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Dispersal of Hatchling Crocodiles *(Crocodylus porosus)* (Reptilia, Crocodilidae)

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ABSTRACT—Dispersal of hatchling crocodiles was investigated by mark-recapture. The rate of movement of crocodiles less than 6 months old was unaffected by their age or the salinity of the water in which they were living. Movement was not random and patterns of movement differed between the lower and middle reaches of rivers. Most animals in the middle reaches moved less than one kilometre during the first month though a few moved much larger distances. Approximately equal numbers moved upstream as downstream. In downstream sections most animals moved more than one kilometre in the first month and almost all of these move upstream.

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INTRODUCTION

There is little information on movements of crocodilians apart from that furnished by studies on *Alligator mississippiensis* (Chabreck, 1965; Hines et al. 1969; Joanen and McNease, 1970, 1971, 1972; McNease and Joanen, 1974; Murphy and Brisbin, 1972). Webb and Messel (1978) investigated movements of *C. porosus* in Arnhem Land, northern Australia, by mark/recapture and found that patterns of movement differed between sexes and areas. They compared movements of one year old crocodiles above and below 30 km up the Liverpool and Tomkinson Rivers. Animals below 30 km on average moved greater distances than those above, and males moved greater distances than females. They suggested that differences in patterns of movement between upstream and downstream areas might be due to formation of creches (aggregations of hatchling crocodiles accompanied by a parent) or to differences in currents.

Chabreck (1965) reported a general drift of tagged alligators away from saline areas towards fresh marsh when salt water started to intrude inland from the sea.

This paper investigates movements of hatchling (< 6 month old) *C. porosus* as influenced by water salinity, age and area. In this study no hatchlings formed creches, hence the effect of area is not confounded by creche formation.

The study was undertaken on the Liverpool and Tomkinson Rivers, northern Australia. The area experiences monsoonal weather and has distinct wet (Nov.–Mar.) and dry (Apr.–Oct.) seasons. Almost the entire lengths of the rivers are fresh at the end of the wet season but saline water starts to intrude upstream in April and the rivers are saline throughout their navigable lengths by the end of the dry season.

Data were collected between January and July 1976.

METHODS

Hatchlings used in this study were from two sources. Eggs were collected from nests beside the upper reaches of rivers and incubated in artificial nests. These hatchlings were branded with an identifying number and released within a few days of hatching near natural nests. Other hatchlings collected as they hatched from natural nests in swamps were branded and released at the nest. Recaptures were made at night from a 5 m boat with a spotlight and "Pilstrom" tongs. Hatchlings were recaught after one month (to test for patterns of dispersal) and at irregular intervals thereafter (to test for the effects of age and salinity on rates of movement).

A total of 176 hatchlings were released and 37 (21%) were recaptured after one month. Nineteen of those recaptured were from downstream release sites and 17 from upstream release sites. Hatchlings released at upstream sites were from artificial nests, those released at downstream sites were from natural nests.

The sites of release and recapture of hatchlings were mapped to allow measurement of dispersive movements. Maps were prepared from aerial photographs, the accuracy of stated locations and distances being ± 0.1 km. Locations are given as km from the mouth of the Liverpool River. Hatchlings were recaptured from a boat and this precluded recapture of animals released in swamps until after they had entered the major rivers or creeks. It is not possible to test for bias due to animals not entering the river but searches of the swamps and the rivers in subsequent years suggest that it is negligible.

All animals were released during the wet season (upstream sites—21 March, 11 May, 16 May; downstream sites—19 February, 10 March, 23 April) when salinities at the points of release were 0‰. At subsequent recaptures salinity of the water at the site of capture was measured with an "Autolab conductivity meter" (limit of reading 0.5‰).

Attempts were made to sex animals but there was no consistency between examinations so possible differences between sexes could not be analyzed.

RESULTS

Effects of Age and Salinity on Movement of Hatchlings

Hatchlings were recaptured at approximately monthly intervals for up to 133 days after release. At each capture the average daily rate of movement since the last capture was calculated. Salinities of the water in which hatchlings were recaptured ranged from 0 to 12.5‰.

Age and salinity were regressed against rate of upstream movement giving the multiple regression:

$$y = 0.076 - 0.00lX_1 - 0.00346X_2$$

where y = rate of upstream movement in km/day, X_1 = age of hatchlings in days and X_2 = salinity of water in which the hatchlings were captured (‰).

The regression did not account for a significant amount of the variance associated with rates of movement (Table 1).

Neither age nor the range of salinities encountered during this study affect movement of hatchlings.

TABLE 1. Analysis of variance on regression of age (X_1) and salinity (X_2) against rate of movement upstream of hatchlings.

Source	SS	df	MS	F
Regression on X_1 and X_2	0.024	2	0.012	0.65 N.S.
Deviations from regression	0.632	34	0.019	

N.S.–not significant at 0.05 level.

Directions and Distances Moved by Hatchlings in Different Areas of the Rivers

The sites of release and recapture of hatchlings after 30 days are given in Figure 1. Patterns of movement differed between those released at upstream locations (above 20 km on the Liverpool and Tomkinson Rivers) and those released within 20 km of the mouth of the Liverpool River. Hatchlings released in the lower reaches on average moved greater distances within the first month (mean = 3.5 km, s = 4.0 km) than those on the upper reaches (mean = 1.8 km, s = 0.1 km).

The proportion of animals moving upstream and downstream differed between the two areas (Table 2). The proportion of animals above 20 km moving upstream as against downstream was much the same whereas a greater proportion of animals below 20 km moved upstream (Fisher's exact test, $P = 0.05$).

Patterns of Dispersal of Hatchlings from Upstream and Downstream Areas

If movement of hatchlings were random the expected distribution of distances moved over a given time would be exponential. A property of exponential distributions is that the sum of squares divided by the square of the mean is distributed as χ^2. If the variance is greater than that of an exponential distribution with the same mean the χ^2 will be larger than that expected by the null hypothesis. If the variance is less than expected the χ^2 will be less than expected. Probabilities less than 0.05 or greater than 0.95 both indicate significant deviation from an exponential distribution. The mean, sum of squares and number of observations of distances moved over one month in upstream and downstream areas is given in Table 3.

The sum of squares to squared mean ratio was significantly greater than expected in downstream areas ($0.01 < P < 0.02$) and significantly less than expected in upstream areas ($0.98 < P < 0.99$).

The distributions of distances moved during the first month in the river are presented in Figure 2. In the upstream area the majority of animals moved less than 1 km, with 26% moving less than 100 m, but four animals moved longer distances (between 3 and 10 km). This accounts for the high sum of squares to squared mean ratio. In the downstream area animals were more uniformly distributed but only two animals moved less than 1 km. Because the distribution was comparatively uniform the mean was large relative to the sum of squares.

DISCUSSION

Hatchlings in this study showed no significant change in their movements with age, suggesting that their patterns of movement are determined by external factors. Directions and

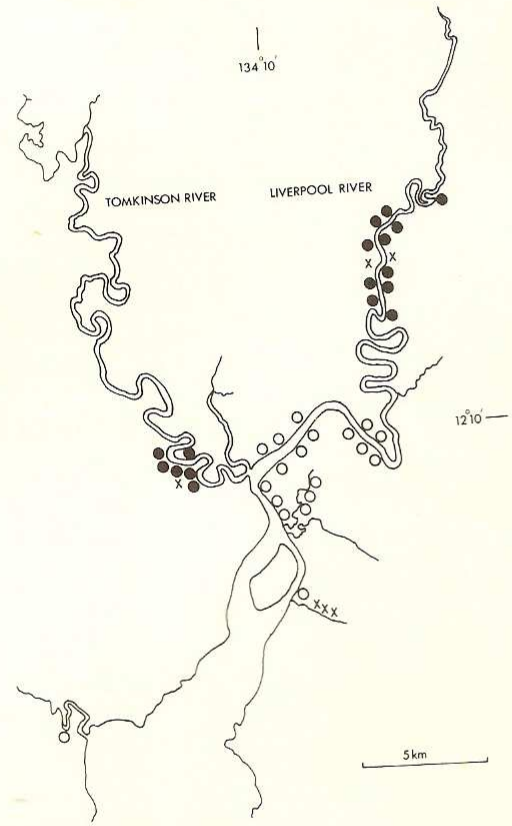

FIGURE 1. Map of the Liverpool and Tomkinson Rivers showing sites of release (X) and points of recapture of hatchlings after one month. Solid dots are points of recapture for hatchlings released at upstream sites. Open circles represent hatchlings released at downstream sites.

TABLE 2. Directions moved by hatchlings.

	Above 20 km	Below 20 km
Number of animals moving upstream	11	19
Number of animals moving downstream	9	4

TABLE 3. Statistics of distances moved by hatchlings over one month in upstream and downstream areas.

	Mean	SS	n	χ^2
Downstream	3.53	89.42	19	7.2
Upstream	1.85	107.44	17	31.5

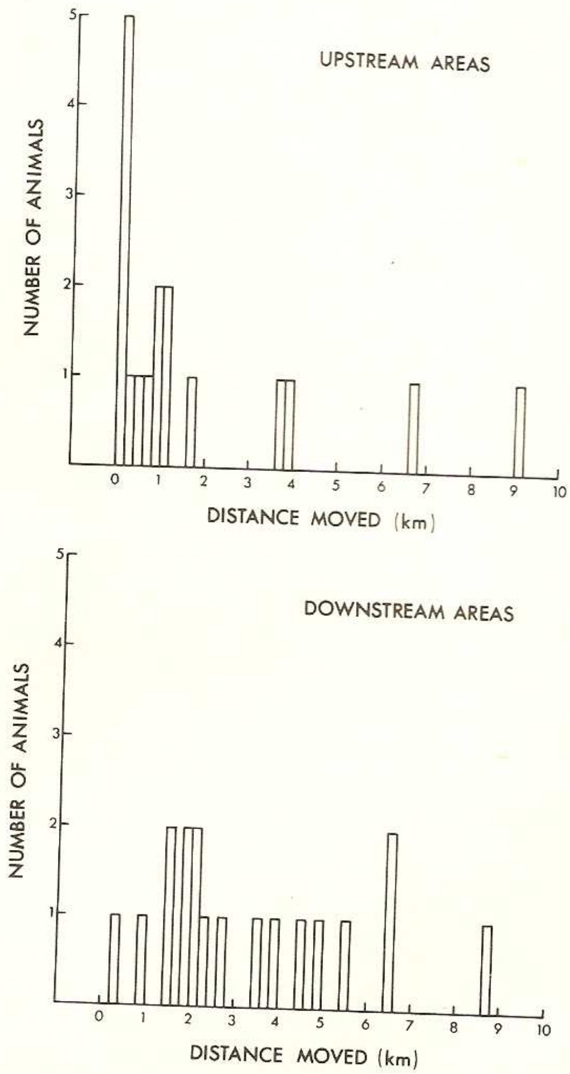

FIGURE 2. Distances moved by hatchlings in upstream and downstream areas during the first month after hatching.

distances moved differed between upstream and downstream areas. The most obvious difference between the areas is in salinity during the dry season but the range of salinities encountered by hatchlings in this study (0–12.5‰) could not be shown to significantly affect movement. Webb and Messel (1978) studied movement of one year old crocodiles in the same area and found similar patterns of movement. They suggested that the differences might be due to hatchlings forming creches in upstream areas but not in downstream areas. However, this does not explain the results of this study as hatchlings did not form creches in either area. Alternative explanations are that the patterns of currents differ between the two areas (Webb and Messel, 1978) or that the lower reaches are unfavorable and young crocodiles actively avoid them. More data are needed on the physical differences between the upper and lower reaches and the effect of these on young crocodiles before any firm conclusions can be reached.

It is possible that crocodiles hatched in artificial nests behave differently to those from natural nests. However, as the results of this study agree with those of Webb and Messel (1978) who studied crocodiles from natural nests any such differences probably did not affect dispersal patterns.

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