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# Survival and Growth of Hatchling *Crocodylus porosus* in Saltwater Without Access to Fresh Drinking Water

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**Summary.** It has been suggested that *C. porosus* select nest sites which provide a source of freshwater for hatchlings during the dry season. From a mark-recapture study, we conclude that hatchling *C. porosus* can survive and grow in hyperosmotic saltwater without drinking freshwater. Hence, the siting of nests is unlikely to be the consequence of a requirement by hatchlings for freshwater. Considered along with other information, our observations imply that hatchling *C. porosus* have functional salt glands.

## Introduction

Although the estuarine crocodile (*Crocodylus porosus*) is distributed widely in fresh, brackish and salt water throughout its range (Neill 1970) and is capable of making extensive sea journeys (Allen 1974), there has been uncertainty about its tolerance for salt water and the nature of its osmoregulatory mechanisms (e.g. Schmidt-Nielsen 1979).

Settling the question of saltwater tolerance of hatchling *C. porosus* is germane to understanding the basis for nest-site selection in the species. In Australia, although nesting occurs in the wet season when the rivers are flushed extensively by fresh water, nests are said to be situated almost always close to a dry season source of fresh or mildly brackish water (Webb et al. 1977). In the downstream sections of the Liverpool and Tomkinson Rivers, Arnhem Land, where high salinities may be encountered quite early in the dry season, Webb et al. (1977) found nests mainly in freshwater swamps adjacent to the river. Upstream, where the saline influence comes either later in the dry or not at all, nests are sited commonly on the river banks. These data suggest that nest-sites may be selected to provide a source of fresh water for hatchlings during the dry season a corollary of which is that hatchlings are physiologically dependent on fresh water. However, other explanations are equally likely; for example, suitable materials for nest construction may be found mainly in freshwater swamps in downstream sections of rivers (Magnusson 1980).

Magnusson (1978) addressed the question of nest-site selection in relation to dry season salinity. He observed that freshly hatched, unfed *C. porosus* lost weight and died far more rapidly in salt water (SW) than in fresh water (FW) and concluded that these animals were dependent upon fresh drinking water for survival. He believed, however, that older (> 30 days) hatchlings and larger size classes no longer needed fresh drinking water. Such results need to be treated with caution, for under laboratory conditions unfed larger *C. porosus*, 0.2–4.0 kg, lose weight, dehydrate and die in SW if no access to FW is provided (L.E. Taplin, pers. obs.). This holds regardless of the crocodile's previous experience of salt water. Nevertheless, observations reported by Messel et al. (1979b) show that hatchlings have been observed frequently where there is no apparent source of FW during the dry season (Table 1).

Dunson's (1970) observations on *C. acutus* and *C. porosus* in the laboratory have added further support to the notion that marine crocodiles may be dependent upon FW for he found little evidence that cephalic salt glands are a major pathway of electrolyte excretion. Dunson attributed the apparent tolerance of *C. porosus* for salt water to a relatively impermeable skin, relatively small surface area: mass ratio (in larger animals) and occasional access to FW. Thus, important questions regarding nest-site selection and mechanisms of osmoregulation in hatchling crocodiles hinge upon an assessment of their ability to survive in salt water without access to freshwater. This paper presents data which show that hatchling *C. porosus* are able to survive and grow under such conditions.

## Materials and Methods

The work involved capture and recapture of a group of hatchlings in a downstream section of the Tomkinson River, Northern Territory (Lat. 12° 9′ S; Long. 134° 11′ E) (Fig. 1) where ambient water salinities exceeded the osmoticity of crocodile body fluids at all stages of the tidal

**Table 1.** Some observations of hatchling *C. porosus* in saline situations where, on the day of the observation, water was hyperosmotic to the blood at all stages of the tidal cycle.
Table compiled from data published by Messel et al. (1979b)

| Locality | Date | Distance up river (km) | Salinity, ‰ (lo-hi tide) | No. of Hatchlings |
|---|---|---|---|---|
| Goomadeer R. | Sept. '76 | 0– 5 | 22–34 | 4 |
| | | 5–10 | 19–30 | 2 |
| | | 10–15 | 16–24 | 4 |
| King R. | Aug. '76 | 20–25 | 29–30 | 5 |
| | | 25–30 | 27–28 | 4 |
| | June '77 | 20–25 | 20–23 | 6 |
| E. Alligator R. | Oct. '77 | 40–50 | ?–28 | 29[a] |
| W. Alligator R. | July '78 | 30–38 | 13–18 | 18 |
| Adelaide R. | July '77 | 15–25 | 24–30 | 20 |
| Victoria R. | Aug. '78 | 45–50 | 30–33 | 2 |
| Mungardobolo Ck. | Oct. '77 | 20–25 | 35–49 | 3 |

[a] Low tide salinity unknown

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cycle. Most of these hatchlings were clustered around a freshwater swamp at km 23.6, one of the few suitable nesting sites for *C. porosus* in the downstream reaches of this river (Magnusson 1980), and were probably derived from a successful nest in this swamp.

The physical and biological characteristics of the Liverpool-Tomkinson river system and its crocodile population have been described in some detail by Messel et al. (1979). The present study was undertaken midway through the northern dry season, from 16 July–2 August, 1979. The study followed 110 days with virtually no rainfall ($<10$ mm total pptn) and 50 days with no rainfall at all. Rainfall of 1 mm was recorded on 22 July. A detailed aerial and ground survey was carried out to locate sources of freshwater in the study area.

Fifteen hatchlings (160–270 g) were captured by hand after spotlighting them at night on a low tide. The capture site of each crocodile was marked on a detailed river map (Fig. 1) and identified by a numbered ribbon tied in the mangrove fringe. Each individual was numbered by scute clipping, weighed and measurements made of both snout-vent length (SVL) and total length (TL). All were released exactly at their respective capture sites. On days 16 and 17 after release, eleven were recaptured and their new locations noted. No attempt was made until November to recapture the three crocodiles near 30 km, when two were re-caught. The same series of measurements was made at recapture and the animals were released again.

High and low tide salinity profiles were determined by measuring surface and bottom salinities using an American Optical salinity refractometer reading to 1%.

## Results

Salinity in the study area varied from 25–34$^{0}/_{00}$ according to the state of the tide, there being little or no stratification with depth.

Only one site of FW inflow to the river was located; two small trickles of water, within 5 m of each other, draining the permanent FW swamp at km 23.6 (Fig. 1). Another FW swamp at km 20.6 had no apparent outlet to the river. The flow from these streamlets was insufficient to influence measurably the river salinity within 2 m of their outflow points. Hatchlings were restricted to the region from km 22.6 to km 24.2 except for 3 individuals in the km 29 to 30 region (Fig. 1). No FW sites were found within 6 km upstream or downstream of the latter group.

Of the eleven crocodiles recaptured in August four were found within a couple of metres of their initial capture point while none had moved more than 400 m (Fig. 1, Table 2). Two were found on the opposite bank.

Lengths were measured on ten of the hatchlings at both beginning and end of the 16–17 day period. There was a significant increase in mean total length at a rate of $0.14 \pm 0.13$ mm d$^{-1}$ ($0.025 < P < 0.001$). Nine of the eleven maintained or increased their weight, the mean rate of weight gain being $0.44 \pm 0.20$ g d$^{-1}$ ($\bar{x} \pm 95\%$ C.L.). Two crocodiles lost weight; one, an apparently healthy animal, at a rate of 0.69 g d$^{-1}$ and one, a runt (whose emaciation had drawn comment at first capture), at 0.88 g d$^{-1}$.

A subsequent survey in November 1979 resulted in the recapture of 6 of the marked crocodiles at a salinity of 36$^{0}/_{00}$. Over the four month period they had grown in total length by $0.40 \pm 0.13$ mm d$^{-1}$ and in body weight by $0.44 \pm 0.27$ g d$^{-1}$. During that time rain had fallen on only 3 days (Oct. 16, 26, 28). Two of these crocodiles were from the group of 3 caught near km 30 in July and were within 0.5 kg of their original capture sites (Fig. 1).

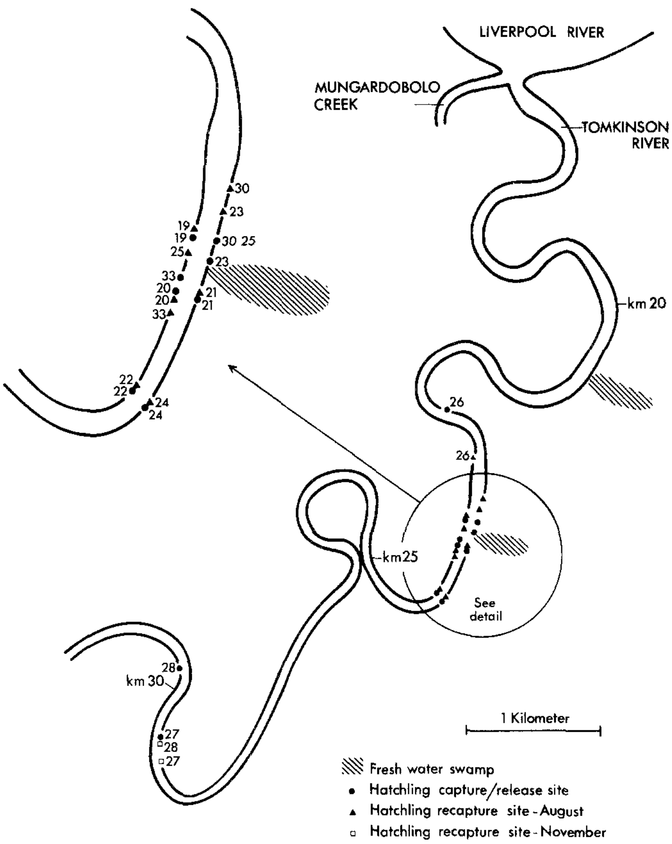

**Fig. 1.** Capture and recapture locations of hatchling crocodiles

**Table 2.** Distances moved by individual hatchlings over 16 day period between release and recapture. Upstream movement is indicated by a negative sign

| Hatchling No. | Distance Moved (m) |
|---|---|
| 19 | − 20 |
| 20 | 0 |
| 21 | 0 |
| 22 | 0 |
| 23 | +250 |
| 24 | 0 |
| 25 | −100 |
| 26 | −400 |
| 30 | +200 |
| 33 | −100 |

## Discussion

Overall, there was no evidence that the hatchlings were in any stress from their being in salt water for periods of up to 4 months. Most grew in both weight and length, and by about the amount one would expect from other studies of growth in *C. porosus* hatchlings (Webb et al. 1977).

Hatchlings and other juveniles in salt water are known to feed on invertebrates, particularly crabs and shrimps (Taylor 1979) and these must impose a considerable load of sodium and other electrolytes. Hatchlings in the study were frequently observed feeding before capture, yet serum Na values (138–154 mM; Taplin, unpubl. obs.) were within the 'normal' range of subadult *C. porosus* (Grigg, in prep.). Furthermore, total body water pools (ml/kg) showed no significant difference between the beginning and end of the study period (Taplin and Grigg unpubl. obs.). There is, therefore, nothing to suggest that any physiological limitation would prevent these hatchlings surviving throughout the remainder of the dry season. In fact, 6 of the original 15 hatchlings were recaptured in highly saline water (36‰) in November.

Was the healthy physiological state of these hatchlings dependent upon access to FW? The high surface area: mass ratio of hatchlings suggests that, if FW is a necessary resource, drinking should occur every few days. Unfed hatchlings (200–300 g) in SW dehydrate rapidly in the laboratory, plasma osmotic pressure and Na concentration rising to over 400 mOsm/l and 200 mmol/l respectively within a fortnight of first exposure. However, in the field we captured hatchlings up to 0.6 km from the nearest FW and recaptured them 16 days later within metres of their original capture site, showing no signs of dehydration or other stress. In addition, two hatchlings were caught near 30 km and recaptured four months later at the same locality with no FW available for distances of at least 6 km. For the hatchling group in the 22.6–25 km region it seems most unlikely that a small crocodile would travel up to 0.6 km and back for a drink and be found 16 days later under the same bush. For hatchlings at 30 km the distances involved are obviously out of the question. The most conservative interpretation of the results is to conclude that access to FW is not necessary for the survival of hatchling *C. porosus* in salt water.

A number of implications follow from this conclusion. Firstly, one must probably look elsewhere for an explanation of the siting of crocodile nests in areas where there is fresh water in the dry season. It seems likely that the correlation is second order and follows from the most favoured nest building materials being those typical of areas subject to freshwater seepage or alongside sections of the river which are mostly fresh in the dry season. Magnusson (1980) notes that the availability of suitable vegetation associations is sufficient to explain the distribution of crocodile nests in this river system.

Secondly, the results imply that hatchling *C. porosus* have active salt glands. Their diet in salt water habitats is mainly marine crustaceans (Taylor 1979) which are electrolyte-rich, yet it is known that juveniles and hatchlings under field conditions are able to maintain the homeostasis of plasma electrolytes along a salinity spectrum from 0–35‰ (Grigg in prep. and Taplin unpubl. obs.). However, *C. porosus* is apparently unable to produce urine which is hyperosmotic to the blood, and both liquid and solid fractions of the urine in crocodiles from saline waters contain only negligible amounts of sodium (Grigg in prep.). Taken together, these observations indicate the presence of a well developed and functional salt gland in hatchling *Crocodylus porosus*.

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