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The Status of the Salt-water Crocodile in the Glenelg, Prince Regent and Ord River Systems, Kimberley, Western Australia

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Department of Fisheries and Wildlife

108 Adelaide Terrace

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THE STATUS OF THE SALT-WATER CROCODILE IN THE GLENELG, PRINCE REGENT AND ORD RIVER SYSTEMS, KIMBERLEY, WESTERN AUSTRALIA.

A.A. Burbidge (Western Australian Wildlife Research Centre, P.O. Box 51, Wanneroo, W.A. 6065) and H. Messel (Department of Environmental Physics, University of Sydney, Sydney, N.S.W. 2006).

ABSTRACT

Counts were made of Salt-water Crocodiles (Crocodylus porosus) in the estuarine portions of the Glenelg, Prince Regent and Ord River systems of the Kimberley Division, Western Australia. During the survey 581 crocodiles were seen, including 143 hatchlings. The number of non-hatchling crocodiles present in the Glenelg system is estimated to be 200 to 259, in the Prince Regent 190 to 246 and in the Ord 235 to 306 (95% confidence limits).

The number of non-hatchling crocodiles present in the six Kimberley river systems now counted is estimated to be between 957 and 1243 (95% confidence limits) and we believe that this constitutes more than half of the total Western Australian non-hatchling crocodile population which is estimated to be, at the most, about 2 000. The potential for the recovery of the Salt-water Crocodile population in Western Australia is not good and culling for the hide trade should not be allowed.

I INTRODUCTION

The Salt-water Crocodile *(Crocodylus porosus)* has suffered a drastic decline in numbers throughout its range due to extreme over-harvesting for the skin trade. In Western Australia the species was protected in April 1970 but until recently there were no data on its current status.

In 1977 the Western Australian Department of Fisheries and Wildlife supported crocodile population studies being pursued by the Department of Environmental Physics, University of Sydney. On that occasion surveys of crocodile numbers and population structure were conducted in the Lawley, Mitchell, Roe, Hunter and Prince Regent River systems of the north-west Kimberley (Messel *et al.* 1977).

It was decided to continue this work in 1978 and accordingly surveys were made in:

1. The Prince Regent River and St George Basin, which could not be surveyed completely in 1977,

2. the Glenelg River system, and

3. the Ord River.

The Glenelg River system was chosen because we had been told that it once contained a large number of crocodiles and a recent visitor had also reported that the species appeared more plentiful there than elsewhere. The Ord River was selected because:

1. It is physiographically different from the rivers surveyed so far in Western Australia, and

2. the tidal portion of the Ord River from Adolphus Island to Turkey Island comprises a Nature Reserve (Reserve No. 31967, of 23 945 ha, for the Conservation of Flora and Fauna, vested in the Western Australian Wildlife Authority). This reserve was created primarily for the protection of the habitat of the Salt-water Crocodile and was declared following a recommendation by Dr H.R. Bustard who reported on the status of the species in 1970.

The work reported here was carried out from the University of Sydney's 21m research vessel "The Harry Messel". Personnel were: H. Messel, A.G. Wells, W.J. Green, K. Brennan (Department of Environmental Physics, the University of Sydney), A.A. Burbidge, J.E. Kinnear and P.J. Fuller (Western Australian Wildlife Research Centre, Department of Fisheries and Wildlife). The vessel was crewed by Commander S.R. Schofield (R.A.N. Ret'd.) (Captain), I. Onley (Engineer) and W. Gill. N.L. McKenzie and J.K. Rolfe (W.A. Wildlife Research Centre) were attached to the team but worked primarily on mangrove bats. Their work will be reported elsewhere.

II METHODS

The methods used for surveying the populations of *Crocodylus porosus* in tidal river systems were as described by Messel (1977) and Messel *et al.* (1978a, b).

During daytime surveys, reflective markers and tapes were placed approximately every 5km along the banks of rivers and creeks (corresponding to night-time surveying time intervals of 10 to 30 minutes). These markers minimize errors in night-time

navigation and break each river system into readily and repeatedly identifiable subsections. The daytime surveys familiarized staff with the stretches to be surveyed at night and permitted measurement of high and/or low water salinity (surface, midwater, bottom) at 2.5 or 5km intervals. Mangrove communities were normally assessed on both banks for species composition, abundance and cover at 2.5km intervals. At each site associations were assessed in quadrats 20m deep and stretching 100m along the river.

During night time surveys, the following environmental parameters were measured and recorded for each marker position:

(1) Air and water temperatures ($\pm$ 0.1^{o}C, using a Digitron temperature gauge).

(2) Surface and bottom salinity (using a salinity-temperature bridge - Autolab Model 602).

(3) Height of exposed bank.

(4) State of the tide, and time interval before or after closest low tide.

(5) Moon phase and age, illumination in foot candles (using an International Light IL700 research radiometer).

(6) Time after sunset.

These data are available upon request by those requiring them for detailed interpretation of the general river surveys. In addition to the measurements in (1), a Grant multipoint temperature recorder provided a general 24 hour air and water temperature profile for the study area.

Night time spotlight counts were conducted from two modified 5.5m work boats, each with three or four staff members. Crocodiles can be easily located with a spotlight as the tapetum of their eyes reflects light and appears as a red glow. Counts can proceed when the tide leaves 60cm or more of exposed bank (see Fig. 1 in Messel *et al.* 1977) on the sections to be surveyed (this requires knowledge of tide times and tidal delays, which are unavailable for most rivers in northern Australia). Most crocodiles are sighted in the shallow water at the edge of the river. Surveying when $\geq$ 60cm of bank is exposed, assures that a minimal number are missed because of screening by vegetation.

Effectiveness, safety and speed of spotting depend largely on adequate daytime preparation. If obstacles are mapped accurately, if reflective markers are placed at obvious sites, and if all

data cards have been prepared in advance, one can survey at speeds near 30km/h - but only if water depth assures safe passage of the work boat. The importance of precise navigation during night time surveys cannot be overstressed.

The survey methods outlined yield a distribution of numbers and size classes for the tidal system. The question then is: what relation do these numbers have to the actual number of crocodiles on the system? The Blyth River calibration survey study was initiated in 1976 to gain some insight into this difficult question (Messel 1977). Since that date, the calibration section has been surveyed 204 times. The study has not been completed, but preliminary analysis indicates that of the factors monitored (1 to 6 above), the two most important are exposed bank (there should be >60cm of exposed bank) and season of the year. On the basis of a number of assumptions, one obtains an estimate for the fraction of the crocodiles sighted and hence an estimate of the actual number present. The assumption is then made that the results determined for the Blyth River are, within small but unknown error, applicable to other tidal river systems. A book is in the course of preparation on this study (Messel *et al.* in prep.). The best estimate to date is that during the dry season (May to November) an experienced spotter will record during one survey 0.62 $\pm$ 0.04 (SD) of the crocodiles present on the surveyed portion of the river system. This implies that in 95 surveys out of a hundred, the number of crocodiles seen lies between 54 and 70% of the actual number of crocodiles present. Further, in 99 surveys out of a hundred, the number seen lies between 52 and 72% of the actual number of crocodiles present.

The location ($\pm$ 100m) of each crocodile spotted was recorded. Whenever possible, the animal was approached to within 6m and its size estimated by an experienced observer, who also noted its situation on the bank or in the water.

The crocodiles sighted were categorized by size classes, as follows: hatchlings, 2 - 3' (60 - 90cm), 3 - 4' (90 - 120cm), 4 - 5' (1.2 - 1.5m), 5 - 6' (1.5 - 1.8m), 6 - 7'(1.8 - 2.1m) and >7' (2.1m). When the size of a crocodile could not be estimated, it was grouped into the category "eyes only" (EO).

The density of crocodiles (omitting hatchlings) was calculated by dividing the number of crocodiles seen by the surveyed length of the river and creeks (km along a midstream point).

III THE GLENELG RIVER SYSTEM

A. DESCRIPTION

The Glenelg River enters George Water (Fig. 1) and has one major tributary - the Gairdner - which enters it about 15km

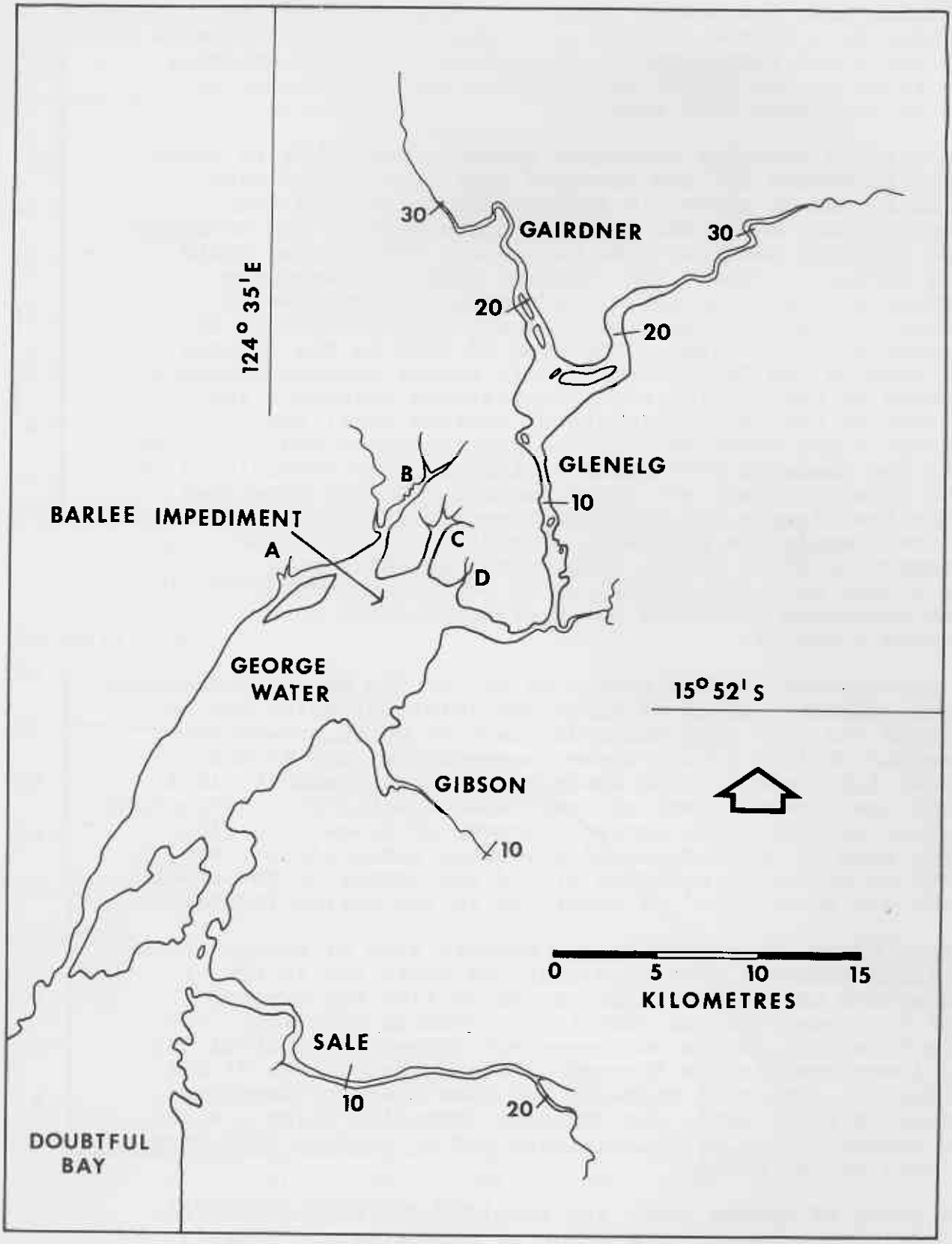

Figure 1. The Glenelg River system.

upstream from its mouth. From 3 to 13km the river is bounded by a narrow, rugged gorge where the tidal currents are swift and form numerous whirlpools. A creek entering the river at 5km cannot be navigated past a rock bar at 8km at less than half tide.

The Glenelg contains extensive sandbars around 22 to 23km, where it widens out,and numerous rock bars beyond 34km. At half tide or above, it is possible to proceed with care to 37km, where the water is quite fresh. The Gairdner also contains numerous rock bars above 30km and we could only survey to 33km. The dominant riverside mangrove community is a mixed low closed-forest of *Camposteмon schultzii* and *Rhizophora stylosa* with an understorey of *Aegiceras corniculatum*. Upstream of 21km on the Glenelg and 25km on the Gairdner *Avicennia marina* becomes dominant, forming an association with *Camptostemon schultzii* and *Rhizophora stylosa*. Thickets of *Ceriops tagal* var. *australis* and occasional *Excoecaria agallocha* and *A. marina* form the landward extensions of the mangrove communities on both rivers. There are approximately 26km^2 of mangroves along the Glenelg and Gairdner Rivers. From 35 to 37km on the Glenelg the riverside vegetation reflects the presence of fresh water, comprising cadjeput trees *(Melaleuca* sp.*)* and *Eucalyptus* as well as mangroves with extensive swards of couch grass *(Cynodon* sp.*)* (Plates 1 and 2).

At the northern end of George Water, at the Barlee Impediment, is an extensive block of mangroves (Plate 3) which can be entered via four main channels, each of which breaks into numerous smaller arms. These channels are here termed Creeks A,B,C and D. The dominant mangrove community is a mixed low closed-forest of *Camptostemon schultzii, Rhizophora stylosa* and *Avicennia marina*. Groves of *Sonneratia alba,* often with an understorey of *Aegiceras corniculatum*, are found on accreting mudbanks around the mouths of the creeks. There are about 23km^2 of mangroves in the Barlee Impediment.

Gibson Creek, which enters the eastern side of George Water, contains numerous rock bars near its mouth and is not surveyable before half tide, at which time the exposed bank is inadequate for effective crocodile counting. The Sale River enters the north-eastern corner of Doubtful Bay. Its lower reaches run through a steep gorge (Plate 4) but contain a number of mudbanks and some areas of mangroves, totalling about 3km^2, the dominant community being a mixed low closed-forest of *C. schultzii* and *R. stylosa* with some *S. alba* at the mouth.

The banks of George Water are mostly rocky and contain few stands of mangroves. One stand of approximately 1.5km^2, dominated by *C. schultzii,* occurs at the north-western margin of the island which forms the eastern boundary of Success Strait.

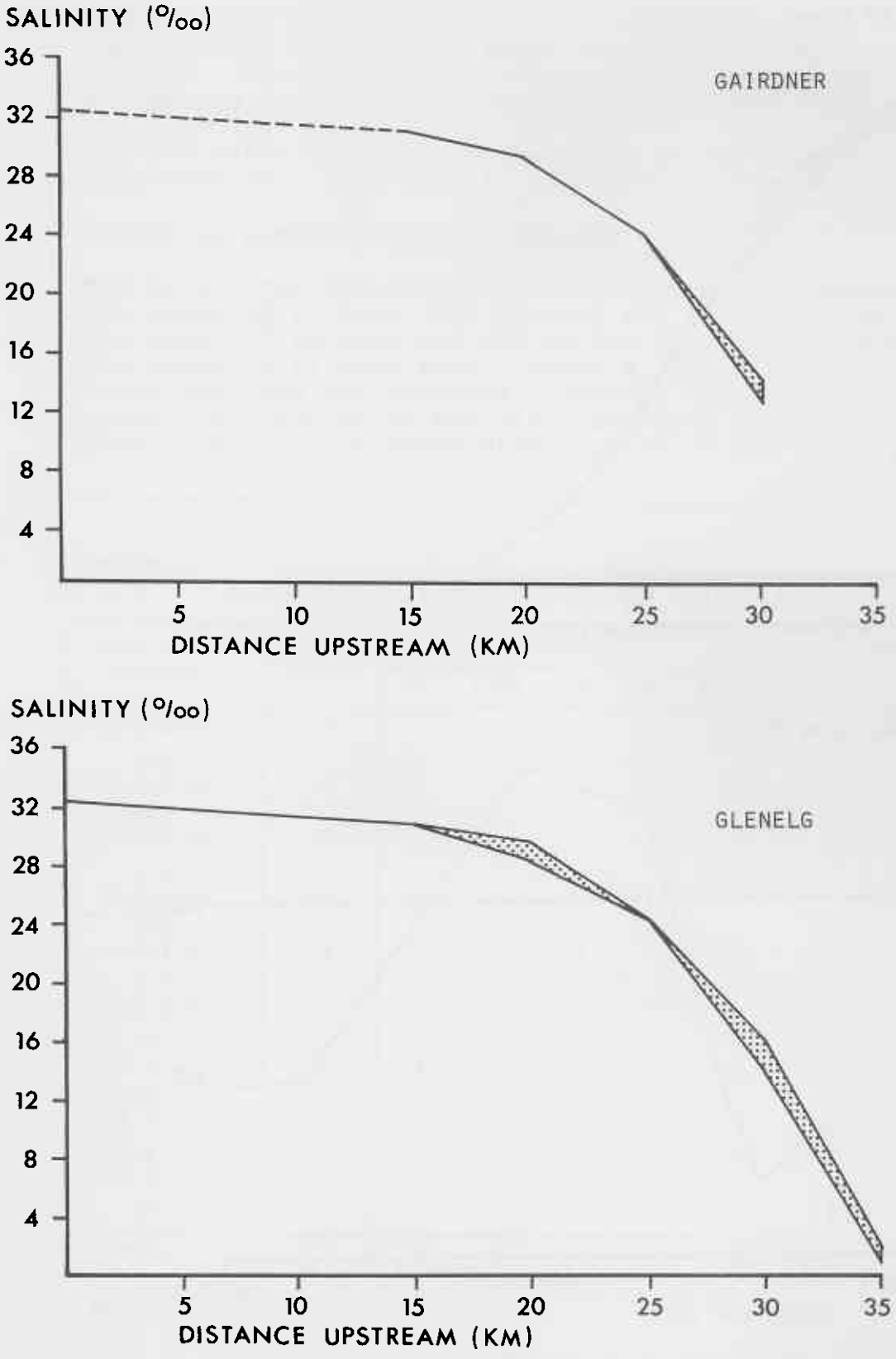

Figure 2. High tide salinity, Glenelg and Gairdner Rivers.

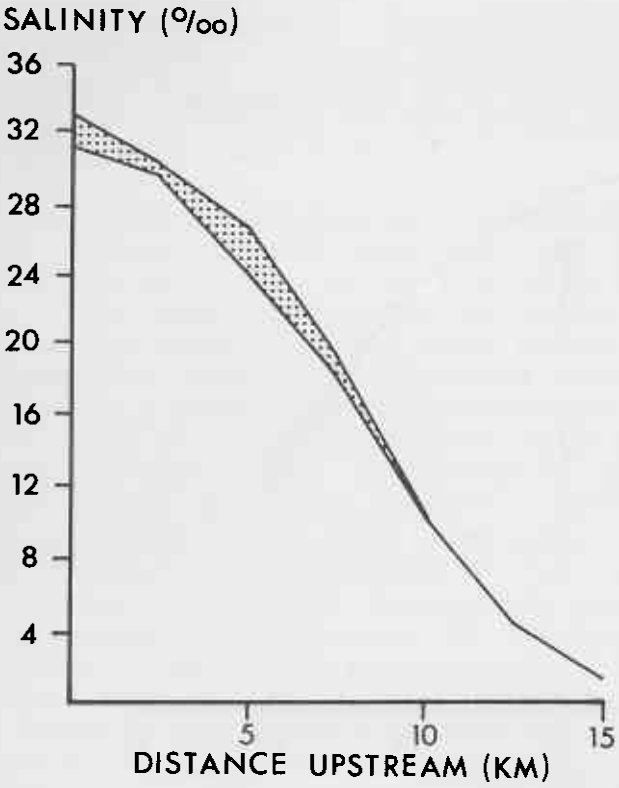

Figure 3. High tide salinity, Sale River.

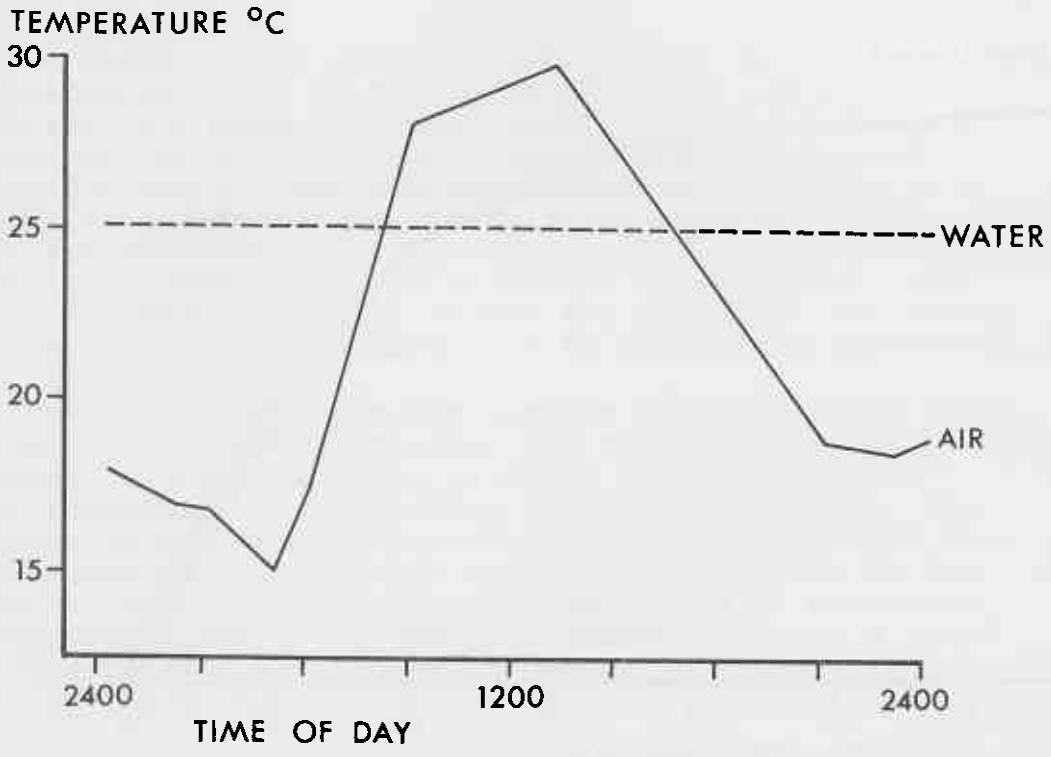

Figure 4. Temperature, Glenelg River at 1.5km, 18 July 1978.

The salinity data (Figs. 2 and 3) show that there was considerable fresh water input to the Sale, Gairdner and Glenelg. Fresh water was also entering the western arm of Creek B in the Barlee Impediment mangrove complex.

Air and water temperatures measured at the Research Vessel (anchored at 1.5km, Fig. 1) are given in Fig. 4.

B. CROCODILE NUMBERS AND SIZE CLASSES

The Sale River and parts of George Water were surveyed on the night of 17 July, the Glenelg and Gairdner Rivers on the night of 18 July and the Barlee Impediment Creeks on the night of 19 July 1978. Creek A in the Barlee Impediment was not surveyed. Table 1 gives the size class distribution of the 213 crocodiles sighted and Figs. 5 and 6 show their distribution in the river system.

TABLE 1. CROCODILE NUMBERS AND SITUATION
GLENELG RIVER SYSTEM, 17-19 JULY 1978.

SIZE IN FEET (metres)	No. of CROCS.	SITUATION						FEEDING
		IV	IVIW	OM	IM	SWOE	MS	
HATCHLING	73					72	1	
2-3 (0.6-0.9)	33			1		32		
3-4 (0.9-1.2)	26					26		
4-5 (1.2-1.5)	33		1	1	1	30		1
5-6 (1.5-1.8)	18			1		16	1	
6-7 (1.8-2.1)	12		1			11		
>7 (>2.1)	12	1				11		
EO<6 (<1.8)	1					1		
EO>6 (>1.8)	5					2	3	
EO								
TOTAL	213	1	2	3	1	201	5	1

Abbreviations:

IV - in vegetation, IVIW - in vegetation in water, OM - on mud, IM - in mud, SWOE - shallow water on edge, MS - midstream, EO - eyes only.

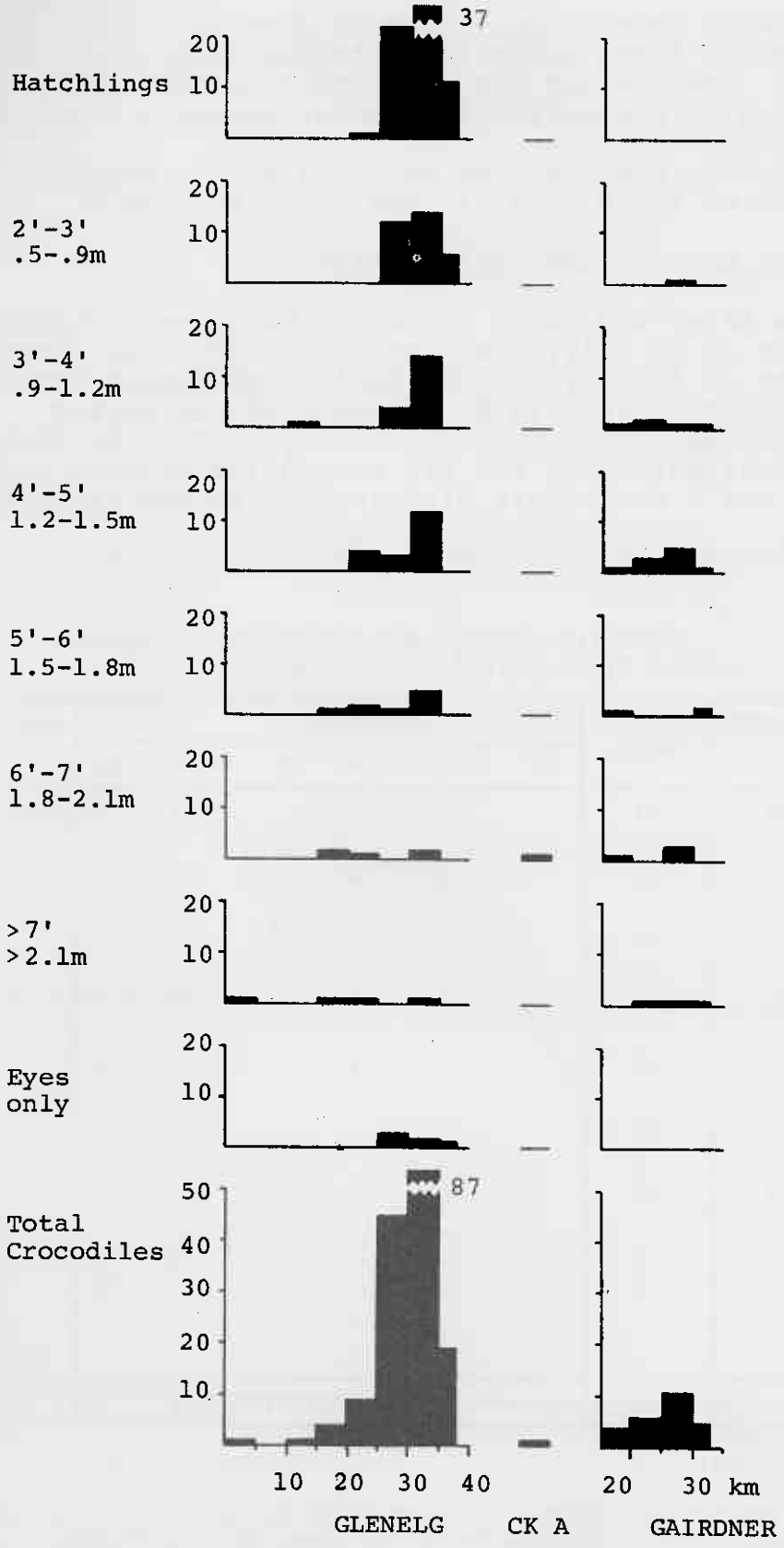

Figure 5. Crocodile distribution, Glenelg and Gairdner Rivers.

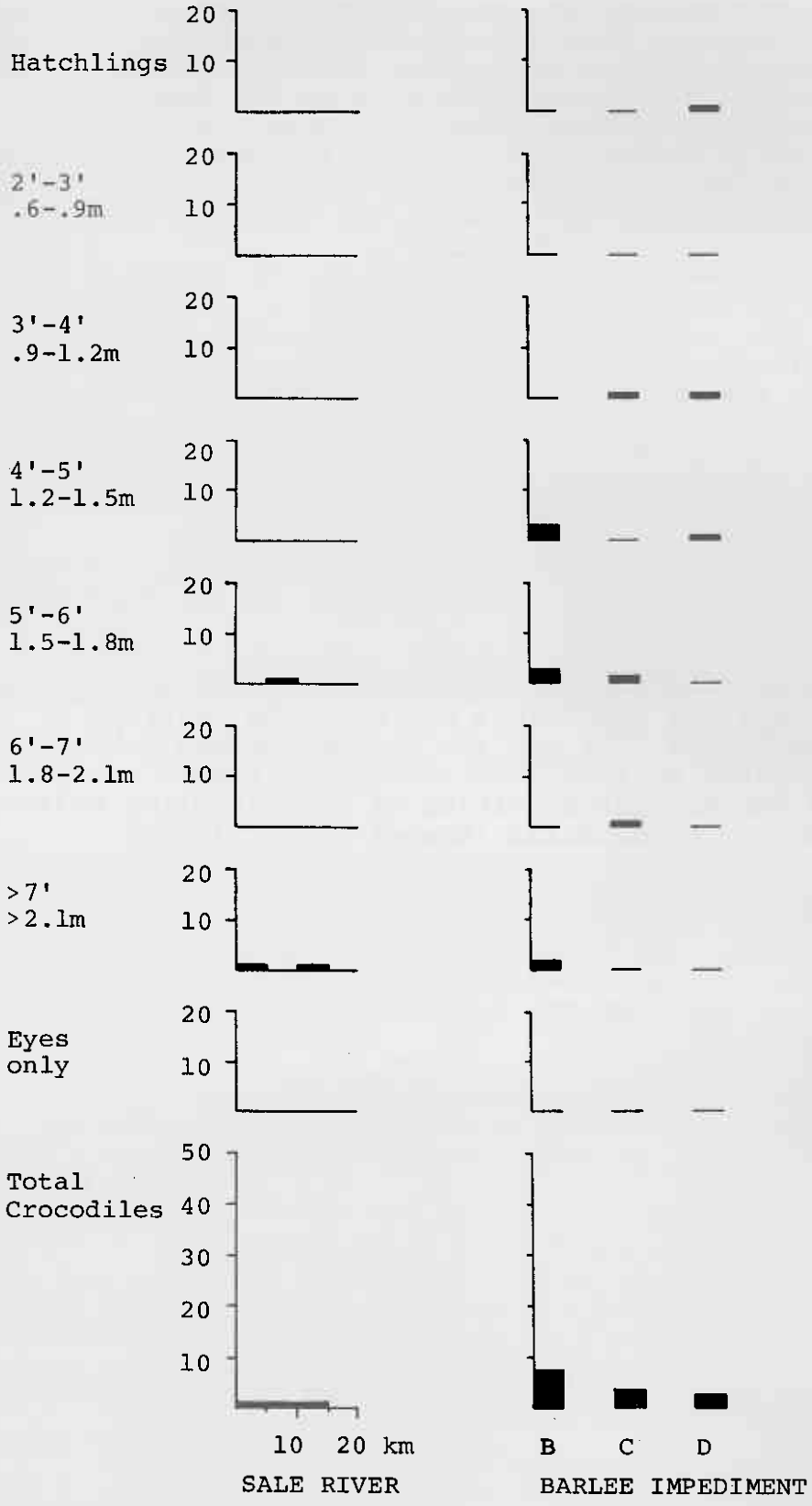

Figure 6. Crocodile distribution, Sale River and Barlee Impediment

Two of the crocodiles, one of 6 to 7 feet (1.8 to 2.1m) and one greater than 7 feet, were located on the banks of George Water, an area which was only partially examined, and the remainder were in the rivers or the Barlee Impediment mangrove blocks. A slide of a crocodile estimated to be 9 to 10 feet (2.7 to 3.0m) long was seen at 23.8km in the Gairdner River. This crocodile was not seen during the night survey.

Seventy-three hatchlings were seen, 71 of which were in the 25 to 37km section of the Glenelg, indicating at least two, and probably more, successful nests during the 1977-78 wet season. The upstream portion of the Glenelg runs through grassy plains which provide suitable breeding habitat (Webb *et al.* 1977). The Gairdner, however, yielded no hatchlings and only one 2 to 3 feet (60 to 90cm) crocodile and apparently does not provide good breeding habitat.

The number of crocodiles in each size class indicates that the Glenelg contains a population which is recruiting successfully.

The 25 to 37km portion of the Glenelg not only contains almost all the hatchlings but also the majority of the non-hatchlings. Of the 135 non-hatchlings observed, 80 were located on this 12km stretch of river, constituting one of the highest densities of non-hatchling Salt-water Crocodiles in Australia (Messel *et al.* 1978b).

The mangrove block at the Barlee Impediment yielded 15 crocodiles, one of which was a hatchling. These crocodiles, undoubtedly came from the Glenelg and provide further evidence for the movement of *C. porosus* over substantial distances and from one habitat type to another (Webb and Messel 1978).

Only three crocodiles were sighted in the Sale River. These were all medium sized animals indicating that this river does not provide good breeding habitat.

The Glenelg River system on the whole contains a Salt-water Crocodile population which appears to be recruiting successfully and, in the absence of poaching, may be on the way to recovery. The upper section of the Glenelg River (25 to 37km Fig. 1) is of considerable importance to the system as a whole since it provides the only breeding habitat. It is vital that this area not be disturbed.

Plate 1. Glenelg River at 36 km. Bank vegetation shows fresh water influence.

Plate 2. Banks of Glenelg River at 37 km, showing extensive sward of couch grass. Note presence of feral donkeys.

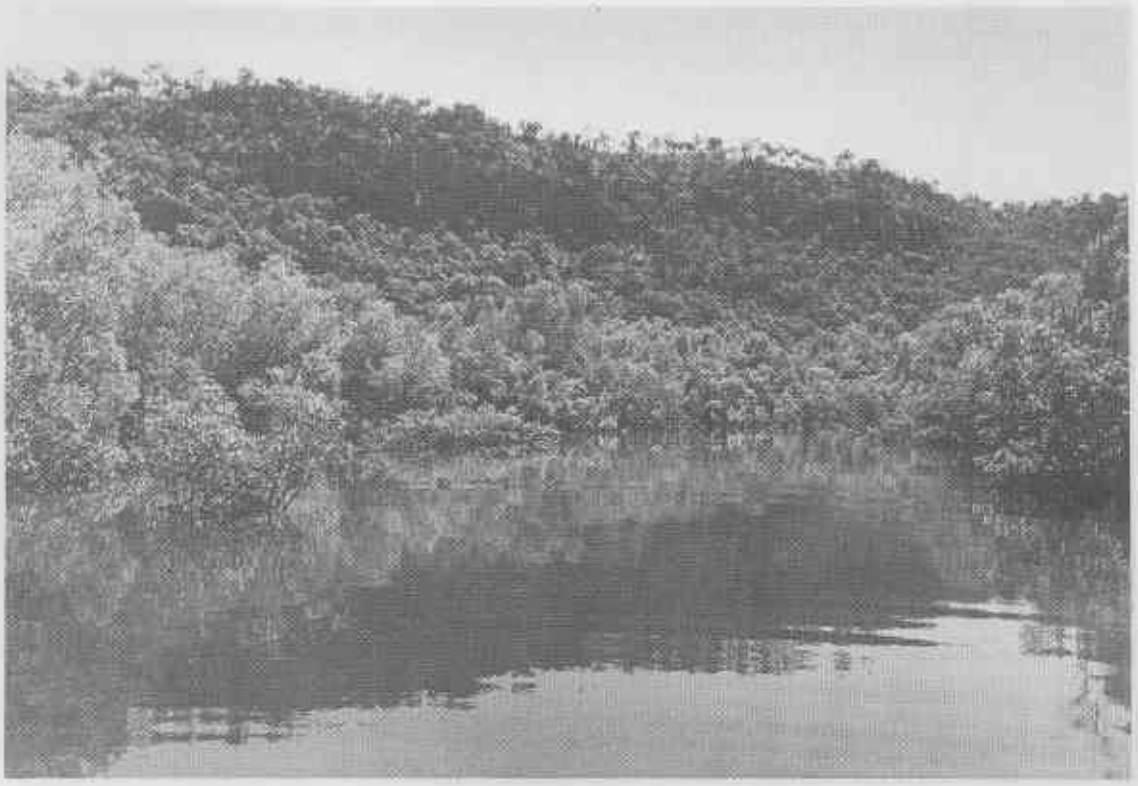

Plate 3. Barlee Impediment mangroves at high tide.

Plate 4. Sale River showing steep banks with limited areas of mangroves and mudbanks.

Plate 5. Tidal creek, Ord River system, at half tide.

Plate 6. Tidal creek, Ord River system, at low tide.

IV THE PRINCE REGENT RIVER SYSTEM

A. DESCRIPTION

A description of the Prince Regent River and St George Basin was given by Messel *et al.* (1977) and a description of the Prince Regent River Nature Reserve can be found in Miles and Burbidge (1975).

Additional time in 1978 allowed us to proceed above the rock bar at 73km as far as 76km (Fig. 7) and to survey completely the two mangrove blocks in St George Basin. Spring tides provided difficult survey conditions.

Fig. 8 shows that a considerable amount of fresh water was entering the river. From 72km to the limit of our survey at 76km, trees along the shore are mainly the mangroves *Camptostemon schultzii*, *Avicennia marina* and *Xylocarpus graniatum* but have an understorey of tall sedges and grasses, which becomes more extensive upstream.

TABLE 2. CROCODILE NUMBERS AND SITUATION ST GEORGE BASIN, 21-23 JULY 1978

SIZE IN FEET (metres)	No. of CROCS.	SITUATION						FEEDING
		IV	IVIW	OM	IM	SWOE	MS	
HATCHLING	25					25		
2-3 (0.6-0.9)	3				1	2		
3-4 (0.9-1.2)	1					1		
4-5 (1.2-1.5)	13					13		
5-6 (1.5-1.8)	12					12		
6-7 (1.8-2.1)	14		1	2		9	2	
>7 (>2.1)	25		1	1		20	3	
EO<6 (<1.8)	2		1			1		
EO>6 (>1.8)	2					1	1	
EO								
TOTAL	97		3	3	1	84	6	-

Abbreviations as in Table 1.

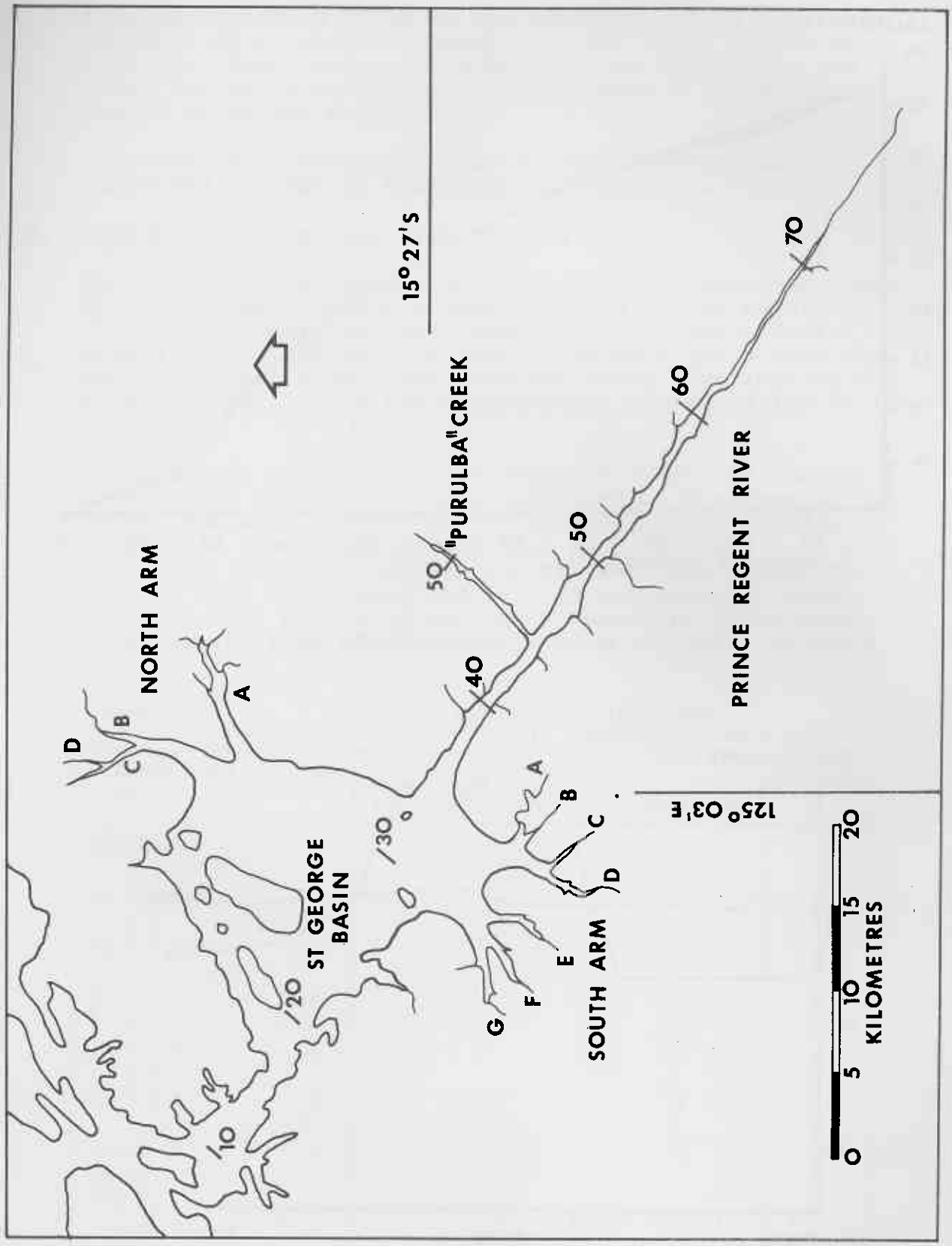

Figure 7. Prince Regent River and St George Basin.

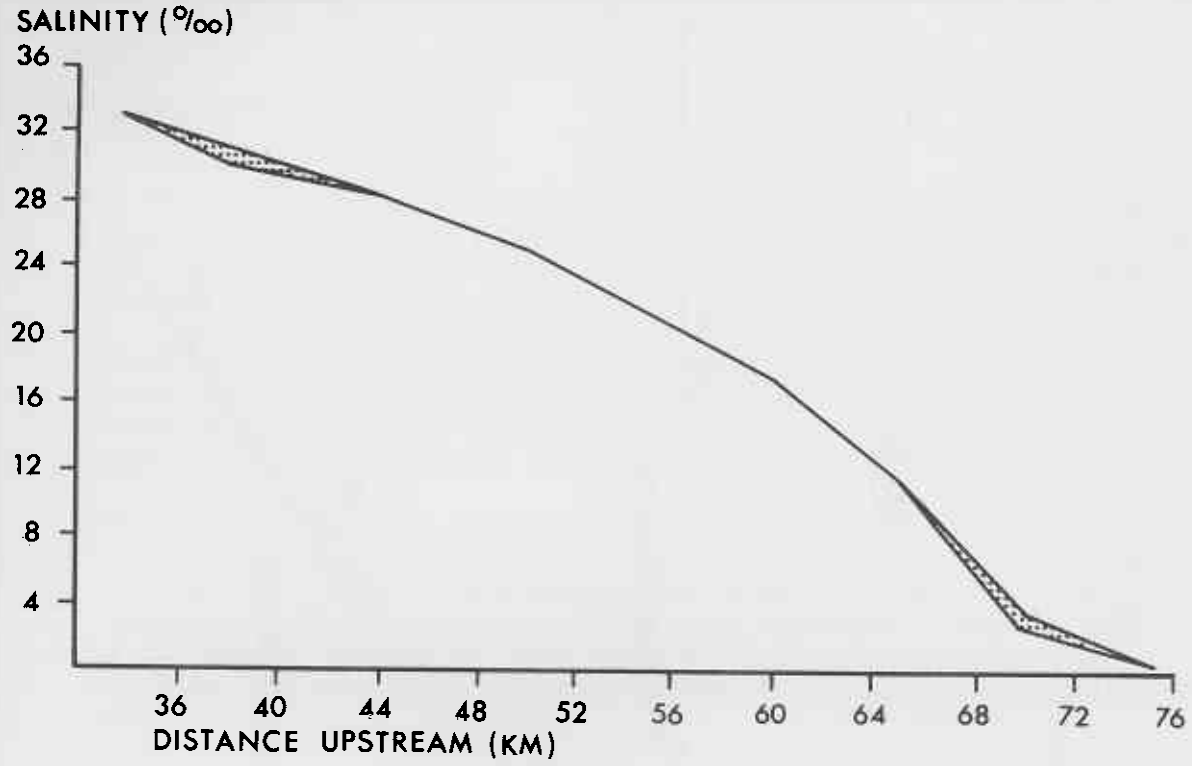

Figure 8. High tide salinity, Prince Regent River

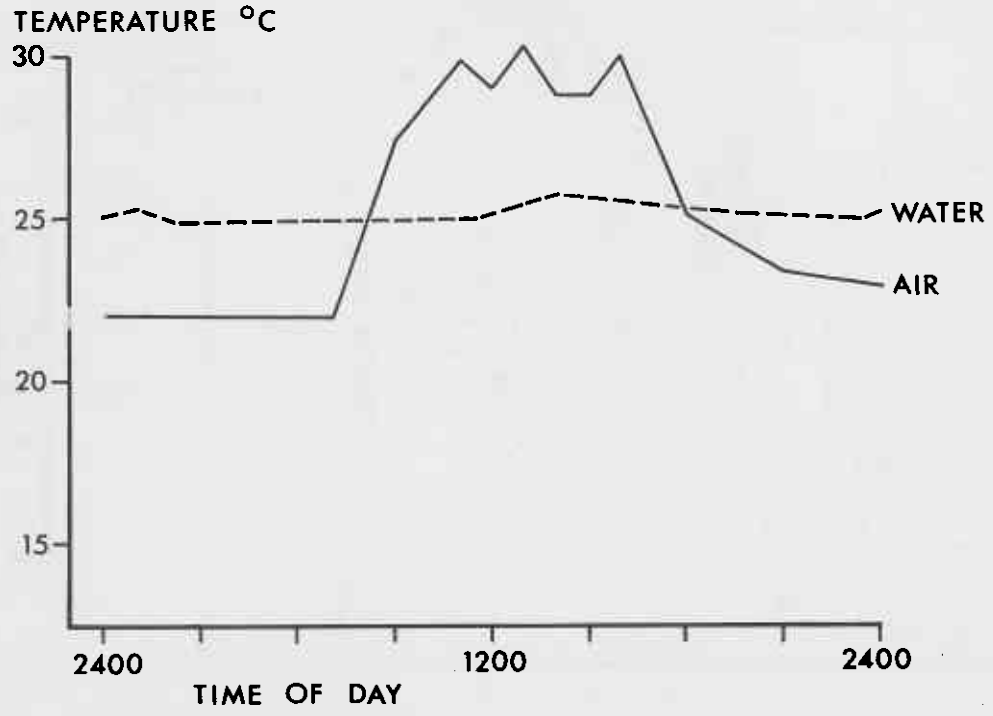

Figure 9. Temperature, Prince Regent River at 34km, 22 July 1978.

Salinity readings taken at the mouth of creeks entering the main river channel showed that all major creeks were flowing. Fresh water was also entering Creek A in the south arm and a small tributary of Creek A in the north arm of St George Basin.

Temperature measurements made at the Research Vessel (anchored at 34km in the River) are given in Fig. 9.

B. CROCODILE NUMBERS AND SIZE CLASSES

The two mangrove-lined arms of St George Basin with their myriad of small channels were surveyed on the nights of 21,22 and 23 July and the Prince Regent River and its creeks on 23 and 24 July 1978. Tables 2 and 3 show the number of each size class seen and their distribution and Figs. 10 and 11 show the distribution of crocodiles in the system.

Ninety-seven crocodiles were observed in the St George Basin arms; 25 of these were hatchlings. Nineteen of the hatchlings were sighted in two adjacent side channels of Creek A in the north arm and five were in Creek A of the south arm (Table 4), suggesting at least one successful nest in each arm during the 1977-78 wet season. These were the only places in the Basin receiving fresh water input at the time of our visit.

TABLE 3. CROCODILE NUMBERS AND SITUATION
PRINCE REGENT RIVER AND ITS CREEKS 23-24 JULY 1978

SIZE IN FEET (metres)	No. of CROCS.	SITUATION						FEEDING
		IV	IVIW	OM	IM	SWOE	MS	
HATCHLING	31			1		29	1	
2-3 (0.6-0.9)	11			1		10		
3-4 (0.9-1.2)	17					17		
4-5 (1.2-1.5)	11					10	1	2
5-6 (1.5-1.8)	8					7	1	
6-7 (1.8-2.1)	6		1			5		
>7 (>2.1)	6		1			2	3	
EO<6 (<1.8)								
EO>6 (>1.8)	1						1	
EO	1	1						
TOTAL	92	1	2	2	-	80	7	2

Abbreviations as in Table 1.

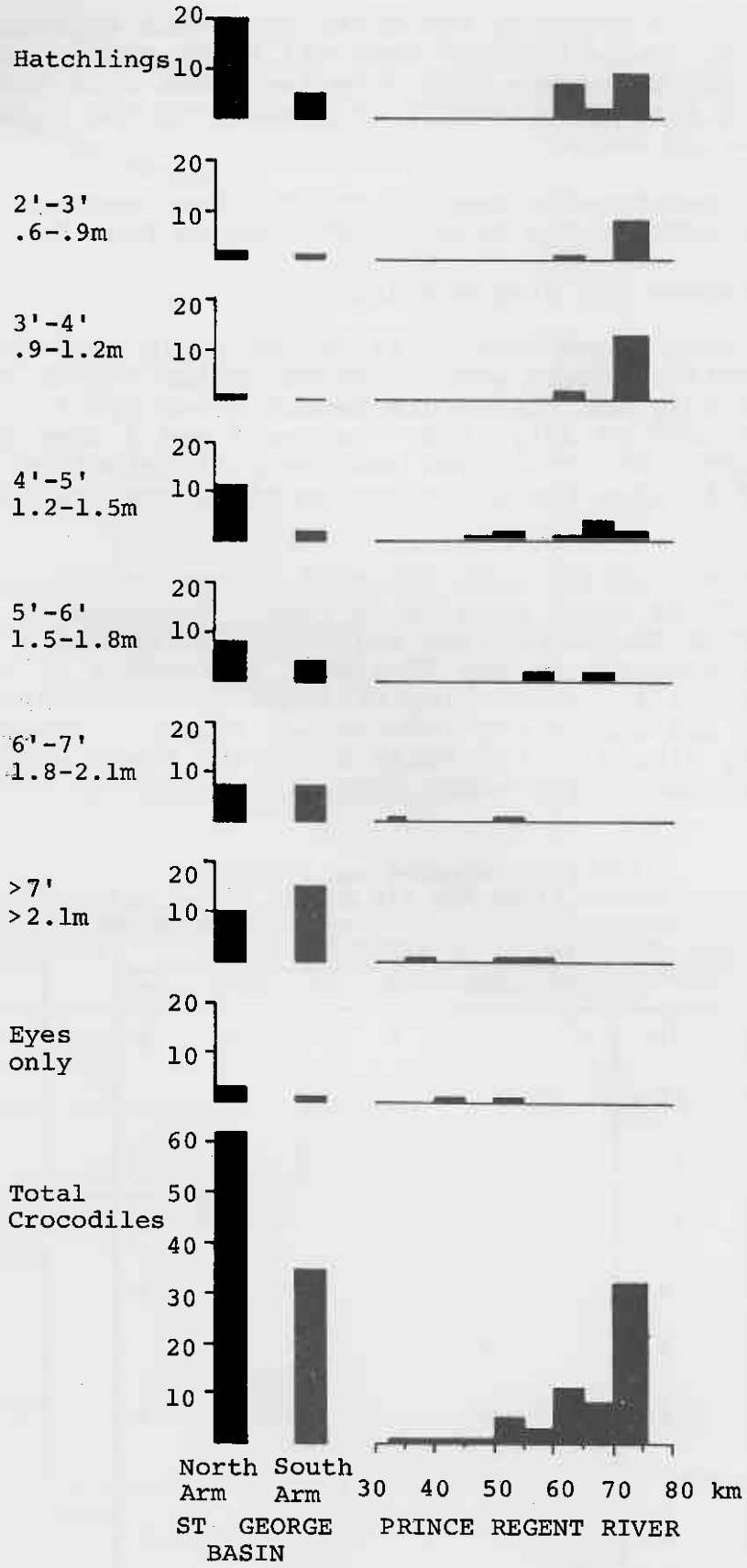

Figure 10. Crocodile distribution, Prince Regent River and St George Basin.

TABLE 4. CROCODILE SIZE CLASSES IN ST GEORGE BASIN CREEKS

Size Class	South Arm Creeks							North Arm Creeks							
	A	B	C	D	E	F	G	A_1	A_2	A_3	A_4	B_1	B_2	C	D
HATCHLING	5	0	0	0	0	0	0	0	1	19	0	0	0	0	0
0.6-1.8m	3	1	1	0	0	1	1	1	4	10	1	3	1	2	0
>1.8m	3	4	2	4	3	3	1	0	4	4	1	2	2	1	1

Ninety-two crocodiles were observed in the Prince Regent River and its creeks; these included 31 hatchlings. Examination of Fig. 10 indicates that there was at least one, and probably two or more, successful nests in the upstream 60 to 76km section of the River. The creek data suggest a further nest in the creek at 58.2km where a group of 11 hatchlings was observed. One hatchling was sighted in each of the creeks at 50.3 and 42.9km but it is not possible to state whether these are the result of local nests or hatchlings drifting downstream in the River.

In 1977 we observed 10 hatchlings in the Basin but these were dispersed and we were unable to say whether they resulted from nesting *in situ* or whether they had drifted downstream (Messel *et al.* 1977).

More hatchlings were sighted in 1978 in the Prince Regent River - 18 compared with three in 1977. At first sight this increase cannot be attributed to our inability to survey above the 73km rock bar last year since we saw only 11 crocodiles above the rock bar on this occasion and only one was a hatchling. However, the fact that 9 of the 11 were in the 2 to 3 feet (0.6 to 0.9m) size class indicates that there were a significant number of hatchlings missed in 1977.

In 1977 we suggested that there were at least three successful nests in creeks running into the Prince Regent River - those at 46.4, 48 (Gariyeli Creek) and 52km. There was no conclusive evidence of nests in any of these creeks this year but, as pointed out previously, the 1978 results indicate a successful nest in one creek, at 58.2km.

These data indicate that successful nesting in the creeks is sporadic, further reinforcing our hypothesis that good nesting habitat in the Prince Regent System is limited in extent. Varying environmental conditions from year to year,

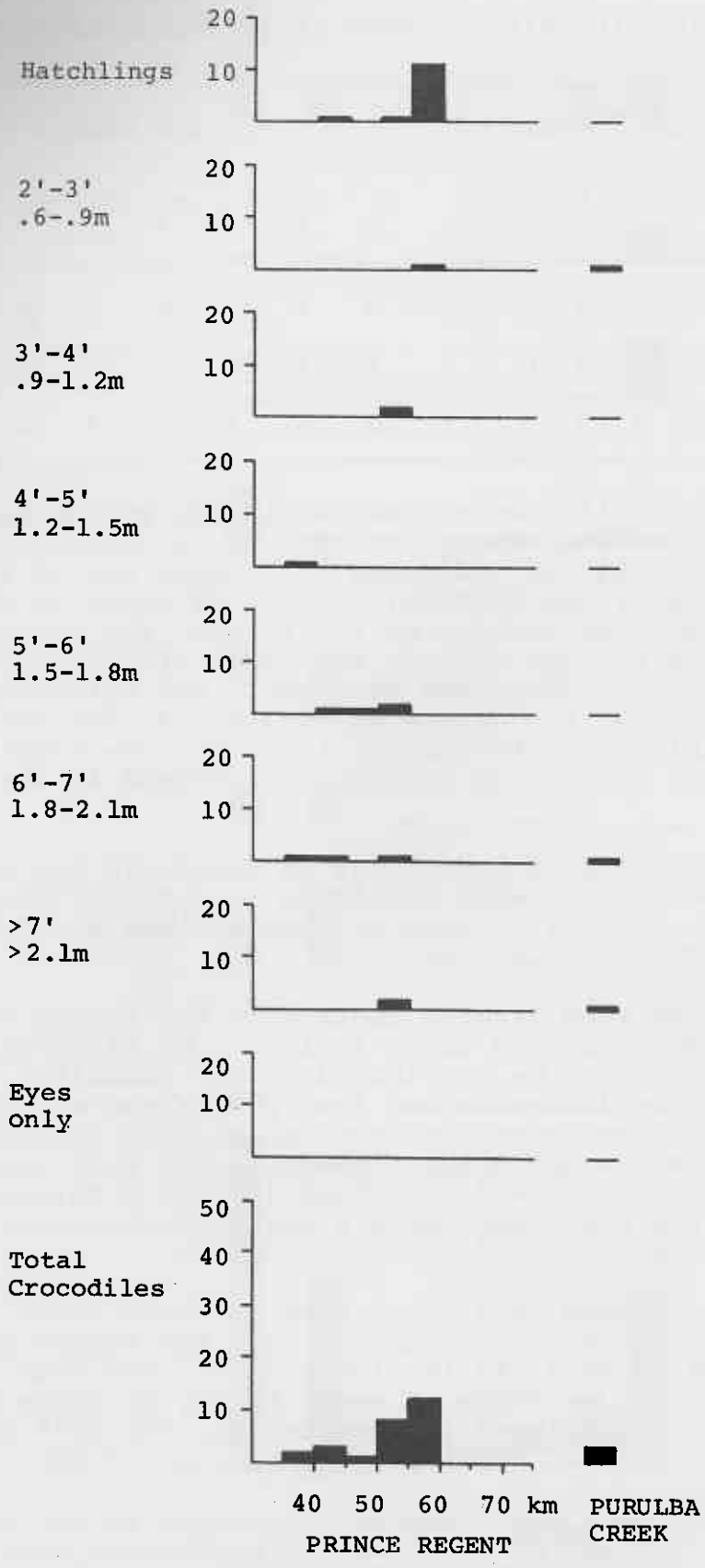

Figure 11. Crocodile distribution, Prince Regent River creeks.

especially the frequency of flooding (Webb *et al.* 1977) may also affect the success of nests.

During the 1977 survey only about one half of the north and south arm "creeks" were surveyed. At that time we saw 72 crocodiles, of which 10 were hatchlings and we postulated that the remaining half contained the same number. This did not prove to be the case since the 1978 survey revealed only 97 crocodiles, 25 of which were hatchlings. One reason for this is that the 1977 survey included the only two breeding creeks in the Basin.

If one compares the number of crocodiles seen in 1977 and 1978 for those creeks surveyed in both years, then the 72 including 10 hatchlings, are to be compared with 75 including 25 hatchlings. The ten 1977 hatchlings would, if they survived, be in the non-hatchling class by 1978 so the 72 crocodiles of 1977 are now to be compared with 75-25 = 50 crocodiles remaining in 1978. Thus, there is evidence for considerable mortality and/or emigration in this population. Comparison of the number in each size class indicates that this occurs not only in the hatchling but in the 3 to 4, 4 to 5 and 5 to 6 foot size classes as well. The decrease amounts to 31% and is similar to that found by one of us (H.M.) in many other river systems in northern Australia.

Evidence for high mortality in hatchlings can be found when examining the number in creeks where nesting occurred during the past wet season. The average number of eggs per nest is 50 (Webb *et al.* 1977) while the number of hatchlings observed were 19, 11 and 5 resulting from at least 3 successful nests. Evidence for the movement of hatchlings and larger size classes can be seen in this and other studies (see Messel *et al.* 1977, Webb and Messel 1978) but the proportion of the reduction in the larger size classes which is due to death or other causes is not known.

Examination of the size structure of the crocodiles observed in each of the north and south arm creeks (Table 4) provides evidence for a major input of small (2 to 6 feet, 0.6 to 1.8m) and large (>6 feet or 1.8m) crocodiles from the Prince Regent mainstream and its creeks. The small crocodiles which appear to have moved into the Basin creek complexes are in the 4 to 5 feet (1.2 to 1.5m) and 5 to 6 feet (1.5 to 1.8m) classes and appear to be almost evenly distributed among the Basin creeks, with perhaps some indication of a lower density further away from the River mouth.

In 1977 we saw 74 crocodiles (including 15 hatchlings) in the River and its creeks compared with 92 (31 hatchlings) in 1978. As discussed above we probably missed a number

of smaller crocodiles last year. However, even if this is ignored, there is a loss of 18% (74 to 61) in one year and an examination of the size structure indicates that this loss is greatest in the 3 to 6 feet (0.9 to 1.8m) size classes. As stated when discussing the St George Basin data it is not known what proportion of this loss is due to mortality as opposed to emigration.

The Prince Regent River and St George Basin, as a whole, yielded 189 crocodiles, 133 of which were non-hatchlings. The combination of a river which provides nesting habitat upstream and large mangrove blocks at its mouth is unique, and further study of the system may lead to a better understanding of movement patterns in the Salt-water Crocodile.

It is undoubtedly the existence of these arms which leads to the unusually high proportion of large (>6 foot or 1.8m). compared to small (2 to 6 feet, 0.6 to 1.8m) crocodiles in the Prince Regent River system. The ratio is 54/78, equivalent to 69%, whereas the mean ratio for all rivers counted in Australia is 27% (Messel *et al.* 1978b). It is possible that in other river systems where similar mangrove blocks do not exist the larger crocodiles move out to sea and a proportion perish.

The system has potential for recovery, containing at least 54 crocodiles over 6 feet (1.8m) long, which are at, or approaching, breeding age. However, the amount of nesting habitat appears to be extremely small and it seems likely that recovery will be very slow. A return to numbers approaching those present before hide hunting took place may take several decades. Any poaching would extend this time or even prevent the recovery ever taking place.

V THE ORD RIVER SYSTEM

A. DESCRIPTION

The Ord River (Fig. 12) enters Cambridge Gulf which in turn empties into Joseph Bonaparte Gulf. The lower, tidal reaches of the Ord from Adolphus Island upstream to about 57km (Fig 12) are a Nature Reserve, the area being set aside primarily for the protection of habitat of *Crocodylus porosus* (see Introduction).

The geomorphology and vegetation of the tidal portion of the Ord have been described by Thom *et al.* (1975). The area we worked in can be divided roughly into three portions:

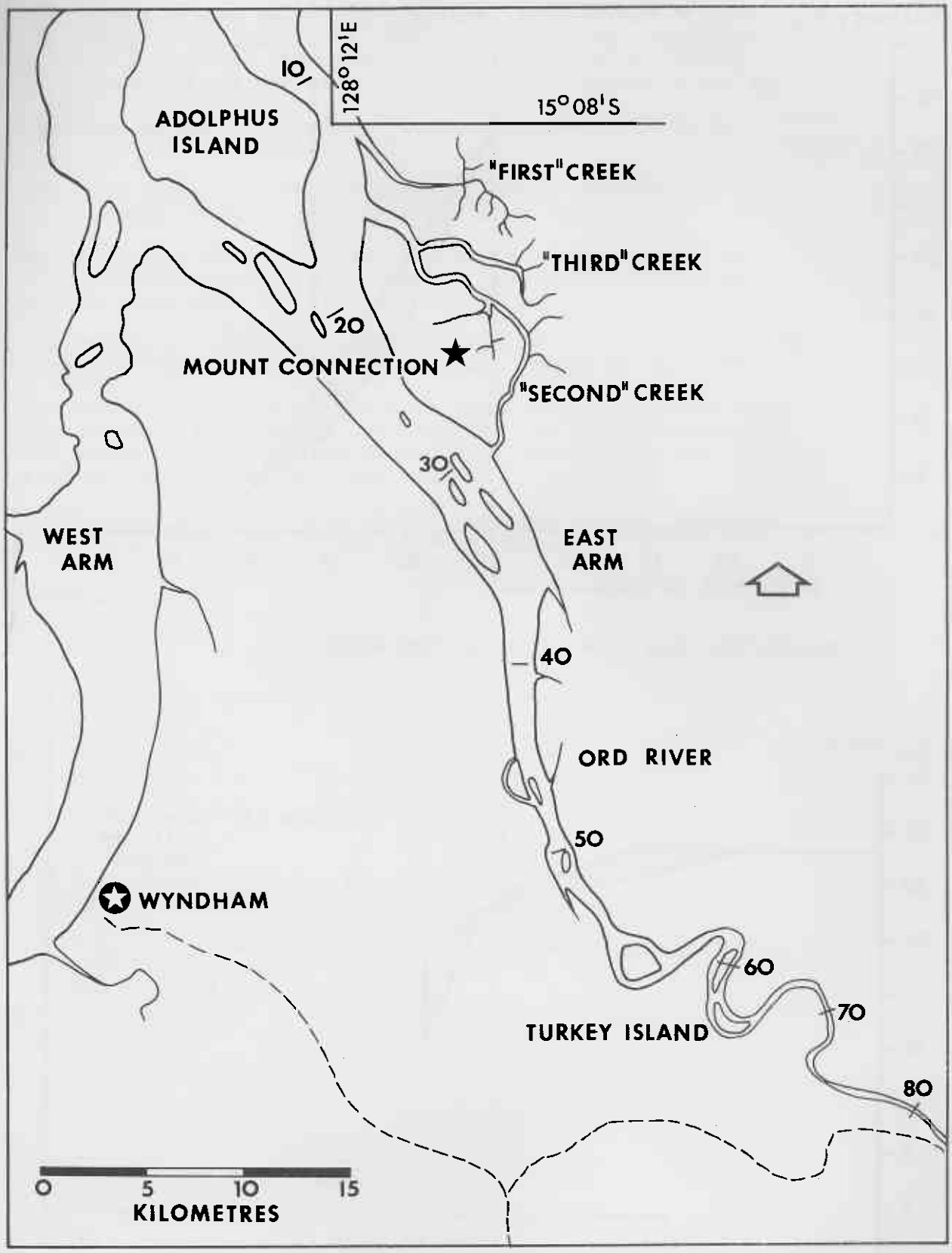

Figure 12. The Ord River system.

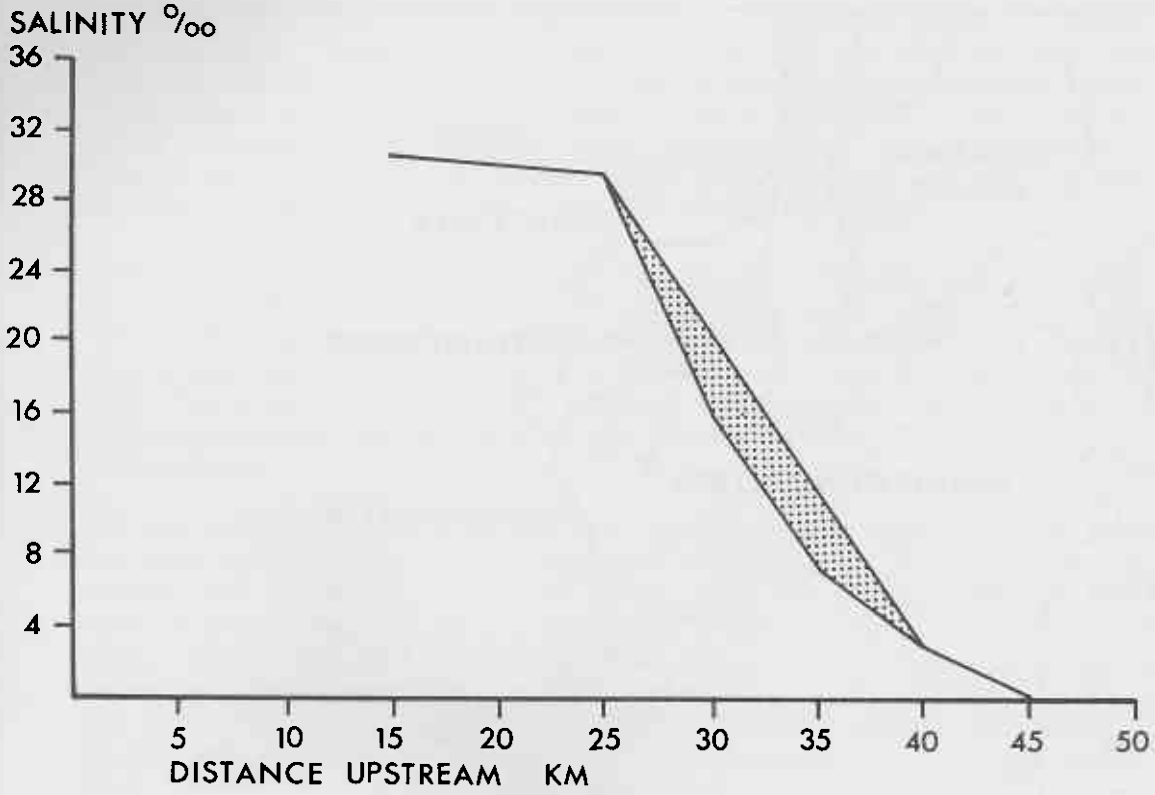

Figure 13. Low tide salinity, Ord River.

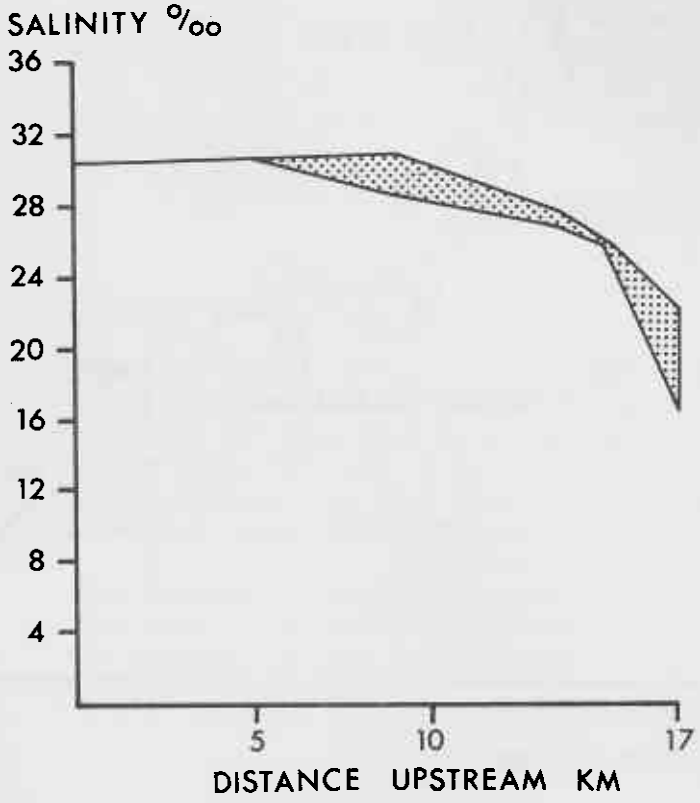

Figure 14. Low tide salinity, "Second" Creek, Ord River system.

(a) tidal creeks near Mt Connection, here termed "First" Creek, "Second" Creek (which forms a loop, separating Mt Connection from the mainland) and "Third" Creek, which is a tributary of Second Creek (Plates 5 and 6),

(b) the estuarine portion, extending from the north to about 50km upstream, and

(c) the upper, freshwater section, which receives an almost constant flow from the dams upstream.

We found that the river had cut new channels upstream of 37km and that available air photography and maps were of little value when navigating.

The Ord River contains extensive sand bars throughout. Rock bars are exposed in some of the tidal creeks at low tide.

The salinity profile of the main river (Fig. 13) shows that considerable fresh water was entering the tidal portion of the river. Salinity data from Second Creek (Fig. 14) reflect those from the River.

Temperature records taken at the Research Vessel, anchored between Adolphus and Barnes Islands, are given in Fig. 15.

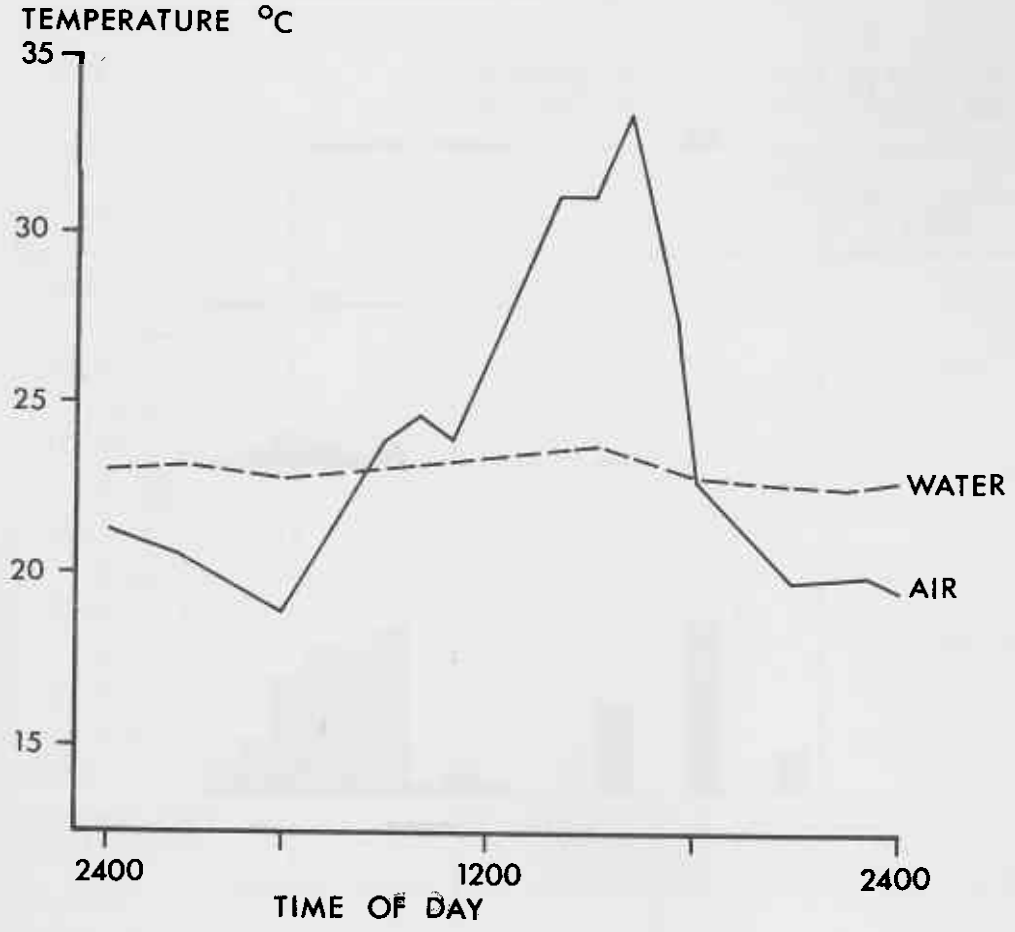

Figure 15. Temperature, Ord River at 18km, 29 July 1978.

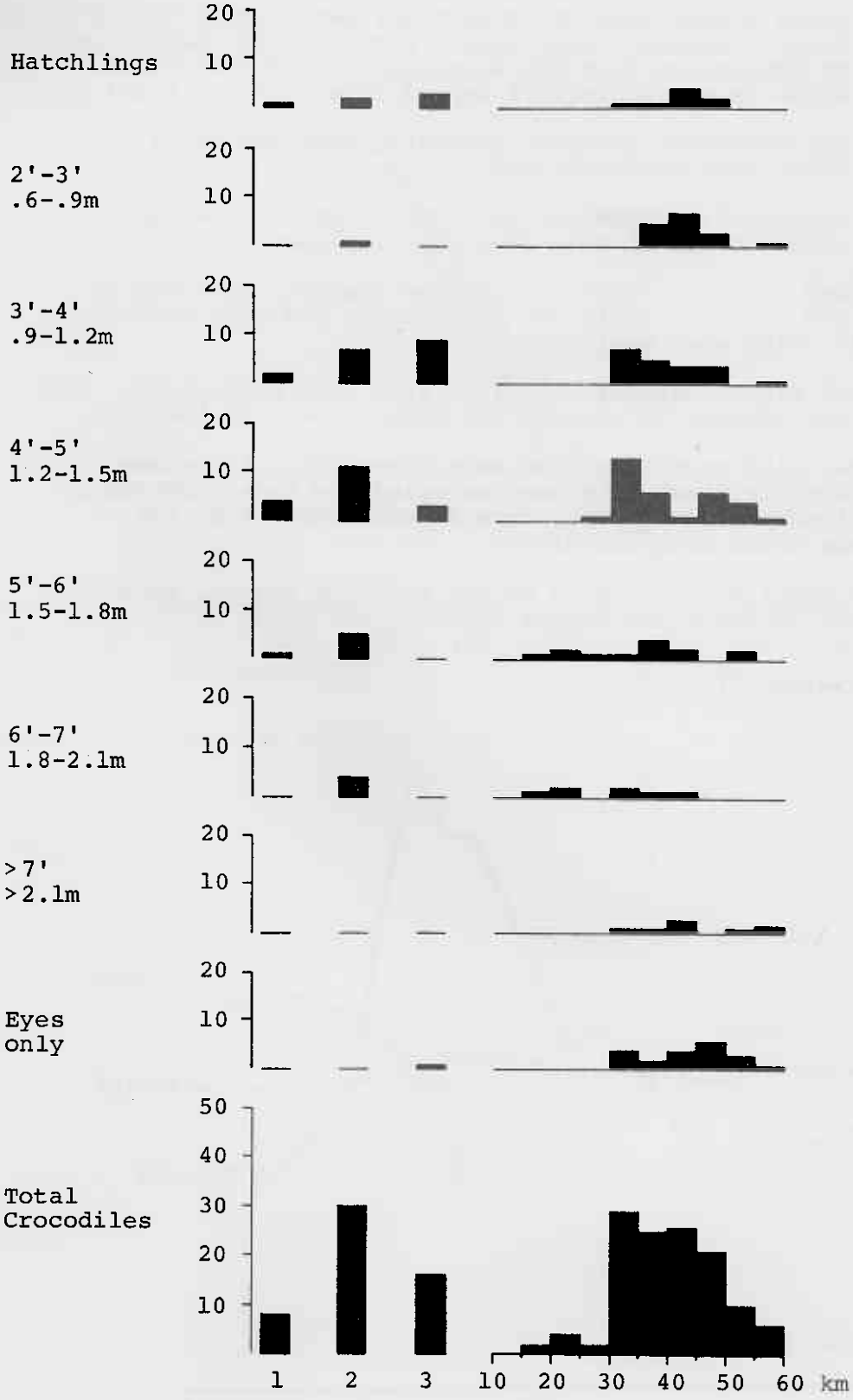

Figure 16. Crocodile distribution, Ord River system.

B. CROCODILE NUMBERS AND SIZE CLASSES

First, Second and Third Creeks and the Ord River from 10 to 20km were surveyed on the night of 28 July and the remainder of the River on 29 July 1978. Table 5 gives the size class distribution of the 179 crocodiles sighted and Fig. 16 shows their distribution in the river system.

Fifty-four crocodiles of which 6 were hatchlings, were sighted in the three creeks. Of the hatchlings one was sighted in First Creek, two in Second Creek and three in Third Creek. From this distribution it appears unlikely that there was a successful nest in the creek area during the 1977-78 wet season. The distribution of all crocodiles sighted in the Creeks - near the mouth of the various channels - suggests strongly that they have moved from the upstream, breeding section of the Ord River. As is the case with the Barlee Impediment in the Glenelg System and the arms of St George Basin in the Prince Regent system, the downstream mangrove blocks appear to be largely inhabited by the so-called "long distance movers" (Webb and Messel 1978) of the *C. porosus* population.

TABLE 5. CROCODILE NUMBERS AND SITUATION ORD RIVER SYSTEM, 28-29 JULY 1978.

SIZE IN FEET (metres)	No. of CROCS.	SITUATION						FEEDING
		IV	IVIW	OM	IM	SWOE	MS	
HATCHLING	14					14		
2-3 (0.6-0.9)	17					17		1
3-4 (0.9-1.2)	39		1		1	37		
4-5 (1.2-1.5)	50	1		2	1	46		1
5-6 (1.5-1.8)	19			1		17	1	
6-7 (1.8-2.1)	11			1		10		
>7 (>2.1)	8					7	1	
EO<6 (<1.8)	7					7		
EO>6 (>1.8)	7					4	3	
EO	7					6	1	
TOTAL	179	1	1	4	2	165	6	2

In the main river channel 125 crocodiles were sighted, of which only 8 were hatchlings. This comparatively low number is possibly due to the sudden release of water from Lake Kununurra through the Ord River Diversion Dam in February 1978 causing many hatchlings to be washed downstream. The sudden release of water from the Ord River Dams should, if possible, be avoided. If necessary it should be restricted to late in the dry season or early in the wet season when it should have less effect on nests and hatchlings.

The Ord River crocodile population is, except for hatchling numbers, surprisingly similar in numbers and structure to that of the Glenelg River which has a non-hatchling crocodile density of 1.75/km for the 77.3km surveyed. The Ord density is 1.68 (98.4km surveyed).

The Ord River appears to have extensive nesting habitat upstream of 40km and must be considered one of the better Kimberley *Crocodylus porosus* rivers.

Bustard (1970) made a brief examination of part of the Ord River and "Second" Creek but sighted only 11 crocodiles. However, his survey techniques were, of necessity, much less thorough than ours and we cannot draw any conclusions from a comparison of the two surveys.

The Ord River Nature Reserve harbours a small Salt-water Crocodile population which appears to have recruited successfully in the recent past. Whether the population is on the road to recovery is not known - further counts will be necessary to document trends.

VI DISCUSSION

We have now systematically counted Salt-water Crocodiles in the majority of the large Kimberley tidal river systems. The only significant areas not surveyed are the Walcott Inlet - Secure Bay area and the West Arm of Cambridge Gulf and their associated rivers, although several small populations no doubt occur, e.g. at the mouth of the Drysdale River.

Our results confirm that the Western Australian *Crocodylus porosus* population, although given total protection over eight years ago has recovered little, if at all, and remains seriously endangered. The overall results are as follows (data from Messel *et al.* 1977 and this study):

System	Total Crocodiles Sighted	Hatchlings	Non-hatchlings
Ord River	179	14	165
Lawley River	44	13	31
Mitchell River	50	8	42
Hunter River	47	11	36
Roe River	176	52	124
Prince Regent River	189	56	133
Glenelg River	213	73	140
TOTAL	898	227	671

Thus a total of 898 crocodiles were sighted of which 227 were hatchlings. Because of the high hatchling mortality rate they should not be included in any estimate of viable population size.

Using the 95% confidence limits given in the Methods section the estimate of the number of non-hatchling crocodiles present in the areas surveyed is:

	Lower Limit	Upper Limit
Ord River	235	306
Lawley River	44	57
Mitchell River	60	78
Hunter River	51	67
Roe River	177	230
Prince Regent River	190	246
Glenelg River	200	259
TOTAL	957	1243

We believe that we have now examined more than half of the better Salt-water Crocodile habitat in the Kimberley. If this is the case, and the crocodile density is in the same order as in those river systems already examined, then the total number of hatchling crocodiles in Western Australia is, at the most, about 2 000.

Considering the vast area inhabited by *C. porosus* in Western Australia this is a very low figure. As discussed in this and the previous report (Messel *et al.* 1977) good nesting habitat appears scarce in the rivers examined and the potential for recovery is low. We cannot say that the populations in any of the rivers we have examined are recovering - indeed one must seriously question whether there are viable populations in the Kimberley, especially in rivers like the Lawley and Mitchell. If the populations do recover then it will not be in any short term period - the recovery will be measured in decades and may, perhaps, require artificial help, such as restocking, in some rivers.

In the meantime a careful watch must be kept on the Western Australian Salt-water Crocodile population to ensure that it is not declining and to provide data for the proper management of the population in the future. We believe that a yearly small scale monitoring programme should be instituted where one or two river systems are monitored annually and other systems at intervals of around five years.

One interesting difference between some Kimberley river systems and those in Arnhem Land has emerged from our studies. Some Kimberley rivers have extensive areas of mangrove-lined tidal creeks near the mouth of the main "breeding" river. This is especially evident in the Prince Regent River, and to a somewhat lesser extent, in the Glenelg River, but they also occur in the Ord, Roe and Lawley River systems. Except in the case of the Lawley these mangrove blocks have numbers of larger crocodiles living in them which have moved from the main river where they hatched. Further study of the relationships between these "holding areas" and their breeding rivers may give clues to the movement patterns of *C. porosus*, since in most Arnhem Land rivers there are no such "holding areas" and many crocodiles moving downstream apparently leave the river system entirely.

As stated by Messel *et al.* 1977 it is clear that there are too few Salt-water Crocodiles in the Kimberley to allow culling for the skin trade. Furthermore we believe that there are still too few animals to allow the taking of significant numbers of crocodiles for farming.

VII ACKNOWLEDGEMENTS

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