation, disease or other causes. However, in order to achieve the support of Parties to CITES for ranching, proponent Parties are required to show that commercial ranching will benefit the wild population.

Management of Wild Populations

The recovery of the Australian population of *C. porosus* has been impaired by external influences. In 1981, Messel *et al.* (1979–1987) expressed concern that netting practices used in the barramundi fishery hindered the movement of crocodiles between rivers and resulted in drowning of large numbers of adult *C. porosus*. They expressed particular concern about continued commercial fishing in the tidal waterways of Kakadu National Park. In 1987 the Australian National Parks and Wildlife Service began phasing out the commercial barramundi fishery, and completed the closure of all tidal waterways in the Park to commercial net fishing in 1989.

Crocodylus porosus is dependent for nesting on the freshwater wetlands scattered throughout the northern part of Northern Territory. These wetlands were degraded seriously by the introduced Asian water buffalo, *Bubalus bubalis*, which removed vast tracts of aquatic vegetation through grazing and wallowing, and breached levee banks, allowing saline tidal water to invade and destroy freshwater environments. The capture and removal of water buffalo and

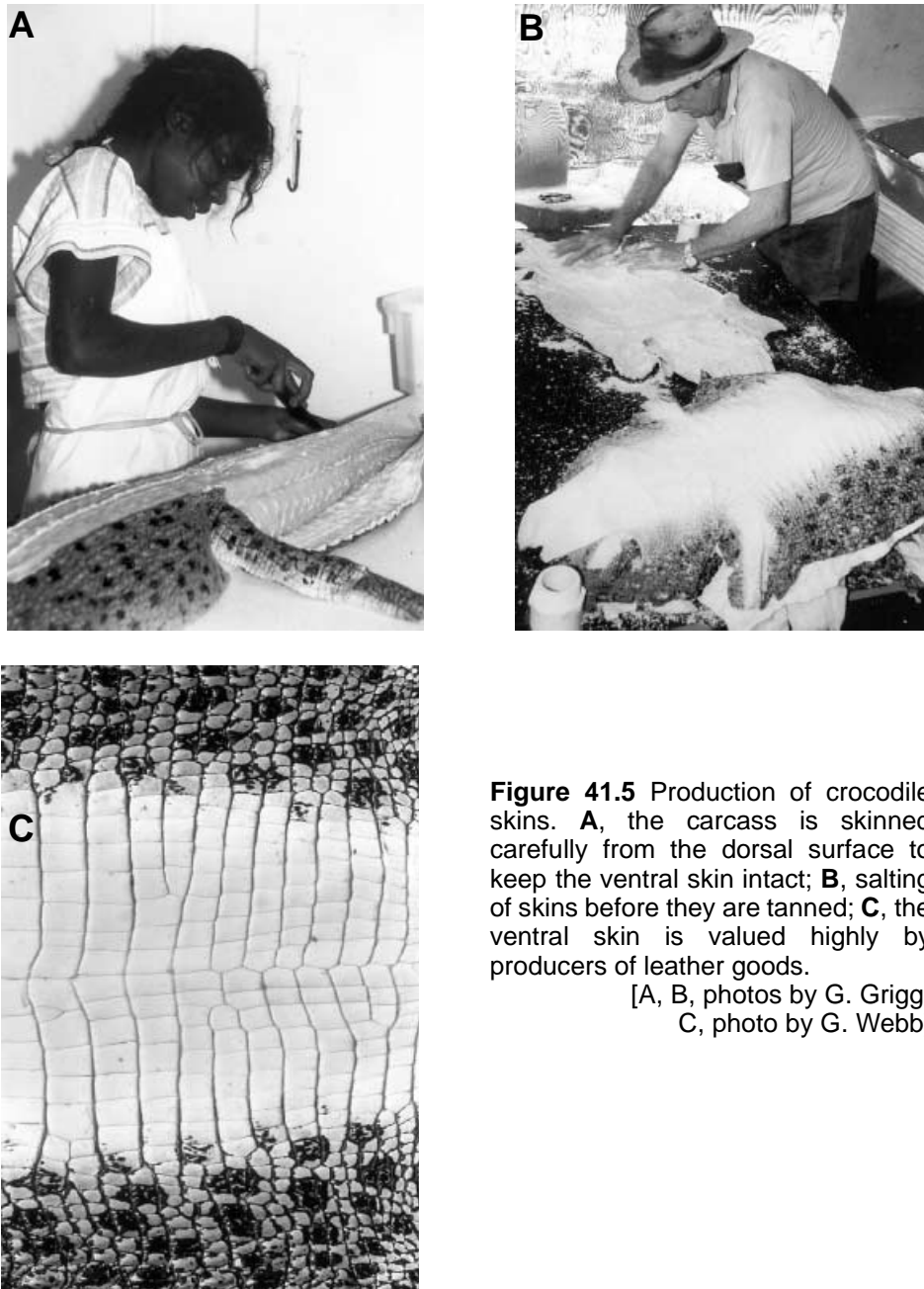


Figure 41.5 Production of crocodile skins. **A**, the carcass is skinned carefully from the dorsal surface to keep the ventral skin intact; **B**, salting of skins before they are tanned; **C**, the ventral skin is valued highly by producers of leather goods.

[A, B, photos by G. Grigg;
C, photo by G. Webb]

cattle as part of a program to eradicate brucellosis and tuberculosis has improved wetland habitats significantly in many coastal areas in the Northern Territory.

Currently, *C. porosus* and *C. johnstoni* are protected by Commonwealth, State and Territory conservation legislation. The removal of animals from the wild, and the possession or export of either species is illegal without a permit. The legislation applies to interstate and overseas trade and to skins or other crocodile products. Commercial use of crocodiles or parts thereof is restricted to specimens that have either been bred in captivity or have been taken in accordance with an approved management program.

Populations of both Australian crocodile species apparently have responded positively to legal protection and management for sustainable commercial use. Greatest numbers of *C. porosus* occur in the tidal rivers and associated coastal freshwater wetlands of the Northern Territory. Fewer occur in Western Australia and eastern Queensland because of limited suitable habitat. It is likely that this has always been true of Western Australia where most rivers drain rocky escarpment country characteristic of the Kimberley region. In Queensland,

suitable coastal wetland habitats and tidal rivers draining into the eastern seaboard have been subject to extensive modification for agriculture, tourism and human settlements.

Management of Commercial Operations

Commercial operations involving crocodiles fall under State control in the first instance. Export of products from such operations requires approval from the Commonwealth Government under the *Wildlife Protection (Regulation of Exports and Imports) Act* of 1982. Individual operations based entirely on captive breeding are required to obtain Commonwealth Government approval before exporting any product derived from the operation.

Conservation management programs, based on the sustainable use of wild populations of *C. porosus* and *C. johnstoni*, have been implemented in Western Australia and the Northern Territory. In Queensland, commercial use of crocodiles is confined at present to closed-system captive breeding farms. Three commercial operations in Western Australia and six in the Northern Territory are based on conservation management strategies that involve regular annual harvests of wild eggs and juveniles for rearing under controlled conditions. Four operations in Queensland are exporting products from animals bred in captivity.

Crocodiles have been the subject of active research and management in the Northern Territory longer than elsewhere in Australia. Population monitoring has shown that commercial ranching is sustainable, and consequently the Northern Territory is implementing a second management program. Annual harvest quotas for *C. porosus* and *C. johnstoni* are determined by the Director of Conservation, based on the extent of nesting by each species. *Crocodylus porosus* eggs are collected from specified harvest areas, artificially incubated and distributed to participating farms under contract to the Government. *Crocodylus johnstoni* hatchlings are harvested by licensed farmers from allocated areas. The management program incorporates annual monitoring to assess the impact of commercial harvesting activities on the local and overall Northern Territory population of each species.

Management programs also include public education campaigns designed to promote general awareness of the dangers posed by crocodiles and responsible behaviour in areas frequented by crocodiles. Management agencies arrange for the removal of problem crocodiles from specified areas in the interest of public safety. These are made available to farms to be grown and skinned or to use as breeding stock, though large males caught as 'problem' animals are rarely successful as farm stock as they often damage enclosures and injure or kill highly valued reproductive females.

Future Directions

The continued conservation of both Australian species of crocodiles depends on retaining suitable areas of their preferred wetland habitats. The Commonwealth Government and the Governments of Queensland, Western Australia and the Northern Territory have established an extensive network of national parks and nature reserves in tropical Australia that, collectively, support viable populations of both species.

The increasing number of successful programs involving the sustainable use of crocodiles and the manner in which IUCN, CITES and other international organisations have embraced the principles of sustainable use of wildlife are clear demonstrations of the emerging importance of regulated commercial trade in conserving wild crocodiles. This strategy provides a practical and increasingly acceptable complementary approach to wildlife conservation through protected area management. In applying this strategy an economic value

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is conferred on the species, its habitat and other species dependent on the same habitat. Species that were formerly regarded as competitors with agriculture or as predatory pests of livestock become perceived as a valued resource, and their habitat is seen as an asset. Rather than alienating rural communities, this approach provides a foundation for changing perceptions and creates incentives to conserve crocodiles and other species outside protected areas.

Crocodiles and alligators can benefit local economies through eco-tourism. Tour operators can show these spectacular animals to clients in relative comfort and safety. Licensed safari operations targetting crocodiles for trophies and collection of live animals for zoos and wildlife parks are other management options.

Provided usage remains within the sustainable capacity of the wild resource, the enhancement of long-term conservation of wild crocodiles can accrue from these commercial activities. Clearly, the long-term conservation of crocodiles in Australia will depend on the adoption of practical policies and management strategies, which should be politically attractive, publicly acceptable and seek to achieve broadly based benefits for communities. The extent to which the general public, and local communities in particular, accept the continued presence of viable numbers of crocodiles in the wild will influence the extent of political sympathy for conservation.