POPULATION RESEARCH ON CROCODILES IN THE NORTHERN TERRITORY, 1984-86

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Within the Northern Territory of Australia, *Crocodylus johnstoni* (the Australian freshwater crocodile) and/or *Crocodylus porosus* (the estuarine or saltwater crocodile) occupy most if not all coastal wetlands, regardless of whether they contain fresh or saline water, or are under tidal influence or not (CCNT 1986a, b). The wetland habitats range from open coastline to densely vegetated swamps, from long meandering tidal rivers with exposed mudbanks to perennial streams in rocky escarpments and scattered flood plain billabongs. The extent of all wetlands is strongly influenced by season - particularly by flooding during the wet season.

The diverse habitats occupied by crocodiles in the Northern Territory make quantification of the distribution and abundance of both species difficult. Survey methods need to be habitat specific, and the numbers of animals or nests counted using different methods may need to be standardized against each other, or corrected to real numbers (absolute densities), depending on the management problems being addressed. Where the proportion of large crocodiles in the population is changing as recovery continues, a new set of variables needs to be accounted for; the visibility of large and small crocodiles is not necessarily the same due to size itself and to size-related effects of wariness (Bayliss et al. 1986).

This paper summarizes the results of a series of investigations aimed broadly at refining survey methodology, and clarifying the relationship between relative densities and absolute densities, particularly with *C. porosus*. It addresses Messel's (1986) criticisms of our 1984 estimate of the *C. porosus* population (Webb et al. 1984) and quantifies the rates of population growth that have occurred since the mid-1970's in various habitats. Preliminary data on the impact of harvesting *C. porosus* eggs from the wild are presented.

HABITATS

Habitats occupied by *C. porosus* and *C. johnstoni* in the Northern Territory are summarized on Fig. 1. The majority of *C. porosus* are either in tidal rivers containing saline water during the dry season (B, C, D), or in coastal flood plain channels, billabongs and swamps (E, F, G, H), most of which contain freshwater throughout the year. Wetlands upstream of these, including river channels in rocky escarpments (I) or on upstream flood plains (J), which often recede to chains of billabongs during the dry season, contain mainly *C. johnstoni*. The two species overlap in many river systems giving recognizable zones of sympatry.

The abundance of *C. porosus* habitats in the Northern Territory was estimated on a regional basis (Fig. 2) from 1:100,000 maps supplemented with aerial photographs and information from helicopter and light aircraft surveys (Webb et al. 1984). A distinction was made between tidal rivers where *C. porosus* were known to breed regularly (major breeding) and those where breeding was unknown or irregular (minor breeding). A distinction was also made between mainstreams, secondary creeks (represented by double lines on the maps and generally less than 100 m wide) and tertiary creeks (represented by single lines on the maps and up to 2 km long).

Notwithstanding the errors involved in any such assessment of habitat availability, the results vary significantly from those used as the basis of a *C. porosus* total population estimate by Messel et al. (1981)

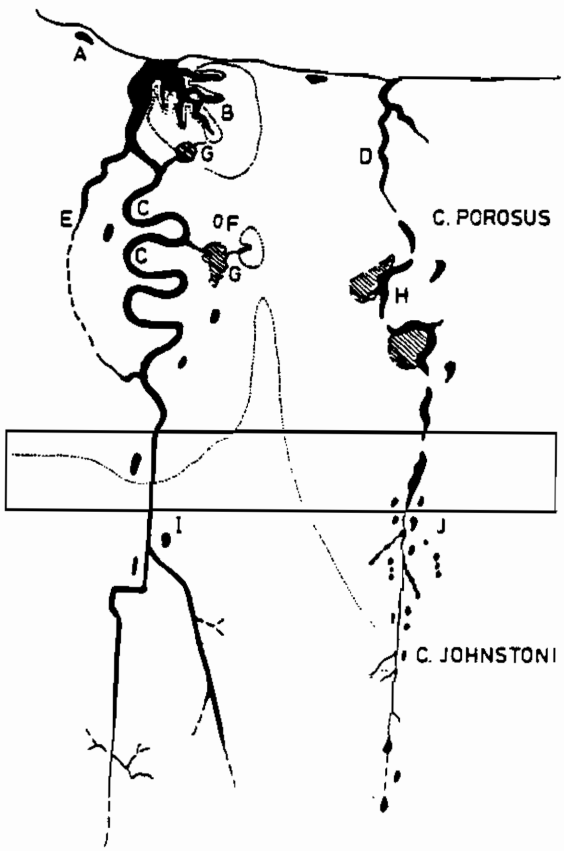

Figure 1. Schematic representation of Northern Territory wetlands occupied by crocodiles. Dotted lines indicate elevated land and cross-hatched lines are freshwater swamps. A, freshwater billabongs behind beach lines; B, a tidal river penetrating into elevated land; C, a tidal river meandering over a flood plain; D, remnant of a meandering tidal river that has become silted; E, tidal flood plain creek with no freshwater input during the dry season; F, isolated flood plain billabongs; G, spring-fed freshwater swamp adjacent to a tidal river; H, isolated sections of an old meandering river no longer open to the sea and containing fresh water and often floating rafts of vegetation; I, non-tidal upper reaches of a river draining rocky escarpment; J, a seasonally flowing mainstream channel that has numerous freshwater billabongs associated with it (after Webb et al. 1987).

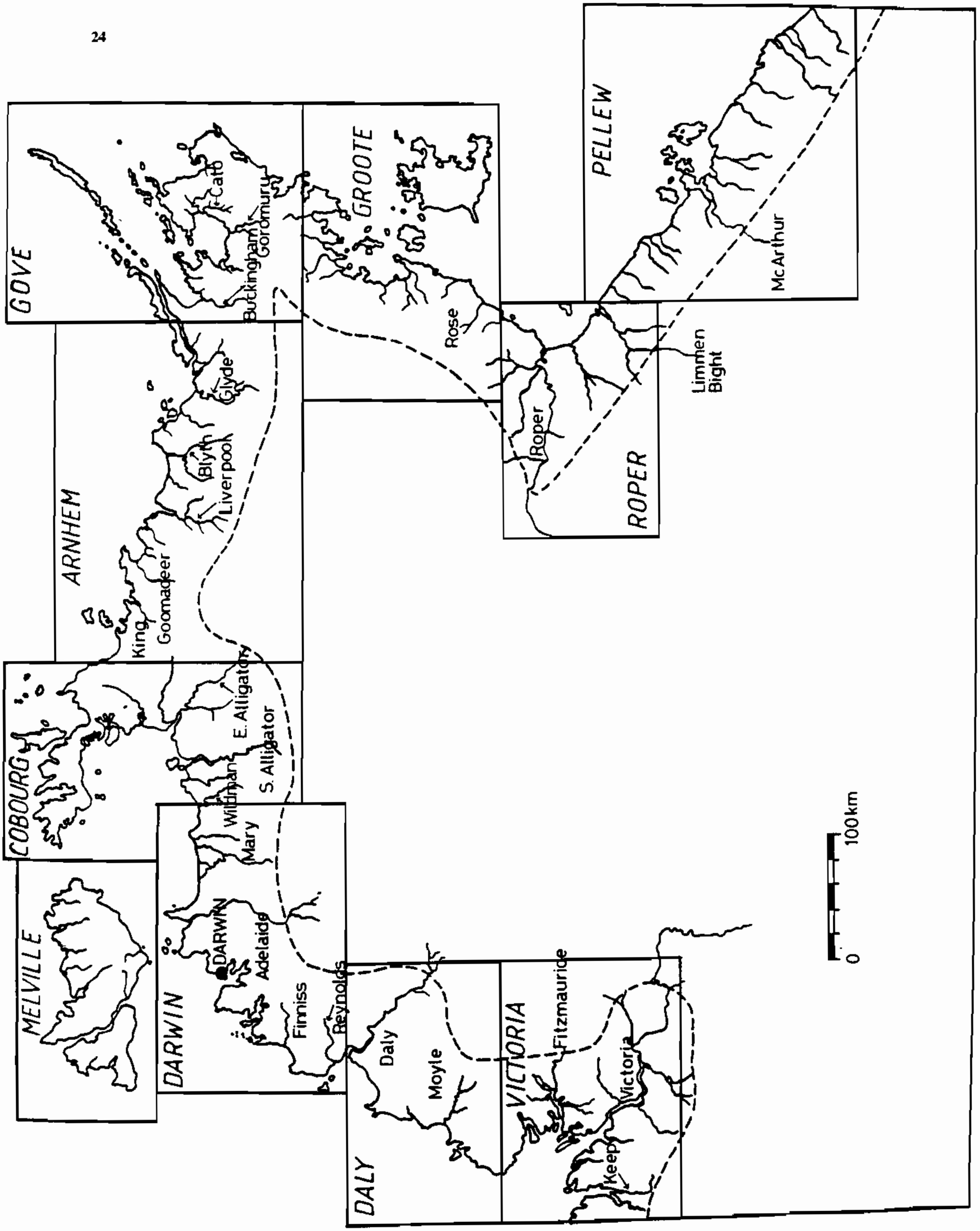

Figure 2. Geographic regions in the Northern Territory in which habitats and population densities have been assessed. The inland limit of *Crocodylus porosus* is indicated by the dashed line.

Table 1. Habitat available for *Crocodylus porosus* in the Northern Territory. C = coastline; C-S = coastal secondary creeks; Mi = minor breeding tiday mainstreams; Mi-S = secondary creeks off minor breeding tidal mainstreams; Ma = major breeding tidal mainstreams; Ma-S = secondary creeks off major breeding tidal mainstreams; TC = tertiary tidal creeks; EC = escarpment channels; FC = flood plain channels; FSw = freshwater swamp.

Region	C km	C-S km	Mi km	Mi-S km	Ma km	Ma-S km	TC No.	EC km	FC km	FSw km^2
Victoria	435	64	949	205	-	-	1487	169	-	13
Daly	233	28	64	31	110	2	146	51	144	1401
Darwin	722	122	233	110	230	67	1425	20	575	392
Melville	683	228	380	428	14	1	1158	-	46	67
Cobourg	1137	127	224	69	329	38	1213	-	224	826
Arnhem	666	56	233	57	350	64	502	64	247	793
Gove	1933	299	142	109	181	155	1090	12	-	61
Groote	1563	190	13	4	81	25	431	152	45	145
Roper	175	26	242	35	292	53	406	44	10	42
Pellew	725	98	705	92	-	-	365	22	-	33
Totals	8272	1238	3185	1140	1587	405	8223	534	1291	3773

and Messel (1986; Table 2). They did not specifically estimate the amount of freshwater swamp or flood plain channel, but recognised it as *C. porosus* habitat and guessed that the population there was 20% of the their estimated tidal population.

As can be seen from Table 1, the regions on Figure 2 have vastly different proportions of different habitat types. Some regions have extensive breeding habitat and little non-breeding habitat, whereas others have the reverse. These differences are summarized on Tables 3 and 4.

In the Victoria and Pellew regions, where the mean annual rainfall is the lowest in the coastal fringe (Fig. 3), there is minimal breeding habitat for *C. porosus*. These areas never contained high densities of *C. porosus* in the past (Webb et al. 1984), and cannot be expected to do so in the future. The suggestion that over 100,000 *C. porosus* were taken from the Victoria River alone (Messel et al. 1984) cannot be substantiated - the total harvest of *C. porosus* skins from the Northern Territory, during the period 1945-46 to 1971, was about 113,000, and a relatively small proportion of these came from the Victoria River (Webb et al. 1984).

"ALL CROCODILES" VERSUS "NON-HATCHLINGS" IN POPULATION ESTIMATES

The extent to which "young-of-the-year" should be included or excluded from survey data pertaining to crocodilian populations depends on the extent to which they can be recognised in surveys, the level of mortality being experienced at the time of survey, and the population statistic being addressed (<u>total population size</u> or <u>rates of recovery</u>).

With *C. johnstoni*, hatching occurs in a six-week pulse at the start of the wet season (November-December), and mortality is approximately 88% during the first year (Smith and Webb 1985). But this occurs almost exclusively during the first wet season, with some 50% mortality within the first two months (Smith, unpubl. data).

By the following dry season, when spotlight surveys are conducted, "young-of-the-year" are an integral part of the population age structure (Fig. 4). Their probability of surviving is the same as that of older sub-adults (Webb and Smith 1984; Smith and Webb 1985), and in spotlight counts (which are often carried out from a vantage point on the edge of a billabong) they cannot be recognised. There is no logical reason to exclude them from estimates of the <u>total population size</u> based on dry season surveys, nor from analyses of <u>rates of recovery</u>.

With *C. porosus*, hatching occurs from March to September, and peaks in April-May. Most spotlight surveys are conducted between June and November of the same year (in the dry season), when hatchlings are mostly 3-4 months of age, but can range from 0 to 9 months of age. In the Blyth-Cadell River System, 81% of the number of "young-of-the-year" estimated from dry season spotlight surveys were represented as 1 year olds the following year. They have <u>higher</u> probabilities of surviving than do older sub-adult year classes (Table 5). Deleting them from estimates of the total population size on the basis of "low survivorship" is simply not supported by the data. They are a significant but highly variable segment of the population and at least the mean number of hatchlings should be included in reports of the <u>total population size</u>.

When assessing <u>rates of population increase</u> with *C. porosus*, greater stability will result if the hatchling size class is deleted, and only non-hatchlings are considered (Fig. 5). This is because the number of hatchlings recruited into the population each year varies with the extent of nesting and embryonic mortality within nests. Within Northern Territory rivers, excluding hatchlings has the effect of increasing the annual rates of recovery by about 1.4% per year, while reducing the standard error of that estimate by about 0.1% (Table 6; see below).

Table 2. A comparison of two estimates of *Crocodylus porosus* habitat availability in the Northern Territory of Australia. MS = mainstream; SC = secondary creeks. "*" the 1000 km of upstream freshwater channel estimated by Messel et al. (1981) equates approximately to the escarpment channel of Webb et al. (1984).

Category	Webb et al. (1984)		Messel et al. (1981, 1986)
Coastline	8272	km	3200 km
Coastal secondary creeks	1238	km	-
Tidal river major breeding (MS+SC)	1992	km	2175.5 km
Tidal river minor breeding (MS+SC)	4325	km	2482.1 km
Flood plain channel	1291	km	-
Escarpment channel	534	km	1000* km
Freshwater swamp	3773	km^2	-
Tertiary creeks	8223	ck's	-

Table 3. Regions of the Northern Territory (Fig. 1) ranked according to the amounts of breeding and non-breeding habitat for *Crocodylus porosus* within them. Rank 1 = lowest and 10 = highest.

	Breeding			Non-breeding	
Area	Swamp	F/Channel	Tidal	Coast	Tidal
Victoria	1	2	1.5	3	10
Daly	10	7	5	2	1
Darwin	7	10	6	6	7
Melville	5	3	3	5	9
Cobourg	9	8	9	8	6
Arnhem	8	9	10	4	5
Gove	4	6	7	10	3
Groote	6	4	4	9	2
Roper	3	7	8	1	4
Pellew	2	1.5	1.5	7	8

Table 4. Areas of the Northern Territory (Fig. 1) ranked according to the abundance of all breeding habitat (rank 1 = highest). When hunters were questioned about the densities of *Crocodylus porosus* that existed in the late 1940s, at the start of commercial hunting, they identified 15 high density (6-12/km), 10 medium density (1-5/km), and 17 low density areas (<1/km) (Webb et al. 1984).

			Historical Densities		
Area	Breeding	Non-breeding	High	Medium	Low
Arnhem	10	3	2	4	6
Cobourg	9	9	3	2	
Darwin	8	6	5		
Daly	7	1	2		
Roper	6	2		1	2
Gove	5	6	1	1	2
Groote	4	4	2	1	2
Melville	3	9		1	
Pellew	2	9			3
Victoria	1	6			2

Table 5. The relationship between age and the probability of being represented in the river the following year for *Crocodylus porosus* in the Blyth-Cadell River system between 1974 and 1984 (data from Messel et al. [1981, 1984] and CCNT as analyzed by Webb et al. [1984]).

Interval (years)	Mean	Maximum	Minimum
0.3-1.3	0.81	1.31	0.56
1.3-2.3	0.69	1.03	0.30
2.3-3.3	0.79	1.03	0.60
3.3-4.3	0.56	0.79	0.36
4.3-5.3	0.56	0.80	0.27

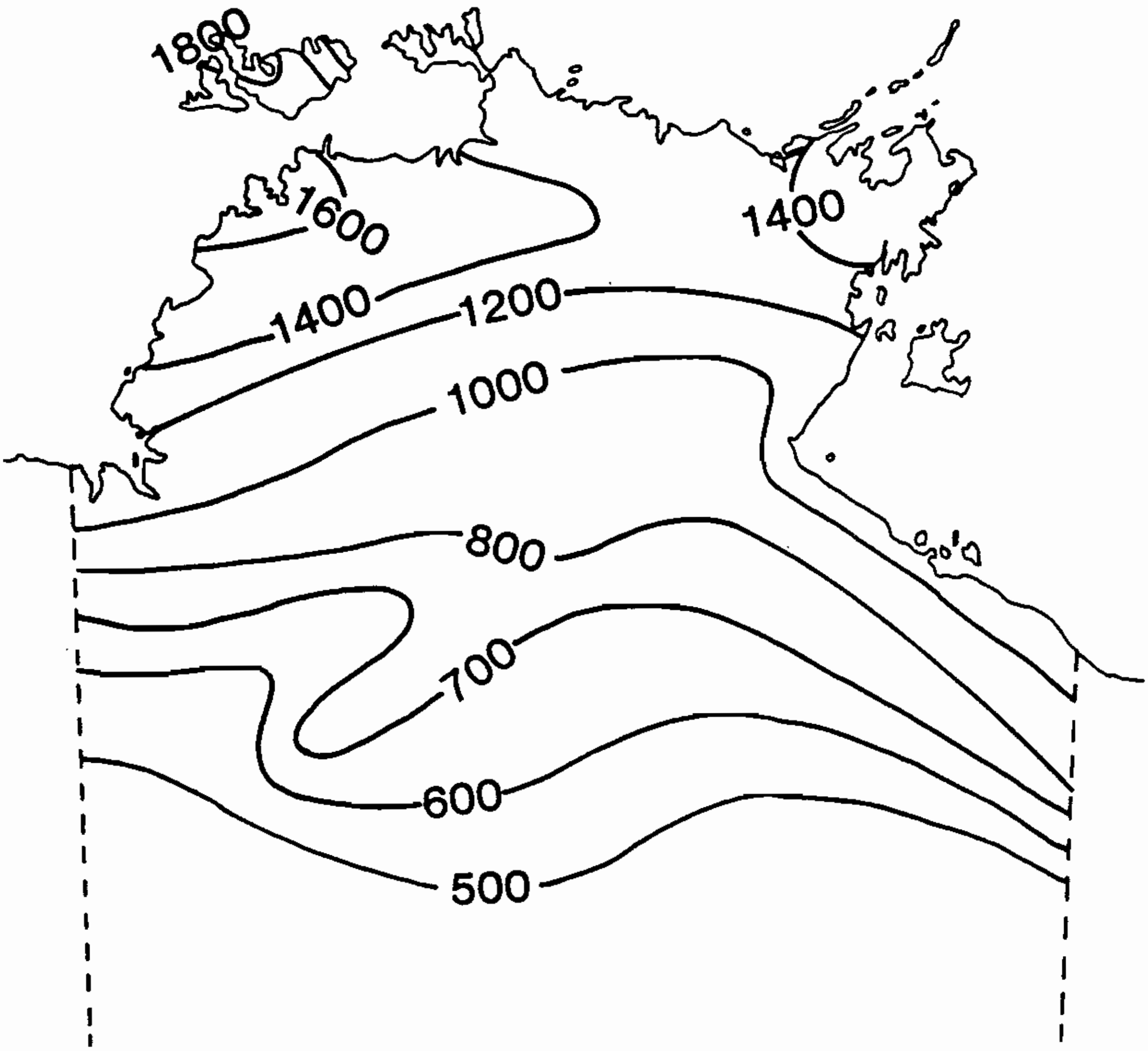

Figure 3. Mean annual rainfall (mm) in the Northern Territory (1873-1984).

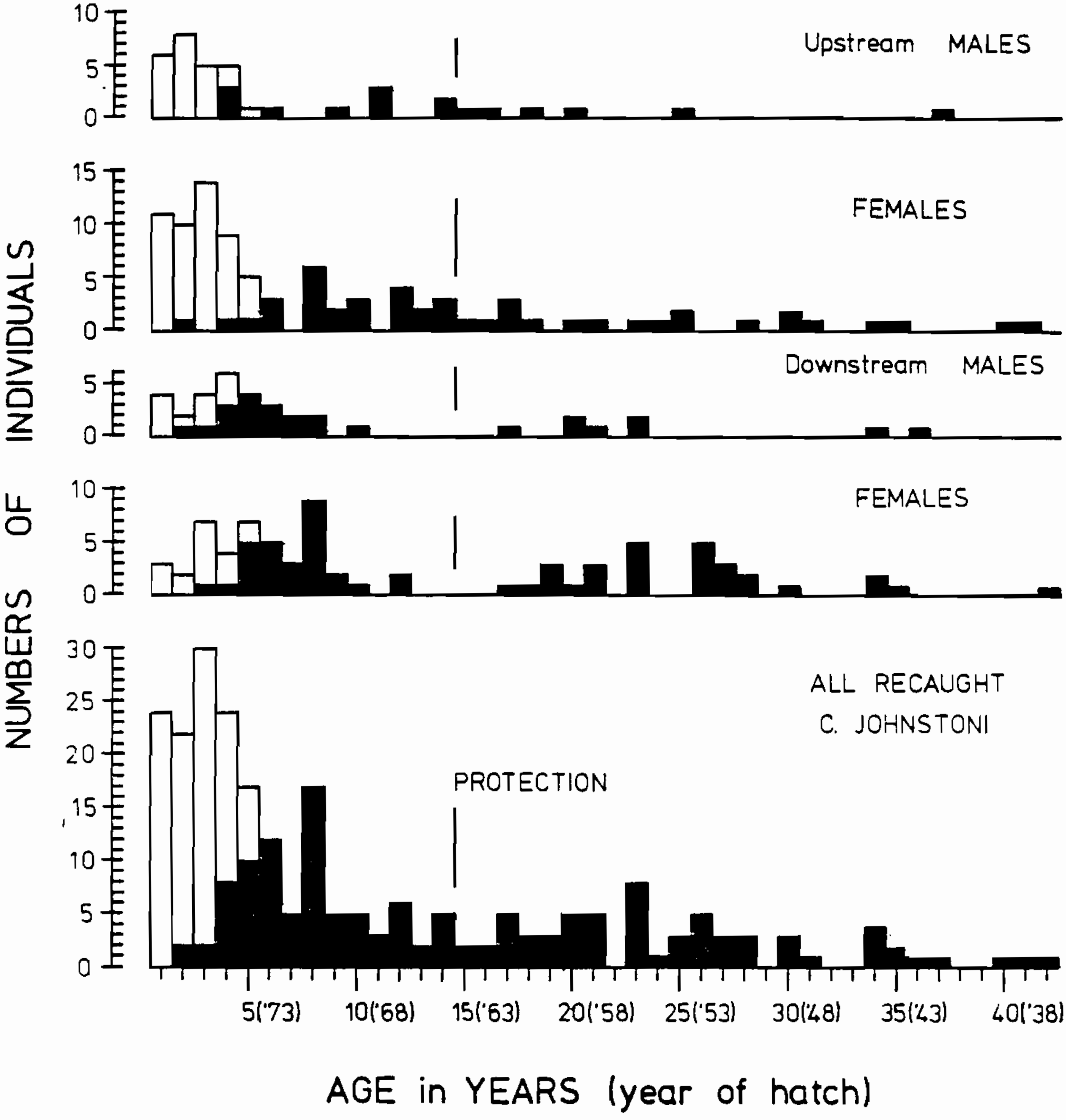

Figure 4. The age structure of a population of *Crocodylus johnstoni* within the Northern Territory (after Webb et al. 1983a).

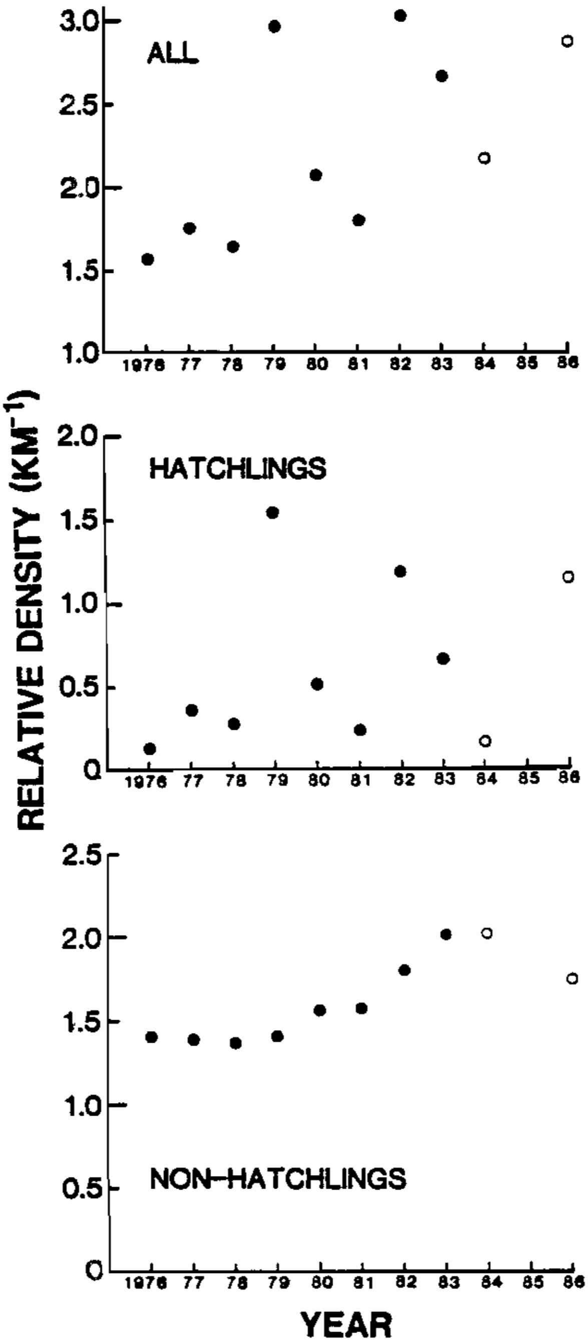

Figure 5. Relative densities of *Crocodylus porosus* in the Liverpool-Tomkinson River system. Closed circles indicate data from Messel et al. (1981) and open circles data from CCNT surveys.

RATES OF *C. POROSUS* RECOVERY

When the Northern Territory introduced protective legislation for *C. porosus* in 1971, the populations had been intensively hunted since 1945-46, and the adult population was reduced to a wary remnant. Within the first 2-5 years after protection, numbers increased rapidly in breeding areas (because recruits were not being harvested), although the average size of individuals was small. In some remote breeding areas this initial increase occurred prior to protection (Fig. 6).

Spotlight surveys carried out by the University of Sydney, the Conservation Commission of the Northern Territory (CCNT) and other organizations were initiated after this initial increase, and thus the analyses in Table 6 refer to rates of recovery from the mid-1970's to the mid-1980's - they underestimate the recovery of numbers that occurred between protection and the mid-1970's (Fig. 6).

These rates of recovery are based on spotlight counts alone and are not corrected for the changing size structure of the *C. porosus* population (see below). All regions from which there are survey data, indicate a positive rate of population increase among non-hatchlings - even low density areas such as Pellew (see Fig. 2). When all crocodiles were considered, the Roper region was the only one which did not have a similar positive rate of increase. It showed a 2.1% annual decrease between 1979 and 1985 [two spotlight surveys only; an additional survey in 1986 was by helicopter, and hatchlings are not detected), which was attributable to the lack of hatchlings counted in 1985 in one side creek of the Towns River (28 in 1979; 0 in 1985).

The exponential rates of increase are generally higher in the "non-hatchlings" than in "all crocodiles", and the mean rates for all areas combined are 8.3% p.a. (all crocodiles) and 9.7% p.a. (non-hatchlings). This is unequivocal evidence of an expanding population.

THE IMPACT OF HARVESTING *C. POROSUS* EGGS

During the 1983-84 season a preliminary one-day harvest of *C. porosus* eggs (994 eggs) was undertaken in the Adelaide River. However during the 1984-85 and 1985-86 *C. porosus* nesting seasons, experimental harvests (3517 and 3470 eggs respectively) were undertaken within parts of three river systems close to Darwin (Finniss, Reynolds, Adelaide; Fig. 2). Eggs from all nests were individually numbered and incubated under controlled conditions, and the post-hatching growth and survivorship of all resulting hatchlings (individually numbered by mutilating a known sequence of tail scutes), is now being monitored within the crocodile farms. The post-hatching performance of these individuals can be correlated with details of individual eggs, nests, habitats and incubation conditions.

All dead eggs were opened and the embryos were used to determine whether death had occurred before or after collection. As a consequence, the mortality within each area up until collection could be quantified (Table 7; data from the 1985-86 nesting season are not yet fully analyzed).

Harvesting eggs at an earlier stage of embryonic development was partly responsible for the reduced mortalities compared to wild incubation, but substantial losses in the field still occurred. These were due to flooding, overheating and what appeared to be asphyxia within sodden, muddy nests.

The impact of reducing hatchling recruitment by harvesting eggs could be expected to be detected in the 2-6' size class the following year. Spotlight surveys within the accessible parts of all areas harvested indicated no major decline in numbers, which is consistent with the view that harvests of eggs will result in a minimal impact on the size of wild populations (Webb et al. 1984, 1987). This approach to harvesting a wild population is atypical, as the general aim is usually to reduce densities to extract a sustainable yield

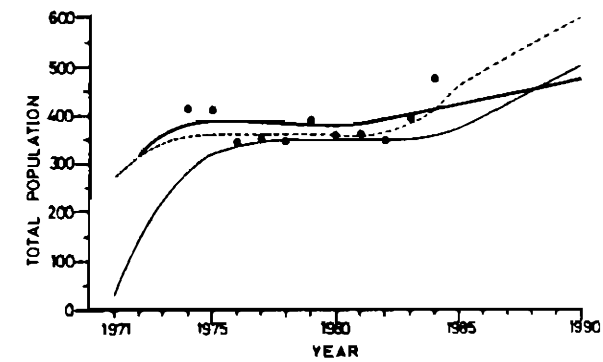

Figure 6. Total population estimates of *Crocodylus porosus* (excluding hatchlings) within the Blyth-Cadell River system as determined from corrected spotlight counts (dots). The dashed line represents the computer simulation of population predicted backwards to 1971 and forwards to 1990. The heavy line applies a density-dependent mortality among juveniles. The thin line does not apply density-dependent mortality, but assumes harvesting had continued up until protection, and that no juveniles were in the population at that time.

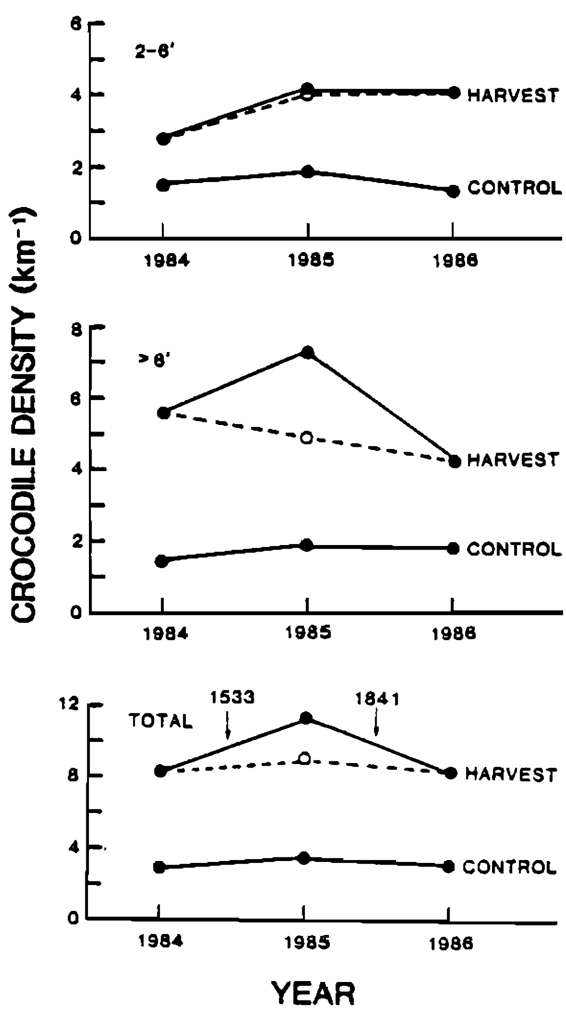

Figure 7. Relative densities of *Crocodylus porosus* in flood plain channels (Finniss-Reynolds River system) in which eggs were harvested and not harvested (1984-86). Numbers refer to the number of eggs harvested during a particular nesting season. Open circles indicate densities with one channel excluded (see text).

Table 6. Exponential annual rates of increase of *Crocodylus porosus* in major river systems within the Northern Territory between the mid-1970s and mid-1980s. Analyses are based on spotlight counts and/or helicopter counts standardized to spotlight counts. Original data from Messel et al. (1981,1986), Webb et al. (1984), and additional unpublished survey results from CCNT and ANPWS (Bayliss 1986). Rates are calculated for all crocodiles (T) and with hatchlings excluded (NH); R^2 is explained variance; "*" only two surveys, regression analysis impossible.

			All Crocodiles			Non-Hatchlings		
Area/River	Years	(N)	r	R^2	p	r	R^2	p
DALY								
Daly	1978-86	(4)	+0.104	0.91	0.10	+0.103	0.95	0.05
	MEAN		+0.104			+0.103		
DARWIN								
Finnis	1984-86	(3)	+0.40	0.01	NS	+0.038	0.01	NS
Reynolds	1984-86	(3)	+0.130	0.03	NS	+0.140	0.03	NS
Adelaide	1977-86	(7)	+0.055	0.84	0.01	+0.035	0.74	NS
Mary	1984-86	(3)	+0.276	0.70	NS	+0.276	0.70	NS
	MEAN		+0.125			+0.122		
MELVILLE								
Andranangoo	1975-84	(5)	+0.072	0.96	0.10	+0.089	0.94	0.10
Johnston	1972-84	(4)	+0.113	0.56	NS	+0.110	0.55	NS
Bath	1972-84	(4)	+0.134	0.74	NS	+0.134	0.74	NS
Dongau	1972-84	(6)	+0.016	0.03	NS	+0.039	0.10	NS
Tinganoo	1972-84	(5)	+0.181	0.73	NS	+0.181	0.73	NS
	MEAN		+0.103			+0.111		
COBOURG								
Wildman	1978-84	(3)	+0.098	0.93	NS	+0.153	0.74	ns
W. Alligator	1977-84	(4)	+0.051	0.99	0.05	+0.056	0.79	NS
S. Alligator	1977-84	(10)	+0.225	0.27	NS	+0.213	0.24	NS
E. Alligator	1977-85	(8)	+0.072	0.64	0.01	+0.058	0.64	0.01
Murganella	1977-84	(4)	+0.096	0.57	NS	+0.114	0.91	NS
ARNHEM								
King	1975-79	(4)	+0.240	0.74	NS	+0.278	0.87	NS
All-Night	1975-79	(3)	+0.271	0.39	NS	+0.271	0.39	NS
Goomadeer	1975-84	(8)	+0.016	0.06	NS	+0.002	0.00	NS
Majarie	1975-84	(7)	+0.040	0.18	NS	+0.035	0.14	NS
Wurugoij	1975-84	(7)	+0139	0.38	NS	+0.135	0.37	NS
Liverpool-Tomkinson	1976-86	(10)	+0.054	0.45	0.05	+0.039	0.71	0.01
Nungbulgarri	1975-84	(8)	+0.089	0.48	NS	+0.071	0.36	NS
Blyth-Cadell	1974-86	(13)	+0.002	0.00	NS	-0.004	0.00	NS
Crab	1981-83	(3)	+0.001	0.00	NS	+0.001	0.00	NS
Ngandadauda	1975-83	(3)	+0.029	0.92	NS	+0.05	0.99	0.10
Glyde	1975-84	(4)	+0.143	0.78	NS	+0.153	0.98	0.05
	MEAN		+0.093			+0.094		

GOVE								
Darwarunga	1975-84	(3)	+0.129	0.89	NS	+0.126	0.90	NS
Habgood	1975-84	(3)	+0.081	0.89	NS	+0.095	0.80	NS
Habgood Ck	1975-84	(3)	+0.001	0.00	NS	+0.001	0.00	NS
Baralminar	1975-84	(3)	+0.096	0.89	NS	+0.096	0.89	NS
Gobolpa	1975-84	(3)	+0.075	0.83	NS	+0.091	0.93	NS
Goromuru	1975-84	(3)	+0.006	0.06	NS	+0.050	0.82	NS
Cato	1975-84	(3)	+0.015	0.25	NS	+0.101	0.92	NS
Peter John	1975-84	(3)	-0.018	0.03	NS	-0.004	0.01	NS
Burungbirinung	1975-84	(3)	+0.096	0.52	NS	+0.222	0.65	NS
	MEAN		+0.053			+0.086		
ROPER*								
Limmen Bight	1979-86	(3)	+0.061	-	-	+0.077	0.94	NS
Towns	1979-86	(3)	-0.110	-	-	+0.006	-	-
Roper	1979-86	(3)	-0.015	-	-	+0.017	-	-
	MEAN		+0.021			+0.033		
PELLEW								
McArthur	1979-86	(3)	+0.055	-	-	+0.054	0.99	0.10
Wearyan-Foelsche	1979-86	(3)	+0.035	-	-	+0.021	0.37	NS
	MEAN		+0.045			+0.038		
MEAN OF ALL AREAS			+0.080			+0.093		
(SE)			±0.013			±0.012		
%pa			+8.3			+9.7		
(N)			40			40		

Table 7. Results of the experimental *Crocodylus porosus* egg harvest in 1984-85 compared to results for wild nests in two of the same areas in the 1980-81 season.

Area:	Melacca	Melacca	Adelaide	Finniss-Reynolds	Finniss-Reynolds
Season	1980-81	1984-85	1984-85	1980-81	1984-85
Wild or harvest	wild	harvest	harvest	wild	harvest
Nests examined	18	19	22	33	26
Eggs examined	917	959	1025	1795	1533
Eggs hatched (%)	35.6	80.3	59.2	29.2	45.7
Eggs infertile (%)	9.4	3.6	7.9	5.0	5.4
Eggs damaged (%)	0.6	0.8	0.4	2.4	2.3
Eggs failed					
1. in field (%)	54.4	9.6	17.9	62.8	26.0
2. in laboratory (%)	-	5.6	14.6	-	20.5

(Caughley 1977). Populations at equilibrium are often reduced by 30-50% (depending on the harvest model used) to achieve maximum sustained-yield.

In the Finniss-Reynolds area (Fig. 7), some channels were harvested and others were not. Analysis of variance of density trends between harvested and unharvested areas (Table 8) showed no significant effect of harvest (the time by experiment interaction was not significant). There was a significant three-fold difference in the densities between the harvested and unharvested areas (Fig. 7), which indicates that harvests were concentrated in the flood plain channels with the highest densities of crocodiles. An increase in the number of >6' animals in 1985 (Fig. 7) was largely due to increased numbers of >6' animals in one harvested channel, but this effect was trivial (time by size class interaction was not significant; Table 8), and unrelated to the harvest of eggs.

In the Adelaide River, no local control was available and so the Liverpool-Tomkinson data were used as a control of sorts. This population is within a tidal breeding system (as is the Adelaide) and had:

1. Similar non-hatchling densities between 1977 and 1979, well before the egg harvests, (Fig. 8); and,

2. A positive rate of increase after 1977-79 (Fig. 8), as did the Adelaide River.

The Blyth-Cadell system, which has been surveyed more regularly, was rejected as a control because its rate of increase was close to zero - lower than that of the harvested population.

Because of the more extensive survey data, analysis of covariance was used to test for differences in density trends over time (Table 9). No significant difference in the average exponential rates of increase (all crocodiles) between the two populations could be demonstrated, regardless of size class (Table 10), indicating no major effect of the harvest (as is obvious from Fig. 9).

Taken together, the survey results from the Adelaide and Finniss-Reynolds areas indicate that some 7,981 eggs were collected from 162 wild nests within 140 km of Darwin, with no significant impact on the wild populations. More data are needed to quantify subtle or longer-term effects, and the study is continuing, but results to date are consistent with predictions of a minor impact.

FLOOD-PRONENESS OF *C. POROSUS* NESTS

A detailed analysis of flood mortality among eggs collected to date is currently being undertaken. Melacca Swamp (our main monitoring area for *C. porosus* nesting), is the least "flood-prone" of the areas currently under study, and mortality due to flooding was modelled over the period 1960-61 to 1980-81 (Webb et al. 1983c). The results indicate flood losses ranging from 0% to 50% per annum, depending on the pattern of annual rainfall (mean = 26%); this indicates a total mortality of between about 20% and 70% of eggs per year (mean = 46%). The degree to which individual nests are prone to mortality due to flooding is largely unpredictable, due to the equally unpredictable timing and extent of wet season rains.

Our random egg harvest (see above) did not appear to have any major impact on the populations, and for economic and safety reasons, the main criteria for an efficient harvest in the future will be the accessibility of nests to collectors, and the number of nests available at the time of collection. By leaving a random sample of nests (those that are inaccessible for a variety of reasons), and by concentrating the harvest at the peak of nesting, the impact should be less than that currently experienced. Attempts to incorporate a predicted probability of embryo mortality (due to flooding, overheating, predation etc.) into the current harvest strategy, may well prove to be costly and cosmetic.

Table 8. Analysis of variance of small (2-6') and large >6') *Crocodylus porosus* density trends between flood plain channels that are harvested for eggs (treatment) and those that are unharvested (control) in the Finniss-Reynolds Rivers system, 1984-86. Relative densities are transformed to natural logarithms. '*' this interaction tests the egg-harvest response. NS = not significant; E = experiment (treatment and control); T = time in years. Flood plain channels are treated as replicates (N=4).

Source	SS	d.f.	MS	F	Significance
Harvest-unharvest (E)	5.49	1	5.49	16.64	$p<0.001$
Time (T)	0.58	2	0.29	0.88	NS
Size-class (S)	0.45	1	0.45	1.36	NS
E.T*	0.02	2	0.01	0.03	NS
T.S	0.03	2	0.01	0.03	NS
E.S	0.17	1	0.17	0.51	NS
E.T.S	0.31	2	0.15	0.45	NS
Residual	11.75	36	0.33		
Total	18.79	47			

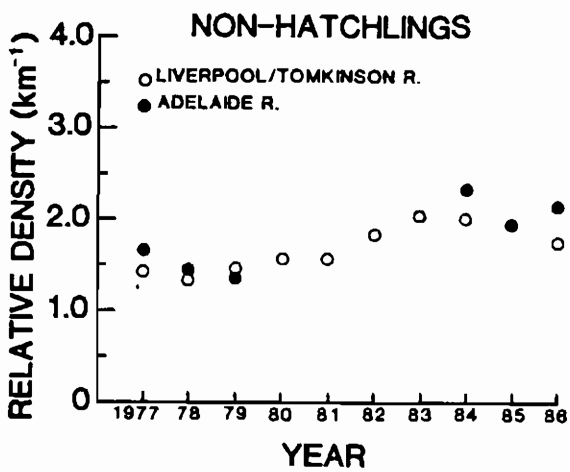

Figure 8. Relative densities of non-hatchling *Crocodylus porosus* in the Adelaide and Liverpool-Tomkinson Rivers, 1976-1986. Closed circles indicate data from Messel et al. (1981, 1986) and open circles indicate data from Webb et al. (1984, unpubl. data).

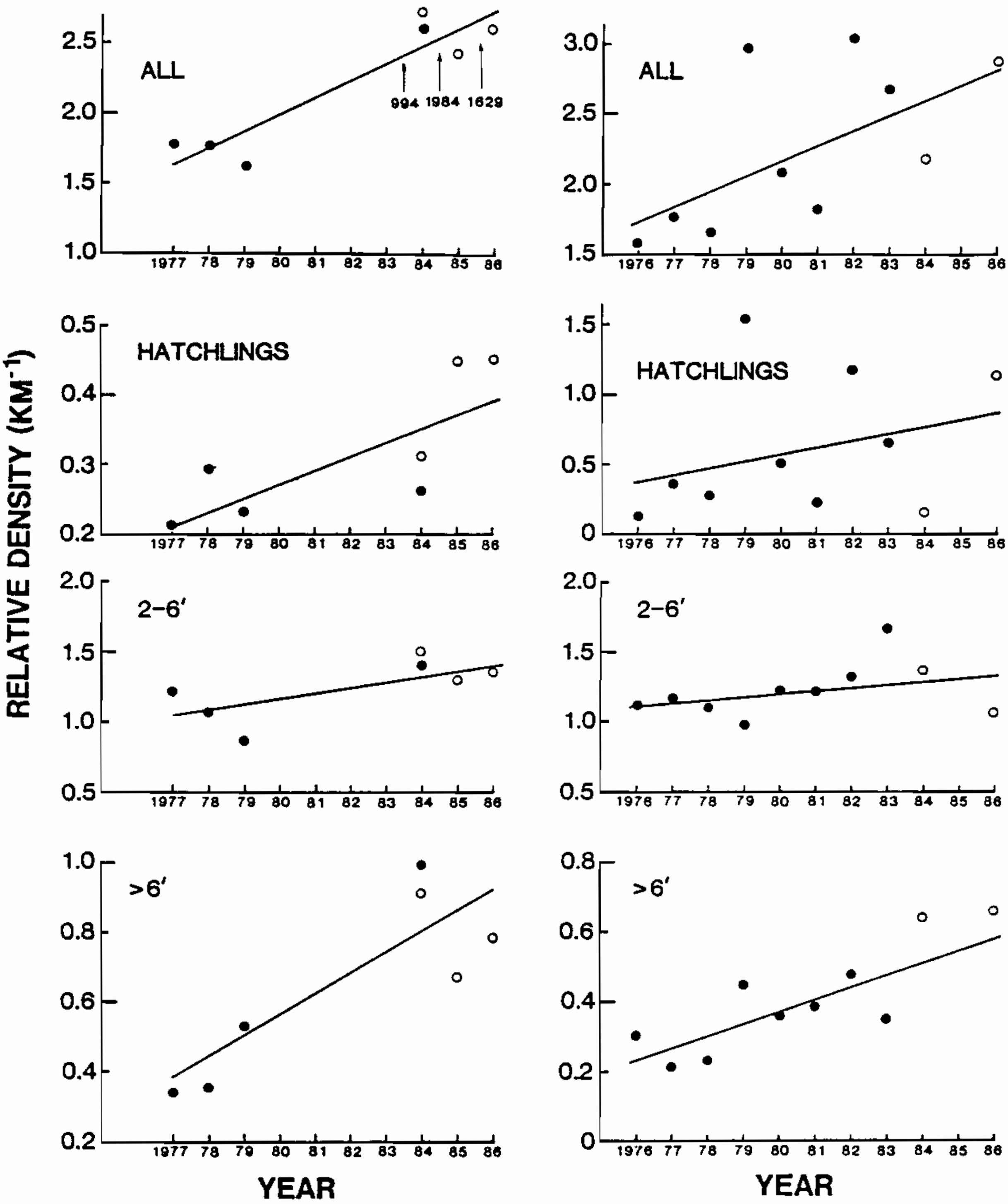

Figure 9. Relative densities of *Crocodylus porosus* in the Adelaide (harvested) and Liverpool-Tomkinson River (unharvested) systems. Numbers refer to the numbers of eggs harvested in a particular nesting season. Closed circles indicate surveys by Messel et al. (1979b, 1981, 1986), and open circles are surveys by the CCNT. Lines indicate the average exponential rates of increase derived by linear regression analysis.

Table 9. A summary of an analysis of covariance between *Crocodylus porosus* density trends in the Adelaide River (eggs are harvested) and the Liverpool-Tomkinson Rivers (eggs are unharvested), 1976-1986. Densities are transformed to natural logarithms. 'Slopes' test significant differences between the average annual exponential rates of increase (r). NS = not significant.

Source	d.f.	F-ratio	Significance
Slopes	1.11	0.01	NS
Intercepts	1/12	0.90	NS

Table 10. Exponential annual rates of increase of *Crocodylus porosus* populations in the Adelaide and Liverpool-Tomkinson Rivers, with standard errors (SE) of the slope and significance of the regression; '*' = $p<0.05$, '**' = $p<0.01$, NS = not significant.

River	Size Class	r (p.a.)	SE	Significance
Adelaide	All	0.055	0.011	**
	Hatchling	0.065	0.021	*
	2-6'	0.034	0.017	$p<0.10$
	>6'	0.099	0.024	*
	Non-hatchling	0.054	0.014	*
Liverpool-Tomkinson	All	0.054	0.021	*
	Hatchling	0.108	0.094	NS
	2-6'	0.020	0.015	NS
	>6'	0.090	0.020	*
	Non-hatchling	0.039	0.009	**

ESTIMATING CROCODILE TOTAL LENGTHS

Estimating the total lengths of crocodiles sighted during spotlight and helicopter counts expands the information contained in survey results. However, many factors affect the ability of an observer to estimate the size of a crocodile accurately (Magnusson 1983), and the precision of such estimates has rarely been quantified. Choquenot and Webb (1987) used a calibrated camera to examine the accuracy of two experienced observers (Fig. 10), and found that one (Observer A) was erratic over all size classes when compared to the other (Observer B).

Observers also vary in the consistency with which they estimate the lengths of the same crocodiles, in the same areas, as found by Messel et al. (1981). For example, when we examined data from re-surveys of the same flood plain channel with the same observer, on six separate occasions, during the same night, a significant relationship was found between the numbers of 2-6' and >6' crocodiles sighted (Fig. 11). These data suggest that, animals in the 2-6' category on one survey were placed within the >6' category in another, because of random error in estimating lengths.

The same type of variation occurs in data collected by different survey teams. Approximately the same number of crocodiles are sighted at the same time (Table 11), but the size estimates and proportions of "eyes only" can vary significantly (Table 12). In the Adelaide River (1984), the CCNT survey teams were apparently more cautious in allocating lengths to crocodiles sighted - they were more likely to place an animal within the "eyes only" category (Table 12).

There appears to be no simple solution to the problem of standardizing observer length estimates, because in addition to variable precision and accuracy, there may be drift with observers who are not regularly sighting and catching crocodiles. A calibrated camera technique (Choquenot and Webb 1987) could overcome some of these problems, and merits further investigation.

In the interim, caution needs to be exercised in the extent to which length estimates are incorporated into bold conclusions about short-term changes in the size and age structure of populations. The size estimating procedure is inherently inaccurate, and long-term data are needed to separate variability due to observers from that due to real changes in the structure of the population.

CORRECTION FACTORS FOR SPOTLIGHT COUNTS

Spotlight counts provide precise relative density indices which can be used to monitor population rates of increase, but they are inherently inaccurate (Bayliss 1987). Animals are usually missed on surveys and deviations from absolute density is termed visibility bias. Correction factors which can be applied to relative density indices are needed to:

1. Standardize relative density indices for any size-related bias in sightability, which could affect the stability of the index over time (if the average size or level of wariness is increasing or decreasing) or in different areas (where the size or wariness of individuals varies);

2. Adjust the relative density indices in habitats where there are different probabilities of detection, to afford comparison;

3. Correct relative density indices to absolute densities for estimating the total population size.

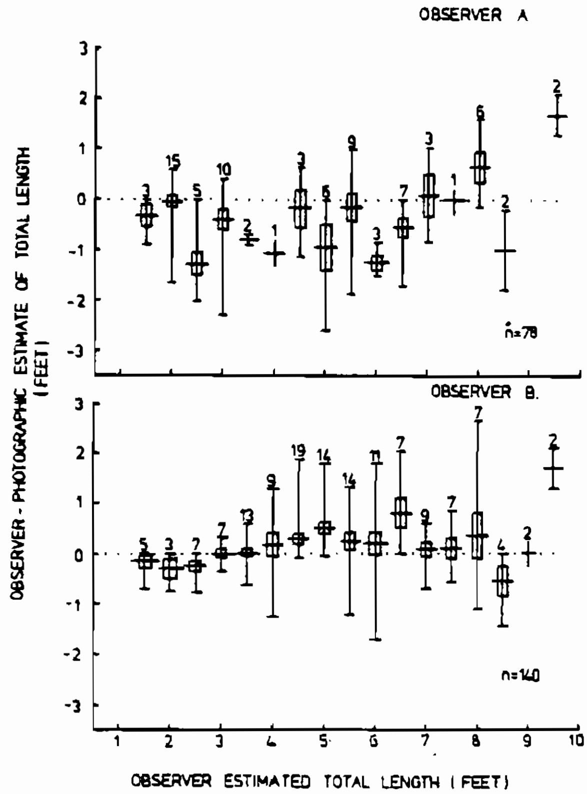

Figure 10. A comparison of spotter estimated sizes (to the nearest half-foot) and those estimated from a photographic method (Choquenot and Webb 1987) for *Crocodylus porosus* sighted during spotlight surveys in the Adelaide River. All photographs were analyzed by the same person. Horizontal lines are the means and ranges; boxes are one standard deviation (SD) on either side of the mean; numbers are the sample sizes for each half-foot category. Values above the broken line indicate an observer is overestimating the size of crocodiles sighted.

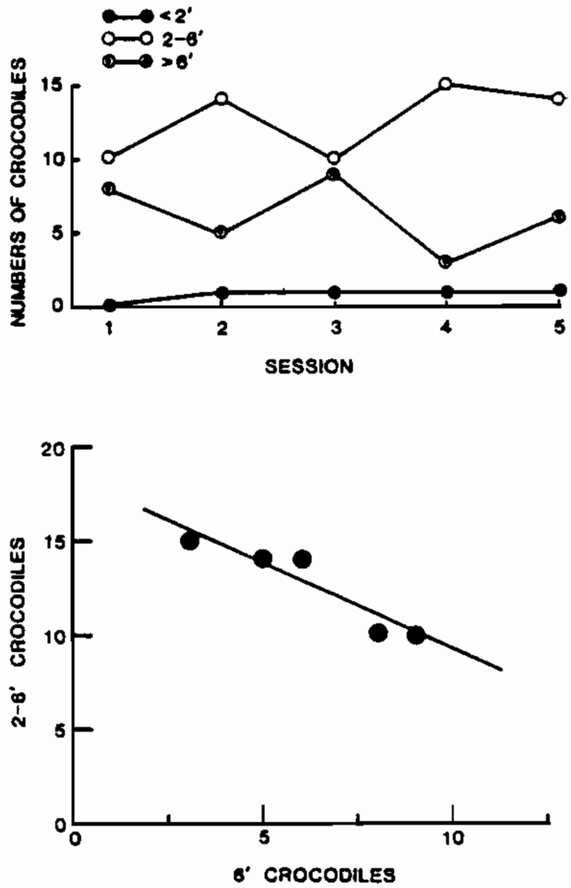

Figure 11. Numbers of different sized *Crocodylus porosus* sighted over five sessions in a flood plain channel of the Finniss River (upper); and the relationship between the number of 1-6' (Y) and >6' (X) crocodiles in the same channel (lower), Y=18.5 - 0.95X (r^2=0.88, n=5, p<0.025).

Table 11. Relative densities of three river systems surveyed independently by the University of Sydney (US; Messel et al. 1986), the Conservation Commission of the Northern Territory (CCNT), and Australian National Parks and Wildlife Service (ANPWS). Also presented is the linear regression equation for these data. '*' = hatchlings excluded.

Relative Density (km^{-1})			
CCNT-ANPWS	US	Year	River
2.718	2.606	1984	Adelaide
0.207	0.206	1985	McArthur
0.116	0.145	1985	Wearyan-Foelsche
3.229	3.114	1984	East Alligator*

Calibration Equation

$$US = 0.021 + 0.955\,(CCNT\text{-}ANPWS)$$
$$(R^2 = 1.00, n=4, p<0.001)$$

Table 12. The size distribution of *Crocodylus porosus* sighted in two independent spotlight surveys of the Adelaide River, at the same time of year, in 1984.

	Messel et al. (1986)		CCNT (unpublished)	
	%	No.	%	No.
Hatchlings	9.6	60	12.7	80
2-3'	5.8	36	8.9	56
3-4'	16.8	105	11.1	70
4-5'	12.6	79	7.6	48
5-6'	10.2	64	9.4	59
6-7'	12.5	78	7.0	44
>7'	19.2	120	15.2	96
"Eyes only"	11.7	73	25.9	163
C. johnstoni	1.8	11	2.2	14
Totals		626		630

1. How Precise are Spotlight Counts?

Replicated surveys of *C. porosus* in tidal rivers and flood plain channels show high precision (Table 13), even with a small number of samples. This precision was even maintained during sessions in which tags were harpooned into the crocodiles in flood plain channels (Fig. 12).

2. Relating Spotlight Counts to Absolute Numbers in Tidal Rivers and Flood Plain Channels

Bayliss et al. (1986) estimated the total population of *C. porosus* within three sections of the Adelaide River using a mark-recapture technique, and obtained a precise estimate of the total population size. They then quantified mean sighting fractions seen in spotlight surveys in each of the three areas (Table 14).

More recently, the same mark-recapture technique was used to estimate the total population of *C. johnstoni* and *C. porosus* in two isolated sections of flood plain channel which were bordered by floating mats of vegetation; sighting fractions were derived in the same way (Table 14). Additional correction factors for *C. johnstoni* in isolated flood plain billabongs devoid of floating vegetation were derived from data in Webb et al. (1983b).

3. Relating Spotlight Counts to Helicopter Counts

Spotlight surveys have other major limitations besides inherent visibility bias. They are time-consuming, expensive, often dangerous, and more importantly, are restricted to habitats that are accessible by boat. There are large areas of crocodile habitat in the Northern Territory that have not been surveyed due to poor or impossible boat access. For *C. porosus*, helicopter surveys are much cheaper and less time-consuming than boat surveys, yet they provide an index of density that relates to that obtained by spotlighting (Bayliss et al. 1986). Helicopter counts are similar to spotlight counts in tidal rivers with large exposed mud-banks, but in tidal sidecreeks they are almost double that of spotlight counts, and hence require a different calibration equation (Table 15). Thus, helicopter surveys can be used to derive different calibration equations for spotlight counts in different habitats. For example, spotlight counts in tidal side creeks record only a small proportion of the total population in such creeks (Bayliss et al. 1986; 35%) due to stream sinuosity (Fig. 13), and these problems are largely overcome by aerial survey.

Helicopter survey techniques are also being developed for *C. johnstoni*, (which is more difficult to see from the air), and the results are also summarized in Table 15. The *C. johnstoni* calibration equation is preliminary and will be refined with additional data from surveys in 1986.

The validity of the equations relating helicopter counts to spotlight counts derived in the Adelaide River were tested in a low density area in 1986. Sections of the McArthur River were surveyed by helicopter in September during high and low bank exposure, and the calibrated helicopter counts were compared to spotlight counts in the same area (Table 16). Even though the relative density was one-twelfth that in the Adelaide River, the calibration equations were applicable. Subsequently, three major river systems (remainder of the McArthur, Limmen Bight, Wearyan-Foelesche) and 25 coastal creeks in the southern Gulf of Carpentaria were surveyed over a two day period, at half the cost of spotlight surveys and taking one-sixth the time. (Surveys in less remote areas can be surveyed at one-quarter the cost of spotlight surveys.)

Table 13. The precision of *Crocodylus porosus* and *C. johnstoni* spotlight counts in different habitats. Data are from: 1 = Messel et al. (1981); 2 = Bayliss et al. (1986); 3 = CCNT (unpubl.). '*' indicates precision measured on sessions where tags were being harpooned into the crocodiles; DS = downstream, US = upstream.

Area	Habitat	Mean	N Sessions	SE (in %)
		Crocodylus porosus		
Blyth[1]	Mainstream, tidal, DS	55-66	28-27	1.1-3.7
Blyth[1]	Mainstream, tidal, US	39-42	15	2.0-4.0
Adelaide[2]	Mainstream, tidal, DS	88	2	0.6
Adelaide[2]	Mainstream, tidal, US	32	2	3.1
Adelaide[2]	Sidecreeks, tidal, DS	30	2	1.6
Finniss[3]	Flood plain channel No. 1	47	5	3.1
Finniss[3]	Flood plain channel No. 2*	36	7	9.7
		Crocodylus johnstoni		
Finniss[3]	Flood plain channel No. 2*	74	7	7.1

Table 14. The mean probability (p) of sighting crocodiles on spotlight surveys in different habitats, with the correction factors (CF) needed to adjust relative densities to absolute densities. Data are from: 1 = Bayliss et al. (1986); 2 = Webb et al. (1983b); 3 = CCNT (unpubl. data).

River	Habitat	Year	*p*	CF
		Crocodylus porosus		
Adelaide[1]	Tidal; downstream	1984	0.66	1.51
Adelaide[1]	Tidal; upstream	1984	0.59	1.69
Adelaide	Mean mainstream			1.60
Adelaide[1]	Tidal; side creeks	1984	0.35	2.86
Finniss[3]	Non-tidal; flood plain channel No. 1	1986	0.64	1.56
Finniss[3]	Non-tidal; flood plain channel No. 2	1986	0.51	1.96
Finniss	Mean non-tidal; flood plain channel			1.76
		Crocodylus johnstoni		
Finniss[3]	Non-tidal; flood plain channel No. 2	1986	0.44	2.27
McKinlay[2]	Non-tidal; billabongs; no floating vegetation	1978	0.66	1.51

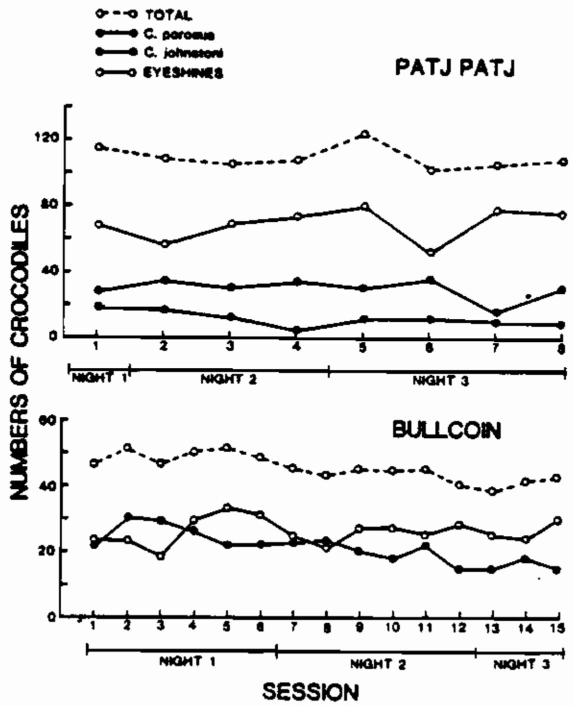

Figure 12. Numbers of crocodiles sighted in two flood plain channels in the Finniss River during a mark-recapture experiment (see text).

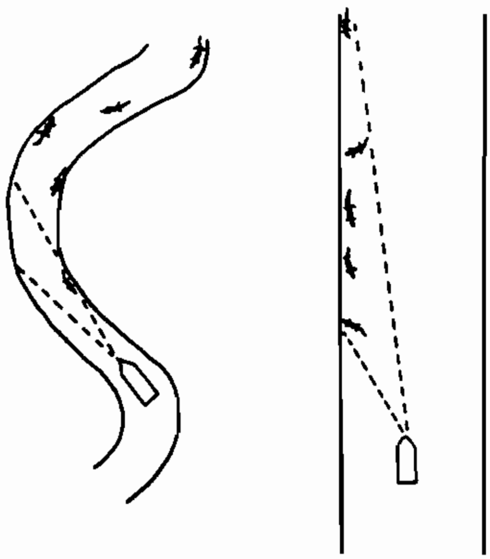

Figure 13. Schematic representation of spotlighting in a mainstream tidal river (left) and a tidal side creek (right). Crocodiles that are a considerable distance from the boat can be counted as eyeshines if they submerge before they have been reached. In side creeks, crocodiles usually submerge close to the survey boat before being detected.

Table 15. Summary of equations used to standardize helicopter counts to spotlight counts. Data are from Bayliss et al. (1986) and unpublished survey results from the CCNT. Equations were derived by linear regression analysis; S = spotlight counts, H = helicopter counts, Banks = number of banks surveyed by helicopter.

Habitat	Banks	Tide	Equation	R^2	N	Significance
			Crocodylus porosus			
Tidal mainstream	1	Spring	$S = 2.07H$	0.98	7	$p < 0.001$
Tidal mainstream	1	Neap	$S = 3.18H$	0.96	8	$p < 0.001$
Tidal side creeks	2	Neap	$S = 0.55H$	0.99	4	$p < 0.001$
			Crocodylus johnstoni			
Non-tidal	1		$S = 64.8 + 7.39H$	0.76	37	$p < 0.001$

Table 16. Comparison between helicopter counts converted to spotlight counts and actual spotlight counts of *Crocodylus porosus* and *C. johnstoni* in a section of the McArthur River. Equations used to convert the helicopter counts to spotlight counts for high (spring) and low (neap) tide bank exposures were derived in the Adelaide River (see Table 15). Data refer to non-hatchlings only.

Bank Exposure	Methods	*C. porosus*	*C. johnstoni*
Low	Helicopter	28	4
High	Helicopter	28	3
High	Spotlight	28	3

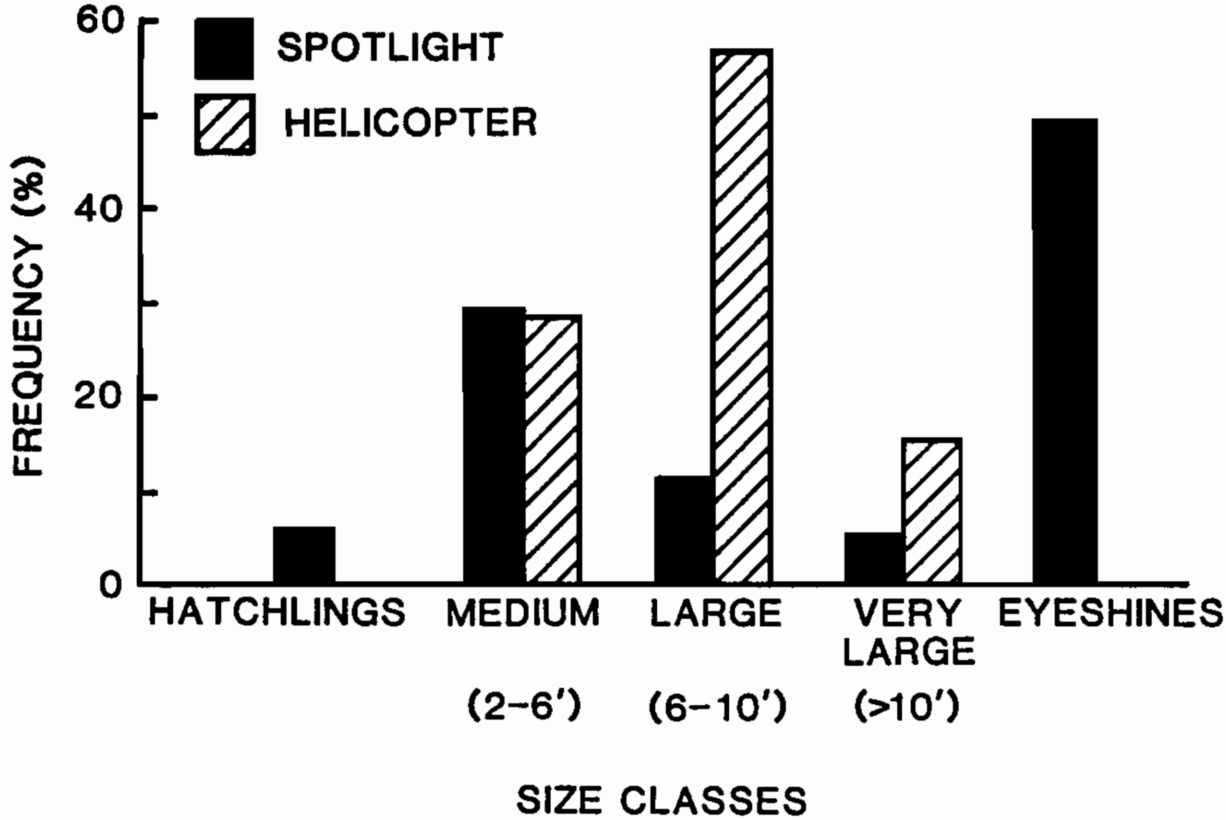

Figure 14. Proportions of hatchlings, 2-6', >6', and eyeshines sighted in spotlight and helicopter surveys in the McArthur River, a low density area.

The size classes of crocodiles seen in helicopter surveys in the McArthur River suggest that the "eyes only" fraction seen in spotlight surveys in this river should be apportioned to the greater than 6' category (Fig. 14), which are presumably more wary of spotlights.

Although there are advantages in spotlight surveys (e.g., a more accurate assessment of the age-size structure of the population, and the proportion of animals that are hatchlings) helicopter surveys are cost-effective and provide most of the information necessary to determine relative distribution and abundance patterns, and to assess long-term trends in the numbers of non-hatchlings. A further advantage is the ability to improve the precision of a population index rapidly by replication at a reasonable cost.

Future research will involve further refinement of the helicopter census technique for both *C. porosus* and *C. johnstoni*, and on calibrating *C. porosus* nest counts by helicopter to estimates of absolute crocodile numbers in habitats that are impossible or difficult to survey by spotlight or helicopter (e.g. densely vegetated freshwater swamps).

4. Relating Absolute Numbers in Flood Plain Channels and Tidal Rivers to Nest Numbers

During the 1984-85 and 1985-86 wet seasons, intensive surveys of *C. porosus* nests were carried out in parts of the Adelaide, Finniss and Reynolds Rivers. These same areas were surveyed by spotlight in 1984, 1985 and 1986, and in three areas the total population of *C. porosus* was estimated using the corrections in Table 14. Accordingly, a relationship was derived between numbers of nests and the total population size (Table 17).

The results indicate that the nesting female portion of the population varies from 4.3% to 13.9% of the total population, with a mean value of 5.7% (6.5% for non- hatchlings). This percentage in turn can be used to estimate the total population of *C. porosus* in breeding areas where nests can be counted. Population monitoring of *Alligator mississippiensis* in Louisiana, where nesting females represent 5% of the population, is based solely on correcting nest counts in this fashion (Joanen and McNease 1986).

Nest counts may also be a more accurate index of the adult crocodile population in areas where females are wary or where they reside outside of the accessible mainstreams. For example, Messel et al. (1979b) counted 3 crocodiles greater than 7' in length in spotlight counts within the Liverpool-Tomkinson River system in 1976, yet there were 38 nests in one season in the same area (Messel et al. 1981). As maturity is reached at 7-8' in females and >11' in males, there were at least some 40-50 crocodiles >7' in the system although only three were sighted (some were no doubt within the "eyes only" category).

5. Standardizing for Size in Spotlight Counts

Large *C. porosus* are more wary than smaller ones (Webb and Messel 1979), and have lower probabilities of being sighted in spotlight surveys (Bayliss et al. 1986). This trend was as apparent 13 years after protection (Bayliss et al. 1986), as it was 4 years after protection (Webb and Messel 1979), and thus it does not appear to be totally explicable on the basis of learned behavior among the older crocodiles which experienced hunting prior to protection (<1971). Increased size appears to be inherently associated with increased wariness in *C. porosus* (Table 18).

Within recovering populations, where the mean size of individuals is increasing with time, size-dependent wariness causes an increasingly pronounced negative bias in density indices. For example, if 105 crocodiles were sighted in a tidal river in 1975, and they were composed of 100 3-4' and 5 7-8' crocodiles, it would indicate a total population of 139 [Table 18; (100 x 1.30) + (5 x 1.71)]. If in 1984 the same number of individuals (105) was sighted, it may superficially appear that the rate of recovery had been zero. Even if

Table 17. The relationship between numbers of *Crocodylus porosus* nests made during the 1984-85 and 1985-86 nesting seasons and the total population in the same areas. T = total numbers of crocodiles; NH = non-hatchlings; CF = correction factors for adjusting number of nests to population size.

River	Year	Habitat	T	NH	Nests	CF T	CF NH
Adelaide	1984	Mainstream 32.0-82.0 km	518	398	26	17.9	15.3
Adelaide	1985	Mainstream 32.0-82.0 km	504	372	23	21.9	16.2
Finniss	1985	Flood plain channel no. 1	72	70	10	7.2	7.0
Finniss	1985	Flood plain channel no. 2	70	70	3	23.3	23.3
Mean						17.6	15.5

Table 18. The probability (p) of sighting *Crocodylus porosus* of different sizes in spotlight counts, as quantified in the Adelaide River in 1984, 13 years after protection (Bayliss et al. 1986). Sizes refer to total length estimated in feet. The correction factors (CF) are the values needed to correct counts of different sized *C. porosus* to absolute numbers.

Size	p	CF
1-2	0.69	1.44
2-3	0.75	1.34
3-4	0.77	1.30
4-5	0.77	1.31
5-6	0.73	1.36
6-7	0.67	1.49
7-8	0.59	1.71
8-9	0.47	2.13
9-10	0.33	3.08
10 +	0.15	6.54

the numbers sighted were corrected with a single correction factor, the rate of recovery would still appear to be zero. However, if the population structure was now composed of 40 2-3', 30 4-5', 20 6-7', 10 8-9' and 5 10'+ crocodiles, the real population would be 177 [(40 x 1.34) + (30 x 1.31) + (20 x 1.49) + 10 x 2.13) + (5 x 6.54)], and there would be a positive rate of increase (+2.7% p.a.).

Because of the errors involved in estimating sizes (see above), our mean annual rates of population increase (Table 6; +8.3% p.a. for all crocodiles and +9.7% p.a. for non-hatchlings) do not account for the changed size structure. Hence the real rates of increase are higher than those given on Table 6.

6. The Adelaide River - A Test Case

Although indices derived from spotlight counts can be used to monitor trends in numbers, they are inherently inaccurate - not all crocodiles are counted. The uncounted population falls into two categories: those within the area surveyed that were not sighted (see above), for whatever reason, and those in areas associated with the mainstream that were not surveyed.

In the Adelaide River system (Fig. 15), 50 km east of Darwin, *C. porosus* occupy a variety of tidal and non-tidal habitats, some of which can be readily surveyed by spotlight and others which cannot. On Fig. 16, the total population size within the Adelaide River is estimated in stages, using appropriate correction factors for different habitats. The stages incorporated into this estimate are:

1. Spotlight counts in 1984 (CCNT, unpublished data) yielded 80 hatchlings and 514 non-hatchlings in the mainstream and its major side creeks; similar results were obtained by Messel et al. (1986, 60 hatchlings and 542 non-hatchlings; a-c on Fig. 16).

2. Using the general mainstream correction factor (1.60) between relative densities and absolute densities (Table 14), these sighted individuals give a total population estimate of 950 animals (128 hatchlings and 822 non-hatchlings). Using correction factors in Messel et al. (1981), similar numbers (95 hatchlings and 889 non-hatchlings; total = 984) are derived (d on Fig. 16).

3. However, separate correction factors are needed for upstream, downstream and side creeks (Table 14), and when these are applied to the spotlight counts, it indicates a population of 1133 individuals (e on Fig. 16).

4. Completely excluded from this estimate is the population which exists year-round in Melacca Swamp (Fig. 15), a heavily vegetated wetland which cannot be surveyed by spotlight. Using nest counts (22 in each of 1984-85 and 1985-86) as the relative density index, and correcting them with the mean correction (17.6) derived in Table 17, an additional 387 animals are indicated; this increases the total population estimate to 1520 (f on Fig. 16).

5. In addition to Melacca Swamp, the flood plains of the Adelaide River contain some 150-200 permanent and semi-permanent billabongs and minor swamps. In 1986, a sample of these was surveyed by both helicopter (106) and spotlight (20). When these indices were corrected to absolute densities, it yielded an additional 80 animals, increasing the total population estimate to 1600 (g on Fig. 16).

6. In addition to these habitats, there are large numbers of small tertiary creeks which are inaccessible to survey boats and which were not surveyed by helicopter, and additional upstream billabongs (that contain *C. porosus* and in at least one case nesting adults) which were not included in our survey. Thus 1600 represents a conservative estimate of the total population of *C. porosus* within the Adelaide River system alone.

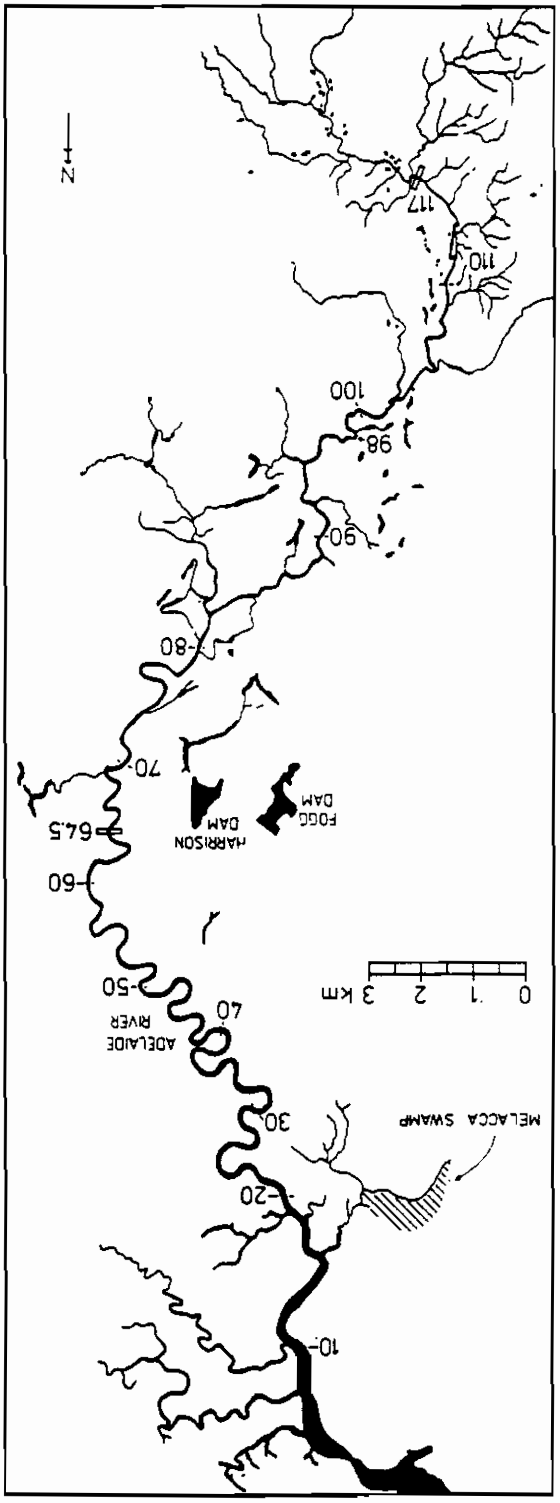

Figure 15. The Adelaide River system. Numbers are river kilometers from the mouth.

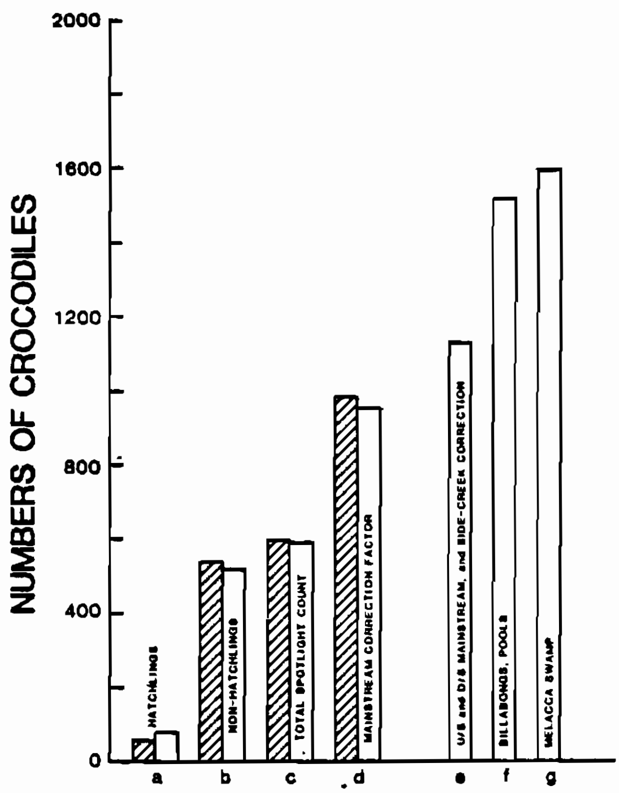

Figure 16. Number of *Crocodylus porosus* in the Adelaide River system: a, hatchlings sighted in spotlight surveys; b, non-hatchlings sighted in spotlight surveys; c, total number of *C. porosus* sighted in spotlight surveys; d, population estimate using mainstream correction factors (see text); e, population estimate using appropriate correction factors for upstream, downstream, and side creek habitats; f, population estimate accounting for *C. porosus* in various billabongs outside of the mainstream; g, total population estimate including *C. porosus* in Melacca swamp. Shaded bars indicate survey data from Messel et al. (1986), and unshaded bars are survey data from the CCNT.

THE SIZE OF THE NORTHERN TERRITORY POPULATION OF *C. POROSUS*

Webb et al. (1984) derived a conservative estimate of the Northern Territory *C. porosus* population of 30,000 individuals, and guessed that the real population was closer to 40,000 when the full extent of unsurveyed habitats was taken into consideration. This estimate was considered an overestimate by Messel (1986) and Messel et al. (1986), yet we had consistently used conservative correction factors:

1. Coastline. Two estimates of the absolute density of *C. porosus* on the coast were obtained; one between Darwin and the Victoria River (0.09/km) and one around the coast of Melville Island (0.38/km). Neither area includes the best breeding areas for *C. porosus* (Table 4), and thus a mean of the two estimates (0.24) is probably more realistic than the lower value (0.09) used by Webb et al. (1984).

2. Coastal Secondary Creeks. Coastal secondary creeks between Darwin and the Victoria River were surveyed by helicopter and the counts were corrected to absolute densities (2.57/km). The 1238 km of coastal secondary creek in the Northern Territory was composed of 638 separate creeks, with a mean length of 1.9 km, which assumes a mean total population of about 5 crocodiles per creek.

3. Major Breeding Tidal Systems. Mainstreams (1587 km) and sidecreeks (405 km; 207 creeks) were lumped in our previous estimate, and given the mean relative density of 3.16 crocodiles sighted per km derived from surveys. This was then multiplied by a conservative correction factor (1.33). The mean mainstream correction factor is closer to 1.6 (Table 12).

4. Sidecreek Corrections to Breeding Tidal Systems. In reality, the probability of sighting crocodiles in tidal sidecreeks is lower than in wide mainstreams (Table 12), and within the Adelaide River corrections for this underestimating bias increased the population by 19%. A similar correction is applicable to other major breeding systems, yet it was not used in our 1984 estimate.

5. Minor Breeding Tidal Systems. Mainstreams (3185 km) and secondary creeks (1140 km; 717 creeks) were lumped in our previous estimate, and given the mean relative density of 0.71 crocodiles sighted per km derived from surveys. This was then multiplied by a conservative correction factor (1.41). The real correction factor is probably closer to 1.6 (Table 12), plus an additional correction is needed for sidecreeks.

6. Flood Plain Creeks. In the original estimate, 1291 km of flood plain channel was given a relative density derived from spotlight counts in 10.5% of the habitat surveyed (5.60 crocodiles sighted per km). This was multiplied by a correction factor (1.56) based on results from a tidal system. The mean correction factor recently derived is 1.76 (Table 12).

7. Escarpment Channels. In the original estimate, the 534 km of flood plain channel were multiplied by a relative density of 0.60 and a correction factor of 1.53; an absolute density of 0.92 per km. Due to the physical characteristics of these channels, the correction factors applicable are probably between those of the upstream tidal areas (1.69) and those of side creeks (2.86).

8. Freshwater swamps. Although some areas of "swampland" were recognised within the Northern Territory, patches of freshwater swamp with high densities of *C. porosus* nests are more restricted (Magnusson et al. 1978). No estimate for this population was made in our original estimate, but given the numbers now estimated in Melacca Swamp alone (387 *C. porosus*), the total population within such habitats in the Northern Territory must be in the 1000's.

9. Tertiary Creeks. The 8223 tertiary creeks identified are an unknown quantity with regard to *C. porosus*. Some of these creeks are completely dry at low tide and others recede to pools. Within

major breeding tidal rivers such creeks (1256 were recognised) have a high probability of containing crocodiles, but along the coast and in low density areas they do not. No estimate was made for them.

10. The Captive Population. As of June 1986, there were 4232 *C. porosus* in captivity in Australia.

The above estimates do not account for the increase in the wild population that has occurred over the last two years, nor does it account for the many bodies of water not included on 1:100,000 maps - 30,000 to 40,000 was a conservative estimate of the *C. porosus* population in 1984.

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