REPORT ON THE POTENTIAL FOR HARVEST OF WILD POPULATIONS OF THE FRESHWATER AND SALTWATER CROCODILES, CROCODYLUS JOHNSTONI AND CROCODYLUS POROSUS, IN WESTERN AUSTRALIA.

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October 13, 1988.

1. POTENTIAL FOR HARVEST OF THE FRESHWATER CROCODILE, CROCODYLUS JOHNSTONI, IN WESTERN AUSTRALIA.

1.1 DISTRIBUTION, HABITAT AND NUMBERS

Distribution.

C. johnstoni is known to be "widespread in the Kimberley wherever there is suitable habitat" (Burbidge 1987). The area of most extensive habitat is considered to be the rugged and inaccessible north-west Kimberley. *C. johnstoni* also occurs well inland along the two largest river basins, the Ord and the Fitzroy (Burbidge op. cit.). The approximate southern limit of its distribution in WA is shown in Figure 1.

Habitat.

C. johnstoni habitat in the Northern Territory has been described (Webb et al. 1987) as the non-tidal freshwater reaches of rivers, which may or may not flow during the dry season. These river channels may be situated in rocky escarpments or plateaus, or they may traverse flood plains. During the dry season *C. johnstoni* congregate where creek lines contract to isolated billabongs. Substrates vary but are typically sand rather than the mud of tidal downstream areas.

This description is also appropriate for *C.johnstoni* habitat in the Kimberley, though floodplains are relatively small in size and number.

The species may tolerate saline conditions, however it is rarely found in tidal rivers, probably due to the presence of the much larger saltwater crocodile, *C. porosus*.

Numbers in Western Australia.

C. johnstoni is on Western Australia's list of fauna which are declared to be "rare or otherwise in need of special protection". The species was placed on the list because it was vulnerable to poaching and therefore in need of "special protection" (eg. heavy fines for illegal capture or killing). It has never been considered a rare species. (refs?)

No attempts have been made to determine (through surveys) the number of *C. johnstoni* in Western Australia and there are no published estimates of total population size.

Although there was significant poaching in accessible habitat during the 1960s and early 1970s, populations in the rugged north-west Kimberley are not thought to have been affected by European hunting (Burbidge 1987). The species has been hunted by Aborigines for many thousands of years, though the size of the harvest is unknown. *C. johnstoni* was first protected by legislation in Western Australia in 1962.

Though very few data are available on which to base an estimate of population size, there are half a dozen professional biologists and wildlife officers who have collectively (and some individually) spent a considerable amount of time over the past 10-15 years working in the Kimberley, often in C. johnstoni habitat.

In an attempt to arrive at a very rough "guesstimate" of total population size, each has been asked to estimate, on the basis of their experience, the minimum number of C. johnstoni which they believe may exist in the Kimberley. Their guesstimates are presented below.

PERSON	MINIMUM ESTIMATE
A	5,000
B	10,000
C	15,000
D	20,000
E	20,000
F	35,000

Disregarding the highest and lowest guesstimates and averaging the remaining four, the minimum guesstimated population is 16,250.

For comparison, the total non-hatchling population of C. porosus in the Kimberley has been reliably estimated (on the basis of considerable survey data) at 2,300 - 2,488 individuals (Messel et al. 1987).

The minimum "guesstimate" of total Kimberley C. johnstoni numbers provided above (16,250) is thus 6.8x the C. porosus figure.

Though this figure is entirely speculative and needs to be confirmed (or otherwise) by survey, it does suggest that, notwithstanding other considerations, C. johnstoni is numerically in a better position to withstand harvesting than C. porosus.

Numbers in Other States

The total number of wild C. johnstoni in the Northern Territory has been placed "on the basis of some crude estimates" within the range of 33,000 - 60,000 individuals (Webb et al. 1987).

I am not aware of any estimates of total numbers in Queensland, where it is described as "common in many areas of the State and ... locally abundant in many rivers" (Taplin 1987).)

Numbers in Particular Localities (Kimberley)

Over the past 10 years, three systematic surveys have been made of crocodile numbers in the near vicinity of Kununurra.

******** Insert Figure showing places named. *********

i) Brennan's Count, Section of Ord River upstream of Diversion Dam, March 1979

In March 1979, a count (at night, from a 10 ft punt) of crocodile numbers in a section of Lake Kununurra by J. Brennan (formerly of the

University of Sydney's crocodile research group) revealed "slightly more than 1000 C. johnstoni" (Burbidge 1987).

(Note: The 56 km of Ord River from the Diversion Dam adjacent to Kununurra townsite upstream to the Ord River Dam is known as Lake Kununurra)

This count was made when the Lake level had been lowered 18 metres below normal to facilitate dam maintenance. Brennan states (letter to Burbidge) that all swamps adjacent to the river upstream of the dam wall were effectively drained. The area surveyed by Brennan and two assistants was from the dam wall to the mouth of "Everglades Swamp", 13 km upstream. The river was apparently too shallow to proceed further and there were no more swamps upstream of the finish point.

1015 C. johnstoni, including 56 "hatchlings" (<1 ft), were actually counted; with an average density of 78 crocodiles per kilometre, range 30-185). Size classes recorded by Brennan are presented in Appendix 1.

Given that the area surveyed still contained some water, it is reasonable to assume that not all crocodiles present were counted. If we assume that conditions were ideal for survey, a conservative estimate of the total number of non-hatchlings present is (1015-56)/0.9 = 1066. (The highest spotlight-count to actual-number ratio obtained by Webb et al. (1983) during C. johnstoni surveys in the NT was 0.9.)

Whether or not all crocodiles in the "effectively drained" swamps adjacent to the 13 km of surveyed river had moved to the river is unknown. To be conservative in these calculations it is presumed they did.

It is extremely improbable, however, that all or even a major proportion of the crocodiles in the remaining, 43 km, unsurveyed stretch of river upstream to the Ord River Dam had moved downstream to the survey area. The river no doubt drained to form a chain of permanent pools (as in former days before the dams were built) and resident crocodiles would have congregated in these pools, as is their normal dry-season habit. If it is assumed that these crocodiles were at an average density of 28/0.9 = 31 non-hatchlings per kilometre (i.e. at the lowest non-hatchling density recorded for any one kilometre section of the surveyed area), then a further 43 x 31 = 1333 C. johnstoni can be added to the number in the surveyed section.

(Note that in 1987 M. Osborn recorded an abundance index by helicopter of 216.5/32 = 6.8 crocodiles/km on a 32 km stretch of the Ord below the Ord River Dam. Using NT-derived ratios for air-to-ground and ground-to-actual, the actual number of crocodiles per kilometre is estimated by that method to be within the range 14 - 34, which spans the figure of 31 per km estimated above. The two estimations are therefore in reasonable agreement.)

This gives a conservative estimate of the total population in the 56 kilometres of river from the Diversion Dam to the Ord River Dam in 1979 of 1066 + 1333 = 2400 C. johnstoni.

ii) Osborn's Count, Ord River between Ord River Dam and Spillway Creek, June 1987.

On 2 June 1987, CALM Wildlife Officer M. Osborn and two other staff from the Kununurra office made a helicopter survey of crocodile numbers in the Ord River between the Ord River Dam and the entrance of Spillway Creek, 32 kilometres downstream. Two flights, one upstream and one downstream, were made 12 minutes apart.

212 live non-hatchling C. johnstoni were counted on the first flight and 221 on the second; average 216.5. No C. porosus were seen. Further details, including size classes, are provided in Appendix 2.

Helicopter counts (which are actually indices of abundance) have not been calibrated against spotlight counts or actual numbers of crocodiles at any site in Western Australia and it is therefore not possible to calculate actual numbers of C. johnstoni in the area at the time of survey. However, some measure of comparison can be derived from work in the Northern Territory.

Helicopter and spotlight surveys of two heavily-vegetated and one open freshwater billabong in the Mary River in 1984 produced air-to-ground ratios of 0.18, 0.29 and 0.80 respectively (Bayliss 1987).

Applying somewhat conservative ratios of 0.4 to 0.7 to the 32 km surveyed section of the Ord, the abundance index of 216.5 crocodiles obtained by helicopter converts to a spotlight index of 309 - 541.

If we now apply spotlight-to-actual-numbers ratios of 0.5 - 0.7 (derived from the McKinlay River study area in the NT; Webb et al. 1983), the total number of non-hatchling C. johnstoni in the surveyed area calculates within the range 439 - 1082.

The area surveyed was 32 km and the total length of river from the Ord River Dam to the Diversion Dam is 56 km. Given that there are extensive swamps known to contain large numbers of crocodiles associated with the river at its downstream end (eg. Packsaddle, Kununurra and the "Everglade" swamps) it is reasonable to assume that the lower (unsurveyed) 24 km section contains at least 2x the number of C. johnstoni per km as the upper, surveyed 32 km.

On this basis the total non-hatchling C. johnstoni population of the Ord River between the two dams (i.e. Lake Kununurra) is within the range (439+(439x2x24/32)) to (1082+(1082x2x24/32)).

That is: 1097 - 2705 crocodiles.

This estimate, based on a number of tenuous assumptions about conversion factors from helicopter indices to ground indices and ground indices to actual numbers, is comparable with the estimate of 2400 C. johnstoni derived above from J. Brennan's 1979 spotlight data.

iii) Osborn's Count, Ord River below Diversion Dam, May 1987.
On 27 May 1987, M. Osborn and assistants surveyed (by helicopter) a section of the Ord River from the Diversion Dam downstream to a point 28 km beyond Carlton Crossing, a total of 97 kilometres.

204 non-hatchling C. johnstoni, 44 C. porosus (which are known to occur as far upstream as the Diversion Dam wall) and 11 large, species-unknown crocodiles were counted. No C. johnstoni were seen downstream of Carlton Crossing. Details are provided in Appendix 3.

Applying the ratios used in ii) above (0.4-0.7 helicopter-to-spotlight and 0.5-0.7 spotlight-to-actual) to this abundance index of 204, the 69 kms of river between the Diversion Dam and Carlton Crossing (the downstream limit of the species' distribution), is estimated to have contained 416 - 1020 non-hatchling C. johnstoni.

Summary of C. johnstoni Numbers in Western Australia

i) Lake Kununurra.
On the basis of Brennan's count of 1015 C. johnstoni in 1979, the total number of non-hatchling C. johnstoni in Lake Kununurra is estimated to have been 2400 at the time of survey.

Using data from Osborn's 1987 helicopter surveys, where an average of 216.5 crocodiles were seen, the total number of non-hatchling C. johnstoni in Lake Kununurra is more-tenuously estimated to be within the range 1097 - 2705.

The two estimates, which were derived from different data sets and calculated by different methods, are thus in reasonable agreement.

The total number of non-hatchling C. porosus in the Kimberley has been estimated at 2300 - 2488 individuals (Messel et al. 1987). Thus it would appear that there may be as many C. johnstoni in Lake Kununurra alone as there are C. porosus in the entire Kimberley. This has obvious implications for any consideration of crocodile harvesting in Western Australia.

ii) Ord River below Lake Kununurra.
Osborn's data for the Ord River below the Diversion Dam suggests a total of 416 - 1020 non-hatchling C. johnstoni in this area.

iii) Other Sites.
Lake Argyle's shoreline length (1 km intercepts) at normal full supply level is 430 kms, including 70 kms of island shoreline, and its area is 740 square kilometres (this increases to over 2000 square kilometres during maximum flood). Lake Kununurra's shoreline length is around 120 km and its area 16 square kilometres.

Though no surveys have been undertaken, many C. johnstoni are known to inhabit Lake Argyle, particularly in the shallow areas to the east and south (M. Osborn and C. Done pers. comm.). Small numbers are regularly caught, usually dead, in fishing nets.

Solely on the basis of relative shoreline lengths and areas, there is reason to believe that Lake Argyle's C. johnstoni population is even larger than that of Lake Kununurra.

Anecdotal information suggests that the dammed waters of the Fitzroy River near Camballin also contain thousands of freshwater crocodiles (C. Done pers. comm.)

iv) Whole Kimberley
A "guesstimate", purely speculative and without a sound scientific basis, of the minimum number of non-hatchling C. johnstoni in the Kimberley, is 16,250.

1.2 BIOLOGY AND POPULATION DYNAMICS

No studies have been made of C. johnstoni biology or population dynamics in Western Australia. There are no data specific to WA concerning size-age relationships, population age structures, sex ratios, male or female age at sexual maturity, nest site preferences, nesting success, hatchling survival, survival rates of other age classes, etc..

Some of these parameters have been determined for the McKinlay River C. johnstoni population in the NT (see Smith and Webb 1985 for a synopsis) and these may be used for a consideration of crocodile harvesting in Western Australia. However, life history parameters may vary considerably from one location to another, particularly for an animal as sedentary as C. johnstoni. For example, in this species there is extreme variation with habitat in the size-age relationship (Webb 1980). Caution must therefore be exercised in extrapolating from one population to another.

Information concerning life history parameters of C. johnstoni populations in the NT, which is relevant to a consideration of possible harvesting levels and strategies in Western Australia, is presented in Appendix 4.

1.3 HARVESTING IN QUEENSLAND AND THE NORTHERN TERRITORY

Queensland
The present management regime in Queensland is cautious and does not allow any harvesting of wild populations of crocodiles, though one farm established at Rockhampton in 1982 has a stock of approx 150 C. johnstoni (Taplin 1987).

Present policy does not allow for the establishment of further farms based on wild-caught stock (of either species) until information on population status is available.

Queensland's intention is to await the results of the Northern Territory's experiments on ranching of C. porosus and C. johnstoni before proceeding along similar lines. Given this intention, the identification of populations capable of sustaining a harvest and the development of an experimental harvest programme are seen as very high priorities for research in the short term.

It is considered that progress in establishment of ranching operations will depend greatly on the identification and protection of major breeding sites able to sustain recruitment into exploited and protected populations (Taplin op. cit.).

Northern Territory

The Northern Territory Government permits both farming and ranching of C. johnstoni.

Eight management areas have been defined on the basis of a trial hatchling harvest conducted on 13 rivers in 1982. All harvesting is now conducted within these eight areas.

Separate research and control (i.e. non-harvest) areas have also been defined.

The eight management areas are on landholdings where cattle grazing is the main form of use.

To date, all harvests carried out have been considered experimental and each team operating in the field has been accompanied by a Conservation Commission ranger (CCNT 1986a).

i) Harvest Strategies

Only eggs and hatchlings are now taken, though a small number of adults were collected on one occasion.

Eggs are collected in August/September each year at the peak of nesting. Hatchlings are collected in November/December and are usually less than a week old.

CCNT encourages the collection of eggs in preference to hatchlings by considering each egg to be equivalent to 0.5 hatchlings when allocating harvest quotas.

Because egg hatching rates in captivity of fresh wild eggs are in the vicinity of 82-91% (CCNT 1986a), ranches can obtain more hatchlings under this 1 egg = 0.5 hatchlings system via egg collection than by direct collection of hatchlings.

Wild stocks also benefit under this system (if eggs are collected in preference to hatchlings) because under normal wild conditions only 30% of eggs hatch; thus, in the wild, 1 egg = 0.3 hatchlings (CCNT 1986a).

Egg collection is only practical, however, where nests are clumped.

ii) Harvest Quotas
Each year, each of the three NT crocodile farms is allocated a *C. johnstoni* egg/hatchling quota of 4,000 eggs/2,000 hatchlings to be taken from the management areas assigned to that ranch for that year. (Note that under standard terminology this is a "ranching" type operation, where crocodiles or their eggs are continually harvested from the wild).

Thus, the total annual commercial harvest of *C. johnstoni* permitted in the NT each year is 12,000 eggs or 6,000 hatchlings or any equivalent combination thereof (e.g. 4,000 eggs plus 4,000 hatchlings).

The CCNT reserves the right to vary quotas each year depending upon the results of annual monitoring of populations in harvested areas.

iii) Actual Harvests of Eggs and Hatchlings
The number of eggs and hatchlings taken each year have actually been somewhat less than the quotas allow, and are as follows. (Source; CCNT 1986a).

Year	Hatchlings (actual)	Eggs (actual)	Hatchling Equivalents (admin)	Egg Equivalents (admin)
1982	4573	0	4573	9146
1983	2269	1563	3050	6100
1984	1953	2191	3048	6096
1985?				
1986?				
1987?				

However, as mentioned in the preceding section, survivorship rates measured in the field indicate that under average wild conditions one egg is actually equivalent to 0.3 hatchlings. In biological terms, therefore, the number of egg and hatchling equivalents harvested is different from the number calculated on an administrative basis above.

In biological terms, annual Northern Territory *C. johnstoni* harvests have been as follows. These are the figures to be used in any consideration of harvest rates and impacts.

			Total	Total

Year	Hatchlings (actual)	Eggs (actual)	Hatch. Equivs. (biol)	Egg Equivs. (biol)
1982	4573	0	4573	15243
1983	2269	1563	2738	9126
1984	1953	2191	2610	8701

iv) Harvest of Non-Hatchlings (Sub-Adults and Adults).
One Northern Territory crocodile farm is experimenting with captive breeding of C. johnstoni. To facilitate this, 50 adult and sub-adult animals were taken from the wild (Finnis and Daly Rivers) in 1981 (CCNT 1986a).

C. johnstoni which appear in popular swimming areas in the Northern Territory are removed (because of the public anxiety any crocodile may arouse in such situations, not because they represent a threat to human safety) and placed on farms. The number "harvested" in this way is presumably small.

1.4 IMPACT OF HARVESTING C. JOHNSTONI IN THE NORTHERN TERRITORY

The impact of C. johnstoni egg and hatchling harvests in the Northern Territory is determined by annual (June-August) monitoring of populations in management (harvest) and control (non-harvest) areas.

Counting at night by spotlight is the monitoring technique in use at present. These counts provide indices of abundance. These are not precise.

Counting by spotlight is expensive (>$28/km), however, and methods of monitoring populations by helicopter are being developed. Early indications are that this method may be 1/4 the cost of monitoring by spotlight, at least for C. porosus (Bayliss 1987).

Some preliminary data from C. johnstoni monitoring programs are presented below, together with corresponding harvest data (CCNT 1986a). All data are from isolated pools and river sections in which the entire area was surveyed before and after harvest, i.e., in this table there is a precise match between the areas harvested and the areas surveyed in successive years.

Mgmt Area	Years	Harvest (eggs)	Harvest (hatchlgs)	Monitoring Results (first count)	Monitoring Results (latest count)
Finniss/Reynolds	83/85	1817	81	196	207
Finniss/Reynolds	"	396	26	108	89

Upper Daly	"		985	503	450
Lower Daly	"	434	1117	664	494
Baines	"		384	272	421
Lower Victoria	"		201	203	538
Lower Victoria	"		128	152	318
Lower Victoria	"		187	180	233
Upper Victoria	82/85		480	318	331
Wickham	"		71	166	135
Wickham	"		24	97	100
TOTALS		2647	3684	2859	3316

In summary, while 2647 *C. johnstoni* eggs and 3684 hatchlings were removed from the above populations during the period 1982-1985, the total number of crocodiles counted in before and after spotlight counts (which provide useful though imprecise indices of abundance) varied from 2859 to 3316.

The CCNT has concluded that the results of these first 3-4 years of monitoring "are consistent with the harvest having no substantial short-term effect on population size" though "clearly data over a much longer time span and careful comparison with control areas will be required in order to quantify more subtle effects" (CCNT 1986a).

(Note: Before and after spotlight indices of total numbers provides a very superficial and potentially misleading basis for determining impact of harvest. What is required is information on numbers in the various age classes. This is not available at present.)

In order to assist our consideration of harvest levels of *C. johnstoni* which might be permitted in Western Australia I have worked these data further to show the relationship between the number of crocodiles counted in the first (pre-harvest) surveys, and subsequent harvest levels.

Harvests have been converted to annual average harvest rates in hatchling equivalents (biological, where 1 egg = 0.3 hatchlings) for each site and are listed in decreasing order of total numbers of crocodiles observed on the first, pre-harvest survey.

TABLE __. Numbers of *C. johnstoni* seen on First (Pre-Harvest) Spotlight Surveys, and annual average Harvest Levels in subsequent years.

Pre-Harvest Spotlight Index	Subsequent Harvest per Annum in Hatchling Equivs (biol)
664	624
503	492
318	160
272	194
203	100

	196	313
	180	93
	166	24
	152	256
	108	72
	97	8
TOTALS	2859	2141

The relationship between the number of *C. johnstoni* counted in each pre-harvest survey (x) and the average number of eggs or hatchlings (in hatchling equivalents) subsequently harvested per year (y) is:

$$y = x - 46 \qquad \text{(actually } y = 0.99x - 46.25\text{)}$$

(correlation coefficient = 0.8906; stnd. error of est. = 94.3)

If we accept the CCNT conclusion that the populations concerned have not been detrimentally affected by 2-3 years of harvesting, and assume comparabilty of NT and WA populations in terms of spotlight-index to actual-numbers ratios and potential impact of harvesting, the above equation may be used to gain a general indication of harvest levels which might be permissable for *C. johnstoni* populations of any given size, as determined by numbers counted during spotlight surveys.

For example, if 300 *C. johnstoni* are counted during a spotlight survey of an area proposed for harvest, it may be reasonable to consider harvesting around 250 hatchling equivalents per year from this area, since x = 300 and y (the number to be harvested per annum) = x - 46 = 254.

1.5 POTENTIAL HARVEST OF C. JOHNSTONI IN WESTERN AUSTRALIA

Location

As indicated above, *C. johnstoni* is abundant in Western Australia, and large numbers occur in very close proximity to a major regional centre, Kununurra.

The only sizeable area of *C. johnstoni* habitat which has been surveyed, albeit imperfectly, in Western Australia is the Ord River, principally that part which lies between the Ord River Dam and the Diversion Dam, i.e. Lake Kununurra. This is a 56 km stretch of permanent water averaging 0.2 to 0.3 kms wide, with extensive swamps adjoining its downstream end.

From the point of view of crocodile numbers and the logistics of harvesting and population monitoring and research, Lake Kununurra appears to be a suitable place for an experimental harvest of *C. johnstoni* eggs or hatchlings, either as a farm- or ranch-type venture.

Lake Argyle and the Fitzroy River at Camballin, both of which are reputed to support thousands of C. johnstoni, are possible alternatives. However no hard population data are available for either of these sites and both would be less favourable logistically than Lake Kununurra as they are further from significant population centres.

Consideration of potential C. johnstoni harvests is therefore restricted to Lake Kununurra, as a starting point.

(Note that a Nature Reserve is proposed for the Packsaddle Swamps area of Lake Kununurra (Burbidge et al. 1987). The implications of Reserve status in relation to harvesting will need to be considered.)

Calculation of Potential Egg and Hatchling Harvests, and Annual Recruitment

i) Using Brennan's data and NT harvest rates to calculate potential Lake Kununurra harvest

An equation, $y = x - 46$ (where x is is the number of crocodiles counted in a pre-harvest spotlight survey, and y is the number of hatchling equivalents which may be harvested per year from the surveyed area) has been derived in Section 1.4 as a tentative guide to appropriate harvest levels for populations of given abundance.

It would be preferable to have hard data concerning actual population size, age structure, sex ratios, breeding performance, survivorship at various ages etc. before embarking on a harvesting program. The above formula is suggested as having some usefulness only where such data are unavailable and, for whatever reason, unobtainable.

In 1979, J. Brennan counted 959 non-hatchlings in his spotlight survey of the lower 13 km of Lake Kununurra (see Section 1.1). Extrapolating from the surveyed area to the entire 56 km of Lake and associated swamps in the same manner as has been done in Section 1.1 to estimate the total population size, the spotlight index for Lake Kununurra computes to $959 + (30x0.93x43) = 2159$.

If we apply the formula $y = x - 46$ to this index, the number of hatchling equivalents which might reasonably be permitted to be harvested from Lake Kununurra per annum is $2159 - 46 = 2113$.

However, because of the unusual conditions that prevailed during Brennan's survey (water level lowered by 18 metres), the spotlight index he obtained is presumed to have represented a very high proportion (90%) of the total number of C. johnstoni present. The equation $y=x-46$ therefore yields a higher proposed hatchling harvest than would have been the case had the spotlight-to-actual ratio been assumed to be within "normal" limits (0.5 - 0.7; Webb et al. 1983).

Applying a "correction factor" of 0.5 - 0.7, the number of hatchlings which one might consider for an experimental harvest (for 2-3 years at least) from Lake Kununurra computes to be within the range $(2159x0.5/0.9 - 46)$ to $(2159x0.7/0.9 - 46)$, i.e 1153 - 1633.

It is emphasised that the above calculations are highly speculative and include many assumptions, possibly incorrect, about comparability between the Lake Argyle _C. johnstoni_ population and populations in the Northern Territory.

An alternative approach to estimating permissible harvest levels, also containing many assumptions of comparability, is as follows.

ii) Using Osborn's data and NT harvest data to calculate potential Lake Kununurra harvest

The index of abundance obtained from Osborn's helicopter surveys of a section of Lake Kununurra from the Ord River Dam to Spillway Creek may also be used to gain an indication of possibly acceptable _C. johnstoni_ harvest rates.

Using Osborn's data, the spotlight index for the Lake as a whole is within the range 216.5/0.7(1 + 2x24/32) to 216.5/0.4 (1 + 2x24/32) = 773 - 1353. (See Section 1.1 for relevant data)

Applying y = x - 46, the number of hatchling equivalents which might be considered for harvest, at least on an experimental basis, falls within the range 727 - 1307.

iii) Using Brennan's data and McKinlay River (NT) population parameters to calculate annual recruitment in Lake Kununurra.

A third approach is as follows.

In the McKinlay River (NT) _C. johnstoni_ population modelled by Smith and Webb (1985), it was estimated that 7.9% of the total population of 963 animals consisted of partially-mature females, i.e. females aged 9-11 years. Fully-mature females (12+ years) formed an estimated 21.9% of the population.

In an average year, the proportions of partially-mature and fully-mature females which bred were 0.286 and 0.844 respectively.

If we assume that the total non-hatchling _C. johnstoni_ population of Lake Kununurra is 2400 (the estimate derived in Section 1.1 from J. Brennan's spotlight data), and also assume that it has similar age structure, sex ratio and age-at-maturity to the McKinlay River population, the numbers of partially-mature and fully-mature female _C. johnstoni_ in Lake Kununurra at the time of survey may be estimated as 197 and 547 respectively.

Assuming the two populations have similar breeding performance, the number of Lake Kununurra females breeding each year would be 197x0.286 + 547x0.844 = 518.

If the average number of eggs per nest is 13.2 (McKinlay River data; Smith and Webb op. cit.), the total number of eggs layed each year would be 6838.

If egg survivorship is 0.295 (ibid.), the number of hatchlings produced would be 2017.

iv) Using Osborn's data and McKinlay River population parameters to caculate annual recruitment in Lake Kununurra.
Applying the same treatment to population estimates (range 1097 - 2705) derived from M. Osborn's 1987 helicopter survey data, the number of hatchlings produced each year is estimated to be within the range 884 - 2184.

v) Potential harvests as % of annual recruitment
The report, "Crocodile Farming in the Kimberley", June 1988, prepared by consultants Tropical Resources Management Pty Ltd (Qld) in association with Resource Consulting Services Pty Ltd (NT), proposes "Single Operator" farms which harvest 500 C. johnstoni hatchlings per year on a continuing basis (ie. a ranching operation), and "Corporate" farms which harvest twice that number.

One Single Operator farm would thus take 500 hatchlings per year; a Corporate farm would take 1000, and one Single Operator plus one Corporate (as proposed in the consultants' report) would take 1500 C. porosus hatchlings per year.

Assuming Lake Kununurra's C. johnstoni population is 2400 and average annual hatchling production is 2017 (Brennan's data and iii above), annual harvests of 500, 1000 and 1500 hatchlings would represent 25%, 50% and 74% respectively of total annual production.

Alternatively, if we assume the population is within the range 1097 - 2705 and average annual recruitment is 884 - 2184 hatchlings (Osborn's data and iv above), annual harvests of 500, 1000 and 1500 hatchlings would represent 23-57%, 46-113% and 69-170% respectively of the presumed total annual production.

Following intensive study, trial harvesting and modelling of the Northern Territoy's McKinlay River C. johnstoni population, Smith and Webb (1985) concluded "If the model's predictions are correct, up to 30% of C. johnstoni eggs or hatchlings could be removed from a population annually. Even with none of these returned to the wild, the population should not be seriously affected. Indeed, 90% of hatchlings or eggs could be removed for 10 years and the population would only be halved."

On this basis it seems reasonable to conclude, even though few hard data concerning Kimberley C. johnstoni abundance and none concerning breeding performance, age-specific survival rates etc. are available, **that a harvest of 500 hatchling equivalents per year from the Lake Kununurra C. johnstoni population would be an acceptable proposition, subject to standard safeguards (annual population monitoring, option of return of captive-raised juveniles, etc.) being imposed.**

500 hatchlings (or a corresponding number of eggs) per annum would also be well within the numbers (1153 - 1633, and 727 - 1307; see i and ii above) which more-tenuous extrapolations from Brennan and Osborn's data and Northern Territory harvest rates suggest might be safely harvested.

Potential Non-Hatchling Harvests

i) Problem Crocodiles
Despite the large sizes (3m+) which it may reach, *C. johnstoni* does not pose a threat to humans. There have been no instances of "problem" freshwater crocodiles in Western Australia. Therefore, in contrast to the situation with *C. porosus*, there is no supply of problem *C. johnstoni* with which to stock farms or ranches.

ii) Other Non-Hatchlings
Aborigines have harvested sub-adult and adult *C. johnstoni* in the Kimberley for many thousands of years. Europeans have also harvested them, quite intensively in a few areas, as recently as the early 1970s (Burbidge 1987). Small numbers continue to be taken accidentally each year as an indirect result of net-fishing (eg. Lake Argyle; M. Osborn pers. comm.)

Given the species' undoubted abundance in Western Australia a small, once-off (though perhaps spread over several years) harvest of sub-adults or adults could be considered for establishment of stock for a captive breeding program. From an experimental point of view it would be preferable if these were not taken from areas proposed for hatchling and/or egg harvest (eg. Lake Kununurra). To do so would make it impossible to distinguish between an egg/hatchling harvest effect and an adult harvest effect.

Camballin may be a potential source, though the size and structure of this population (thought to be in the thousands; C. Done pers. comm.) would need to be confirmed prior to determining an acceptable harvest level.

Lake Argyle would have the attraction of containing animals of the same genetic stock as Lake Kununurra, thus avoiding possible concerns about mixing animals (non-hatchlings and hatchlings) from different gene pools in captivity. However Lake Argyle is also proposed as a control area for the egg/hatchling harvest. Perhaps the Lake is large enough to be divided into both harvest and control areas. Surveys would be needed to decide this.

Note that exceptionally large *C. johnstoni*, some more than 3.5 metres in length, are found in Lake Kununurra. These are possibly the largest specimens found anywhere. Animals of this size would presumably have considerable appeal in the tourism industry as captive (and wild) specimens.

1.6 RECOMMENDED COURSE OF ACTION

(Assuming proponent interest and a Government decision in favour of *C. johnstoni* harvesting)

i) Examine feasibility of hatchling and/or egg harvest on Lake Kununurra (most promising option), Lake Argyle or Fitzroy River near Camballin or any other site which a proponent has reason to believe may have a harvestable population that contains in excess of 2000 non-hatchlings.

Priority: Essential prior to selection of population to be harvested, confirmation of harvest feasibility and selection of most appropriate harvest strategy.

To be undertaken by: Proponent, with CALM observer.

Cost to CALM: Lake Kununurra; One officer, 5 nights in Nov/Dec (?) (hatchling harvest) plus 10 days in Aug/Sep (?) (egg harvest).

ii) Given present knowledge, CALM's preferred option for a *C. johnstoni* harvest site should be Lake Kununurra. It is the only site for which some hard data exists; its crocodile population appears to be large enough to provide an acceptable harvest for at least one Single Operator farm, and it is close to Kununurra, a major Kimberley town and site of CALM's regional headquarters.

iii) On the limited data available, it would appear reasonable for CALM to permit a Lake Kununurra harvest of 500 hatchlings (or 1000 eggs) per annum for ten years, as proposed for establishment of one "Single Operator" crocodile farm - subject to certain safeguards (listed in iv below) being imposed.

iv) As a condition of permit, CALM should reserve the right to require farmer(s) to make available 5% of the number of eggs collected and 10% of the number of hatchlings collected, after they have been raised to 1 metre in length (as required by the CCNT in the Northern Territory). These could be used for restocking of the harvested population in the unlikely event that this proves necessary.

CALM should also retain the right to lower permitted harvest levels should annual population monitoring show this to be necessary.

v) If egg harvest appears practicable, it should be the preferred strategy (least impact on recruitment), in which case it will be essential to carry out surveys to determine which nests are least-likely to succeed and therefore most-favoured for harvesting.

Priority: Essential if eggs, rather than hatchlings, are to be harvested.

To be undertaken by: Proponent and CALM.

Cost to CALM: 2 officers two periods of two weeks per year for two years (initially), then once every five years for duration of harvest program. Helicopter hire.

vi) Pre-harvest, then annual, helicopter and spotlight surveys of population to be harvested and control (non-harvest) population(s).

Priority: Essential (required by Commonwealth legislation, if products to be exported).

Surveys must be by spotlight for first 5 years at least as small size classes (hatchlings and 1-2 year-olds) are missed in helicopter surveys. In years 4 & 5 test and calibrate helicopter surveys and, if more cost-efficient and population not declining, use in preference to spotlight surveys in subsequent years.

To be undertaken by: CALM

Cost to CALM: Spotlight surveys; 3 officers for 5 nights each year for 5 years. Boat purchase. Helicopter surveys; 2 officers every year of harvest program, commencing year 4. Helicopter hire (x4 to cover more distant control areas).

vii) Pre-harvest mark-and-recapture project to determine actual numbers, age structure and sex ratios of population proposed for harvest.

Priority: Highly desirable, though not essential, unless a larger harvest than that proposed in this report is being contemplated.

To be undertaken by: CALM

Cost to CALM: 3 officers four months per year for two years. Boat. Gear.

viii) Obtain scientifically-based estimate of size and distribution of total Kimberley C. johnstoni population.

Priority: Desirable (essential for Commonwealth export permit?).

To be undertaken by: CALM

Cost to CALM: 2 officers 6 months. 150 hours helicopter.

ix) Although the Consultant's report does not propose a harvest of C. johnstoni sub-adults or adults, total numbers are undoubtedly sufficient to allow a small (<60), once-off harvest to occur. This harvest should be spread over a number of years (say 5) and should not be from an area where eggs or hatchlings are to be harvested.

Lake Argyle may be suitable and, if so, would be the preferred option as its crocodiles are of the same genetic stock as the Lake Kununurra population. Possible mixing of genotypes (see x) below) would therefore not be a concern.

A survey would be necessary to confirm that this population does indeed exceed 2000 animals before approval to harvest could be given.

Annual post-harvest surveys of the population to be harvested would also be essential.

x) If C. johnstoni stocks are obtained from both Western Australia and some other source it should be a condition of licence that the various stocks are kept separate genetically as significant variation in genotype may be expected from one locality to another with this relatively sedentary species.

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2. POTENTIAL FOR HARVEST OF THE SALTWATER CROCODILE, CROCODYLUS POROSUS, IN WESTERN AUSTRALIA.

2.1 DISTRIBUTION, HABITAT AND NUMBERS

Distribution

Crocodylus porosus is found in near coastal parts of the Kimberley from King Sound near Derby to the Northern Territory border (Bustard 1970, Burbidge 1987). Individuals are occasionally sighted as far south as Broome, and in recent years there have been unconfirmed reports of a crocodile in the vicinity of Port Hedland. There are occasional reports of the species penetrating well inland; eg,. a 13' animal shot around 1978-79 on Kalyeeda Pool, 230 km from the mouth of the Fitzroy River and 60km upstream of Fitzroy Weir (P. Fuller; pers. comm.)

Habitat

The habitat of *C. porosus* in the Kimberley has been described as follows.

"The areas of the Kimberley inhabited by *C. porosus* differ markedly from most of the Northern Territory ... The Kimberley coastline and hinterland are chiefly composed of steep, rugged, ancient, deeply faulted sandstones. Access up many rivers is blocked to crocodiles by waterfalls and their associated gorges. There are few areas of floodplains and very few freshwater swamps; hence breeding habitat is scarce. It would appear, therefore that the carrying capacity of the Kimberley river systems and the Kimberley as a whole is much less than that of the Northern Territory" (Burbidge 1987).

(The only significant areas of freshwater swamp around the Kimberley coastline are that of the lower Ord River (Parry Lagoons), which is certain to contain some *C. porosus*; a large swamp at the head of Walcott Inlet which appears promising, and perhaps there are swamps along the lower Fitzriy River. *C. porosus* has apparently been reliably reported as far up the Fitzroy as the crossing at Myroodah Station, -- km below the Barrage at --. (Burbidge pers. comm.)

"One interesting difference between some Kimberley rivers and those elsewhere in northern Australia is the presence of extensive areas of mangal (mangroves) at their mouths." These contain "relatively high numbers of larger crocodiles" (ibid).

Numbers in Western Australia

C. porosus is on Western Australia's list of fauna which are rare or otherwise in need of special protection. The species was placed on the list because it was considered to be low in numbers and vulnerable to poaching (ref?)

The species was hunted heavily in the 1950s and 1960s and suffered dramatic declines in abundance in a very short period of time. It is considered that *C. porosus* has not yet recovered to its former abundance (Messel *et al.* 1987)

There have been two comprehensive surveys of *C. porosus* distribution and abundance in Western Australia.

i) Surveys by Messel et al. in 1977-78.
In 1977 and 1978 seven river systems were surveyed by the University of Sydney's Crocodile Research Group under contract to, and in conjunction with, the WA Department of Fisheries and Wildlife.

527.3 km of tidal waterways were surveyed; 898 *C. porosus* were sighted, of which 671 were non-hatchlings. Using formulae derived from intensive survey programs in the Northern Territory, Messel *et al*. calculated the actual number of non-hatchlings within the areas surveyed to be within the range 1048 - 1152 (95% confidence levels).

Messel *et al*. believed they had surveyed "more than half of the better *C. porosus* habitat in the Kimberley", and, on this basis, calculated "lower limits" of 2127 - 2275 for the total number of non-hatchlings in the Kimberley at the time of survey (Messel *et al*. 1987).

ii) Surveys by Messel et al. 1986
In 1986, Messel et al. resurveyed most of the systems covered in 1977 and 1978, plus the West Arm of the Cambridge Gulf. The total length of tidal waterway surveyed was 790.4 kms, in which 978 non-hatchlings were sighted. The actual number of non-hatchlings in the areas surveyed was calculated to be 1541 - 1667.

Messel *et al*. have estimated that their combined surveys have now covered some 67% of the important tidal habitat in the Kimberley. On this basis, their latest estimate (1986) for the total non-hatchling *C. porosus* population in the Kimberley is 2300 - 2488 animals (Messel *et al*. 1987).

(Note that in Section -- below the total number of non-hatchling *C. porosus* in the Cambridge Gulf/Ord River region is estimated to be around 1100 - 1250 (actually 1086-1249). Messel *et al*.'s estimate for the entire Kimberley seems low in comparison. Without knowing the basis of their estimate of 67% coverage it is not possible to fully account for this discrepancy. A partial explanation may be the fact that only "important tidal habitat" was considered. If there are large areas of low quality habitat these may add significantly to total crocodile numbers. A re-examination seems warranted.)

Comparison of Messel et al.'s 1977-78 and 1986 Survey Results for the whole Kimberley.

Messel *et al* surveyed 790.4 km of tidal waterways along the Kimberley coast. Of these, some 486 km had been surveyed previously, in 1977-78. The total number of non-hatchling *C. porosus* counted in the resurveyed areas increased from 593 (1977-78) to 774 (1986); an increase of 31%. The density of non-hatchlings in resurveyed areas increased from 1.2/km to 1.6/km. However, the additional areas surveyed in 1986 yielded a lower number of crocodiles than had been anticipated. Taking this into consideration, Messel *et al*. estimate that the total Kimberley population has increased by only 8.8%, from 2127-2275 (1977-78) to 2300-2488 (1986) (Messel et al. 1987).

A simple comparison of total numbers or densities ignores the fact that crocodile populations are made up of many "cohorts" (groups of animals hatched in the same year). For a more complete understanding of the "status" of a population it is necessary to examine changes in the number of animals in each of a number of age or size classes.

Survey results for areas surveyed in both 1977-78 and 1986 are as follows.

(Sizes are in feet, "H" represents hatchlings and "EO" is eyes only, i.e. animals whose presence was detected by their eyeshine in the spotlight but whose size could not be determined.)

	Numbers in Size Class									95%
Survey	H	2-3'	3-4'	4-5'	5-6'	6-7'	>7'	EO	Total	Levels
77-78	206	111	115	139	76	54	56	42	799	924-1022
1986	38	25	120	137	110	124	130	128	812	1213-1325

Messel et al. have regrouped these data into "important size classes" and and distributed animals in the EO class on a 50:50 basis to the 3-6' and >6' size classes as larger crocodiles "are known to normally be the most wary". The result is as follows.

Survey	H	2-3'	3-6'	>6'	Total
77-78	206	111	351	131	799
1986	38	25	430	319	812

A number of important points emerge from these data.

i) The number of hatchlings counted in 1986 was 82% lower in 1986 than 8-9 years previously.

ii) The number of animals in the 2-3 ft range (the previous year's hatchlings) was 77% lower.

iii) Numbers in the range 3-5' were comparable between the two survey periods.

iv) There were many more crocodiles greater than 5' in the 1986 survey than in 1977-78; the biggest difference being an increase of 132% in the number >7' which were seen.

It is readily apparent from the above that those crocodiles which were present in 1977-78 are surviving well and growing larger.

However, the number of animals in the smallest size classes has declined considerably. The cause (or causes) of this decline are unknown, however Messel et al. have offered two possible explanations.

One is that the two preceeding wet seasons may have been poor nesting seasons. The 1985-86 wet season was apparently "dry" until very heavy rainfall at the end of January. Messel et al. suggest that most nests laid down in January were not likely to have survived, due to widespread and heavy flooding.

However Messel et al. also point out that the wet season of 1984-85 was relatively dry with little flooding in the tidal waterways of the Kimberley. They believe that "it should have been a very successful nesting season with little or no loss of nests due to flooding". If that was the case, many more animals in the 2-3 ft size range should have been sighted in July 1986, however numbers in this category were 77% down on 1977-78 figures.

A second explanation which has been offered is that hatchling recruitment (i.e. the number of hatchlings emerging from the nest at the end of the wet season) in the two seasons prior to the July 1986 survey was in fact much higher than the data suggest, "but that the hatchlings and 2-3' animals were cannibalised by the increasing number of large animals."

A third possible factor, not suggested by Messel et al. (presumably because all of the major Kimberley tidal systems surveyed in 1986 had a paucity of hatchlings and 2-3' animals) is loss of quality of nesting habitat. In the Ord River area, at least, much suitable nesting habitat and many C. porosus nests have apparently been damaged or destroyed by introduced animals, principally cattle, in recent years. This may partly account for the observed decline in numbers of smaller animals.

Surveys of nesting habitat during and at the end of the wet season would be necessary to determine whether the decline in numbers of small animals sighted represents a real decline in nesting success or hatchling recruitment and, if so, the factor or factors responsible for this decline.

In conclusion, Messel et al. believe that the Kimberley C. porosus populations that they surveyed in 1977-78 were "badly depleted" due to particularly high hunting pressure during the early 1960's. "The species has now had some 16 years to recover (since the Commonwealth ban on export of crocodile products), but ... this recovery is now still only in its early phase and complete protection must continue to be accorded to the species" (Messel et al. 1987).

Numbers in Other States

Webb et al. (1984) have "conservatively estimated" the Northern Territory C. porosus population in 1984 as 30,000 to 40,000 individuals, and "may be 50,000."

However, Messel (1986) estimates the NT population to be 12,000 non-hatchlings.

There are several reasons for this dicrepancy. The most important is a difference of opinion about the number of crocodiles which may exist in unsurveyed areas, principally freshwater swamps.

In Messel's opinion, "mainstreams and secondary creeks constitute overwhelmingly the C. porosus habitat in Australia" (and, by implication, the Northern Territory), and "the combined area of all perennial freshwater floodplain channels accounts for less than 20% of that (C. porosus) habitat" (Messel 1987). Accordingly, Messel guesses the C. porosus population of these freshwater swamps to be about 20% of the tidal population.

Webb et al. (1984), on the other hand, estimate that the total swamp population at least equals the tidal population.

Other factors which contribute to the marked difference in estimates relate essentially to differences in sightability of crocodiles (according to habitat, size and wariness), and the extent to which these have or have not been allowed for in extrapolating from numbers seen to actual numbers (Webb 1986; Messel 1987).

Only further systematic surveys and mark-recapture experiments can resolve these differences of opinion.

The sizes of the WA and NT wild C. porosus populations may be compared using Messel's Kimberley estimate (2300 - 2488) with Messel's NT estimate (12,000) or with Webb's NT estimate (40,000 - 50,000). Using the former, the WA population is ---th that of the NT. Using the latter, the fraction is ---th.

The Queensland wild population has been estimated as 3000 (Messel 1980; 1986). Webb et al. (1984) consider that "insufficient data are available to estimate realistically the total population sizes in Queensland and Western Australia".

Numbers in Captivity

The total number of Australian C. porosus in captivity in 1984 has been conservatively estimated at 4,600, with 4,351 of these being on crocodile farms (Webb et al. 1984b).

Numbers in Particular Tidal River Systems (Kimberley)

It would be impractical to routinely harvest C. porosus (particularly large animals) from the more-remote river systems of the Kimberley. The only large (relatively) C. porosus population which is in close proximity to a sizeable town is that of the Cambridge Gulf - Ord River region near Wyndham and Kununurra.

A sizeable portion (much of Cambridge Gulf plus the lower Ord River) of this region was surveyed by Messel et al. in 1986. The remainder of the Ord (that part which contains C. porosus) was surveyed by M. Osborn in 1987.

i) Cambridge Gulf and the lower Ord River

Messel et al. obtained a non-hatchling spotlight index of 278 for the portions of Cambridge Gulf and the Ord which they surveyed in July 1986. Approximately 60km of the lower Ord were surveyed, to within 7.5 km of House Roof Crossing. The actual number of non-hatchlings in the surveyed area was calculated to be 422 - 490 (95% confidence levels).

Burbidge (pers. comm.) has estimated the proportion of Cambridge Gulf and lower Ord crocodile habitat covered by the 1986 survey to have been as follows:

The total length of habitat in the False Mouths of the Ord (which have not been surveyed) is estimated to be 351.3 km. The remaining length of unsurveyed habitat is estimated to be 195.5 km, including 107.5 km of the Gulf itself. This brings the total unsurveyed area to 547 km.

Burbidge suggests that the density of crocodiles in the unsurveyed area is likely to be lower than that recorded in the remainder of the Gulf as a whole (0.9/km) and similar to that of the Gulf's "west arm" (0.6/km).

On this basis, the total number of non-hatchling C. porosus in the Gulf and lower Ord area may be estimated as 422+(422x547/302x0.6/0.9) to 490+(490x547/302x0.6/0.9) = 932 - 1082.

ii) Remainder of the Ord River

On 26 July 1986 Messel et al. surveyed the Ord River to within 7.5 kms of House Roof Crossing (Old Carlton Crossing). On 27 May 1987 M. Osborn surveyed the Ord River from the Diversion Dam downstream to 28 kms beyond House Roof Crossing by helicopter. The two surveys thus overlapped by 20.5 km.

20 km of the zone of overlap coincides exactly with Messel's "Ord River Mainstream, 60-80 KM" survey sector, in which Messel counted 38 C. porosus. Osborn counted 14 C. porosus in this 20 km river section.

We may therefore assume a ratio of 38:14 for Messel's 1986 spotlight data versus Osborn's 1987 helicopter data.

Upstream of the zone of overlap (as far up as the Diversion Dam, the limit of occurence of C. porosus in the Ord) Osborn counted 49-14 = 35 C. porosus (See Section --). If we apply a factor of 38/14 to convert from helicopter to spotlight, the spotlight index for this stretch of river is 35x38/14 = 95. Using Messel's spotlight-to-actual formula, the actual number of non-hatchling C. porosus in the Ord River upstream of the limit of Messel et al.'s 1986 survey may be estimated as 136 - 175.

This may be added to the previously calculated figure of 932 - 1082 crocodiles in the Gulf and lower Ord, and produces **a total estimated non-hatchling C. porosus population for the entire Cambridge Gulf - Ord River region of 1086 - 1249.**

2.2 BIOLOGY AND POPULATION DYNAMICS

No studies have been made of C. porosus population dynamics or breeding biology in Western Australia. There are no data specific to WA concerning size-age relationships, sex ratios, male or female age at sexual maturity, nest site preferences, nesting success, hatchling survival, survival rates of other age classes, etc..

Some of these parameters have been determined for C. porosus populations of selected river systems in the Northern Territory (eg. ---------, -- et al 19--). These studies have shown that life history parameters may vary significantly from system to system. Caution must therefore be exercised in extrapolating from one system to another. For example, there is substantial variation in ---- , though not as much as in C. johnstoni populations.(ref)

Webb et al. 1984 have provided a most useful "selective review" of knowledge whih has been gained in the Northern Territory of the biology and population dynamics of C. porosus. This information is relevant to a consideration of possible harvesting levels and strategies in Western Australia and is therefore presented in Appendix --.

2.3 POTENTIAL HARVEST OF C. POROSUS IN WESTERN AUSTRALIA

Historical

Aborigines have utilized crocodile meat and eggs for the past 20,000 to 40,000 years (McBryde 1979; Flood 1983). Webb et al. (1984) observe that "The impact of this harvesting is unknown, but it should not be ignored. In river systems such as the Liverpool and Blyth (Northern Territory), Aboriginals know of almost all nest sites used, and until recently appeared to have harvested all eggs found".

The number of C. porosus taken in european times is uncertain. Webb et al. (1984) have investigated the number of animals killed in northern Australia during the 26 year period (1945-1971) of intense commercial hunting and have "generously estimated" the total harvest of C. porosus within the Northern Territory as 140,000 (actually 139,000). This estimate comprises 113,000 skins; 6,000 (5%) shot but not retrieved, and a guess of 20,000 (maximum) small crocodiles (hatchlings and yearlings <2' long) taken for the curio trade.

The total Australian harvest for this period is estimated as 270,000 to 330,000; a figure which also assumes 5% killed but not retrieved, and 45,000 juveniles for the curio trade (Webb et al. 1984). The total number of skins may therefore be estimated as 215,000 to 270,000.

The origin of skins was "probably in the vicinity of 45% Northern Territory, 45% Queensland, and 10% Western Australia (ibid). On this basis, and allowing for the "generous" nature of the harvest estimates, the total number of C. porosus skins (adults and sub-adults) taken from Western Australia in the 25-odd years prior to protection (1970 in WA) may be in the vicinity of 20,000 to 25,000.

Allowing for a small percentage shot but not retrieved and a few thousand hatchlings and yearlings for the curio market, the total harvest of all size classes of C. porosus from Western Australia was possibly around 25,000.

Webb et al.'s estimate, "considerably more biased towards overestimation than ... the Northern Territory estimates" is "approximately 26,000".

Little is known of the distribution of the post-1945 C. porosus hunting effort in the Kimberley. However Bustard 1970 provides some interesting records.

" ... in 1961 a group of four shooters returned to Broome after four months in the Collier Bay area north of Derby with 582 skins all of the saltwater crocodile."

"A crocodile shooter writing to the Chief Warden of Fauna from Yampi Sound, in July 1968 stated, "Five years ago I did a six week shooting trip and took 50 (saltwater) crocodiles over 7'6". Five years previously I took twice that number in as many days. Nowadays I'd be lucky to even see one."

"Father Sands (sic) at Kalumburu describes the shooting of 35 crocodiles in four days in daytime in Admiralty Gulf, six or seven of which exceeded 14' in length."

"He (Father Sanz) informed me that shooting only started in the area 5-6 years ago (63-64) and that in two years over 3000 were shot between Scots Strait (Bigge Island) and Cape Londonderry. Most, however, came from Admiralty Gulf."

Bustard (1970) concluded from his observations and enquiries that a "... catastrophic decline (in numbers of C. porosus) has taken place within this decade in many areas" and "... the crocodile skin trade is finished in Western Australia".

Cambridge Gulf and Ord River Region
i) Harvest of Adults

Messel et al. sighted 281 C. porosus in the 301.8 km of Cambridge Gulf and lower Ord waterways which they surveyed in 1986. Numbers of crocodiles in each size class were as follows:

Numbers Sighted in each Size Class									Estimated Actual Numbers
H	2-3	3-4	4-5	5-6	6-7	>7	EO	Total	
3	2	32	43	48	30	50	73	281	422-490

Messel et al. grouped these size classes and apportioned the EO ("eyes only") category to the (3-6') and (>6') size classes on a 50:50 basis, with the following result:

H	(2-3')	(3-6')	(>6')	Total
3	2	159	117	281

The size (total length) at sexual maturity for C. porosus has been reported as "around 3.2m (10ft 8ins) and 16 years of age" for males, and "about 2.2m (7ft 3ins) and 10 years of age" for females (Groombridge 1987).

In order to estimate the total number of sexually mature female crocodiles in the area surveyed it is firstly necessary to allocate a proportion of the EO category to the >7' size class. If we do this in a manner similar to that of Messel et al., the number of animals (sighted) in the >7' size class is 50 + (73x1/2x50/80) = 73.

Applying Messel's formula, the actual number of >7 ft C. porosus in the area surveyed is estimated to be 103 - 137, and the total number in the Gulf and the lower Ord is estimated to be 103+(103x547/302x0.6/0.9) to 137+(137x547/302x0.6/0.9) = 227 - 302.

Assuming the C. porosus population in that part of the Ord River surveyed by Osborn in 1987 has a similar size structure to that of the population in the remainder of the Gulf/Ord area, the number of >7 ft C. porosus to be added may be estimated as 136x(227+302)/(1082+932) to 175x(227+302)/(1082+932) = 36 - 46.

The total number of >7 ft C. porosus in the entire Cambridge Gulf and Ord River region may, therefore, be estimated as 263 - 348.

The sex ratio of adult C. porosus in the wild is not known, however a sample of 302 juveniles caught in a tidal river is reported by Webb et al (1987) as having a ratio (expressed as the proportion of males) of 0.51, which was not signifiantly different from 0.50.

Assuming a sex ratio of 0.5 for the >7ft size class, **the total number of female >7 ft *C. porosus* (i.e. sexually-mature females) in the Cambridge Gulf / Ord River region is estimated to be be 131 - 174.**

An alternative approach to the calculation of numbers of sexually-mature females involves the use of size-specific correction factors provided by Bayliss et al. (1987) and Webb et al. (1984). These correction factors are derived from capture-recapture data obtained from the downstream section of the Adelaide River (NT), and are as follows.

Size Class	p	CF
1-2'(H)	0.693	1.443
2-3'	0.745	1.342
3-4'	0.769	1.300
4-5'	0.765	1.307
5-6'	0.733	1.364
6-7'	0.673	1.486
7-8'	0.585	1.709
8-9'	0.469	2.132
9-10'	0.325	3.077
10'	0.153	6.536
(>7')		3.029

(H = hatchlings, p = the probability of being sighted on any one survey, and CF is the correction factor to be applied. In calculating CF's, "eyes only" sightings form part of the unseen portion of the population.)

Using these correction factors the actual numbers of crocodiles in each size class in the surveyed area is estimated to be:

H	2-3	3-4	4-5	5-6	6-7	>7	Total
4	3	42	56	65	45	151	366

Using Messel's formula, the number >7' and the Total were estimated above to be 103 - 137 and 422 - 490 respectively. Messel et al.'s formula therefore produces a less conservative estimate of total numbers, but a more conservative estimate of numbers >7' and therefore of sexually-mature females. The following calculations are therefore based on the Messel-derived estimate of numbers >7'.

The Consultants' report models a "Corporate" and a "Single Operator" farm.

The Corporate model is based on the assumption that "20 adult (breeders) *C. porosus* are taken from the wild each year for 5 years and 400 hatchlings are taken from the wild each year for 4 years to provide an earlier cash flow. The Single Operator farm "reduces the above take from the wild assumptions by half .."

The Consultants propose the establishment of one Corporate and one Single Operator farm simultaneously.

The proposed C. porosus harvest is therefore 30 adult (breeders) each year for 5 years and 600 hatchlings per year for 4 years.

"Adult (breeders)" means crocodiles aged 10-11+ years, according to the Consultants' model (Appendix 4.1 of consultants' report). Their report is not clear concerning the proposed sex ratio of farm "breeders", however it appears to be 1:1.

A harvest of 30 breeders per year would represent (assuming sex ratio in the wild of >7' C. porosus is 50:50 and that this is the ratio wanted) 15 sexually-mature females per year. In the first year this would be 15/131 - 15/174 = 8.6% - 11.5% of the total number in the entire Gulf/Ord region. With a harvest sex ratio of 1:1 a somewhat larger percentage of sexually-mature males would be required since male size at maturity is greater than 10', not 7'.

Some mortality of breeders during capture and transport must be allowed for, as deaths in transport of large crocodiles are frequent. Allowing for an arbitrary death rate of 15%, the number of sexually-mature females to be taken from the wild each year becomes 15x100/85 = 18. **In the first year of harvest this would represent 18/131 - 18/174 = 10.3-13.7% of the total number in the Gulf/Ord region.**

It has been proposed that this adult harvest commence in 1989 and continue for 5 years. Without recruitment to the breeding stock during this period, a harvest of 18x5 sexually mature females would represent 90/131 - 90/174 = 52-69% of the total present.

However significant recruitment to the breeding stock can be expected until 1994 at least, since Messel et al.'s data indicate that in 1986 there were substantial numbers of crocodiles in the 3-6' size class.

Using --- it is possible to estimate the level of recruitment to the breeding stock during the 5 year period. This is estimated to be ------ (full details in Appendix --). A harvest of --- would therfore take -- and reduce the number of -- by -- or --%.

Appendix -- Expected Recruitment to the Cambridge Gulf C. porosus population in the period 1987 -1995.

1. Numbers

i) As reported in Section -- above, in July 1986, Messel et al sighted:

Numbers Sighted in each Size Class

H	2-3'	3-4'	4-5'	5-6'	6-7'	>7'	EO	Total
3	2	32	43	48	30	50	73	281

ii) Messel then grouped several classes and allocated the EOs on a 50:50 basis to the (3-6') and (>6") groupings. If, for the purposes of these calculations, we revert to the original size classes and allocate the EOs to these classes in proportion to the number seen in each class, after allocating to the grouped classes on a 50:50 basis, the result is as follows: (note that an alternative approach is to follow the Bayliss et al and Webb et al route - perhaps do this in an Appendix. The "problem" is that you have to come back to Messel data anyway)

	Numbers in each Size Class						
H	2-3'	3-4'	4-5'	5-6'	6-7'	>7'	Total
3	2	41.5	55.8	62.2	43.7	72.8	281

iii) Applying Messel's formulae (also on p287 of Monograph No. 1), the actual numbers (95% confidence levels) of *C. porosus* in each size class in the area surveyed are estimated to be:

		Numbers in each Size Class				
H	2-3'	3-4'	4-5'	5-6'	6-7'	>7'
<10	<10	51.0-72.7	70.6-95.7	79.4-106	58.4-85.0	102-137

(The number of hatchlings and 2-3' animals can not be estimated by means of Messel's formula 'cause number sighted was <10)

iv) The number of animals in each size class in the whole Gulf/lower Ord area (using Burbidge's estimate of the proportion of the area which was surveyed 43.5%)) is estimated to be:

	Numbers in each Size Class					
H	2-3'	3-4'	4-5'	5-6'	6-7'	>7'
<10	<10	113-160	156-211	175-234	129-188	225-302

v) The helicopter index for the remaining unsurveyed section of the Ord River was 35 and this was converted to a spotlight index of 95. If we assume that the size structure of the croc popn in this stretch of river was comparable with that of the area surveyed by Messel the 95 crocs may be allocated to size classes as follows:

H	2-3'	3-4'	4-5'	5-6'	6-7'	>7'	Total
1.0	0.7	14.0	18.9	21.0	14.8	24.6	95

(The assumption is unlikely to be strictly true as 12 large crocs have been removed from a section of the river during the past 4 years, -- in the - years prior to the 1986 Messel survey. However it is not possible to determine actual population structure from the once off heli survey and given the relatively small number of animals involved any inaccuracy introduced by this assumption is small relative to --)

vi) Applying Messel's formulae, the estimated actual number in each size class is:

H	2-3'	3-4'	4-5'	5-6'	6-7'	>7'
<10	<10	14.6-27.1	20.9-35.5	23.6-39.0	16.5-32.0	30.4-50.3

vii) Adding these to the estimates of iv) above, the number of animals in each size class in the entire Cambridge Gulf/Ord River Region may be estimated as: (maths are incorredt - have mathematician do it)

H	2-3'	3-4'	4-5'	5-6'	6-7'	>7'
<10	<10	128-187	177-246	199-273	146-220	255-352

***** The crunch is converting from age to size and vice versa. Need to do more reading on this **********

2. If we assume survivorship rates of :
   - about 70% from hatching to three to four months of age;
   - about 54% during the first 12 to 14 months;
   - about 72% (mean annual) from one year to six years;
   - about 72% from six years to maturity;
   - 99% between 12 and 60 years of age, and
   - 95% between 60 and 70 years of age (and that all remaining animals die at 70 years),

3. Then without harvesting (and without density-dependent mortality) one could expect the folowing population structure in the years 1987 to 1995

1987
1988
1989
1990
1991
1992
1993
1994
1995

4. With harvesting at the rate of -- and no compensatorey factors we could expect the age structure in years 1987 to 1995 to be:

1987
1988
1989
1990
1991
1992
1993
1994
1995

It should be noted, however, that recruitment to the breeding stock in subsequent years (3-4 years (check ***) at least) may be very much reduced (with or without adult harvesting) since very few animals in the hatchling and 2-3' size classes were sighted in 1986. It is not possible to be more definite on this without better information on the size and structure of the population, age-specific survival rates, and the extent to which compensatory factors may influence recruitment to the breeding stock if harvesting of adults is permitted.

****

Webb et al. (1984) have produced relationships for predicting the approximate ages of known-sized juvenile C. porosus in the Blyth-Cadell River system of the NT. These are as follows.

Age in years	Total Length Size Classes <2'	2-3'	3-4'	4-5'	5-6'	6-7'	>7'
0.3	100%	-	-	-	-	-	-
1.3	-	99%	9%	-	-	-	-
2.3	-	1%	68%	3%	1%	-	-
3.3	-	-	23%	58%	7%	-	-
4.3%	-	-	-	32%	48%	4%	-
5.3%	-	-	-	7%	36%	16%	5%
>5.3	-	-	-	-	8%	80%	95%

(Ages are in 1 year increments of 0.3 because the Blyth-Cadell population surveys were conducted during the dry season, usually 3-4 months after peak hatching in April/May.)

If we apply these relationships to the estimates of actual numbers which were produced above by applying Bayliss et al.'s size-specific correction factors, the estimated age structure of the C. porosus population in the surveyed portion of the Gulf and lower Ord at the time of survey (July 1986) is as follows:

Age Classes (years) 0.3	1.3	2.3	3.3	4.3	5.3	>5.3	Total
4	7	31	47	51	42	185	367

Females reach sexual maturity at 10 years and males at 16 years (Groombridge 1987). On this basis the small number of females aged 1.3 years or less in July 1986 will reach sexual-maturity in 1994-95 and males of the same two cohorts will reach sexual-maturity in the year 2000-01.

Therefore, if a 5-year harvest of adults were to begin in (say) 1989, a possible decline in recruitment of females to the breeding stock (due to apparently-poor recruitment of juveniles in the two seasons prior to the 1986 survey) could be expected to coincide with the breeding season following the last year of adult harvest.

Under the same scenario, a possible decline in recruitment of males to the breeding stock would occur some 6 years after the last year of adult harvest.

Surveys in intervening years will, of course, give a good idea of whether these declines in recruitment to the breeding stock will actually occur, or whether compensatory factors will either partially or wholly negate the apparent decline in recruitment of juveniles.

Whether recruitment of hatchlings has improved in the two wet seasons (1986-87 and 1987-87) following Messel et al.'s 1986 survey is unknown and can only be determined by further survey.

Because of the limited nature of the available data, and the current uncertainty concerning the level of recruitment (hatchling) to the Cambridge Gulf/Ord River *C. porosus* population it is recommended that any harvest of adults be limited in number.

Data from a Harvested Area

As indicated above, in recent years the number of large crocodiles in the Kimberley has increased. So has the number of people in the region, and their mobility. Occasionally, one or two of these large crocodiles have caused problems by "hanging around" near river campsites and swimming areas. These "problem" crocodiles have generally been removed, usually by live-capture and transport to a crocodile park in Broome. During the past -- years, some -- problem crocodiles have been taken from the wild.

One of the areas harvested is the Ord River, where "12 large saltwater crocodiles have been removed ... in the last 4 years. 5 from the APB camp (near House Roof crossing) and 7 from near Collins Creek" (M. Osborn in lit.).

Quite fortuitously, the crocodile population of this river has also been systematically surveyed, albeit once-off (after the harvest) and by helicopter (M. Osborn in lit.). Thus on 27 May 1987 Osborn and two assistants surveyed 97 kms from the Diversion Dam to a point 3 km downstream of Collins (Reedy) Creek.

The survey area was divide into a number of sections and the number of crocodiles seen in each was recorded. The three survey sections in which *C. porosus* were sighted were Buttons Gap to Sandy Beach, Sandy Beach to upstream boundary of Agriculture Protection Board (APB) quarantine area, and APB to 3 kms downstream of Collins Creek respectively.

Results for these sections were as follows.

River section	Nos. of *C. porosus* in each Size Class 3-4'	4-6'	6-10'	10'+	Total	Unknown	*johnstoni*
BG-SB			2	3	5	8	30

SB-APB			4	3	7	2	96
APB-CC	4	12	13	4	33		30
Totals	4	12	19	10	45	10	156

No C. porosus less than 3' in length were seen. The ten crocodiles recorded as "species unknown" were "either large crocodiles seen at a distance, then diving or large crocodiles seen swimming, underwater and diving, making identification difficult" (in lit.). Numbers of C. johnstoni observed are also indicated.

If we assume "large" means >6', and, taking into account the number of >6' C. porosus and C. johnstoni seen in each sector, distribute the "unknowns" to each species and 50:50 to the 6-10' and 10'+ classes of C. porosus, the result is as follows:

River section	Numbers in Size Class 3-4'	4-6'	6-10'	10'+	Total	Kms	C. porosus Density (/km)
BG-SB			4	5	9	14	0.6
SB-APB			4	3	7	11	0.6
APB-CC	4	12	13	4	33	41	0.8
Total	4	12	21	12	49	66	0.7

The interesting point to emerge from these data is the fact that in sections BG-SB and SB-APB only large (>6') C. porosus were seen. However, in the sector APB-CC, where 12 large crocodiles have been removed in the past 4 years, nearly 50% of the animals seen were less than 6' in length. The density of crocodiles did not decrease.

While these data are merely suggestive and no firm conclusions can be reached concerning the consequences of large crocodile removal, the data are not in disagreement with the proposition that the number of large C. porosus in a river system or region and survivorship in small size classes (hatchlings and yearlings) may be inversely related (Messel et al. 1987).

If significant numbers (say 5+) of large crocodiles are to be removed from any one locality in future it would be most useful to determine the structure of the population (and that of a control area) before removal, and to monitor any subsequent changes. Only by this means could some more definitive statement about the consequences of large crocodile removal or harvest be made.

Conclusion re Potential Harvest of Adults

The Consultants' report suggests that a harvest of 10 adults per year for 5 years would be adequate for the establishment of one Single Operator farm. Allowing for an arbitrary 15% mortality during capture and transport, the total annual harvest becomes 12 adults per year. Assuming a 1:1 sex ratio, a harvest at this level would take some 3.4-4.6% of the estimated 131-174 sexually-mature females in the region in the first year.

Given:
i) the various safeguards which would be imposed (before and after population surveys, provision for return of a percentage of captive-raised juveniles in the event of egg or hatchling harvest occuring)

ii) that harvesting would be limited to one of the many Kimberley river "systems" which contain C. porosus populations

iii) that the harvested adults are intended to form the nucleus of a closed crocodile breeding farm, and harvesting of adults beyond the first 5 years required for establishment is not proposed

iv) that a small proportion may be available as "problem" animals which would, in any case, require removal.

it is considered that a harvest of up to 12 sexually-mature C. porosus (no more than 6 females) per year for 5 years would not threaten the viability of the Cambridge Gulf/Ord River population or the long term conservation objective of allowing the species to return to former levels of abundance.

It is recommended, however, that approval to undertake a harvest of adults be conditional on a survey of nesting success and hatchling recruitment showing that these are at levels necessary to sustain the population and permit continued growth.

It is also recommended that an estimate of the number of sub-adult and adult C. porosus that are currently being taken (killed) as an indirect consequence of net-fishing, or by souvenir hunters or vandals be obtained. Efforts should then be made to reduce the number of animals which are taken in this way.

ii) Harvest of Hatchlings or Eggs

As indicated in Section 2.1 above, Messel et al. sighted very few C. porosus hatchlings during their July 1986 surveys of the major Kimberley river systems. The total number seen on 486 km of previously-surveyed waterways was 38. 206 hatchlings had been sighted in the same areas 8-9 years previously. Numbers of hatchlings sighted thus decreased by a substantial 82%. Numbers of animals in the 2-3' size class were also down substantially, indicating poor recruitment for at least three years.

The total number of C. porosus hatchlings sighted in all surveyed portions of the Cambridge Gulf and lower Ord River system in 1986 was 3. On this basis, the hatchling spotlight index for the total Gulf area (surveyed plus unsurveyed portions) may be estimated as $3+(3x547/302x0.6/0.9) = 6.6$. This figure is too low to permit calculation of actual numbers present as the formula used for this purpose requires the number sighted to be greater than 10. Where 10 hatchlings are sighted, the actual number present computes to be within the range 10 - 22.

The number of hatchlings in a 97 km section of the Ord River surveyed by helicopter (M. Osborn) in 1987 is unknown. Hatchlings are too small to be sighted from the air. It is considered unlikely, however, that this section of river would contribute significantly to the total number estimated for the remainder of the Gulf/Ord region.

The actual number of hatchlings in the entire Cambridge Gulf and lower Ord River area in July 1986 is therefore estimated to be minimal, and perhaps as low as 10-20.

What is not known is whether this low number is due to reduced nesting success (i.e. a low hatch rate) or low survival of 0-4 month old hatchlings. The number of hatchlings which may be available for harvesting immediately after hatching (within 1 week or so) is therefore unknown and can only be determined by wet-season surveys of breeding habitat. Similarly, the number of eggs which may be available for harvest (Jan-Feb) can only be determined by survey.

Until such surveys are done, it is obviously impractical to consider undertaking (or appproving) an egg or hatchling harvest of any size, let alone the 600 hatchlings per annum proposed by the Consultants to supply a Corporate and a Single Operator farm.

PROPOSED COURSE OF ACTION
(Assuming proponent interest and a Government decision in favour harvesting of Kimberley stocks of C. porosus.

1. Surveys to determine whether hatchling survival in the Cambridge Gulf/Ord River region is as low as Messel et al.'s data suggest. If it is, the population may be in serious difficulty. Under these circumstances, commercial-scale hatchling harvests would be neither practicable nor advisable.

Priority: Essential before a soundly-based decision to allow egg or hatchling harvest could be made.

To be undertaken by: Proponent and CALM.

Cost to CALM: Two weeks for nest survey (plus 50 hrs helicopter hire); two weeks (2 officers) for hatchling survey (plus boat hire or purchase)

2. If surveys of 1. above show that an egg or hatchling harvest from the Cambridge Gulf/Ord River region is practicable and acceptable from the point of view of maintenance of wild crocodile stocks, pre-harvest and subsequent annual monitoring of the population in harvest and control (non-harvest) areas would be necessary to monitor impact.

3. If harvest of eggs or hatchlings proceeds, CALM should reserve the right to require the proponent(s) to make available 5% of eggs collected and 20% of hatchlings collected, after they have been raised to juveniles of 1m in length. These could be used for restocking of the harvested population in the event that this proves necessary.

4. CALM should encourage egg harvest in preference to hatchling harvest in order to minimise any potential impact on the population.

5. Harvesting of adult C porosus should not be sanctioned until surveys (1. above) show that the current level of hatchling recruitment is adequate to sustain the population proposed for harvest

6. Subject to 5. above being satisfied, a harvest of 12 adult C porosus (no more than 6 females) per year for up to 5 years from the Cambridge Gulf/Ord River area could be considered, subject to certain safeguards.

7. Safeguards which would need to be imposed include before and after surveys of the crocodile populations of harvest and control (non-harvest) areas, and retention of the right to require farmer(s) (as per 3. above) to make available captive-raised juveniles for possible restocking of the harvested population should this prove necessary.

8. CALM should take steps to reduce the number of C. porosus currently being killed accidentally (as a consequence of net fishing) or unlawfully.

9. The State Government should immediately proceed with declaration of the various Nature Reserves, National Parks and marine reserves proposed for protection of C. porosus populations and their habitat.

10. Government should encourage tourism ventures designed to enable tourists to see C. porosus in the wild in order to place economic value on thier habitat. CALM to prepare a code of conduct designed to enable tourists to --- and protect --- and safety ----.

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DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Form CLM 608

FROM: C DONE
REGIONAL MANAGER - KIMBERLEY
TO: JIM LANE
WILDLIFE RESEARCH CENTRE - WOODVALE

OUR REF: 156.3
YOUR REF:
ENQUIRIES: C DONE

Dear Jim,

I have a few comments which you may care to consider before finalizing the crocodile report. In general I found the report a very useful summary. Many thanks for sending it up.

Comments.

P1 1.1 Distribution

I query whether the "most extensive habitat .... inaccessible North West Kimberley." I think that the Ord and Fitzroy Rivers could be the most extensive habitat although I know that the species exists in numbers in the area you mention. Only a survey of the relative numbers would give us a line on this.

P2 1.1 i) Brennan's Count

I doubt that the level of Lake Kununurra could be lowered by 18 metres. My understanding is that the Diversion Dam Gates are 40' high (about 12 metres) and I suspect that the water was drained out by this amount. (The Water Authority have since confirmed that the level was probably lowered by 9 - 10 metres at that time).

P5 iii) Other Sites

Lake Argyle may be over rated as a source of C.johnsoni. In the early 1980's very heavy poaching of crocodiles is suspected of having occured. I know that in 1979 (when I flew around the lake with P.Gowland who was the Dept of Agriculture's ornithologist) there were very large numbers (no guess on how many) of large (>2m) C.johnsoni. I have not done this exercise since but from my ground and water based activities around the lake I believe that a large percentage of these mature crocodiles were illegally removed.

> Mr J. Lane

I further speculate that because the Lake only filled in 1973 that the crocs I saw were probably resident in the river prior to it being dammed and were therefore very much favoured by the new habitat for several years allowing them to grow bigger than "normal" size at a very quick rate. I further speculate that Lake Argyle is a poor breeding site for C.johnstoni because of the extreme annual range in water level which varies by 6 - 10 metres annually, and which does not support dense perimeter vegetation or big permanent swampy areas such as are found along Lake Kununurra. Recruitment to the Lake would largely be from tributary rivers and creeks during the wet season.

Some Large crocodiles still exist in the Lake as they are occasionally caught in fishermen's nets and we also have the phenomenon of crocodiles being carried down Spillway creek (the subject of several reports by Mike Osborn & myself) and eventually dying there. To my knowledge no survey work has been done of C.johnstoni populations in the lake, but this is required before any harvesting takes place. This information is certainly needed before we suggest Lake Argyle as the source of fresh water crocodile breeding stock for any crocodile farming operation (see Executive Summary P3)

Fitzroy River

My ~~questionnaire~~ [questimate] of he population in the dammed sections of the Fitzroy River near Camballin of "thousands" is of course just a guess, but a figure of <1000 would be very likely. Geikie Gorge has some 500 crocodiles in a 4.5km section. (Spotlight survey— M.Osborn) The Fitzroy River is probably very prolific.

P11 1.5 Potential Harvest
Packsaddle Swamp area should be excluded from any harvest.

P12 Para 6. reference to "L.Argyle" should be L.Kununurra.

P14 i) Problem Crocodiles

I am starting to think that we should be careful about saying that C.Johnstoni poses no threat to humans. We had an incident at Geikie Gorge in 1987 where a man's foot was bitten (unprovoked) and there are a number of other reports of people being bitten when the freshies have been trodden on or cornered etc. It is not incon~~currable~~[ceivable] a small child could be at risk from a big freshie.

Carey — Pls ring Chris Done, thank him for the most useful comments, and ask him if he means "less than" 1000 (as written) or more than 1000. [signature] 7/4

P15 para 2. "Lake Kununurra" mentioned twice. First one should be "Lake Argyle."
para 3. The large freshies at the base of the Ord Dam are a tourist feature in themselves. It will be necessary to exclude

them from any harvesting program.

P17 para ix) and subsequent para.
See my previous comments on the potential suitability of Lake Argyle for harvesting C.johnstoni.

P21 (para 2) Another factor which may have been even more wide reaching than the introduction of cattle in reducing the available habitat for nesting along the lower Ord is the actual damming of the river. It is my opinion that the whole ecology of the lower river has changed drastically along with physical effects such as water temperature, water depth, seasonability of water, width of river, profusion of weed growth (cumbungi etc). Some of these factors may be beneficial to crocodile nesting habitat and others are and probably not.

P27 Last paragraph.
We are trying!

Done

C DONE
REGIONAL MANAGER - KIMBERLEY

1/11/88
CD/df

JIM

Yes, should be more than.

Carey
8.11