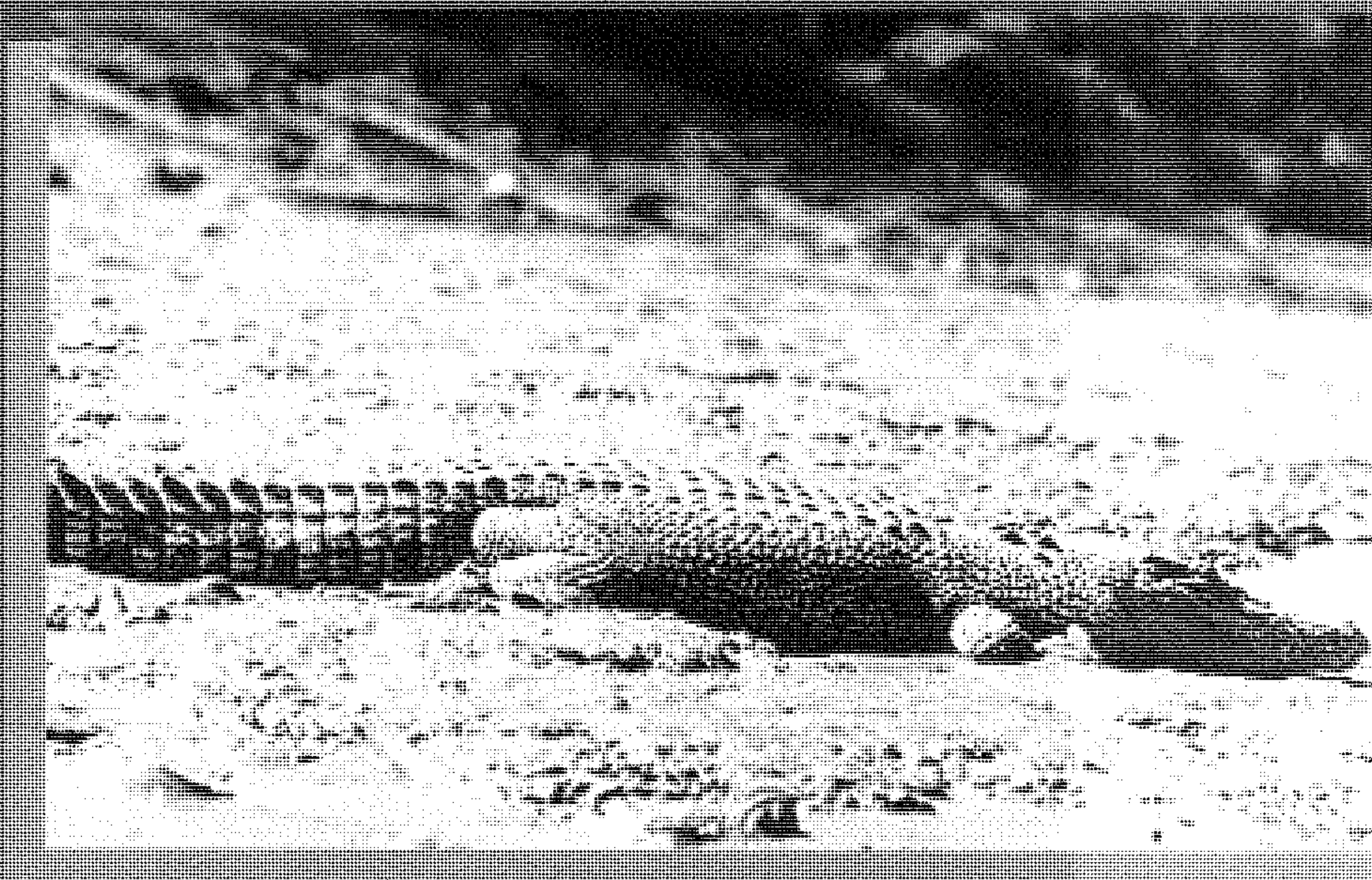
Crocodile Specialist Group, Species Survival Commission

CROCODILES

6th Meeting

1982



Proceedings of the 6th Working Meeting of the Crocodile Specialist Group
Victoria Falls, Zimbabwe & St Lucia Estuary, South Africa
19 - 20 September, 1982

(Unedited and Unreviewed)

IUCN
The World Conservation Union

CROCODILES

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Special Reprint of the Proceedings of the 6th Working Meeting of the Crocodile Specialist Group

of the Species Survival Commision of IUCN - The World Conservation Union

convened at

Victoria Falls, Zimbabwe
and
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CROCODILES

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C R O C O D I L E S

Proceedings of the 6th Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of the International Union for Conservation of Nature and Natural Resources convened at

Victoria Falls, Zimbabwe

and

St. Lucia Estuary, South Africa

19 to 30 September 1982

International Union for Conservation of Nature and Natural Resources

Avenue du Mont Blanc, CH-1196, Gland, Switzerland

1984

The International Union for Conservation of Nature and Natural Resources (IUCN) was founded in 1948, and has its headquarters in Gland, Switzerland; it is an independent international body whose membership comprises states, irrespective of their political and social systems, government departments, and private institutions as well as international organizations. It represents those who are concerned at man's modification of the natural environment through the rapidity of urban and industrial development and the excessive exploitation of the earth's natural resources, upon which rest the foundations of his survival. IUCN's main purpose is to promote or support action which will ensure the perpetuation of wild nature and natural resources on a world-wide basis, not only for their intrinsic cultural or scientific values but also for the long-term economic and social welfare of mankind.

This objective can be achieved through active conservation programs for the wise use of natural resources in areas where the flora and fauna are of particular importance and where the landscape is especially beautiful or striking, or of historical, cultural, or scientific significance. IUCN believes that its aims can be achieved most effectively by international effort in cooperation with other international agencies, such as UNESCO and FAO.

The World Wildlife Fund (WWF) is an international charitable foundation for saving the world's wildlife and wild places. It was established in 1961 under Swiss law, and at present jointly shares headquarters with those of IUCN. Its aim is to support the conservation of nature in all its forms (landscape, soil, water, flora, and fauna) by raising funds and allocating them to projects, by publicity, and by education of the general public and young people in particular. For all these activities it takes scientific and technical advice from the IUCN.

Although WWF may occasionally conduct its own field operations, it tries as much as possible to work through competent specialists or local organizations.

Among WWF projects financial support for IUCN and for the International Council for Bird Preservation (ICBP) has highest priority, in order to enable these bodies to build up the vital scientific and technical basis for world conservation and specific projects. Other projects cover a very wide range from education and ecological studies and surveys to the establishment and management of areas as national parks and reserves and emergency programs for the safeguarding of animal and plant species threatened with extinction.

WWF fund-raising and publicity activities are mainly carried out by National Appeals in a number of countries, and its international governing body is made up of prominent personalities in many fields.

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SUMMARY OF THE MEETING

From 19 to 24 September 1982, the Crocodile Specialist Group (CSG) met in Victoria Falls, Zimbabwe, with the support of the Department of National Parks and Wild Life Management of Zimbabwe and the Crocodile Farmers Association of Zimbabwe and in conjunction with the Symposium on Crocodile Conservation and Utilization. Then following visits to national parks, the meeting was reconvened from 27 to 30 September in St. Lucia Estuary, Republic of South Africa, with support of the Natal Parks, Game and Fish Preservation Board. Attendance at both meetings was open to anyone actively involved with crocodile conservation or farming.

Following the precedent of earlier meetings, the CSG agenda was organized around four broad topics: 1) reports on the conservation status of the various crocodilian species and populations, 2) review of management options, 3) research development, and 4) CSG determined priorities for conservation action and other decisions taken by the Group. A total of more than 40 papers and audiovisual presentations were given at the Victoria Falls and St. Lucia meetings. Of the 24 papers on status, management, and research presented by CSG members, 14 appear below (see Table of Contents). A summary of the discussion of conservation priorities and other business follows immediately.

CONSERVATION PRIORITIES

RECOMMENDATIONS TO THE CITES SECRETARIAT

Australian submission to CITES. After lengthy discussion led by G. Letts and H. Messel and involving all members present at the meetings and several absent members who had submitted their comments by post, the CSG found that it could not support the Australian government proposal to transfer its populations of *C. porosus* from Appendix I to Appendix II of CITES. More than a decade of censusing of populations across all of northern Australia indicates that most populations are not yet recovered. In addition, the Australian government submission does not contain sufficient detail on what populations and size classes might be harvested from the wild if the transfer to Appendix II were approved; how such hunting or collecting might affect aboriginal Australians who revere the crocodiles and aboriginal lands where much of the best crocodile habitat occurs; what licenses, permits, or seals will be required for hunters, farmers, dealers, and exporters of legal hides; and how legal hides might be marked or otherwise distinguished from illegal hides. The information on marking of legal hides is important not only for effective management of any hunt in Australia, but also as an aid to other *C. porosus*-producing nations that might find it necessary to distinguish between hides poached illegally within their national jurisdictions and legal Australian hides. Until census of the wild populations indicates a general increase in numbers or at least a significant increase in some populations, and until the inadequacies of the present submission are corrected, the proposal from the Australian government is premature and cannot be supported.

Zimbabwe submission to CITES. The CSG unanimously supported the submission to the CITES from the government of Zimbabwe seeking the transfer of their C. niloticus populations from Appendix I to Appendix II. Several decades of annecdotal observations combined with more recent censuses of wild populations document recovery of crocodiles throughout Zimbabwe. The Zimbabwe submission answers questions on all aspects of management of the crocodile resource--protection of wild crocodiles in parks and sanctuaries; control of nuisance crocodiles; harvest of wild eggs to stock farms and ranches; licensing of farmers, dealers, and exporters; marking of legal hides; and use of security seals to verify legal shipments--and can serve as a model for other nations to follow.

REVIEW OF STATUS AND MANAGEMENT OF CROCODILES IN AFRICA

Following the formal discussion of the Zimbabwe submission to CITES, the CSG and other participants at the Victoria Falls and St. Lucia meetings reviewed the present knowledge of crocodile conservation throughout Africa. The much of the discussion involved A. C. Pooley's "The Status of African Crocodiles in 1980" published in the 1982 Proceedings of the 5th Working Meeting of the CSG. The many African participants in the meetings contributed their personal observations to the discussion. As a result of this review, the CSG and the Victoria Falls symposium participants found that they could not support the transfer or delisting under CITES of any Appendix I populations of African crocodiles until more data had been gathered on the status of wild populations and on the effective management of the crocodile resource.

TRAINING OF PERSONNEL

The CSG recognizes that many populations of crocodilians will not be conserved, will not be managed for the maintenance of natural ecosystems and for the sustained benefit of local people, in the absence of trained crocodilian biologists and ecologists. Such professionals are needed to conduct the research that produces the data needed for development of management programs. As a consequence, the CSG has given the training of crocodilian biologist/managers its very highest priority. Every member of the CSG with the resources to do so will endeavor personally to train more crocodilian conservation personnel.

PRIORITY PROJECTS

The CSG placed high priority on initiating conservation programs on the critically endangered:

Chinese alligator, Alligator sinensis
Black caiman, Melanosuchus niger
Slender-snouted crocodile, Crocodylus cataphractus
Orinoco crocodile, Crocodylus intermedius
False gharial, Tomistoma schlegeli

COMMENDATIONS

The CSG noted the successful efforts some nations are making in conserving their crocodilian resource. Of particular note is the massive programs supported by the government of India for the conservation of its gharial, saltwater crocodile, and mugger crocodile populations, and by Zimbabwe for the conservation of its Nile crocodile populations. Also to be commended are the small programs underway in the Philippines on the Philippine crocodile, C. mindorensis, and in the Ivory Coast for the conservation of Nile and slender-snouted crocodiles.

CSG NEWSLETTER

Peter Brazaitis and Myrna Watanabe have agreed to compile and edit the CSG Newletter until the next Working Meeting. Unless the list becomes too long, the Newsletter will be sent to CSG members, consultants, correspondents, and other people working with crocodilians. CSG members are encouraged to send the editors information for inclusion in the Newsletter.

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Names of CSG members are capitalized.

THE STATUS OF CROCODILE POPULATIONS IN PAPUA NEW GUINEA

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INTRODUCTION

Papua New Guinea has long been dubbed the "Paradise Isle" by dint of being the home of the fabulous Birds of Paradise. One respect in which it lives up to this name is in its potential for wildlife conservation and management. It is a large island with only a small population--3.0 million people in nearly half a million square kilometers (National Statistics Office 1982), with high mountains, virgin forests, and virtually impenetrable swamps abounding.

It is also fortunate enough to have a government committed to the conservation of the environment, one of the five stated National Goals written into the Constitution. More than 10 percent of the landmass of Papua New Guinea consists of freshwater swamps (Paijmans, 1976), and it contains the world's third largest river by volume, the Fly (Roberts, 1978). Much of the coast is mangrove fringed. The fresh- and saltwater swamps have seen relatively little development and still contain substantial populations of crocodiles.

Papua New Guinea has two species of crocodiles: Crocodylus porosus (the saltwater or estuarine crocodile), a wide ranging species found all the way from the New Herbrides to India; and the endemic C. novaeguineae novaeguineae (the freshwater crocodile), found in Papua New Guinea and neighboring Irian Jaya.

Analysis of the last five years' trade figures show that 81 percent of all crocodiles caught in Papua New Guinea are freshwater and 19 percent are saltwater. However, taking into account the greater accessibility of saltwater populations to exploitation, the true proportions are likely to be even more in favor of freshwater crocodiles.

As a generalization, one can say that the saltwater crocodile prefers the coastal swamps, estuaries, and lower reaches of the large rivers and more open water systems inland. The freshwater crocodile is most common in the vast areas of heavily vegetated swamps associated with the rivers and lakes.

In actual fact, considerable overlap between the two species occurs. Saltwater crocodiles are found more than 500 km upriver on the Fly and Strickland Rivers (Hall, 1981), and populations of both species often live in the same lake (see Aerial Surveys). In the island provinces, where only saltwater crocodiles live, they also occupy habitat which would be called typical freshwater habitat (Whitaker, 1980). It is not known to what extent the present distribution reflects the historical distribution, or whether it is an artifact of earlier hunting, combined with differing patterns of population recovery.

The major areas of crocodile habitat are shown in Figure 1. In the north the most important area is the flood plain of the Sepik River where river movements have caused the creation of large numbers of frequently overgrown oxbows, lagoons, and lakes, many overgrown waterways, and much scroll country on the river bends. All of these are important nesting habitats for crocodiles, and this area currently produces the bulk of the harvest. Towards the lower part of the river roughly equal numbers of each species are found, with the proportion of saltwater decreasing upstream. In the Western Province the large Fly and Strickland Rivers used to support large numbers of saltwater crocodiles in the lower reaches. These animals were extensively shot out in the 1950s and 1960s, but may be recovering. However, this area is of most importance for the freshwater crocodile. The swamps around the upper reaches of the Fly, Strickland, June, and Boi Rivers, all contain large freshwater crocodile populations, and as the human population densities there are extremely low, hunting pressure is only slight (Hall, pers. comm.). This area alone could virtually ensure the future of the freshwater crocodile.

By contrast the adjacent Gulf of Papua is a complicated delta system with large areas of mangrove. The saltwater crocodile is more common there than the freshwater species, which is more restricted to the river's upper reaches. Workers in this area feel that there has been a significant expansion of the saltwater crocodile population here in the last two to three years (Rose, pers. comm.), although we do not yet have confirming data.

Smaller mixed populations occur farther east along both coasts. Many of the islands contain populations of saltwater crocodiles, but the freshwater species does not occur there. Ratios of the two species, as indicated by live purchase at farms in a number of locations, are also shown in Figure 1.

For at least 2,000 years, crocodiles traditionally have been exploited in Papua New Guinea for both meat and eggs for consumption (Allen, 1977). Due to the relatively small human population, this is unlikely to have had a significant effect on the wild population (Behler, 1976; Hope, 1977), and it seems that at the time of the arrival of Europeans, crocodiles were very common in virtually all lowland rivers and swamps (Whitaker, 1980). With the arrival of expatriate hunters and buyers in the 1940s, and the subsequent high demand for skins, this balance was significantly altered. In the 1950s and 1960s large volumes

of skins were exported from Papua New Guinea. Due to its predominance in the more accessible open waters, it was the saltwater crocodile which took the brunt of the exploitation. Many areas, such as the lower reaches of the Fly and Sepik Rivers which had supported large saltwater populations, were virtually shot-out (Behler, 1976).

Government concern about overexploitation of the crocodiles was the main factor in the establishment of a Wildlife Section in the Department of Agriculture Stock and Fisheries in 1966. This Wildlife section, under the guidance of Max Downes, was responsible for the development of the country's innovative policy of a crocodile industry based on the farm rearing of wild-caught hatchlings. Another important move was the introduction of a law banning the sale of skins of more than 20 inches "commercial belly width" (rather than by length, crocodiles in Papua New Guinea are classified according to the belly width of the skin, a measurement made between two specified thoracic scutes.), hence protecting the breeding stock. These measures seem to have halted the population decline and during the 1970s Papua New Guinea was producing a steady crop of between 25,000 and 50,000 freshwater crocodiles and 4,000 and 10,000 saltwater crocodiles a year (see Trade Statistics). Fluctuations during this period seem to have been dependent on the dry season water level, when most crocodiles are caught, as is indicated by the similarity in trends between the two species. No overall decline is apparent. The previous steady drop in average size (which also indicates overexploitation as larger skins are preferred) was also reversed.

MONITORING AND ECOLOGICAL RESEARCH

It is obvious that any worthwhile management of a wild population must be based on as full an understanding as possible of the animal's biology and of all factors affecting its productivity. It must also include detailed monitoring of the wild population to examine the effects of the cropping; only in this way can an approach to the goal of "maximum sustainable yield cropping" be made.

The most immediate requirement for the monitoring program is to be able to assess whether populations in different areas are constant, increasing, or decreasing. For this purpose, it is not necessary to know exactly how many crocodiles there are in an area. It is considered a higher priority to try and establish an index of population change rather than concentrating on producing a total population figure of more questionable accuracy. Our knowledge of crocodile population dynamics is not sufficiently advanced for even an accurate figure for the population size to be able to tell us whether present cropping levels are sustainable.

Direct Counts

The logical starting point for such a programme would seem to be to conduct a census to discover the size of the resource, a task which

Figure 1.

DISTRIBUTION OF CROCODILES IN PAPUA NEW GUINEA.

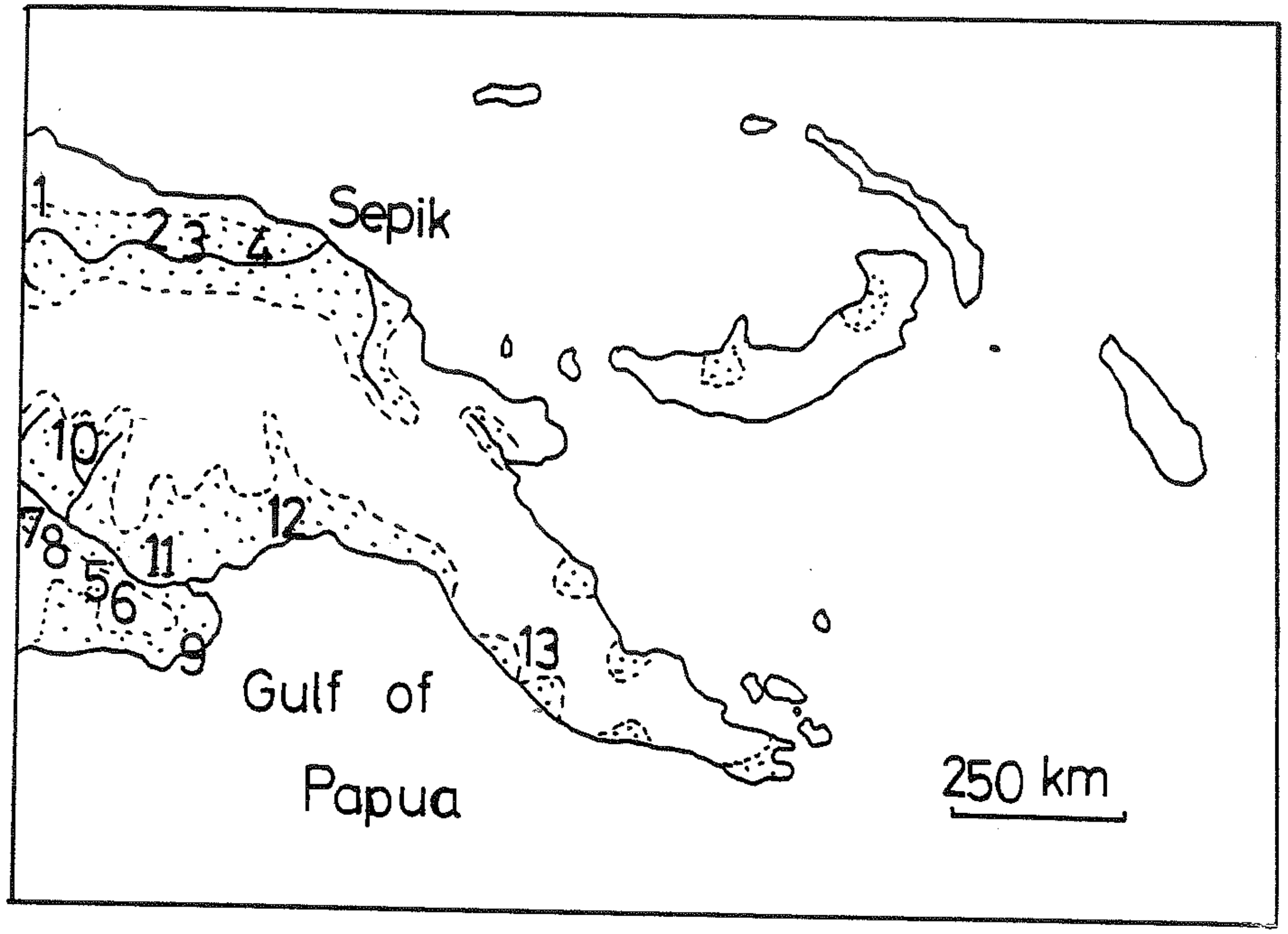
SUITABLE CROCODILE HABITAT

SPECIES DISTRIBUTION ON A RANGE OF CROCODILE FARMS

	FARM	%FW	%SW		FARM	%FW	%SW
1.	GREEN RIVER	98	2	8.	KAMOVAI *	96	4
2.	AMBUNTI	80	20	9.	DARU *	79	21
3.	PAGWI	80	20	10.	BABOA	97	3
4.	ANGORAM	84	16	11.	BALIMO	75	25
5.	INAPOROKO *	73	27	12.	KIKORI	21	79
6.	PUKADUKA *	66	34	13.	PORT MORESBY	67	33
7.	BOSSET *	98	2				

THESE ARE ALL AS INDICATED BY THEIR TOTAL 1981 LIVE CROCODILE PURCHASES, EXCEPT THOSE MARKED *, WHICH ARE FROM A 1981 STOCK-TAKE AS DETAILED IN BALSON (1981).

Fig One



outside bodies have long advocated for Papua New Guinea. One of the easiest methods of censusing crocodile populations is by direct counts of animals at night utilizing the bright reflections from a crocodile's eyes with a spotlight. Such night counts of river systems have been successfully used in Australia (Messel, 1977; Messel et al., 1978; Messel et al., 1979-81) for the last 10 years.

One problem encountered with this method is that the number of crocodiles seen depends on a variety of other factors, such as relative air/water temperatures, water level, weather, stage of moon, vegetation, and level of past hunting, and not just the density of crocodiles. Where conditions are relatively uniform, and it is known that a substantial proportion of the population is accessible to the counting team, it is worthwhile making sufficient repeat counts to use multiple regression to assess the effect of each variable. A true population figure can then be calculated.

Unfortunately, in Papua New Guinea there are a number of problems with this technique. Conditions are extremely variable so separate conversion factors for each area would be required, and many factors, such as the level of past hunting, would be impossible to quantify. However, the main problem is that only a very small proportion of the population is accessible. Most of the crocodiles in Papua New Guinea do not live on the rivers. They live in the vast areas of overgrown channels, choked oxbows, levees, and swamps behind the open water. These areas could not be sampled by this method, due to the density of vegetation and lack of open water. A census of the rivers would be of dubious value and probably not worth the expense of obtaining correction factors for it.

This can best be illustrated by an example. Montague (1981) quotes details of a night count census he conducted in the Lake Murray District in 1979/80 during which he recorded 1,112 crocodiles. Using the conversion factor that 63 percent of crocodiles are visible (as calculated in Northern Australia by Messel et al., 1981) he claimed the area contained 1,765 crocodiles. Since then an analysis of the trade statistics for that area has been conducted, and during this period it was producing a mean minimum annual crop of 4,724 crocodiles. Clearly he can only have been sampling a small proportion of the population.

Direct counts have therefore been rejected as a primary data base, as it is considered an inappropriate method for the conditions existing in Papua New Guinea.

Aerial Surveys

In some countries aerial surveys can be used to directly count crocodiles either in the water or basking on the bank (Cott, 1968; Graham, 1968; Parker and Watson, 1970; Watson et al, 1971; Turner, 1977). Unfortunately, in Papua New Guinea most of the crocodiles live in heavily vegetated swamps where visibility of the crocodiles is poor. It was therefore decided to concentrate the census work on crocodile nests (Graham, 1980). Not only do aerial nest surveys provide data on the segment of the population we are most concerned with, the breeding females, but crocodile nests are more visible than the crocodiles and they do not run away or bite.

This method has been chosen to calculate an index of population change which is considered to be most appropriate for local conditions. It is based on repeat annual helicopter counts of nests in preselected sites. These sites were chosen from areas considered to be reasonably productive and include both areas with high and low population densities, but considered to have potential for supporting larger numbers. Areas also have been selected to include a range of sites known to have high, medium, and low hunting pressure. It is appreciated that selection of sites in this manner precludes the use of the results for extrapolating a total population figure; however, changes in these areas should be proportional to changes in the total population. Random censusing of a large enough sample to allow small changes to be identified would be prohibitively expensive.

We are systematically covering adjacent swamp areas as well as the annual census sample sites. It is hoped that within the next two to three seasons, most of the suitable crocodile nesting habitat in the middle Sepik will have been censused at least once. We will then be in a far better position to use the aerial counts to quantify the size of the resource. A major handicap to any current extrapolation is the absence of vegetation maps of sufficient accuracy and reliability to allow stratification of the habitat.

Routes are carefully plotted on aerial photographs and the same route flown in consecutive surveys, with band width, height, and speed held constant. When a nest is seen, closer examination is made to confirm identification and to classify the nest as active or inactive. Counts are conducted at 25 knots (ground speed) at a height of 45 meters (150 ft.), and with one observer covering a 100 meter wide band.

When feasible, a drop is made to the nest for species identification and data collection. If it is not possible, then an attempt is made later to visit the nest by boat or on foot, if it is thought that this will not cause hunters to follow later and raid the nest.

Figures 2 and 3 show two sample sites in the East Sepik in consecutive surveys. Kwandimbe lagoon was surveyed in the low-water of 1980 and 1981 and the high water of 1982. It can be seen that there was no change in the observed breeding population from 1980 to 1981. The next survey will be in October 1982. Figures 3 and 4 show the Wasui and Wagu Lagoon area in the low water survey in 1981 and the high water survey of 1982. Both locations contain breeding populations of both species, though there is a seasonal difference in nesting.

Fig 2

Aerial surveys of Kwandimbe Lagoon

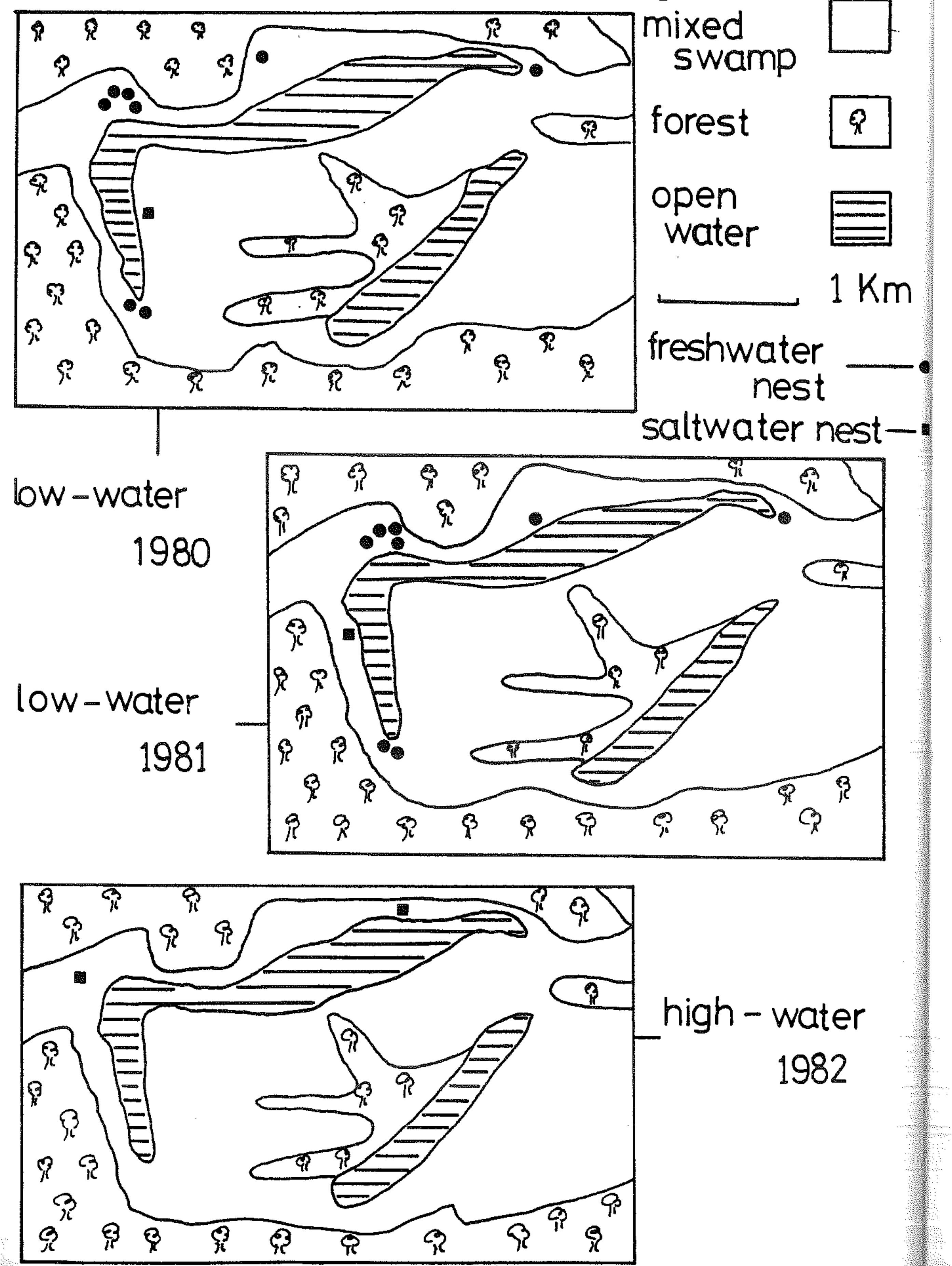


Fig 3

Aerial survey of Wasui and Wagu Lagoons. Low-water 1981

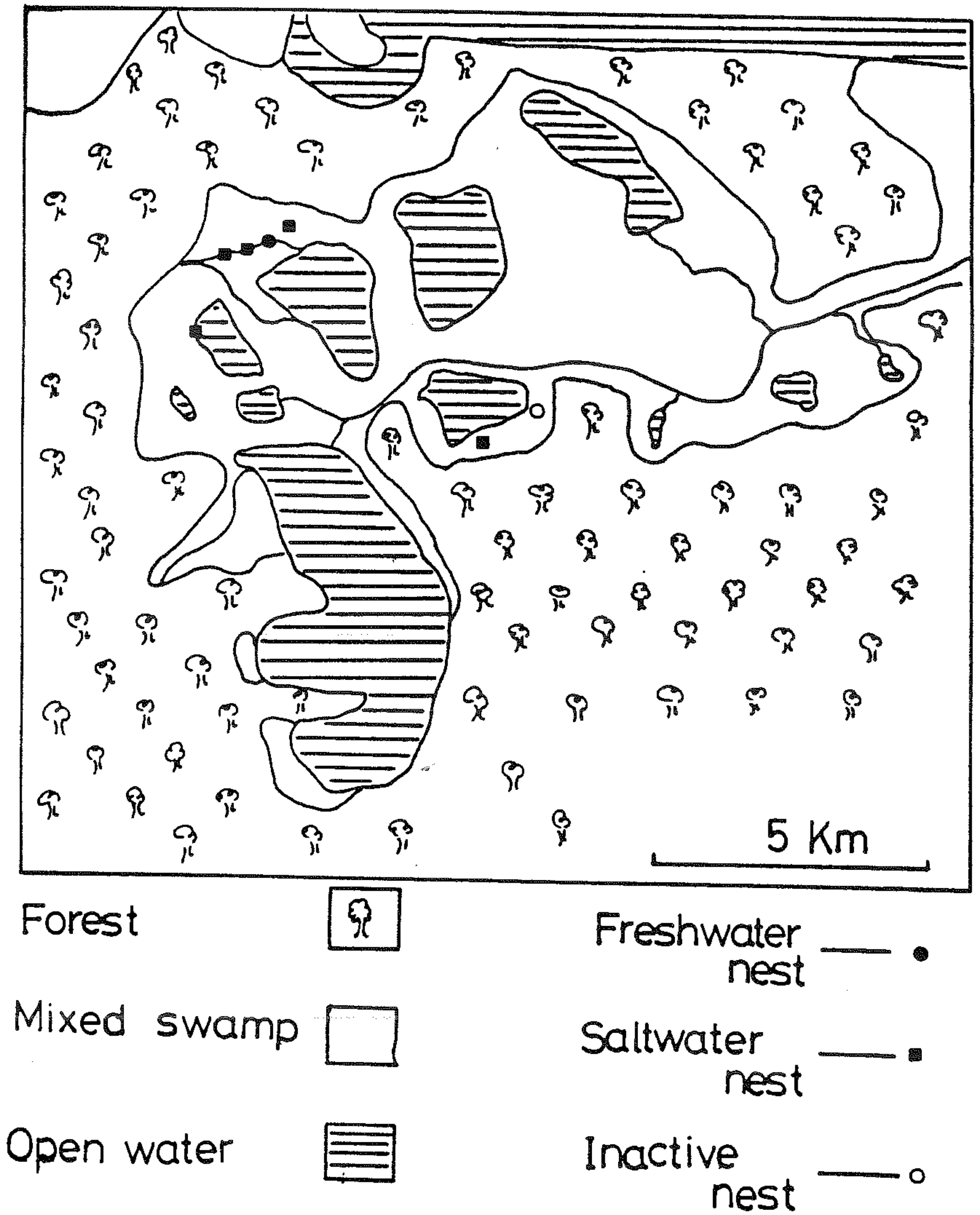
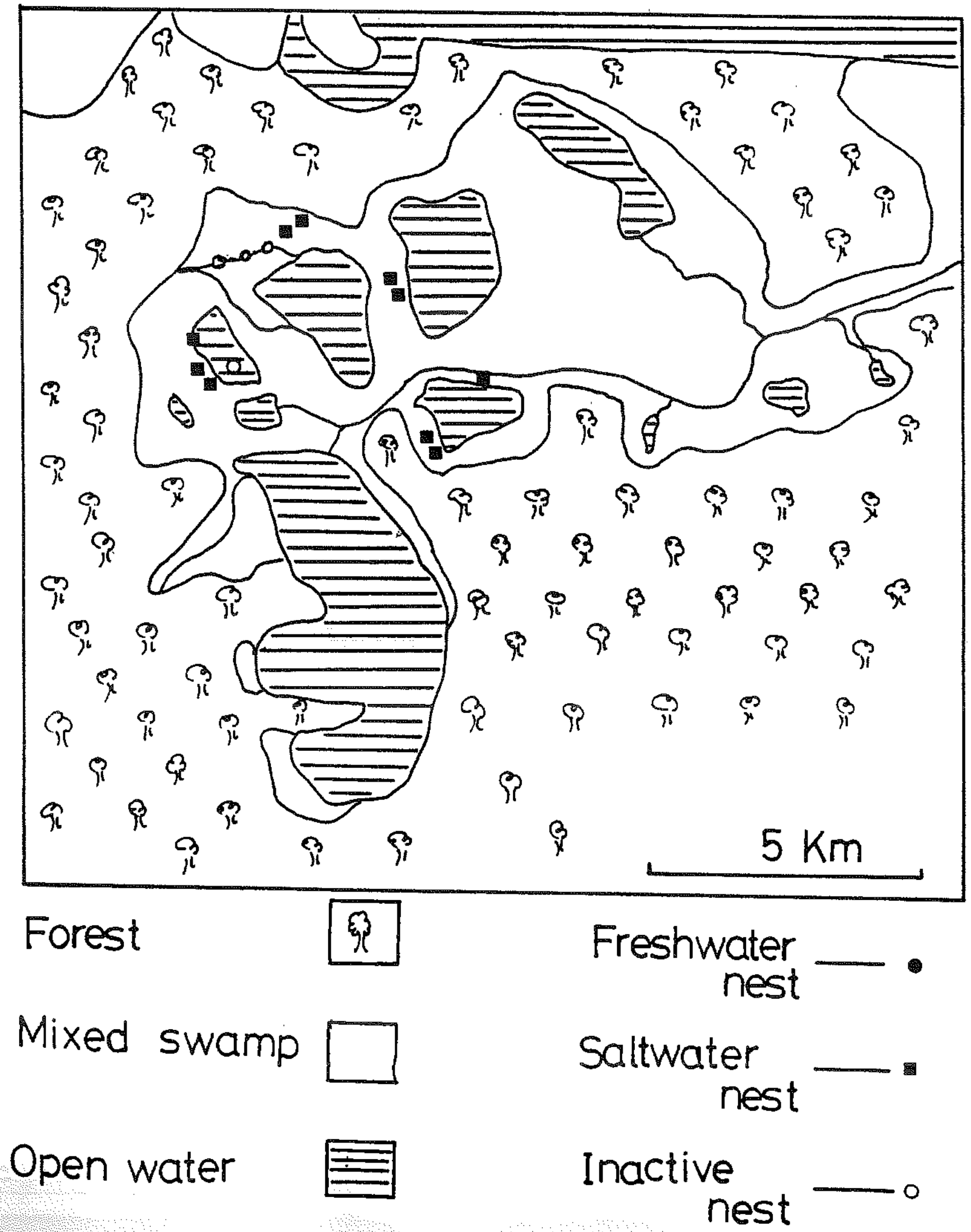


Fig 4

Aerial survey of Wasui and Wagu Lagoons. High-water 1982



Not all nests will be visible in an aerial survey such as this, but visibility in different habitats can be assessed from nests known from ground surveys. The use of identical flight routes in each year minimizes any effect differences in visibility would have on the results. This will be reviewed when more is known about the rate of vegetation succession in the area.

Helicopter surveys are also good at identifying key nesting areas which may not be known from ground visits, either because of access problems or because the local villagers do not exploit the nests and so do not know of their existence. A good example of this is the Kwarsu Lagoon (Fig. 5), which was not known to the local field officer until the 1981 survey. Within the 2 km^2 of floating vegetation surrounding the two small lakes were 13 active freshwater nests, mainly supported by strong patches of Acrostichum ferns.

Aerial surveys also allow access to a sample of nests yet undisturbed by hunters, therefore allowing studies of future exploitation levels to be conducted. This method of surveying is appropriate to almost all of the Sepik and Ramu floodplains, much of Western Province, and parts of the Papuan Gulf. Financial constraints obviously limit survey time and subsequently the sample size. It is anticipated from current results, that the annual census will include approximately 250 nests (at 1981 densities). It will obviously be some time before we can identify trends, let alone understand them.

Close examination of "nests" is required to differentiate them from structures of similar appearance made by pigs for sheltering their young.

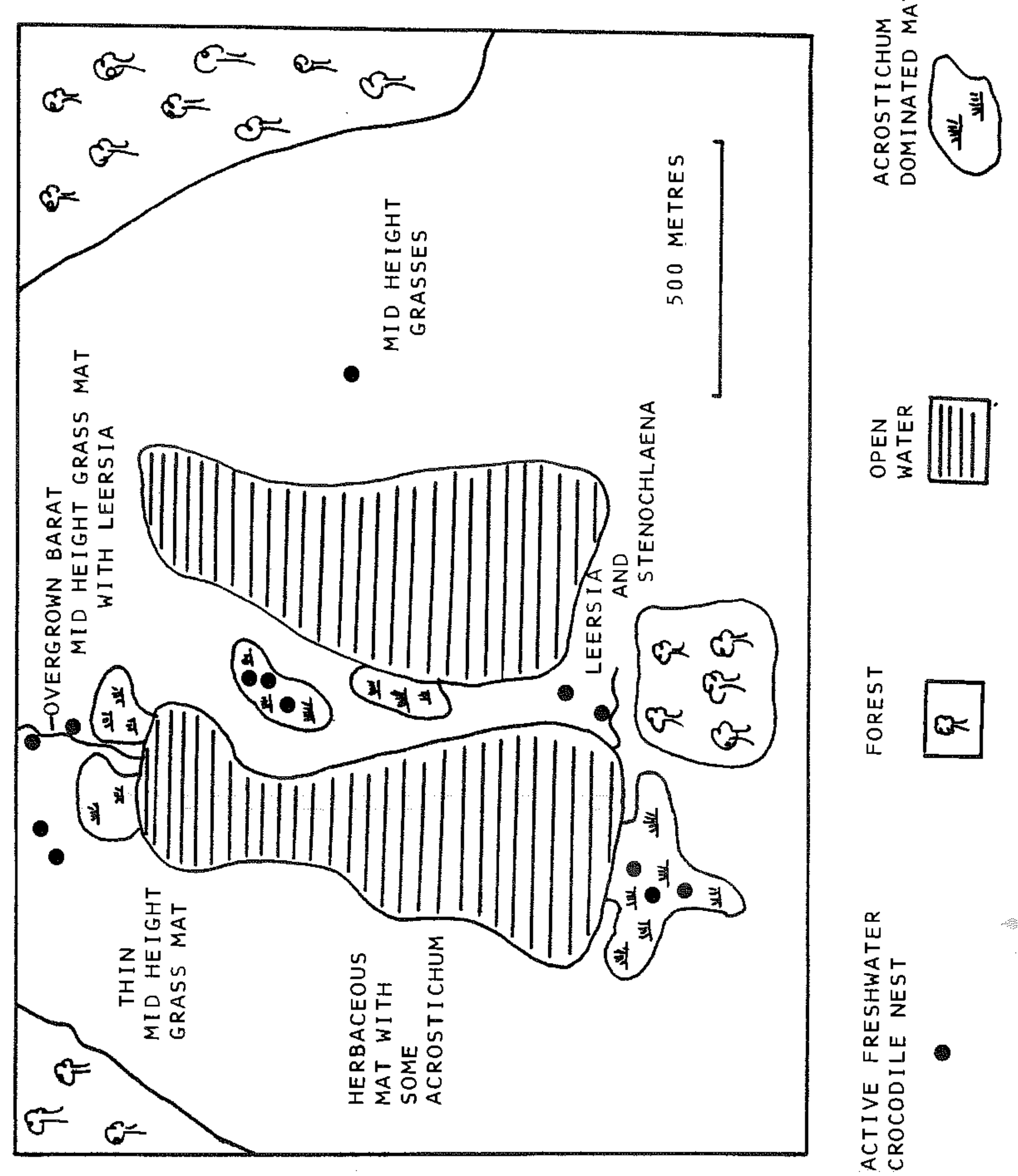
An obvious initial worry was whether close helicopter inspections, and particularly drops onto the nests, would cause nest abandonment. Return visits have not shown any evidence of this, and nests which had drops made at them in 1980 were not moved in 1981 (see Fig. 2). We will try to get sufficient data to prove this.

Nest Visits

Prior to the establishment of the monitoring component to the crocodile project, virtually no biological information concerning the breeding of freshwater crocodiles was known. This information is required to make correct management decisions leading towards sustainable yield cropping. Our knowledge is still far from complete. Although *C. porosus* has been extensively studied in Australia, conditions in Papua New Guinea are very different. The extremely secretive nature of both crocodile species, particularly after hunting, makes direct observations on them in the wild extremely difficult. Fortunately most of the data required to examine productivity can be obtained from inspections of the nests alone. The tradition of nest exploitation in the Sepik and Western Provinces has resulted in a strong local knowledge of nests, and local hunters have been able to guide us to a large number of nests in these areas. In Gulf Province, where there is not such a tradition, data collection is much slower.

Fig 5

AERIAL SURVEY OF KWARSU LAGOONS, SEPIK LOW - WATER 1981



Results of the studies on the nesting ecology of both species appear in a number of project documents (Graham, 1981; Hall, 1981; Cox, in prep.) and so will not be detailed here.

Some of the most important information from a management point of view concerns factors affecting nest failure. In Australia, it was found that flooding destroyed more than 90 percent of saltwater crocodile nests (Webb, 1977). If Papua New Guinea had similar levels of flooding it would be necessary to move population cropping from the hatchling stage to the egg stage. It has been found, however, that flooding is of only minor importance in Papua New Guinea. In Western Province it is believed only to cause failure in one percent of nests (Hall, 1981). Nests are either built on relatively high banks, and above the maximum high water level, or are on floating vegetation mats which rise with the water level. Here, nest success has been calculated to be high, with as many as 75 percent of eggs hatching. Principal mortality factors are man, wild pigs (Sus scrofa), and monitor lizards (Varanus spp.).

In the Sepik most nests are on floating mats and flooding is of minimal importance. Man is the largest principal factor in saltwater crocodile egg mortality (Cox, pers. comm).

Due to concern about nest visits, an early study showed that visited nests do not have a lower hatching frequency, nor is the percentage of nest site reutilization affected the following year. It would therefore seem that, if care is taken, these visits are not detrimental (Hall, loc. cit.).

In the Sepik, the best studied area, the freshwater crocodiles are restricted to breeding during low water periods, whereas the saltwater crocodiles breed all year, with significantly more breeding during high water. It is interesting to note that at the government farm in Port Moresby breeding in both species is during the wet season and appears to be induced by the first rains.

Another advantage which has accrued from nest visits, together with research on the government farms, is the correlation which has become evident between female size (age) and clutch/egg size (Graham, 1981). Although there may be other yet unknown factors involved, the correlation is sufficient to allow nest examination alone to be used to examine the age structure of the breeding females in an area. This allows for a check on the level of recruitment to the breeding population.

Trade Statistics

Full details on that segment of the population which is cropped must be known for any management decisions. Previously, this information has only been available at the time skins are exported and consists of compounded skin figures from a number of areas. This is insufficient to check individual populations, and it is theoretically possible that it could hide even substantial declines in particular areas.

To overcome this factor we have introduced a system whereby each crocodile removed from the wild population will be recorded at the point of first transaction. Hence, a far more detailed picture will emerge. To ensure maximum cooperation, the dockets used are paid for by the national government and make the obligatory record keeping for every buyer much simpler. These have been well received by all people in the trade.

The information from the dockets is transferred to computer for ease of data handling. If biological analysis is required, the crop is divided into different age classes. Further information is required on growth rates in the wild before confidence can be put in the age distribution. Although the crop alone cannot tell us all we need to know about the population, it is of great assistance. Caution must be exercised, as the farming system is substantially altering hunting methods. One species may become easier to capture than the other. It does give a good indication, however, of whether sufficient animals are reaching maturity to replace any deaths in the breeding populations.

As the crocodile management project is run for commercial as well as conservation motives, the trade statistics are also of great interest from an economic viewpoint. The steady increase in average size of exported skins (Fig. 6) which has occurred for both species since 1975 is therefore taken as a sign of progress in the aims of the project.

Catch per Unit Effort

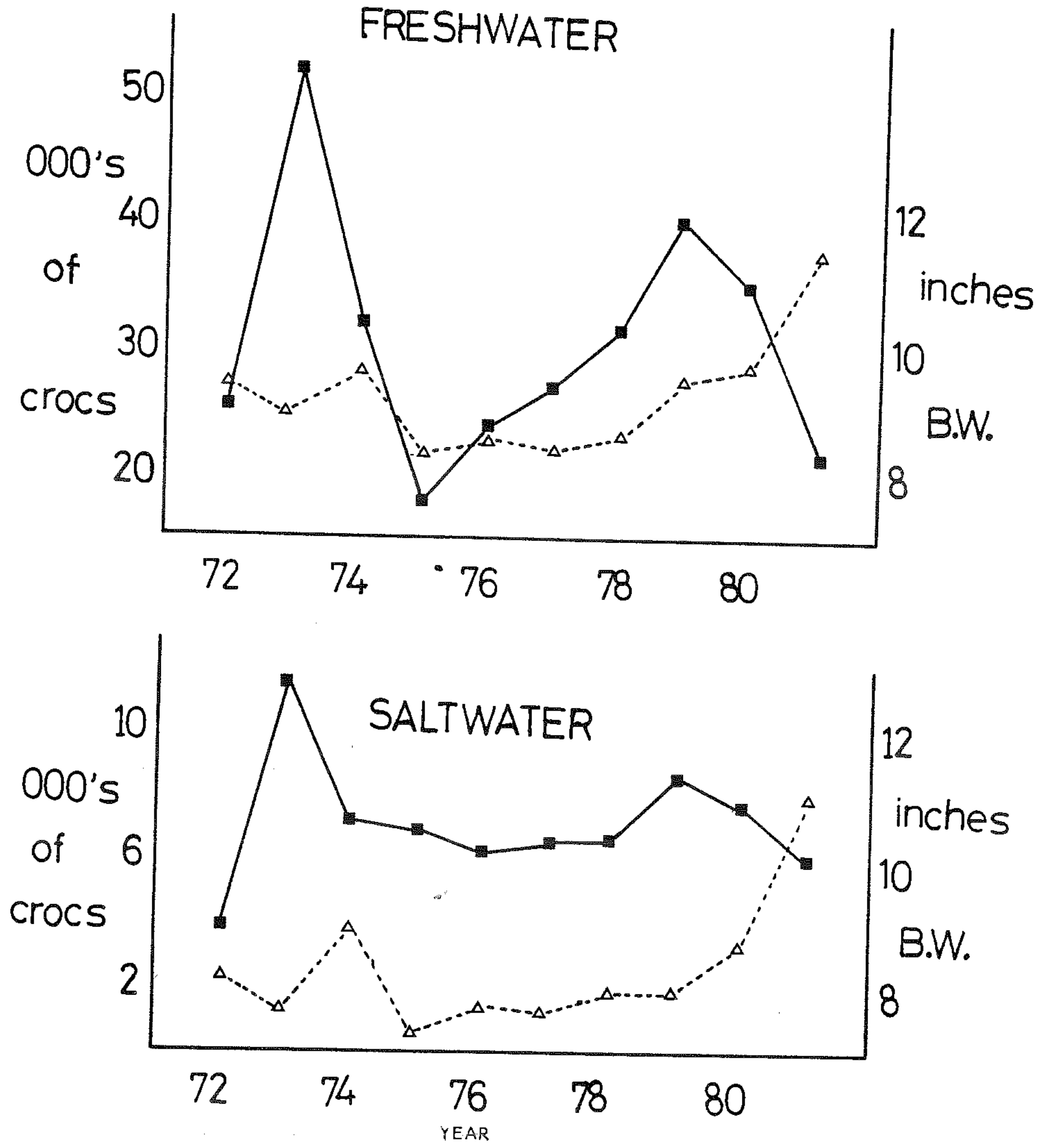
There are some areas in Gulf Province, particularly the mangrove swamps, where both aerial surveys and ground visits are extremely difficult. In these areas two pilot schemes are being conducted to monitor population changes by examining the catch of a selected group of hunters obtained over a known period of hunting. This is recorded on every hunting trip they make and will be analyzed in the same way as fish catch statistics. It will obviously be some time before we can really assess the potential of this monitoring method.

Crocodile Tagging

We still have virtually no information on some important aspects of the biology of wild crocodiles in Papua New Guinea and assumptions have to be made based on information from farmed animals. Two of the most important of these are growth rates (needed to accurately age wild populations) and mortality rates. As an assumed high juvenile mortality is frequently referred to, but yet has to be proven, for a recovering population (Webb *et al.*, 1977; Webb, 1978; Burgin, 1980), juvenile mortality must still be determined. If it is proven that the period of high mortality occurs before our present cropping levels, we will have to consider starting to harvest at the egg stage.

Experimental design for a large scale tagging scheme is being drawn up. This should be underway within the next six months with the anticipated assistance of a UN sponsored consultant.

Fig 6



ANNUAL MINIMUM CROP OF CROCODILES TAKEN IN P.N.G. ■——■
MEAN SIZE OF EXPORTED SKINS △----△

Captive Breeding and Husbandry Research

Up to date findings on crocodile husbandry in Papua New Guinea appear in Bolton (1981) and are reviewed in a recent paper on crocodile farming in Papua New Guinea (Rose, 1982). The sections of most relevance to the conservation and management of the population are those of captive breeding and hatchling care.

Breeding has not been conducted on a commercial level in Papua New Guinea, as government policy has been that if the wild population can sustain the cropping, it is in the best interests of the rural people for hatchlings to be caught by village hunters for stocking the commercial farms. All breeding has been for research purposes on government farms, and is conducted in small colonies under conditions as close to natural as possible with disturbance kept to a minimum. Eggs are removed from the nests only approximately 10 days prior to hatching.

The government has now granted permission for commercial farms in Papua New Guinea to conduct breeding, and the two major farms have both 00pressed a wish to conduct trials. Breeding stock would either come from the government farms or would be commercial stock not culled. As described in Bolton (1981), we have now developed methods of hatchling care and feeding which give good growth rates and relatively low mortality. Out of the 409 saltwater crocodiles hatched this year, 84 percent were still alive after six months. Seventy-one percent of the freshwater hatchlings also survived. Not only is good hatchling care essential if breeding is to be undertaken for commercial or restocking reasons, but it allows for greater flexibility in choosing the optimum cropping age. Previously, poor survival of small hatchlings precluded cropping at below 3-4 inches belly width, whereas in the future cropping could even be carried out at the egg stage.

In a few locations, village farms already rely on egg collection for their stock. Where local food supplies are suitable, these can be very successful; for instance an abundant supply of freshwater prawns at Momeri village in the Sepik has allowed hatchlings, taken as eggs, to grow very rapidly and with very low mortality (Cox, pers comm).

Population Simulation

With the kind assistance of the United States Fish and Wildlife Service, a computer simulation model has been adapted for the Papua New Guinea populations. This program is now fully operational and has had trial runs. Once we have more detailed parameters for growth and mortality, it is anticipated that the program will be extensively used to model population changes under alternative management strategies. It would also be used to generate sensitivity studies to identify the most crucial areas for further research.

CONSERVATION MEASURES

As has frequently been stated, the whole crocodile management project can be considered as a conservation measure. It shifts the emphasis of the cropping away from the more vulnerable adults to the more readily replaced young. It also contains a monitoring program that feeds directly into management decisions; the ecologically sound (though in practice hard to achieve) principle of "maximum sustainable yield harvesting" will be the project's overall goal (project rationale is explained in Downes, 1971, 1978; Bolton and Laufa, 1982; Rose, 1982).

For such a management strategy to be successful, it is vital that sufficient protection be given to the breeding stock. With this in mind, legislation was enforced nationwide in 1975 which makes it illegal to trade in skins of more than 20 inches commercial belly width. However it now appears that, particularly in freshwater crocodiles, breeding starts under this size and consideration is now being given to lowering this limit to 16 inches. As any increase in breeding stock should increase the young available for farm rearing, such a size limit reduction can be argued from both conservation and economic viewpoints (Hollands, 1982).

More difficult than protection of the adults is the problem of protection of the nests, which are frequently raided for eggs to eat. When considering conservation in Papua New Guinea, a degree of appreciation of the system of land tenure is needed. More than 95 percent of land in the country is still held under traditional ownership, which means that all crocodiles (and nests) on that land are owned by the landowner who has full power over what he does with them. Conservation of the nests therefore only can be enacted by continual publicity and encouragement in the villages by crocodile project and wildlife staff. The economic return from the hatchlings is also a powerful argument. Definite progress has been made in most areas. In Western Province, removing eggs for eating is now very rare (Hall, 1981), while in parts of the Sepik it is still common. As people know our officers strongly disapprove, people will not readily admit to the practice, and so accurate statistics are hard to obtain.

The current handing over of live supply networks to provincial governments, who will have to run them on commercial grounds, should have beneficial effects. The envisaged price increase for live young will not only help shift the wild killing to live capture, but will increase the attraction of leaving nests to hatch. A reduction in maximum size limit would also halt the practice of setting baited shark hooks at nests, a practice which is still occurring in the hope the female will yield a legal size skin. As this is a practice that directly affects crocodile production, it is a serious problem.

The presence of 35,000 crocodiles on farms acts as a buffer to overexploitation, and provides animals for selected restocking programs in areas where overhunting in the 1950s and 1960s substantially reduced the saltwater populations. One area in Gulf Province has had 43 adult saltwater crocodiles released into it. The results of this pilot scheme are being studied before the next release is made. Before release took place, a formal agreement was made with the local people who agreed not to kill the crocodiles (Anon., 1981).

Preliminary discussions are also underway in the Sepik and Western Provinces to obtain local agreement for release sites there. Commercial farms are aware that if the monitoring program feels it necessary they would be obliged to provide a set percentage of their stock, reared to breeding size, for restocking. One of the provincial governments, which is at present establishing a commercial farm, has already agreed to reserve a set quota of adults for release (Rose, pers. comm.).

Once an effective live purchase system was established to allow the sale of hatchlings, moves were made to prevent the wasteful slaughter of small crocodiles which would be better sold to farms. After a large scale survey of village opinion was made, a law was enforced in 1981, with considerable local backing, which banned the sale of skins under 7 inches belly width.

In Papua New Guinea the main thrust of conservation is on a local level. Instead of nationally owned parks, villages are encouraged to establish their own management areas; wildlife officers help draw up rules and management plans, and these are then administered by a local committee. These frequently prevent poaching of crocodiles or eggs by neighboring villagers and make campaigns of nest preservation and bans on killing adults much easier to operate. At present two key crocodile breeding sites in the Sepik and another in Central Province are being established as wildlife management areas, and it is anticipated that more will be declared in the future. Unfortunately, land ownership disputes frequently cause long delays in the declaration of these areas.

SITUATION OVERVIEW

The monitoring section of the crocodile management project is very new and methods are still being developed. Monitoring population trends is a long-term task with no immediate answers. It will be a number of years before a clear picture emerges. It is being treated as the highest priority item for the project with increased emphasis being planned. At present, the monitoring team consists of four full time officers (one provided by UNDP) with other back-up staff and field assistants. An additional scientist is being recruited at present.

As we have not had sufficient information to be able to confidently assess the size of the Papua New Guinea crocodile population, no official figures are quoted. When figures are quoted (e.g., "200,000," Medem, 1976; "an expanding population of 200,000," Grey, 1982), they have been from outside people and with little data to back them up. It is hoped that from our aerial surveys, which not only cover the selected sample

sites, but are slowly covering all suitable habitat in the Sepik, we will soon be able to put a figure on the breeding population for this area. An attempt will be made to see if quoted figures are of the right order of magnitude, based on our ground counts and current surveys.

Graham (1981) detailed hunter based surveys and used helicopter based surveys to determine the percentage of nests that hunters knew of, and used these figures to make an approximate population estimate. In an area where the helicopter survey showed 71 nests, hunters knew of 52 nests. From the number of known nests seen on the survey, it was concluded that 38.8 percent of nests are visible from the air, hence hunters knew of only 28 percent of existing nests. Extrapolating this out for the whole flood plain would indicate there are between 80,000 and 100,000 freshwater crocodiles producing 138,000-178,000 eggs a year and between 20,000 and 26,000 saltwater crocodiles producing 52,000-67,000 eggs a year. These figures seem to be in line with the numbers being found as more of the Sepik is covered by the aerial surveys.

As the Sepik floodplain is heavily hunted and contains only 30 percent of the available suitable habitat, it would appear the true population is likely to be more than double the previously quoted figures.

The crocodile industry in Papua New Guinea is not only important to the country as an export earner, but is really the only cash income that people can get in many areas where there is little agricultural potential. The switch to farming, still very actively encouraged by the government, and the ban on small skins have significantly boosted the value of the industry. When full production of farmed skins is reached, the industry should earn Papua New Guinea about US $3.6 million a year. It is believed that this can be achieved without endangering the wild population.

Both species of crocodile in Papau New Guinea would seem to be in a fairly safe position. Any overexploitation would be identified by one or more of the following methods:

(1) The aerial surveys would show any decline in the breeding population.

(2) Nest visits allowing the determination of age for nesting females would show if there was insufficient recruitment to the breeding population.

(3) The skin statistics from hunted populations would show if insufficient animals appear to be approaching breeding age.

Two areas that will require careful attention in the coming years are the effects of Salvinia and barramundi fishing. The Salvinia infestation of Sepik lagoons is aready being tackled by a UN team, but it is likely to be a few years before it is eradicated. Although crocodiles still nest on heavily infested lagoons, the long term effects on food availability are not known. One agent known to be responsible for the deaths of a number of adult crocodiles is the placement of large mesh nets for barramundi. It has not yet been possible to assess the effect of these drowned adults on the breeding population. This would seem to be an area in which conservation based on controlled exploitation has an advantage. If barramundi nets have to be banned in certain areas the arguments of a multi-million dollar crocodile lobby might be more effective than one made on purely conservation grounds.

If it appeared that populations, either in certain areas or the whole country, were in serious decline the situation could still be managed. The presence of 35,000 crocodiles on farms in the country acts as a substantial buffer against extinction. Restocking with animals produced from these farms could also be used in isolated areas where just one species (e.g., saltwater) had been overhunted in the past and the introduction of a set "release quota" could be established for farms.

We therefore believe that the Papua New Guinea crocodile management project should be encouraged as an example of how conservation and economic exploitation can go hand in hand. As most of the world's remaining natural populations exist in developing countries that have to take utmost account of economic implications, such projects should substantially help conservation at the global level.

ACKNOWLEDGEMENTS

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CLASSIFICATION AND POPULATION STATUS OF THE AMERICAN ALLIGATOR

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Since passage of the Endangered Species Act of 1973, the U.S. Fish and Wildlife Service designated that the American alligator (*Alligator mississippiensis*) be placed in three basic classifications: endangered, threatened, or threatened due to similarity of appearance (S/A) throughout its range in the southeastern United States. These categories simply designate status of the animal in relation to its recovery or rate of recovery. Generally, the status of endangered indicates a low population within a geographic area, whereas the threatened status indicates an increasing population well on its way toward recovery. Threatened due to similarity of appearance indicates a recovered population. Other important factors are considered in making these determinations. These include habitat evaluations; state research, management, and enforcement programs; natural mortality; utilization; the adequency of regulatory mechanisms; and miscellaneous other factors. Today, alligators are classified as threatened in 23.8 percent of their range, as endangered in 61.8 percent of their range, and as recovered in 14.4 percent of their range (Table 1). The historic stronghold of the alligator is for practical purposes the 38.2 percent of the range presently classified as recovered (threatened S/A) or threatened. Peripheral range areas and counties with limited habitat (a large percentage of the overall range) will probably retain a restrictive classification status indefinitely. Therefore, one must take this into consideration when interpreting Table 1. Classification status reviews are periodically conducted by the U.S. Fish and Wildlife Service, usually as a result of state petitions to change the legal status of the alligator. The collection of biological information pertaining to status reviews has greatly enhanced management capability for the alligator.

Since the IUCN/CSG meeting in Gainesville, Florida, August 12-16, 1980, the U.S. Fish and Wildlife Service reclassified the biological status of the alligator in only one state. As a result of reclassification, the entire State of Louisiana was classified as threatened S/A, effectively returning management authority back to the State.

The American alligator in Texas has been proposed for reclassification from Endangered and Threatened to Threatened due to

TABLE 1. Alligator Classification Status by State--September 15, 1982

	Number of Counties			
	Threatened S/A	Endangered	Threatened	Total
Mississippi		55		55
Alabama		33		33
North Carolina		21		21
Texas		60	14	74
Arkansas		3		3
Oklahoma		1		1
Georgia		74	21	95
Louisiana	63			63
Florida			64	64
South Carolina		23	5	28
TOTAL	63	270	104	437
Percent	14.4	61.8	23.8	

similarity of appearance (Federal Register 9/13/82). A final rule, if approved, will change the status of all alligators in Texas to the special category of Threatened due to similarity of appearance.

In August of 1980, the U.S. Fish and Wildlife Service issued a final rulemaking allowing the nationwide sale of alligator meat and parts. Rules and regulations governing the sale of Louisiana alligator meat and parts were promulgated by Louisiana's Food and Drug Control Unit, Office of Health Services and Environmental Quality, and the Louisiana Department of Wildlife and Fisheries and adopted by the U.S. Fish and Wildlife Service in the August 1980 rulemaking.

Population Status by State

Ten states contain alligators in all or parts of the state. In general, alligator populations are increasing throughout the range. Areas on the fringes of the range generally have stable populations and cannot biologically harbor high densities characteristic of states bordering the Gulf of Mexico.

Louisiana. The 1982 coastal marsh population, where nest count indices were used to calculate population levels, increased approximately 27.3 percent as compared to the 1981 census. Water levels affect the degree of nesting, a factor which must be considered when making annual population estimates based on nest transects (McNease and Joanen, 1978). Nest count estimates have shown an annual increment of approximately 13 percent since initiation of the surveys in 1970. In areas of the state where the nest count method is not feasible, standardized night count transect lines were conducted. Night count data were then applied to population modeling. Louisiana personnel surveyed 27 different areas of the state, covering a total distance of some 235 miles. Alligators per mile averaged 3.3 for the 27 transects (Chabreck, 1981).

Florida. Population increases are occurring throughout Florida (T. Hines, personal communication 1980). One inland lake surveyed by the nest count method increased from 45 nests in 1978 to 90 nests in 1979. Summarization of night count data by year demonstrated an average of 5.0 alligators observed per mile in 1974, 4.6 per mile in 1975, 6.3 per mile in 1976, 9.4 per mile in 1977, 6.8 per mile in 1978, 7.4 per mile in 1979, and 8.3 per mile in 1980 (A. Woodward, personal communication 1982).

Georgia. A 1982 alligator population survey indicated population increases are occurring in most of Georgia. An analysis of population trends by counties showed that 61 were increasing and 41 were stable. The statewide population was estimated at approximately 101,644 over a 102 county area, with 9,100 square miles of alligator habitat (S. Ruckel, personal communication 1982).

Texas. The 1982 statewide population was estimated at 85,865, a 25 percent increase since 1980. Alligator habitat was estimated at 5,735

square miles in 1982. The statewide average density was estimated at 15 alligators per square mile (B. Brownlee, personal communication 1982). Seven night count surveys covering 31.8 miles averaged 3.8 alligators per linear mile in Texas.

Alabama. No current population estimates are available for Alabama. Five night count routes covering 51 miles in length were run and averaged 2.3 alligators per mile (Chabreck, 1981).

Arkansas. The alligator's range is limited in Arkansas. The trend for Arkansas alligators indicates a stable to slightly increasing population. Since 1972, the state restocked 2,700 alligators from Louisiana in 34 counties lying within the historic range of the species (S. Barkley, personal communication 1982).

South Carolina. Of 28 counties containing alligators in South Carolina, 12 reported increasing populations. Increases were estimated as much as 5 percent. Sixteen counties reported stable populations. The best habitat is associated with the coastal impoundments and marshes, comprising approximately 100,000 acres in Georgetown, Charleston, Colleton, and Beaufort counties. The next tier of counties inland represents moderate to high alligator densities and a significant amount of habitat particularly in Berkley and Jasper counties. The amount of suitable alligator habitat from these counties to the fall line diminishes rapidly with generally isolated ponds supporting small populations. South Carolina reports approximately 250,000 acres of alligator habitat statewide (T. Murphy, personal communication 1982).

North Carolina. Alligator populations in 23 North Carolina counties were reported as stable to slightly increasing. The largest concentrations of alligators are located in Brunswick County in the southern part of the state (P. Doerr, personal communication 1982).

Mississippi and Oklahoma. No current population estimates are available for these states. Mississippi's night count data for 55.9 miles of survey lines indicated an average of 1.4 alligators per mile (Chabreck, 1981). Oklahoma reports alligators occurring in only McCurtain County. This small population is characterized as slightly increasing (F. James, personal communication 1982).

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CONSERVATION FUTURE OF THE SALTWATER CROCODILE

CROCODYLUS POROSUS SCHNEIDER IN INDIA

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Saltwater crocodiles are extinct or badly depleted in most of the states of India where once they were numerous. The present Government of India/FAO/UNDP-assisted State Projects will guarantee the continuing existence of the remaining populations of *C. porosus* in India.

The saltwater crocodiles in India suffered a dramatic decline in numbers as a result of a combination of poaching and habitat loss (FAO, 1974). Bustard and Choudhury (1980) pointed out that the saltwater crocodile has been extinct in the South Indian States of Kerala, Tamilnadu, and Andhra Pradesh for over forty years, the last known individual being shot in Tanjore District of Tamilnadu in 1936 (Biddulph, 1936). The Bhitarkanika Sanctuary in Orissa is the only sanctuary in India where a good *C. porosus* population is now available, but its integrity is seriously threatened by habitat encroachment. Apart from the Orissan population, today saltwater crocodiles occur in India in Sunderbans (West Bengal), where they are very rare, and the Andaman and Nicobar Islands where the rate of habitat loss, apart from direct loss of the crocodiles, is a cause of great concern. With the initiation of the Government of India/FAO/UNDP Project Crocodile Breeding and Management, early in 1975, attention was focused on the survival status of India's three species of crocodiles.

The conservation future of saltwater crocodiles in different States of India is discussed separately below.

i) Sunderbans (West Bengal)

A project for conservation of saltwater crocodiles was begun in Sunderbans by the State Forest Department, West Bengal in 1976. Sunderbans is the largest mangrove area in the world. A large part of it is in Bangladesh, but the Indian portion extends to 200,000 hectares (Blasco, 1977). As part of the conservation program, in May 1979 the State Forest Department carried out their first release back to the wild of 40 saltwater crocodile juveniles. There is a proposal for the release of a few more.

There is concern for the future of saltwater crocodiles as the area is being exploited by refugees, mostly from Bangladesh.

ii) Andaman and Nicobar Islands

Chaterjee (1977) noted that the saltwater crocodile "is widely distributed and is found in almost all the islands of the Andaman and Nicobar Groups. Unrestricted persecution of these animals by local people in the past has greatly reduced their numbers. Much destruction is also caused by collecting their eggs whereby the entire brood is wiped out. The slaughter of these animals has been greatly reduced since implementation of the Wildlife (Protection) Act." Whitaker and Whitaker (1978) highlighted the need to carry out detailed surveys to determine the crocodile population in Andaman and Nicobar Islands. Choudhury and Bustard (1980) showed that the position of the saltwater crocodile is not safe in the Andamans today. They recorded 97% destruction of nests in the 1977 nesting season, almost entirely as a result of egg robbing by settlers. Seventeen percent of nest guarding females were killed in that year alone.

Beginning in 1979 the Andaman Forest Department initiated a Government of India-assisted Project on Conservation of saltwater crocodiles within the Territory.

iii) Andhra Pradesh

The major remaining mangrove area in the State, Coringa Reserve Forest in the Godavari Delta, was declared a sanctuary (Coringa Wildlife Sanctuary) in July 1978 with the aim of rehabilitating the saltwater crocodile, extinct in Andhra Pradesh (Bustard and Choudhury, 1981). Three 1.2 m crocodiles, which had been hatched from eggs collected from the Andamans, were released into this area in March 1978. A few more may be released.

iv) Tamilnadu

The Tamilnadu Forest Department began a rehabilitation project and already has released 12 saltwater crocodiles, provided by the State Forest Department, Orissa, into Pitchavaram in the Cauvery Delta, the sole remaining mangrove area in the State.

v) The Bhitarkanika Wildlife Sanctuary (Orissa)

The Bhitarkanika Wildlife Sanctuary (gazetted in April 1975), comprising 176 km^2 of reserve and protected forests, is located in the deltaic region of the Baitarani-Brahmani rivers in Cuttack District, Orissa. The habitat consists of deltaic mangrove swamps growing on rich alluvium. Some areas have been bunded for cultivation purposes; in all unbunded areas, however, mangrove vegetation is dominant (Kar and Bustard, in press).

Daniel and Hussain (1975), based on their field work during 1973, highlighted the unique situation of the Bhitarkanika mangroves and their saltwater crocodile populations. This sanctuary is the only remaining habitat of saltwater crocodiles in India where large breeding size crocodiles still occur; but their future is not yet completely safe (Kar and Bustard, 1981; Kar and Bustard, in press). In 1975-1976 a project for conservation of the saltwater crocodile was initiated by the Forest Department of Orissa with assistance from the Government of India.

These conservation steps included active management by collection of wild-laid eggs for safe captive incubation and rearing of the resultant young to a safe release size (1.2 m), combined with strong protection of the sanctuary--including the mangrove forests, crocodiles, and other forms of wildlife.

Until now (1982), 200 saltwater crocodiles have been released back into the wild. There is a program for further releases in order to build up a good breeding population in the future.

At present, 645 crocodiles from hatchlings to the 7-year-old age groups are being reared under good husbandry conditions at the Research and Conservation Centre, Dangmal. A captive breeding programme that maintains a few breeding size crocodiles, including one partial albino female crocodile has been set up (Kar and Bustard, 1982). This will provide opportunities to determine the breeding requirements and reproductive biology of saltwater crocodiles.

This project is the only successful project of its kind in India, although the habitat is still under pressure of encroachment by refugees.

CONCLUSIONS

The situation of the saltwater crocodiles is precarious, although a few countries are now taking some steps to conserve the species. In India the situation is grievous. The Andaman population of saltwater crocodiles is not yet safe. In West Bengal, the encroachment and habitat exploitation would seem likely to doom the future of saltwater crocodiles, although the State Government has started a project to conserve the species.

The best future in the entire country would appear to be in Orissa, in the Bhitarkanika Wildlife Sanctuary; however, even here only about 20 breeding females are left. The sanctuary is small, is under heavy encroachment, and many people live in it. In spite of the best efforts of the Saltwater Crocodile Research and Conservation Centre, the future cannot be bright unless the physical integrity of the sanctuary can be guaranteed for all time.

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THE CONTINUING AND MYSTERIOUS DISAPPEARANCE OF A MAJOR FRACTION OF SUB-ADULT *Crocodylus porosus* FROM TIDAL WATERWAYS IN NORTHERN AUSTRALIA

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ABSTRACT: In previous publications we have developed a model of the dynamics of *Crocodylus porosus* populations on the tidal waterways of northern Australia, based on the results of repeated censuses. A highly important element of this model is the continuing loss of a major fraction of sub-adults. In this paper, by utilizing the results of surveys in June-July 1982 and additional analysis of previous survey results, we give further support for our contentions about the high losses and considerably more detail about the some 30 percent or so of the non-hatchling population that survive. The reasons for the high losses remain, to some extent, a mystery. A very dynamic situation prevails, with movement of both adults and sub-adults between TYPE 1 river mainstreams, their extreme upstream reaches, and non-TYPE 1 systems (such as swamps, waterholes, and coastal or non-coastal saline creeks). Through use of a small boat and a helicopter we have been able to survey previously inaccessible components of our monitoring area. With this additional knowledge we have been able to very considerably sharpen our understanding of the population changes occurring in our monitored systems. A detailed description and analysis of the systems and the population changes are presented within the framework of our model of the population dynamics. There is good evidence for a gradually increasing ratio of large to small animals, but no support for any contention of major population increases. Our discussion also suggests that adult *C. porosus*, rather than sharks, could be the major predators of sub-adult *C. porosus*.

INTRODUCTION

The eleven year systematic and continuing study of *Crocodylus porosus* in the tidal waterways of northern Australia by the University of Sydney Crocodile Research Group has done much to elucidate the behavior, physiology, population status, and population dynamics of this hitherto relatively poorly studied species. Like all such studies, it has given rise to more questions than answers and has encouraged further and more sharply defined research.

The present paper is directed towards bringing more sharply into focus, by using the results of our latest surveys in June 1982, some of the major findings (discussed later) of our previous study of the population dynamics of C. porosus in tidal waterways. The results of this study have been presented in a series of 17 monographs and 2 reports by Messel and his co-workers (Messel et al., 1979, 1980, 1981, 1982). We also report on our latest results on the status of the C. porosus population in the 330 km of TYPE 1 to TYPE 3 tidal waterways east and west of our northern Arnhem Land headquarters at Maningrida, on the Liverpool-Tomkinson Rivers System. These relatively undisturbed waterways constitute our population dynamics and status monitoring systems (see Monograph 1, pp. 15 and 440).

The model we have built up for the dynamics of C. porosus populations on the northern Australian coastline (see Monographs 5, 7, 9, 10, 11, 16, 17, and especially Monograph 1, Chapter 6) and which has been able to account in a consistent fashion for the results of our surveys of some 100 tidal systems is as follows:

The tidal waterways of northern Australia have been classified according to their salinity signatures into TYPE 1, TYPE 2, and TYPE 3 systems as delineated in Monograph 1, Chapter 3, Figure 3.4.11A (see pp. 100 and 101). TYPE 1 systems are the breeding ones and non-TYPE 1 systems are usually poor or non-breeding systems. It is the TYPE 1 systems which account for the major recruitment of C. porosus; the other systems contribute to a lesser degree, and they must depend largely upon TYPE 1 systems for the provision of their crocodiles. In Table 9.2.1 (Monograph 1, p. 419), our results show that in TYPE 1 systems some 27 percent of the crocodiles sighted are hatchlings, whereas in TYPE 2-3 systems this figure falls to 14 percent and in TYPE 3 systems down to 4 percent, showing a much decreased hatchling recruitment in non-TYPE 1 systems. In TYPE 3 systems the percentage of crocodiles in the hatchling, 2-3', and 3-4' size classes combined is some 11 percent, whereas in TYPE 1 systems it is at least 52 percent. On the other hand, the percentage of crocodiles in the $\geq$(4-5') size classes is some 39 percent in TYPE 1 systems and 73 percent on TYPE 3 systems (see Monograph 1, p. 431).

It appears that the populating of the non-TYPE 1 systems results mostly from the exclusion of a large fraction of the sub-adult crocodiles from TYPE 1 systems; a small fraction of these excluded crocodiles apparently find their way into non-TYPE 1 systems. Adult crocodiles appear generally to tolerate hatchlings, 2-3', and sometimes even 3-4' sized crocodiles in their vicinity (but not always--they sometimes eat them [see page 43, Monograph 14] or kill them [see page 334, Monograph 1]), but not larger crocodiles. Thus once a crocodile reaches the 3-4' and 4-5' size classes, it is likely to be challenged increasingly not only by crocodiles near or in its own size class (see Monograph 1, pp. 454-458) but by crocodiles in the larger size classes and be excluded from the area it was able to occupy when it was smaller. Crocodile

interactions appear to increase around October, during the breeding season (see Monograph 1, p. 445). A substantial fraction ($\sim$80%) of the 3-6' sized crocodiles may thus be excluded from the river or be predated upon by larger crocodiles. Of those crocodiles that have been excluded, some may travel along the coast until by chance they find a non-TYPE 1 waterway; others may take refuge in freshwater swamp areas and billabongs nearby; others may go out to sea and possibly perish (perhaps because of lack of food, as they are largely edge shallow water feeders, or they may be taken by sharks). Those finding non-TYPE 1 systems frequent these areas, which act as rearing stockyards, for varying periods, until they reach sexual maturity, at which time they endeavor to return to a TYPE 1 breeding system. Both sub-adults and just mature adults might attempt to return and be forced out of the system many times before finally being successful in establishing a territory in a TYPE 1 system. The crocodiles may have a homing instinct (this important point requires further study), and even though a fraction of crocodiles finally return to and remain in a TYPE 1 system, the overall numbers missing--presumed dead--remain high and appear to be some 60-70 percent. Since a large fraction of crocodiles sighted in non-TYPE 1 systems must be derived from TYPE 1 systems, they are predominantly sub-adults or just mature adults (see Monograph 1, p. 431). The loss factor which appears to occur during the exclusion stage can be expected to be lower for movements into and out of swamp areas than for movement into and out of coastal non-TYPE 1 systems.

The above model for the dynamics of C. porosus populations in tidal waterways was first proposed in 1979 (see Monographs 1, 9, 10, and 11) using the survey and resurvey results on some 100 tidal waterways on the northern Australian coastline. Since that date the 330 km of tidal waterways acting as our monitoring systems were resurveyed in October 1980, July 1981, and October 1981, and these results were included in Monograph 1 (the main Monograph of the series) as an "Addendum August 1981," pages 440 to 446, and as a "Stop Press, October 1981," pages 14 and 15. The 1980 and 1981 data provided further strong support for the model proposed, confirming for the sub-adults, the extraordinary heavy loss factor of some 60-70 percent--missing, presumed dead. Because of these heavy losses, it was not surprising that our data indicated no overall increase in non-hatchling numbers; the number of small (3-6') crocodiles appeared to be steady or decreasing, whereas the number of large crocodiles ($\geq$6') appeared to be increasing slightly. (See Monograph 1, Tables on page 14, also see caption to Table 3 for division of "eyes only" classes.)

We have been, and still are, somewhat perplexed by certain aspects of these results. For instance, so far we have been unable to substantiate suggestions as to what happens to the missing sub-adults. This is the major subject matter of the present paper.

RESULTS

In Table 1 we have updated those parts of Table 9.2.1 in Monograph 1 that relate to the 330 km of tidal waterways constituting our monitoring

Table 1. Number of C. porosus sighted within each size class on tidal waterways of the 330 km of control systems (see text) during night-time spotlight surveys. The midstream distance surveyed and density of non-hatchling crocodiles sighted on it is shown, as are the 95% confidence limits for the estimate of the actual number of non-hatchlings present. The TYPE classification of each waterway is given also.

		Size Class Numbers								km	Density	95%	
Systems	Total	H	2-3	3-4	4-5	5-6	6-7	≥7	EO	surveyed	(crocs/km)	levels	TYPE
MONOGRAPH 1													
Blyth-Cadell													
Oct. 74	387	89	81	147	58	6	2		4	91.9	3.2	454-524	1
Nov. 75	353	50	106	81	72	23	4	2	15	94.9	3.2	462-532	
Sept. 76	348	82	63	104	46	14	7	6	26	92.0	2.9	403-469	
Nov. 76	307	61	61	103	47	10	4	2	19	92.0	2.7	371-435	
Apr. 77	327	72	70	108	48	10	2	4	13	92.0	2.8	386-450	
May 77	333	88	60	94	55	13	4	1	18	92.0	2.7	370-432	
June 77	365	108	36	102	69	13	10	3	24	90.5	2.8	389-453	
Sept. 77	386	105	45	132	47	17	4	4	32	90.5	3.1	427-495	
Oct. 77	360	112	68	83	47	18	8	3	21	90.5	2.7	375-439	
June 78	432	173	65	81	67	15	6	4	21	90.5	2.9	393-457	
Sept. 78	399	155	60	79	56	18	8	6	17	90.5	2.7	369-431	
MONOGRAPH 1 (continued)													
Blyth-Cadell													
June 79	465	123	91	93	59	31	16	26	26	94.5	3.6	524-598	
Oct. 80	400	119	89	71	48	22	9	4	38	92.9	3.0	427-495	
July 81	366	76	86	84	43	24	11	9	33	90.1	3.2	442-510	
Oct. 81	315	72	77	60	32	20	16	7	31	89.2	2.7	367-430	
June 82	408	136	42	59	49	31	22	20	49	91.9	3.0	413-479	
Nov. 82	347	111	43	66	46	28	15	10	28	92.5	2.6	356-418	
MONOGRAPH 5													
Goomadeer													
Aug. 75	46		27	7	5	4			3	45.3	1.0	61-89	1
Sept. 76	52	18	5	8	5	1	3	3	9	45.3	0.8	44-68	
June 77	50	2	9	13	10	6	2	1	7	45.3	1.1	65-83	
July 79	90	29	14	7	14	10	6	1	9	45.3	1.4	84-116	
June 81*	43	6	5(3)	11(3)	8(1)	4	3	1	5	45.0	0.8	49-73	
Oct. 81	45	17	3	13	6	1			5	45.0	0.6	35-47	
June 82	61	18	5	12	5	2	4	4	11	45.3	0.9	58-84	
Oct. 82	54	9	7	9	11	5	4	3	6	45.3	1.0	61-87	

Table 1. (continued)

Systems	Total	Size Class Numbers H	2-3	3-4	4-5	5-6	6-7	≥7	EO	km surveyed	Density (crocs/km)	95% levels	TYPE
MONOGRAPH 5 (continued)													
Majarie													
Aug. 75	12	1	1	2	2	1	1	2	2	20.1	0.5	11-25	3
Aug. 76	7			3					4	20.1	0.4	7	
July 79	18			1	7	4	1	3	2	24.1	0.7	21-39	
June 81	19			2	2	4	2	3	6	21.2	0.9	22-40	
Oct. 81	17			3	4	2	1		7	22.0	0.8	20-36	
June 82	17	2	1	1	2	2	1	3	5	23.8	0.6	17-33	
Oct. 82	12				4	5	1	1	1	23.3	0.5	13-27	
Wurugoll													
Aug. 75	4				3	1				16.4	0.2	4	3
Aug. 76	1								1	16.4	0.1	1	
July 79	9					2	2	4	1	16.4	0.5	9	
June 81	6			1	1	1	1	1	1	16.4	0.5	6	
Oct. 81	8		1	1	1	3			2	16.4	0.5	8	
MONOGRAPH 5 (continued)													
Wurugoll													
June 82	7					2		2	3	16.2	0.4	7	
Oct. 82	8	1			2	2	1	1	1	16.4	0.4	7	
MONOGRAPH 7													
Liverpool-Tomkinson													
July 76	248	19	39	58	29	15	6	3	79	158.9	1.4	346-406	1
May 77	245	40	6	51	59	30	13	5	41	145.1	1.4	307-365	
Oct. 77	228	56	7	39	62	24	9	1	30	123.4	1.4	256-308	
Sept. 78	233	37	18	37	65	19	14	8	35	141.4	1.4	293-349	
July 79	515	289	11	39	43	34	29	20	50	150.0	1.5	341-401	
Oct. 79	355	161	16	36	37	29	17	23	36	141.1	1.4	290-346	
Oct. 80	295	71	51	37	32	29	12	14	49	140.6	1.6	337-397	
July 81	256	26	52	48	29	23	15	15	48	140.6	1.6	347-407	
Oct. 81	254	34	33	50	34	23	14	14	52	141.1	1.6	331-391	
June 82	467	193	29	64	50	37	23	17	54	141.1	1.9	416-482	
Oct. 82	384	144	16	48	51	25	21	17	62	141.1	1.7	363-425	

Table 1. (continued)

Systems	Total	Size Class Numbers H	2-3	3-4	4-5	5-6	6-7	≥7	EO	km surveyed	Density (crocs/km)	95% levels	TYPE
MONOGRAPH 7 (continued)													
Nungbulgarri													
Aug. 75	29		4	11	3		1		10	15.0	1.9	37-59	1**
July 76	15	2		3	5	1	1		3	13.6	1.0	14-28	
June 77	14	2	2		6	1	1		2	13.6	0.9	13-27	
July 79	35	10		4	4	6	5	2	4	14.8	1.7	31-51	
June 81	27	2	4	10	4		1		6	14.8	1.7	31-51	
Oct. 81	25		2	12	4	2			5	14.8	1.7	31-51	
June 82	23		1	8	4	3	1	1	4	14.8	1.6	28-48	
Oct. 82	29		1	9	8	2	2	4	3	14.4	2.0	37-59	

*Numbers in parenthesis give numbers of crocodiles removed by biology researchers before survey

**Previously classified as TYPE 2

systems. It is to be noted that these include a mixture of TYPE 1 to TYPE 3 systems. Results for our June 1982 resurveys are included. Perhaps it is appropriate to state here that the data in Table 1 do not lend themselves to quick answers or facile statements, and furthermore that they do not reflect the almost inconceivable effort which has gone into obtaining them.

Table 2 is an update of the important and informative Table 6.2.31 from Monograph 1, again with the results for the June 1982 resurveys included. Table 2 is obtained using Table 1 and highlights a number of salient features of the data.

A further convenient way of viewing the data is shown in Table 3, which is an update of Table 6.2.30 from Monograph 1 but with results for the Liverpool-Tomkinson Rivers System (Monograph 7) included. Though Tables 1, 2, and 3 present data for the overall river systems, they do not show results broken down for the major components of the systems. In Tables 4 and 5 we show summary results for the number of crocodiles sighted in the hatchling, small, and large size classes during the general night-time surveys of the major components of the Blyth-Cadell and Liverpool-Tomkinson Rivers Systems.

DISCUSSION

A study of Table 1 shows that on the Blyth-Cadell System, despite the continuing and substantial yearly input of hatchlings, there has been no increase (in fact a decrease is indicated) in the number of non-hatchling crocodiles sighted during general night-time surveys of this waterway between October 1974 and June 1982, though there were a number of important variations during intervening surveys which indicate a potential recovery. We shall discuss these variations later.

Neither has there been a significant increase on the Goomadeer, Majarie, Wurugoij, or Nungbulgarri Systems between the first survey carried out in 1975 and the June 1982 resurvey.

The number of non-hatchling crocodiles sighted on the Liverpool-Tomkinson System during the July 1976 survey was 229, whereas on the June 1982 survey the number was 274, indicating a significant (at the 95% level) increase in the number of non-hatchling crocodiles. As on the Blyth-Cadell System there is variation from year to year and within years.

Consideration of data from numerous surveys and resurveys leaves little doubt that the number of crocodiles sighted, reflects well the number of crocodiles on the waterways (Chapters 4 and 5, Monograph 1) and hence that the variations referred to are real. We have pointed out time and again (Monograph 1, Chapter 4, and Monographs 4 to 14) that one is viewing a highly dynamic situation. Apparently a major cause of this highly dynamic and fluctuating situation is increased interaction between animals in various size classes as the population proceeds through the

Table 2. UPDATE Table for the Blyth-Cadell Rivers System showing the 2-3', 3-4', and 4-5' size classes grouped together (2-5') and the size classes above those in another group (≥5'). We have also grouped the crocodiles sighted into small (2-6') and large (≥6').

Survey	Totals	Hatchlings	2-5'	≥5'	Small 2-6'	Large ≥6'	3-6'	Small / Large
26 October 74	387	89	286	12	292	6	211	48.7
1 November 75	353	50	263	40	289	14	183	20.6
MAJOR FLOODING								
23 September 76	348	82	221	45	240	26	177	9.2
4 November 76	307	61	217	29	230	16	169	14.4
11 April 77	327	72	230	25	242	13	172	18.6
3 May 77	333	88	215	30	231	14	171	16.5
8 June 77	365	108	215	42	232	25	196	9.3
16 September 77	386	105	234	47	257	24	212	10.7
23 October 77	360	112	204	44	226	22	158	10.3
10 June 78	432	173	219	40	238	21	173	11.3
12 September 78	399	155	200	44	221	23	161	9.6
NO FLOODING								
10 June 79	465	123	251	91	287	55	196	5.2
4 October 80	400	119	220	61	249	32	160	7.8

Table 2. (continued)

Survey	Totals	Hatchlings	2-5'	≥5'	Small 2-6'	Large ≥6'	3-6'	Small / Large
HEAVY FLOODING								
9 July 81	366	76	223	67	253	37	167	6.8
19 October 81	315	72	179	64	204	39	127	5.2
DRY WET--MINOR FLOODING ONLY								
25 June 82	408	136	166	106	205	67	163	3.1
6 November 82	347	111	164	72	197	39	154	5.1

LIVERPOOL-TOMKINSON RIVERS SYSTEM

Summary Table for the overall Liverpool-Tomkinson rivers System (Monograph 7)

18 July 76	248	19	152	77	180	49	141	3.7
25 May 77	245	40	129	76	166	39	160	4.3
27 October 77	228	56	118	54	147	25	140	5.9
27 September 78	233	37	131	65	156	40	138	3.9

Table 2. (continued)

Survey	Totals	Hatchlings	2-5'	≥5'	Small 2-6'	Large ≥6'	3-6'	Small/Large
			NO FLOODING					
16 July 79	515	289	109	117	152	74	141	2.1
19 October 79	355	161	101	93	136	58	120	2.3
15 October 80	295	71	136	88	173	51	122	3.4
			HEAVY FLOODING					
2 July 81	256	26	145	85	176	54	124	3.3
5 October 81	254	34	134	86	166	54	133	3.1
			DRY WET--MINOR FLOODING ONLY					
12 June 82	467	193	161	113	207	67	178	3.1
16 October 82	384	144	135	105	171	69	155	2.5

Table 3. Summary Table showing for each survey of the overall Blyth-Cadell Rivers System the number of crocodiles in the size classes indicated. The EO classes have been added together in each survey and 50% of these have been distributed equally among the 3-4', 4-5' and 5-6' size classes; the remaining 50% have been distributed to the ≥6' size classes with 1/3 being allocated to the 6-7' size class and 2/3 to size classes ≥7'. This weights the distribution heavily in favour of larger crocodiles, which are known to normally be the most wary. For 1974, all EO crocodiles were put in the ≥7' size class.

	Totals	H	≥2'	≥3'	≥4'	≥5'	≥6'	≥7'	km Surveyed	Density
26 October 74	387	89	298	217	70	12	6	4	91.9	3.24
1 November 75	353	50	303	197	114	40	14	7	94.9	3.19
					MAJOR FLOODING					
23 September 76	348	82	266	203	95	45	26	15	92.0	2.89
4 November 76	307	61	246	185	79	29	16	6	92.0	2.67
11 April 77	327	72	255	185	75	25	13	9	92.0	2.77
3 May 77	333	88	245	185	88	30	14	7	92.0	2.66
8 June 77	365	108	257	221	115	42	25	11	90.5	2.84
16 September 77	386	105	281	236	99	47	24	15	90.5	3.10
23 October 77	360	112	248	180	94	44	22	10	90.5	2.74
10 June 78	432	173	259	194	110	40	21	11	90.5	2.86
12 September 78	399	155	244	184	103	44	23	12	90.5	2.70

Table 3. (continued)

	Totals	H	≥2'	≥3'	≥4'	≥5'	≥6'	≥7'	km Surveyed	Density
NO FLOODING										
10 June 79	465	123	342	251	154	91	55	35	94.5	3.82
4 October 80	400	119	281	192	115	61	32	17	92.9	3.02
HEAVY FLOODING										
9 July 81	366	76	290	204	115	67	37	20	90.1	3.22
19 October 81	315	72	243	166	101	64	39	18	89.2	2.70
DRY WET--MINOR FLOODING ONLY										
25 June 82	408	136	272	230	163	106	67	37	91.9	2.96
6 November 82	347	111	236	193	123	72	39	19	92.5	2.55

EQUIVALENT TABLE FOR LIVERPOOL-TOMKINSON SYSTEM

18 July 76	248	19	229	190	119	77	49	30	158.9	1.44
25 May 77	245	40	205	199	142	76	39	19	145.1	1.41
27 October 77	228	56	172	165	121	54	25	11	123.4	1.39

Table 3. (continued)

	Totals	H	≥2'	≥3'	≥4'	≥5'	≥6'	≥7'	km Surveyed	Density
27 September 78	233	37	196	178	136	65	40	20	141.4	1.39
NO FLOODING										
16 July 79	515	289	226	215	168	117	74	37	150.0	1.51
19 October 79	355	161	194	178	136	93	58	35	141.1	1.38
15 October 80	295	71	224	173	128	88	51	31	140.6	1.59
HEAVY FLOODING										
2 July 81	256	26	230	178	122	85	54	31	140.6	1.64
5 October 81	254	34	220	187	129	86	54	32	141.1	1.56
DRY WET--MINOR FLOODING ONLY										
12 June 82	467	193	274	245	172	113	67	35	141.1	1.94
16 October 82	384	144	240	224	166	105	69	38	141.1	1.70

Table 4. Number of C. porosus sighted within the hatchling, small and large size classes on the three major components of the Blyth-Cadell Rivers System: Blyth mainstream, Blyth sidecreeks and Cadell River.

	Blyth Mainstream			Blyth Sidecreeks			Cadell			Totals		
	H	S	L	H	S	L	H	S	L	H	S	L
26 October 74	41	207	6	1	3	0	47	82	0	89	292	6
1 November 75	41	177	11	3	11	2	6	101	1	50	289	14
MAJOR FLOODING												
23 September 76	48	159	14	2	16	5	32	65	7	82	240	26
4 November 76	40	142	10	3	16	1	18	72	5	61	230	16
11 April 77	65	142	6	3	17	3	4	83	4	72	242	13
3 May 77	74	144	10	0	15	3	14	72	1	88	231	14
8 June 77	88	129	19	2	23	4	18	80	2	108	232	25
16 September 77	75	164	19	2	18	2	28	75	3	105	257	24
23 October 77	76	136	14	3	15	2	33	75	6	112	226	22
10 June 78	136	148	14	1	21	4	36	69	3	173	218	21
12 September 78	115	130	15	1	17	1	39	74	7	155	221	23
NO FLOODING												
10 June 79	85	171	40	1	15	9	37	101	6	123	287	55

Table 4. (continued)

	Blyth Mainstream			Blyth Sidecreeks			Cadell			Totals		
	H	S	L	H	S	L	H	S	L	H	S	L
4 October 80	86	139	22	0	16	4	33	94	6	119	249	32
HEAVY FLOODING												
9 July 81	48	144	27	2	25	3	26	84	7	76	253	37
19 October 81	37	127	28	3	13	2	32	64	9	72	204	39
DRY WET--MINOR FLOODING ONLY												
25 June 82	84	118	41	1	14	6	51	73	20*	136	205	67*
6 November 82	55	116	26*	0	9	3	56	71	11*	111	197	39

*Bias to large

recovery phase and towards eventual equilibrium conditions. Presumably at that stage there would be certain broad steady state ratios between the number of animals in the various size classes. These ratios could be expected to be system dependent.

Our data have revealed a number of unexpected features. One of these is the surprisingly long period of time that it has taken for the population to even show signs of an increase. C. porosus in the Northern Territory has not been hunted legally since 1971, and one might be tempted to assume that the population would surely have recovered to much high numbers during the intervening 11 years. Even a brief study of Table 9.2.1 in Monograph 1 (covering some 100 tidal waterways in northern Australia) and Tables 1 to 3 in the present paper shows that it has not, and furthermore that any major sustained increase can be expected to be measured in terms of decades (Monograph 1, Addendum, p. 445).

The Blyth-Cadell and Liverpool-Tomkinson Systems are among the best TYPE 1 tidal waterways for C. porosus in northern Australia. However, while 292 small and 6 large crocodiles (Table 3) were sighted on the Blyth-Cadell System during the October 1974 survey (the results for the November 1975 survey were much the same), on the June 1982 survey only 205 small and 67 large crocodiles were sighted. It is common knowledge that the Blyth-Cadell System was shot out illegally in 1972 (apparently a thorough job was done by white hunters), and hence one would expect the remaining large animals to still be very wary in 1974. Thus it is likely that the six large animals sighted were not a fair indication of the number of large animals remaining on the two rivers in 1974. There could have been substantially more large animals (see Monograph 1, p. 339) in the System, but they were too wary to be sighted.

Thus the results in Table 2 and 3 do not provide evidence for an increasing population on the Blyth-Cadell System; instead they indicate a static or decreasing one, however with the population structure changing. During the November 1975 survey, the ratio of small to large crocodiles sighted was 20.6; on the September 1976 survey it was 9.2 (Table 2). For the two 1981 surveys, this ratio was only 6.8 and 5.2, and for the June 1982 survey it was down to 3.1. It is to be noted that the ratio sometimes varies considerably from survey to survey during the course of a single year; however, the long term trend on the Blyth-Cadell System is downward.

Unfortunately on the Liverpool-Tomkinson System the first reliable survey of the waterway was not made until 1976, so we are unable to compare data with other waterways, especially with the Blyth-Cadell System for 1975. A survey of the Liverpool-Tomkinson System was made in 1975 under the guidance of an assistant (no longer with the research program) to one of the authors (H.M.); however on that occasion, as on many others during 1975, youthful confidence unbacked by sufficient knowledge led to the accumulation of much worthless data--at enormous cost both financially and scientifically. On the July 1976 survey, 180 small and 49 large crocodiles were sighted (Table 2) yielding a (small/large) ratio of 3.7, which is to be compared with ratios of 9.2 and 14.4 for the two 1976 surveys of the Blyth-Cadell System. On the June 1982 survey, 207 small and 67 large crocodiles were sighted yielding a ratio of 3.1, which surprisingly is the same as that obtained for the Blyth-Cadell System. As shown in Table 2, there has been variation among surveys in the ratio of small to large crocodiles sighted, but these variations have not been nearly as large as those found for the Blyth-Cadell System. The increase in the number of large animals sighted on the Liverpool-Tomkinson System has been much less than on the Blyth-Cadell System.

It is known that the Liverpool-Tomkinson System was not as thoroughly shot out as the Blyth-Cadell System (personal communication to H.M. by the then two main aboriginal crocodile hunters at Maningrida, Silas Roberts and Billie Yirrinyin, both of whom worked on H.M.'s crocodile research project during the early 1970's), and that a substantial number of large animals remained on the system when serious hunting of C. porosus ceased at Maningrida in the late 1960's. That large numbers of large crocodiles were shot on the Liverpool-Tomkinson cannot be doubted, for one of the authors (H.M.) recalls seeing in 1972 pathways in Maningrida outlined by large C. porosus skulls. During the course of writing the present paper, the authors had the fortunate opportunity of a discussion with Colonel (Retired) Syd Kyle-Little, who was a Native Affairs Patrol Officer in the Maningrida area from 1946 to 1950 (he was revisiting this area in June 1982, after some 30 years), and who initiated a trial aboriginal project there for the shooting of C. porosus for skins. As a patrol officer he kept a daily diary in which he entered many casual observations of C. porosus. From his observations he had concluded that the Blyth-Cadell System not only contained the largest crocodiles but also contained considerably more than the Liverpool-Tomkinson System. The smallest crocodiles they shot for skins were 3 m in length and the average was 4.5 m. The largest crocodile shot and measured with a tape measure was 6.6 m; this animal was shot on the bank near the mouth of the small creek at km 48.7 on the Blyth River. According to Kyle-Little, large crocodiles were very numerous, and he and two aboriginal helpers shot, on the Liverpool-Tomkinson System, 17 animals on the first night; all animals were $\geq$4 m in length. Every crocodile shot (some 150) had the stomach contents looked at, and on five or six occasions portions of smaller crocodiles were observed in the contents. He spent much time camped near various freshwater billabongs in the area and states that he never saw many C. porosus in these--usually two or three. He believes that the small numbers are determined by the very limited food supply available in the billabongs.

We have already referred to the surprisingly long period of time that it has taken the C. porosus population to even show signs of a sustained increase. Why is this so? Tables 1 to 5 show that year after year there is recruitment of hatchlings into the systems--at various levels, sometimes high and sometimes low. We know that some 50 percent of these

Table 5. Number of *C. porosus* sighted within the hatchling, small and large size classes on the three major components of the Liverpool-Tomkinson Rivers System: Liverpool mainstream, Liverpool sidecreeks, and Tomkinson (normally 57.0, 27.4, and 56.7 km respectively, but distances can vary from year to year--see page 16, Monograph 7; note especially that during the 1976 Tomkinson survey, the river was surveyed to km 80.1 and that some 11 small and 7 large crocodiles were spotted between km 75-80; normally the Tomkinson is surveyed to km 73.7).

	Liverpool Mainstream			Sidecreeks			Tomkinson			Totals		
	H	S	L	H	S	L	H	S	L	H	S	L
18 July 76	11	64	14	4	27	7	4	89	28	19	180	49
25 May 77	13	67	12	4	28	7	23	71	20	40	166	39
27 October 77	23	77	13*	5	20	4*	28	49	9	56	147	25
27 September 78	13	69	21	7	20	5	17	67	14	37	156	40
NO FLOODING												
16 July 79	24	63	29	5	24	21	260	65	24	289	152	74
19 October 79	17	63	32	2	21	5	142	52	21	161	136	58
15 October 80	28	61	25	17	25	7	26	87	19	71	173	51
HEAVY FLOODING												
2 July 81	8	75	23	1	23	8	17	77	24	26	176	54
5 October 81	2	74	19	2	26	9	30	66	26	34	166	54

Table 5. (continued)

	Liverpool Mainstream			Sidecreeks			Tomkinson			Totals		
	H	S	L	H	S	L	H	S	L	H	S	L
DRY WET--MINOR FLOODING ONLY												
12 June 82	7	66	30	8	36	10	178	105	27	193	207	67
16 October 82	6	82	27	3	32	18	135	56	258	144	171	69

*Bias to large

survive from June of one year to June of the next (Monograph 1, Chapter 8) and enter the 2-3' size class; yet there appears to be little or no increase (and in the case of the Blyth-Cadell a decrease) in the number of non-hatchling crocodiles sighted on the tidal waterway. What is happening? Let us examine the matter more closely.

Consider the Blyth-Cadell System (Table 2). Note that during the October 1974 survey (or alternatively one may use the November 1975 survey; the end result will be essentially the same) 292 small and 6 large crocodiles were sighted. By the time of the June 1982 survey every one of these 292 small crocodiles would, if they survived, be in the large size class, yet in June 1982 only 67 large crocodiles were sighted, or 61 more than in 1974. Thus the minimum loss of sub-adults is (292-61)/292 = 79%. This figure is probably an underestimate because of the wariness in 1974 of the large C. porosus remaining in the Blyth-Cadell System (referred to previously). On the Liverpool-Tomkinson System the situation is much the same; the 180 small crocodiles sighted during the July 1976 survey could all be expected to be in the large size class by June 1982. There were 49 large crocodiles sighted on this first survey and only 67 on the June 1982 survey, giving a loss of (180-18)/180 = 90%.

An alternative way of viewing the matter is given on page 336 of Monograph 1. Consider the number of hatchlings sighted on the latest survey of each year on the Blyth-Cadell System between 1974 and 1981. Hatchling recruitment has been (89 + 50 + 61 + 112 + 155 + 123 + 119 + 72) = 781. From our captive-mark-recapture study (Monograph 1, Chapter 8), it is known that the loss of hatchlings between September and the following June is some 30 percent and from June to the following June it is some 50 percent. Using these estimates, then some 501 of the 781 hatchlings could be expected to have entered the 2-3' and non-hatchling class. The number of non-hatchlings sighted in the October 1974 survey (Table 3) was 298, and in the June 1982 survey it was 272, that is (501 + 26) = 527 non-hatchlings appear to be missing. Not only have the 501 animals recruited in the intervening 1974-1982 period disappeared but some 26 of the original 298 animals are missing also. For the Liverpool-Tomkinson System the recruitment of hatchlings between July 1976 and October 1981 was at least (19 + 56 + 37 + 161 + 71 + 34) = 378, and using the same loss estimates as for the Blyth-Cadell System, one finds that some 249 hatchlings should have entered the non-hatchling class. There were 229 non-hatchlings sighted on the waterway during the July 1976 survey and 274 on the June 1982 one, yielding an increase of 45. Thus one may reason that the 249 non-hatchlings recruited into the waterway, in the period 1976-1982, gave rise to 45 additional non-hatchlings only, and that there has been a loss of some 82 percent of the non-hatchling class. No matter which way one views the matter, it is evident that there are very high and continuing losses of non-hatchlings, and that these losses occur predominantly in the small (2-6') size class. There appear to be some (527 + 204) = 731 non-hatchling crocodiles missing from the sections normally surveyed on the

Blyth-Cadell and Liverpool-Tomkinson Systems alone for the period concerned. Thus the fact that there is little evidence for a major increase in the number of non-hatchling C. porosus sighted is not surprising.

But what has or is happening to the missing non-hatchling crocodiles? This appears to be an exceedingly difficult question to answer and we have been pondering on it over the past three years as we continue to survey and gather more data. We are still almost as mystified about the matter now as we were in 1979 (see pages 14, 15 and 440 to 446, Monograph 1), however certain aspects of the problem are becoming defined more sharply. Study of Table 2 reveals that a small fraction (some 15 to 20 percent) of the 731 missing crocodiles cannot be classified as missing - presumed dead. We shall now discuss these.

On some surveys and in some years, the number of small and/or large crocodiles sighted shows a major increase over the immediately previous survey. It appears that when there is such an increase; it occurs around the June-September period; this was the case on the Blyth-Cadell System in June 1979, when our surveys revealed a major influx of both small (from 221 to 287, significant at the 99 percent level) and large animals (from 23 to 55). On the Liverpool-Tomkinson System, the July 1979 survey showed a major increase in the number of large animals sighted (from 40 to 74) but no increase for small animals. In fact, as discussed in Monograph 1, pages 441 to 445, it appears that a major increase in the number of large C. porosus sighted was a general phenomenon on the tidal waterways of the northern Australian coastline during the June-August 1979 surveys, with the exception of Arnhem Bay (Monograph 11).

We suggested that the common factor, which may have been connected with this general influx of animals, was the exceedingly dry wet season of 1978-1979 and the severe drought conditions which prevailed until the wet season of 1979-1980. Such conditions might be expected to force any itinerant animals in swamp areas and semipermanent waterholes back into the tidal waterways. However, we pointed out that there are a number of worrisome points about this; firstly, there are very few swamp areas in the vicinity of the Blyth-Cadell System (certainly not enough to hold the number of animals involved), and secondly, if the sub-adults were returning from non-TYPE 1 tidal waterways elsewhere (for instance the Milingimbi Complex, see Monograph 9), then why would a very dry wet season and severe drought conditions trigger the return of sub-adults to TYPE 1 systems from non-TYPE 1 systems. In addition there were indications of an increase, rather than a decrease, in the number of non-hatchlings sighted in TYPE 3 systems in August 1979 (see the results for Majarie and Wurugoij Creeks, Table 1). Finally, how does one account for the decrease in the number of large crocodiles (from 74 to 58) spotted on the Liverpool-Tomkinson System during the October 1979 survey (Table 2); where did they disappear to? The missing crocodiles could not have returned to the freshwater swamps and/or billabongs from which it was postulated they had come, for these were even drier in October than in June and July. One is thus tempted to dismiss the "drying up swamp and billabong" explanation for 1979. However, the 1981-1982 wet season along the northern Arnhem Land coastline was again a dry one, and again there has been an influx of large animals into the Goomadeer (from 3 to 14), Blyth-Cadell (from 39 to 67), and Liverpool-Tomkinson (from 54 to 67) Systems (see the results for the June 1982 surveys in Tables 1 and 2). The increase in the number of large animals sighted on the Liverpool-Tomkinson System was accompanied by a major increase of small animals (from 166 to 207, significant at the 95 percent level), whereas this was not so for the Blyth-Cadell and Goomadeer Systems. In June 1979 the increase in the number of large animals sighted (from 23 to 55) on the Blyth-Cadell System was accompanied by a significant increase at the 95 percent level (from 221 to 287) in the number of small animals sighted. However, on the Liverpool-Tomkinson System this was not so.

Thus we ask what role, if any, do the dry wet seasons play in determining the influx of small and especially large C. porosus onto the main sections of the tidal waterways?

It is to be noted from Table 2 that on the second survey of the Liverpool-Tomkinson System in 1979, namely the October survey, the number of large animals spotted had decreased (from 74 to 58), but still was at a considerably higher level than for the September 1978 survey when only 40 large animals were spotted. The number of small animals sighted had also decreased, but not significantly, from 152 to 136. For the Blyth-Cadell System there was a similar occurrence; however, the next survey, after the June 1979 one, could not be made until October 1980; the drop in the number of small animals was from 287 to 249, just missing being significant at the 95 percent level.

Our results thus suggest that as the number of large animals increases on a TYPE 1 tidal waterway, the number of small crocodiles usually decreases or increases marginally only. Furthermore the results suggest that the disappearance or main ejection of small crocodiles from TYPE 1 waterways may occur around the October period, the breeding season, and they provide support for the model we proposed for the dynamics of C. porosus populations.

Note again the results for the number of small and large animals sighted on the Blyth-Cadell and Liverpool-Tomkinson Systems since 1979. On the basis of those results one might guess that the number of small crocodiles which will be sighted on the October 1982 survey of the Liverpool-Tomkinson System will be less than on the June 1982 survey. One might also expect to see a small decrease on both the Blyth-Cadell and Liverpool-Tomkinson Systems in the number of large crocodiles sighted; for it could be expected that a number of the large animals which entered the systems between the 1981 and 1982 surveys would still not be sexually mature (or just) and hence might be excluded by the breeding adults. The October 1982 survey may well provide some interesting results.

It is of interest to note that the number of both small and large animals sighted on the Blyth-Cadell and Liverpool-Tomkinson Systems during the June 1982 surveys are almost identical (Table 2), though the situation was much different when our surveys first started in the mid 1970s. The major increase in the number of small crocodiles sighted on the Liverpool-Tomkinson during the June 1982 survey is probably the result of the large hatchling recruitment on the Tomkinson River over the 1978-1979 wet season (Table 5). But where were these small animals in the intervening period; where did they come back from? The same question applies to the influx of large crocodiles on both the Liverpool-Tomkinson and Blyth-Cadell Systems. In an attempt to throw some light on these questions we must consider the two waterways in more detail.

The Liverpool-Tomkinson System is in many ways similar to the Blyth-Cadell System and at first sight the two TYPE 1 systems appear to parallel one another to a large degree (Monographs 1, 7, and 15). The Liverpool-Tomkinson System lies some 30 km to the west of the Blyth-Cadell System. The Blyth River has a major tributary, the Cadell River (TYPE 1), which joins it at km 19.1. The Liverpool River also has a major tributary, the Tomkinson River (TYPE 1), which joins it at km 17.0. The maximum navigable (by 4 m survey boat) length of the Liverpool mainstream is 66.3 km (normally can be surveyed to km 60 only), whereas for the Blyth mainstream it is 59 km (normally can be surveyed to km 49.8 only). Both mainstreams have large upstream drainages. If one compares low tide salinities towards the end of the dry season at corresponding distances on the Liverpool and Tomkinson Rivers, one finds that the Liverpool salinity is lower than that for the Tomkinson by a factor of 3 or so (Monograph 7). Looking at the Blyth and Cadell Rivers, the Blyth has salinities several times lower than the Cadell (Monograph 1, Chapter 3). Thus in the two systems, from the point of view of salinities, the Liverpool parallels the Blyth, and the Cadell parallels the Tomkinson. In its upstream reaches, past km 50, the Blyth River shows typical freshwater habitat; past km 56 the river is very rocky and after km 59.8 it breaks up into a series of freshwater waterholes. Correspondingly, the Liverpool River becomes sandy past km 60 and is joined by the Mann River at km 68. Both streams break up into a number of rivulets and numerous semipermanent and permanent freshwater waterholes in stony country. On the Liverpool, sporadic C. porosus might get upstream of the Mann Junction. Typically, the number of C. porosus sighted on the upper navigable freshwater sections of both of the mainstreams falls off rapidly (Monograph 1, Chapters 6, 9, and Addendum; also Monographs 7 and 12).

The maximum navigable length of the Cadell River is some 30 km (from km 19.1 to 48.8); this is followed by some 4.5 km of shallow, narrow, giant log strewn waterway, running through dense jungle. There is a narrower sidecreek running off from the mainstream at km 48.8, and this runs through similar jungle for some 2 km until it peters out in waterholes. As viewed from a helicopter, the habitat looks as if it might be suitable as a refuge for some sub-adults, but the amount of sunlight getting through the dense jungle canopy would be limited on many sections. The river finally breaks up into a series of small semipermanent and some eight larger permanent freshwater waterholes. It is to be noted that the dry season food supply for C. porosus in these would be fairly limited, as the supply is only effectively replenished during some of the wet seasons.

The Tomkinson River, on the other hand, has a much longer navigable length of some 64 km (from km 17 to 81.3, but normally can be surveyed to km 73.7 only), beyond which it shallows out over a distance of several km into a semipermanent paperbark swamp which can be dry or wet during a given dry season, depending upon how wet the previous wet season was. Upstream of km 70 the banks become lined increasingly with Melaleuca and though the stream is narrow (some 6 to 8 m), the mud banks are usually gently sloping. The terminal section of the river upstream of km 70, though providing excellent C. porosus habitat, floods almost every year. Both the Cadell and Tomkinson Rivers are still tidal at their endpoints for navigation.

The nature and extent of the sidecreeks varies considerably between the Blyth-Cadell and Liverpool-Tomkinson Systems. On the Blyth-Cadell System there is only one major sidecreek, namely Creek B at km 3.5, which has a navigable section of 4.1 km; Creeks A, C, D, F, and G have a total navigable length of some 8 km only. These minor creeks, which are on the downstream km 0-15 section of the Blyth River, usually become hypersaline towards the end of the dry season and are TYPE 2-3. On the Liverpool-Tomkinson System there are a number of more substantial creeks:

	Type	Navigable length (km)
Gudjerama Creek at km 5.5	3	5.8
Morngarrie Creek at km 14.4	3	2.9
Mungardobolo Creek at km 17.0	3	8.7
Maragulidban Creek at km 30.0	1	7.8
Atlas Creek at km 58.4	1	1 to 2.8

Mungardobolo Creek is one of the most hypersaline creeks in northern Australia, and we discussed previously at some length (Monograph 7, also Monograph 1, Chapter 7) the matter of the itinerant C. porosus sighted in it. Essentially, it appears to be a small TYPE 3 rearing stockyard for sub-adults, large and small, excluded from elsewhere on the Liverpool-Tomkinson System.

On the other hand, Maragulidban Creek is a relatively short TYPE 1 system, joining the Liverpool mainstream at km 30. It becomes quite narrow with steep cut-away banks and is quite log-strewn upstream of our normal terminal survey point at km 37.8, but not as log-strewn as the unnavigable end section of the Cadell River. Beyond km 37.8, the stream winds a further torturous course for some 7 km through relatively thick jungle and then breaks up into a series of semipermanent and permanent

freshwater waterholes, which are not as large as those on the Cadell River. At approximately km 44, there is a sidecreek which runs for some 2 km through exceedingly dense jungle, finally breaking out into a shallow semipermanent paperbark swamp. The upstream sections of both the Cadell River and Maragulidban Creek are quite similar and undoubtedly could provide a refuge for some sub-adults--probably mostly in the large size class--excluded from other sections of the systems.

We now examine the number of C. porosus sighted during the various surveys on the component parts of each system with a view to trying to track down where the increases and decreases occur. Tables 4 and 5 contain the relevant data.

Consider the small crocodiles sighted on the Blyth-Cadell System during the 1975 and 1976 surveys. It will be noted that the number of small crocodiles sighted on the system dropped significantly at the 95 percent level, from 289 to 240, between the November 1975 and September 1976 surveys; this decrease occurred mainly on the Cadell River, though there was a decrease of 18 small animals sighted on the Blyth mainstream also. The major flooding that occurred over the 1975-1976 wet season was of historic dimensions, and this may well have been connected with the decrease in the number of small animals sighted (Monograph 1, p. 335). However, the decrease in small animals was associated with an increase from 14 to 26 in the number of large animals sighted. This increase was mainly on the Cadell River and this too might have been responsible for the decrease in small animals. We are unable to say where the small animals disappeared to or what happened to them.

The number of both small and large animals sighted then fluctuated within surprisingly narrow limits until the June 1979 survey. During this survey, on the Blyth mainstream, the number of large animals sighted increased dramatically from 15 to 40 and from 23 to 55 for the overall Blyth-Cadell System. For us it was exciting to see so many large animals; they were mostly concentrated at the mouth region of the Blyth River and on the sidecreeks of the downstream section of the river. Where had these animals come from, and were they coming into the river or leaving it? Since they were not sighted during the September 1978 survey, the evidence points to these animals trying to gain entrance to the waterway. The number of small crocodiles sighted also increased significantly at the 95 percent level, from 221 to 287; there being an increase of 41 small animals on the Blyth mainstream between km 15 and 35; 27 of these were in the 2-3' size class and these were mostly sighted on the km 20-30 section. Ten of the remaining 14 animals in the 3-6' size class were sighted on the km 0-20 mouth section. There was also an increase of 27 small animals on the Cadell River of which 6 were in the 2-3' size class and 21 in the 3-6' size class; 15 of the latter were in the 3-4' size class. The distribution of the crocodiles along the Cadell River suggests that most of the 3-6' animals may have come downstream from the inaccessible extreme upstream section of the waterway. Note that there had been no increase in the number of large animals sighted on the Cadell River on the June 1979 survey.

On the October 1980 survey of the Blyth-Cadell System, the number of non-hatchling crocodiles sighted had decreased from the June 1979 level, from 342 to 281; significant at the 95 percent level. This decrease consisted of a drop of 38 small animals and 23 large ones. As shown in Table 4, it appears that the loss of both small and large animals was largely from the Blyth mainstream (32 and 18 respectively); five large animals were also missing from the sidecreeks. Again we are unable to say what happened to these animals. There was little change on the Cadell River.

The survey of July 1981 revealed a situation much like that of the October 1980 survey, with only minor changes in the number of large and small crocodiles sighted on the Blyth-Cadell System. However, the October 1981 survey revealed a further major decrease, from 253 to 204, significant at the 95 percent level, in the number of small animals sighted. Note that the number had by then gone down from 292 in 1974 to 204. The losses occurred on all three major components of the Blyth-Cadell System. On the Blyth mainstream, the losses occurred on the downstream and extreme upstream sections; on the Cadell the losses were on the downstream sections. Interestingly, there was an increase of small animals on the upstream end sections of the Cadell, suggesting that some of the missing animals may have moved into the inaccessible region of the Cadell discussed previously. The loss of small animals from the mouth region of the Blyth suggests that the animals may have left the waterway, if they are alive at all. The number of large crocodiles remained essentially the same.

The survey of the Blyth-Cadell System in July 1982 showed essentially no increase in the number of small animals sighted (there was a loss of 35 [2-3'] but a gain of 36 [3-6'] animals, mostly in the 4-6' range); a decrease of 9 animals on the Blyth mainstream was counterbalanced by an increase of 9 on the Cadell. However, the distributional pattern of the small animals along the Blyth mainstream and the Cadell had changed since the October 1981 survey. Whereas on the October 1981 survey some 30 small animals were sighted on the km 0-20 section of the Blyth mainstream, on the June 1982 survey, 54 small animals were sighted on the same section. On the other hand, the number of animals on the km 25-40 section had decreased from 69 to 30. These results suggest that the small animals downstream may have been in the process of being excluded from the waterway by large crocodiles (or since many were in the 4-6' range, they may have been entering it?). This possibility is supported by the fact that there was an increase from 39 large animals sighted on the system during the October 1981 survey to 67 during the June 1982 one; 17 of the increase of 28 were sighted on the km 0-15 section of the Blyth mainstream and its sidecreeks, thus suggesting strongly that these large crocodiles had entered the Blyth through its mouth. A total of 31 large C. porosus were sighted on the km 0-15 mouth section and sidecreeks; exactly the same number were sighted on this section during the June 1979 survey. However, whereas there was no increase in large animals sighted on the Cadell during the June 1979 survey (the number fluctuated between 0 in 1974 to 9 in October 1981), the June 1982 survey shows 20 large animals in the Cadell--an increase of 11, and all this increase occurred on the mouth sections of the Cadell. Since the Cadell joins the Blyth River at km 19.1 and since there was no increase at all in the number of large animals sighted upstream on the Cadell, it appears that the 11 new animals also entered the Blyth-Cadell System through the Blyth River mouth. The increase of 9 small animals sighted on the Cadell is interesting, for their distribution along the river is such as to suggest exclusion from the Blyth mainstream. The October 1982 survey of the Blyth-Cadell System may well reveal considerable readjustment between the increased number of small and large animals sighted on the mouth sections of both the Blyth and Cadell Rivers and show not only a small decrease (mentioned earlier) in the number of large animals sighted on the overall Blyth-Cadell System but perhaps a further decrease in the number of small animals sighted as well. However, it is difficult to believe that the number of small C. porosus could decrease much further on the system, and it appears that a stage is being reached where the number of small animals sighted will commence increasing, but with the number of large animals increasing faster, thus yielding a decreasing, but fairly fluctuating ratio of small to large C. porosus.

As is evident from our discussion, consideration of the survey results for the Blyth-Cadell System can be indicative only as to where the fluctuating numbers of small and large crocodiles disappear to and return from. Most of these large C. porosus are in the 6-8' size class and thus are sexually immature or just sexually mature animals, for it is known that females are often sexually mature when they reach the 6-7' size class (see Monograph 1, p. 339, also personal communication from Dr. Gordon Grigg). The evidence suggests strongly that most of these large crocodiles and a substantial fraction of the excluded small crocodiles leave and re-enter the Blyth-Cadell System through the mouth of the Blyth River. Those that leave go out to sea and are probably lost, or they travel along the coastline until they reach another tidal waterway to which they gain entrance.

To the east of the Blyth River mouth, the closest tidal waterways are those discussed in Monograph 9: Ngandadauda, Bennett, Darbitla, Djigagila and Djabura Creeks, all TYPE 3 or 2-3 waterways, and which provide excellent rearing stockyards for sub-adult and just mature C. porosus, referred to in our model. However to reach the first of these waterways, Ngandadauda Creek, necessitates a sea journey of some 36 km and the rounding of Cape Stewart. This creek is also joined to Creek B on the Blyth River by an open paperbark swamp, and crocodiles could move from one to the other during the height of the wet season (see Monograph 9, p. 39). There is a very small but distinct channel joining the two creeks.

When last surveyed in June 1979, 39 large and 44 (3-6') animals were sighted in the creeks above, and since they are all TYPE 3 or 2-3 waterways, nearly all the animals sighted must have been derived from elsewhere. The Blyth-Cadell System is probably one of the sources for these crocodiles.

Between the Blyth River mouth and the Liverpool River (to the west) there are four small TYPE 3 coastal creeks, each having extensive sand bars at the mouth and which may be entered only from the sea with great difficulty, even at high tide. The first two of these, Beach (local name) and Anamayirra Creeks, are some 10 km from the Blyth River mouth. Crab Creek (local name) and another unnamed creek, so small as to be of no consequence, are a farther 13 km to the west. We were able to gain entrance by land and to survey Crab Creek in October 1981 for the first time and sighted two large animals in it. For the June 1982 survey, a helicopter was chartered from Darwin (some 320 km from Maningrida) so that access could be gained to Anamayirra and Beach Creeks and two large waterholes on the Cadell River, and to check various other regions hitherto inaccessible to us. On the spotlight survey of Beach and Anamayirra Creeks, 13 small and 9 large animals were sighted, thus revealing two further good rearing stockyards for crocodiles excluded from TYPE 1 systems nearby, such as the Blyth-Cadell and Liverpool-Tomkinson. Both Anamayirra and Beach Creeks drain paperbark swamps, and Anamayirra Creek then breaks into a number of waterholes, containing sporadic C. porosus--we caught one of these in 1976. Our June 1982 survey of these waterholes revealed no crocodiles.

The only other areas to which crocodiles, excluded from the sections of the waterway normally surveyed, could move to or come from in the vicinity of the Blyth-Cadell System are the Cadell River waterholes and the extreme upstream sections of the Blyth and Cadell River mainstreams.

As reported on page 446 of Monograph 1, in October 1980 we surveyed the extreme upstream freshwater sections of the Blyth River from our normal terminal point at km 49.8 to km 59 and the two large waterholes extending from km 59.8 to 64.6. We sighted six crocodiles (H, EO>6', 7-8', 2-3' and 6-7' in that order) on the km 49.8-56 section, none on the km 56-59 section, and none in the two large waterholes. We resurveyed the km 49.8-59 portion of the river in July 1982. On this survey, only five crocodiles were sighted, one hatchling and four large, all between km 50.1 and 54.5. Strangely the stream appears to be barren not only of crocodiles but of fish also, upstream of km 55-56.

On the Cadell River, we are unable to survey upstream of km 48.8 because the stream shallows and narrows beyond that point and is strewn by giant logs as it winds a further tortuous 4.5 km through dense jungle --undoubtedly we would sight a number of both small and large crocodiles if we were able to survey it, for the waterholes which the stream drains do contain some small and large C. porosus. There are eight main permanent waterholes at varying distances upstream of km 53.3, with a total length of some 10 km. Using a vehicle or a helicopter to gain

entrance, we were able to survey four of the main waterholes with lengths of 4.0, 2.0, 0.9, and 0.8 km. Our surveys revealed 2 small and 12 large crocodiles, 5 in each of the large waterholes and 2 each in the smaller ones. Thus as suspected, the waterholes do provide limited alternative habitat for a small number of both small and large C. porosus which may be excluded from the river system proper.

Thus one is led to the conclusion that there is sufficient alternative habitat for that relatively small percentage (15-20%) of both small and large crocodiles which leave and later re-enter the TYPE 1 Blyth-Cadell System and that such crocodiles are sighted in these. However, we are unable to provide direct proof with specific animals; this can only be done using capture-mark-recapture methods or radio telemetry. However, there are a number of major difficulties related to the use of either method. The capture and handling of an animal may well be the cause of it leaving the system temporarily (see Monograph 7, pp. 75 and 76, for a case at point)--how is one to know? This matter is particularly relevant for the present study concerning, apparently, excluded and returning animals. In addition there would be the great difficulty and cost of endeavoring to capture a very large fraction of the sub-adults inhabiting a waterway, for one would have to use passive techniques to minimize the problem referred to above. Some 15 to 20 percent of the sub-adults appear to remain on a TYPE 1 waterway, another 15 to 20 percent appear to fluctuate in and out of the waterway (or proceed to the more inaccessible and normally unsurveyable sections), with the remainder entering the missing, presumed dead class; for a meaningful study, it would be necessary to work with a very large fraction of the animals in a system. There is also the technical difficulty of running a microprocessor based telemetry system (which would have to be used) in a remote area such as Maningrida. Finally, there is the major stumbling block of scientific permits; these are required by law before a crocodile may be captured. The Northern Territory Government demonstrated recently how dangerous and costly it can be to try to carry out a research program requiring scientific permits, when it launched a prosecution against one of the authors (H.M.) who was holding two, supposedly valid, permits. This not only wrecked some very important scientific work (see Monograph 1, pp. 387 and 438) but also effectively ensured that we do not proceed with radio telemetry studies of C. porosus. The risk of further prosecution appears to be far too great. We need to use an alternative method and have some ideas on this matter.

We now turn to the some 527 small crocodiles in the missing, presumed dead class on the Blyth-Cadell System. What has happened to them? We have direct evidence that over the past year at least three large animals were drowned in barramundi fishermen's nets set outside and inside the mouth of the Blyth River, where, as discussed previously, the density of animals appearing to leave or enter the river is greatest. As to the remainder, we are simply unable to say, and radio telemetry or capture-mark-recapture methods are unlikely to provide the answer, for once an animal is dead, these methods are unlikely to be of value. It is known that large C. porosus sometimes kill smaller C. porosus, and it is known that they sometimes eat smaller C. porosus (see Monograph 1, pp. 33 and 334). It is known that large sharks take crocodiles also, for recently a 16 foot white pointer was caught in Moreton Bay, Queensland, with a 4-5' C. johnstoni in its stomach, and our own studies have documented many cases of C. porosus being bitten by sharks which are very prevalent in the tidal waterways of northern Australia, especially in the mouth sections. However, hitherto we believed these were isolated cases. Now we wonder about it and are becoming more convinced that mature adult C. porosus and sharks may account for the high fraction of missing, presumed dead C. porosus.

Just as for the Blyth-Cadell System, we can give also, a detailed analysis of the number of C. porosus sighted on the three major components of the Liverpool-Tomkinson System (Table 5). The analysis runs along the same lines but there are important differences between the two systems. Note the essential constancy of the number of small crocodiles sighted on the Liverpool mainstream during the surveys between 1976 and 1982. There is some indication of perhaps a minor drop in the number of small crocodiles sighted as the number of large animals increased. Note too the exceedingly small recruitment of hatchlings on the Liverpool mainstream, which of course could partly account for the fact that there has been only minor variations in the number of small animals sighted.

The small recruitment of hatchlings is difficult to understand for there are numerous nesting sites on the mainstream (see Monograph 7, p. 34). For our capturing program in 1973, 1974, and 1975 we know that there were at least 62, 34, and 60 hatchlings respectively on the Liverpool mainstream in those years. The figure of 11 hatchlings during the November 1976 survey is understandable, for the wet season of 1975-1976 was of historic dimensions and the Liverpool System was flooded accordingly. No nests could have survived the exceedingly high flood levels and the few hatchlings sighted in 1976 probably came from one or more swamp nests. Since 1976, the maximum number of hatchlings sighted has been 28. This simply does not correspond with the excellent nesting habitat on the Liverpool mainstream or with the number of large animals sighted on it.

It will be noted that there was only minor recruitment of hatchlings on the sidecreeks on the river system, but in 1979 and again in 1982 there was, relatively speaking, very heavy recruitment of hatchlings on the Tomkinson River. The Tomkinson also has some excellent nesting habitat and almost the same number of large animals are sighted on it during surveys as on the Liverpool mainstream. Did Magnusson's disturbance of nesting and large animals during the course of his Ph.D. nesting studies between 1975 and 1977 on the Liverpool-Tomkinson have something to do with the matter? It seems farfetched, but we know of no other relevant factor. The matter of breeding and nesting on the Liverpool-Tomkinson obviously requires more detailed study.

The increase in the number of large animals sighted during the 1979 surveys of the Liverpool mainstream occurred mostly downstream of the mouth of Maragulidban Creek which joins the Liverpool mainstream at km 30. The decreases which followed in 1980 and 1981, also occurred on the same sections. There was an increase of 11 large animals sighted on the June 1982 survey of the mainstream, and 8 of these were again centered on these sections; the remaining three were sighted on the km 3-10 mainstream mouth section, indicating their arrival via the river mouth.

One should now note the major increase from 5 large animals sighted on the sidecreeks during the September 1978 survey to 21 on the July 1979 survey and then the drop back to 5 for the October 1979 survey. The increases and decreases took place largely on Maragulidban and Mungardobolo Creeks. The results suggest strongly that Maragulidban Creek is acting as a major channel for the entry and departure of large animals--but not for small crocodiles. To check this matter further, it was decided to use a small dinghy rather than our normal survey boat, and to survey upstream as far as possible beyond our normal terminal point at km 37.8. We were able to survey to km 42.5 which is some 2.6 km before the stream breaks up. Only one large crocodile was sighted, in the EO>6' class, and no small crocodiles were seen. Thus our suggestion that Maragulidban Creek acts as a channel, between the paperbark swamp and waterholes, which start at km 49.8, for the entry and departure of large but not small C. porosus gains support.

On the Tomkinson River (Table 5) the number of large animals sighted during surveys has varied from 28 in July 1976 to 9 in October 1977, gradually rising to 27 in June 1982. The decrease from the 20 large animals sighted in the May 1977 survey to 9 sighted on the October 1977 survey was spread fairly evenly over all sections of the river surveyed normally. Those animals lost from the mouth section of the Tomkinson may have left the Liverpool-Tomkinson System. However, it is more likely that these, as with the other large animals (probably sexually immature sub-adults or just mature adults) missing from the upstream sections of the river, were forced by the breeding adults of October 1977 even further upstream onto the terminal sections. On these sections, nesting appears to take place seldomly, and we have been unable to gain entrance to them on most surveys. Support for the view just expressed is provided by the survey of July 1979 when the number of large animals sighted was 24, having increased from 9 in October 1977. The increase occurred predominantly on the upstream sections of the Tomkinson.

Also note the decrease in the number of small animals sighted on the Tomkinson during the October 1979 survey. Though this decrease is not significant statistically, it does point to the small animals being excluded by breeding adults on the Tomkinson where most of the nesting on the Liverpool-Tomkinson System appears to be taking place. The increase from 52 small animals sighted on the October 1979 survey to 87 for the October 1980 survey is accounted for purely by an increase of 36 (2-3') animals arising from the 142 hatchlings sighted during the October 1979 survey. Using results on survivorship for the Blyth-Cadell System (Monograph 1, Table 8.4.1), one would have expected some 50 percent, or 71 of the 142 hatchlings, to be in the 2-3' size class by October 1980. Thus the increase of 36 (2-3') animals appears to be too small by a factor of about 2 and the missing portion must have been either excluded, probably to the upstream terminal sections of the Tomkinson referred to, and/or entered the class missing, presumed dead. The number of small crocodiles sighted on the July and October 1981 surveys then decreased from the 87 of the October 1980 survey to 77 and 66 respectively, but the results of the June 1982 survey show a significant increase at the 95 percent level in the number of small animals sighted on the Tomkinson, the number rising to 105. In addition, on Mungardobolo Creek, there was an increase of six small and two large crocodiles. It should be recalled that the Tomkinson and Mungardobolo both join the Liverpool mainstream at km 17.0. Of the increase of 45 small animals on the Tomkinson and Mungardobolo, 9 were in the 2-3' size class, derived from hatchling recruitment the previous year, 29 were in the 3-5', and 7 in the 5-6' size classes, and hence it appears that the major increase consisted of animals derived from the large hatchling recruitment on the Tomkinson in 1979. The increase in the small size classes was distributed relatively uniformly over the Tomkinson and Mungardobolo, indicating that the animals had come downstream from the normally inaccessible terminal sections of the Tomkinson. By making special efforts during the June 1982 survey, we were able to survey the Tomkinson from our normal terminal point at km 73.7 to km 81.3. We spotted 32 *C. porosus* as follows: 1 (3-4'), 7 (4-5'), 5 (5-6'), 5 (6-7'), 3 (>7'), and 11 (EO), thus supporting our suggestion that the terminal sections of the Tomkinson are providing rearing stockyards for sub-adults excluded from other sections of the waterway. In the future, we shall make great efforts to survey this section of the waterway during the course of our normal surveys.

From our discussion, it appears that though there are many similarities between the Blyth-Cadell and Liverpool-Tomkinson Systems, there are also a number of important differences. Whereas on the Blyth-Cadell System there are relatively few alternative areas for excluded sub-adults to go to, on the Liverpool-Tomkinson System the opposite appears to be the case. Thus, whereas sub-adult *C. porosus* on the Blyth-Cadell System appear to be excluded and re-enter largely via the mouth of the Blyth River, on the Liverpool-Tomkinson System there are alternative rearing stockyards within the system, such as the terminal sections of the Tomkinson and Maragulidban or within TYPE 3, Mungardobolo Creek. In view of this one might expect that the percentage of sub-adults classified as missing, presumed dead, on the Liverpool-Tomkinson System would be less than on the Blyth-Cadell System. However as we have seen, the reverse appears to be the case. We had previously suggested in our model that sharks might be the main predator on sub-adult *C. porosus*. Though not dismissing this suggestion at this stage, our discussion above also suggests that one of the main predators of sub-adult *C. porosus* may be adult *C. porosus*.

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APPENDIX ON SURVEY

OF WATERWAYS IN THE MANINGRIDA

MONITORING AREA--OCTOBER-NOVEMBER 1982

LIVERPOOL-TOMKINSON AND SURROUNDING WATERWAYS--SURVEYS OCTOBER 16-NOVEMBER 1, 1982

1. Liverpool Mainstream (Table 5)

There was an increase from 66 small crocodiles sighted during the June 1982 survey to 82 small crocodiles sighted during the October 1982 survey. This increase occurred just upstream and downstream of the mouth of the Tomkinson River, and hence it is likely that it is accounted for by small crocodiles excluded from the Tomkinson River.

A small decrease--from 30 to 26--in the number of large animals sighted on the mainstream could be real or just normal fluctuation in counts; however, the distribution of the large animals sighted varied considerably from that in June 1982. From km 3-30 there were 19 large animals sighted in June 1982, whereas in October 1982 only 14 were seen. As discussed below, a number of large crocodiles probably moved from the Liverpool mainstream into the sidecreeks.

The extreme upstream section of the Liverpool mainstream (km 60-66.4) was surveyed for the first time, and five small and three large *C. porosus* were sighted. This section, which is quite shallow, very sandy, and stump-ridden, provides limited alternative habitat for sub-adults driven from the more desirable sections of the mainstream.

The number of hatchlings sighted on the mainstream remained essentially constant (6 instead of 7).

2. Tomkinson River (Table 5)

As predicted after the June 1982 survey, the number of small crocodiles sighted on the section of the Tomkinson, normally surveyed (km 17.0-73.7) dropped dramatically, from 105 to 56 (∿47%).

There also was a decrease from 18 to 11 in the number of small animals sighted on the extreme section of the Tomkinson (km 73.7-81.3), not included in the normal survey section.

The number of large animals sighted decreased only marginally from 27 to 25 on the km 17-73.7 section, and the number of hatchlings sighted decreased from 178 to 135. However, it should be noted that there was an input of hatchlings from one or more late nests during the intervening period. A late June nest sighted at km 65 in July 1982 (no nests laid down after the end of March had been observed previously) was excavated by October, and some of the hatchlings sighted on the Tomkinson, were very small--obviously coming from successful late nest(s).

The number of large crocodiles sighted between km 73.7-81.3 did not change (13), however their increased number (from 4 to 11) on the km 17-30 mouth section suggests that a number of large animals were being excluded from the upstream breeding sections of the Tomkinson (km 30-73.7) where the number had dropped from 23 to 14.

Comparison of the number of small crocodiles sighted during the June and October surveys on each of the sections of the Tomkinson shows that, with the exception of the km 20-30 section, the losses were fairly uniform throughout the river, including the extreme km 73.7-81.3 section. The missing (105-56) = 49 small crocodiles from the km 17-73.7 section (of which 37 were in the 3-6' size classes) and the missing (18-11) = 7 from the 73.7-81.3 section (all in the 3-6' size classes) must either be "missing, presumed dead" or have been excluded from the surveyable sections of the river; recall the 16 additional small animals sighted on the Liverpool mainstream (actually there was an increase of 19 [3-6'] and a loss of 3 [2-3'] animals), mainly near the mouth of the Tomkinson. Some may have been forced upstream of km 81.3, since 13 crocodiles were sighted on the terminal 1.3 km surveyed from km 80-81.3. However, the Tomkinson becomes very shallow upstream of km 81.3 and soon simply peters out, so the amount of adequate habitat there is limited. Comparison of the June and October histograms for the km 73.7-81.3 section of the river shows the crowding of the crocodiles towards the terminal portion of this section. However, it should be noted that heavy barramundi activity was observed there during the survey of the km 73.7-81.3 section, and hence the crocodiles may have been concentrating there because of the plentiful supply of food.

Exclusion and even killing of the sub-adults by the mature animals, especially during the breeding season, which occurs around the October-November period, appears to be a major factor involved in the decrease and redistribution of sub-adult C. porosus. These factors could be expected to be more important on the Tomkinson than on the Liverpool River, since most of the successful breeding appears now to be taking place on the Tomkinson rather than on the Liverpool River--even though the number of large C. porosus sighted on each is closely the same. Our results bear this out.

During the night-time survey of km 73.7-81.3 on November 1, 1982, a (7-8') freshly dead male C. porosus was found floating in the water at km 73. It appeared to be in excellent condition and had blood coming from its nostrils--it was probably killed by a blow from a larger crocodile.

3. Sidecreeks of the Liverpoor River (Table 5)

A minor decrease in the number of small animals sighted, from 36 to 32, is essentially accounted for by the decrease from 17 to 12 in the number sighted on Mungardobolo Creek; there were minor variations of one to two small crocodiles on the other sidecreeks.

The most noteworthy change occurred in the number of large animals sighted, the number increasing from 10 in June to 18 in October, with 5 of the increase occurring on Gudjerama Creek (from 1 to 6); 1 on Mungardobolo (3 to 4), and 2 on Maragulidban Creek (5 to 7). These animals probably include the six large animals not sighted on the Liverpool-Tomkinson mainstreams. Both Mungardobolo and Gudjerama Creeks are TYPE 3 and hence do provide temporary alternative habitat for the excluded large crocodiles.

4. Overall Liverpool-Tomkinson Rivers System (Tables 1, 2, 3 and 5)

Table 5 shows the overall results for the various detailed changes between the June and October 1982 surveys, discussed above--a decrease of 49 hatchlings (193 to 144), a decrease of 36 small crocodiles (207 to 171) of which 23 were in the 3-6' size classes, and an increase of two large C. porosus (67 to 69). A portion of the 13 (2-3') animals can probably safely be assumed to be in the class missing, presumed dead; however, some of the remaining 23 (3-6') missing animals could even be among the additional 10 (3-6') animals sighted on the waterways of Rolling and Junction Bays (Table 1, 2, 6, and 7).

These changes are in keeping with the predictions made by our model for the dynamics of a population of C. porosus and provide further support for its basic correctness. A minor variation occurred in relation to the number of large animals sighted; rather than decreasing slightly as predicted, there was an increase of two. This variation is partially accounted for by the three additional large animals sighted on Mungardobolo and Maragulidban Creeks and by the five large animals entering TYPE 3 Gudjerama Creek near the mouth of the Liverpool rather than leaving the river system. They might well be excluded later in the breeding season.

The results shown for the number of non-hatchling C. porosus sighted on the Liverpool-Tomkinson Rivers System during surveys from 1976 to 1982 provide some evidence for the commencement of a slow recovery in the C. porosus population on this waterway. Though the number of non-hatchlings sighted dropped from 274 for the June 1982 to 240 for the October 1982 survey, this latter number is still greater than that for any previous year's survey. When this fact is combined with the sighting of 144 hatchlings during the October 1982 survey, then it is likely that the non-hatchling numbers will continue to rise, albeit slowly, with a generally decreasing small/large ratio. Fairly wide fluctuations, however, may be expected.

THE TIDAL WATERWAYS OF ROLLING AND JUNCTION BAYS, OCTOBER 11-14, 1982

Table 6 summarizes data shown in Table 1, which were obtained during surveys of the tidal waterways of Rolling and Junction Bays from 1975 to 1982.

Table 6. Number of C. porosus sighted within the hatchling, small and large size classes on the tidal waterways of Junction and Rolling Bay, which are within the Maningrida monitoring area. *Numbers in brackets give numbers of crocodiles removed by Biology researchers before survey.

	GOOMADEER			WURUGOIJ			MAJARIE			NUNGBULGARRI			TOTALS			
	H	S	L	H	S	L	H	S	L	H	S	L	H	S	L	S/L
August 75	--	44	1	--	4	--	1	7	4	--	23	6	1	78	12	6.5
July/August/ September 76	18	23	11	--	--	1	--	5	2	2	10	3	20	38	17	2.2
June 77	2	41	7	NO SURVEY			NO SURVEY			2	10	2				
NO FLOODING																
July 79	29	49	12	--	2	7	--	13	5	10	16	9	39	80	33	2.4
HEAVY FLOODING																
June 81	6	30* (7)	7	--	3	3	--	11	8	2	21	4	8	65* (7)	22	3.0
October 81	17	25	3	--	7	1	--	12	5	--	22	3	17	66	12	5.5
DRY WET--MINOR FLOODING ONLY																
June 82	18	29	14	--	3	4	2	8	7	--	19	4	20	59	29	2.0
October 82	9	35	10	1	4	3	--	9	3	--	21	8	10	69	24	2.9

Table 7. Number of C. porosus sighted within the hatchling, small and large size classes on the major component tidal systems within the Maningrida monitoring area. *Numbers in brackets give numbers of crocodiles removed by Biology researchers before survey.

	Blyth-Cadell System			Liverpool-Tomkinson System			Rolling and Junction Bays			Totals			
	H	S	L	H	S	L	H	S	L	H	S	L	S/L
Aug/Nov 75	50	289	14	Data Unusable			1	78	12				
July/Sept 76	82	240	26	19	180	49	20	38	17	121	458	92	5.0
May/June 77	108	232	25	40	166	39	4	51	9+	152	449	73+	6.2+
October 77	112	226	22	56	147	25	No Surveys						
September 78	155	221	23	37	156	40	No Surveys						
NO FLOODING													
June/July 79	123	287	55	289	152	74	39	80	33	451	519	162	3.2
October 80	119	249	32	71	173	51	No Surveys						
HEAVY FLOODING													
June/July 81	76	253	37	26	176	54	8	65* (7)	22	110	494* (7)	113	4.4
October 81	72	204	39	34	166	54	17	66	12	123	436	105	4.2

Table 7. (continued)

	Blyth-Cadell System			Liverpool-Tomkinson System			Rolling and Junction Bays			Totals			
	H	S	L	H	S	L	H	S	L	H	S	L	S/L
					DRY WET--MINOR FLOODING ONLY								
June/July 82	136	205	67	193	207	67	20	59	29	349	471	163	2.9
Oct/Nov 82	111	19		144	171	69	10	69	24	265	437	132	3.3

+See Table 6; Majarie and Wurugoij Creeks were not surveyed thus resulting in the omission of a few small and large animals. Hence the value of S/L is probably slightly TOO LOW.

The Goomadeer River and Nungbulgarri Creek are both small TYPE 1 systems (note that Nungbulgarri was previously incorrectly classified as TYPE 2); the normal surveyable distance being 45.3 km and 14.8 km respectively. Hatchling recruitment on the Goomadeer, to date, has been relatively small, and on Nungbulgarri it has been almost negligible, even though both waterways contain some excellent nesting habitat. Upstream of the terminal survey points, both streams break up into a number of riverlets and semipermanent and permanent freshwater billabongs. These could provide limited alternative habitat for crocodiles excluded from the sections normally surveyed.

Wurugoij and Majarie Creeks are typical coastal hypersaline creeks--TYPE 3 systems--and hatchling recruitment on them is negligible. They do, however, act as temporary rearing stockyards for sub-adults and just mature adults excluded from the TYPE 1 systems nearby--the Goomadeer, Nungbulgarri, and the Liverpool-Tomkinson Systems, and one notes significant readjustment in numbers of both small and large crocodiles between the systems--compare for instance the results for the June and October 1982 surveys; some of the missing 23 (3-6') animals from the Liverpool-Tomkinson System could account for the increase of 10 small animals (mostly 4-5' and 5-6') sighted in the waterways of Rolling and Junction Bays.

Examination of Table 6 shows that within each of the four waterways there was substantial variation in the numbers of small and large *C. porosus* sighted during the surveys carried out between 1975 and 1982; for instance the number of non-hatchlings (small and large) sighted varied from 90 in 1975 to 55 in 1976, to 113 in 1979, to 78 in October 1981, and to 93 in October 1982. As we have pointed out on previous occasions (Monograph 1, Chapters 4 and 5, or see present main paper), the number of crocodiles sighted reflects well the number of crocodiles on the waterways and hence that the variations are usually real. These variations highlight further the highly dynamic situation which prevails on the tidal waterways--the movement within, into, and out of the waterways, the continuing loss of a very large fraction of the sub-adult population--and emphasize the need to consider broad groups of adjacent waterways over a period of a number of years, otherwise one could easily be misled by considering results for the survey only or from one or just part of one tidal system. Thus due care must be exercised when one attempts to draw conclusions from the survey data for Rolling and Junction Bay waterways alone. The number of small crocodiles sighted on these four waterways in August 1975 was 78, in October 1982 it was 69, with wide variations occurring for the intervening years. The number of large crocodiles sighted varied between 12 in August 1975 and October 1981 to 33 in July 1979. At best one may conclude that the population of non-hatchling *C. porosus* on these four waterways is remaining steady or increasing slowly, and that there is some slight indication that the size structure of the population is changing slowly with the ratio of small/large tending downwards.

ANAMAYIRRA, BEACH, CRAB, AND TOMS CREEK AND CADELL GARDENS BILLABONG

1. Cadell Gardens Billabong--October 31, 1982

This 2 km long billabong had been surveyed in October 1981, at which time four crocodiles were sighted in it, three EO and one 6-7'. The resurvey this year yielded three crocodiles, two EO and one 3-4'.

2. Toms Creek--October 25, 1982

This short (8.9 km) hypersaline coastal creek on the western shore near the mouth of the Liverpool River (Monograph 15, p. 133) was surveyed annually from 1976 to 1979 inclusive, but at no time were more than two non-hatchlings sighted. One resurvey this year yielded two (4-5') crocodiles and one hatchling only, again demonstrating that for reasons unknown, Toms Creek is not favored as a refuge for sub-adults excluded from the Liverpool-Tomkinson Rivers System. The creek is only slightly hypersaline (40%) and high fish activity--especially of mullet --was observed.

One hatchling was also sighted during the July 1979 survey of the creek. A helicopter survey was therefore made of the upstream sections of the waterway on October 28 and a number of possible nesting sites observed, but no old nests were sighted. It appears that there is some freshwater inflow into the creek, even at the end of the dry season, thus preventing the creek from becoming overly hypersaline. In 1974, one of the authors (H.M.) sighted two (3-4') crocodiles buried in mud underwater; the water in the shallow pond, beyond km 6, was only some 15 cm deep.

We have always experienced great difficulty in getting into or out of Toms Creek at night. During 1979, four separate attempts were made (at great cost) before the creek was surveyed. Our 1982 survey was made easier with the help of a helicopter to ferry in survey staff. However, Toms Creek lived up to its reputation on this occasion also; a 20-25 knot NE wind sprang up near the end of the survey making the return boat journey to Maningrida difficult.

3. Crab Creek--October 28, 1982

Utilizing vehicular access, Crab Creek was surveyed in November 1981 and again in October 1982. This is also a very short (3 km) shallow hypersaline creek and only the west arm is surveyable by dinghy at tide levels when EB >60 cm. Only two crocodiles (EO >6, >7) were sighted in November 1981 and one (EO >6) during the October 1982 survey.

4. Anamayirra and Beach Creeks--October 23-24, 1982

These two adjacent coastal hypersaline creeks are only some 10 km to the west of the mouth of the Blyth River and both could provide excellent

alternative habitat for crocodiles excluded from it. The creeks were surveyed in July and again in October 1982. Sixteen non-hatchlings were sighted on Anamayirra Creek on both occasions (9S, 7L in July; 11S, 5L in October), whereas on Beach Creek six non-hatchlings (3S, 3L) were sighted in July and only three (3S) in October.

The survey results for the coastal creeks are somewhat surprising as one might have expected to have sighted more excluded crocodiles in them in October-November than in June-July. But this was not the case. The crocodiles missing from the Liverpool-Tomkinson and Blyth-Cadell Rivers Systems must have gone elsewhere (Milingimbi Complex?) or have been killed by the larger mature adults. Our finding, during the course of the October-November 1982 surveys, of the freshly dead (7-8') crocodile on the Tomkinson River and the sighting of a (7-8') *C. porosus* with one rear limb freshly torn off (see Cadell section notes) provides further support for the hypothesis that a substantial fraction of sub-adult or just mature crocodiles are killed by the larger animals.

BLYTH-CADELL RIVERS SYSTEM--NOVEMBER 6-8, 1982

1. Cadell River (Table 4)

Following the June 1982 survey of the Cadell River it was predicted, both for the Cadell and Blyth Rivers, that one could expect the number of small *C. porosus* sighted to remain essentially constant and for the number of large crocodiles sighted on it to decrease. These predictions have turned out to be correct for the Cadell, and as we shall shortly see, for the Blyth River as well. As may be seen in Table 4, 73 small crocodiles were sighted on the June survey and 71 on the October one. The number of large animals sighted decreased from 20 in June to 11 in November; the decrease occurring on the mouth sections of the Cadell River, precisely where the original increase from 9 in October 1981 to 20 in June 1982 had taken place. These crocodiles undoubtedly had come in and also left via the Blyth River at km 19.1. Not all of the missing nine large *C. porosus* are necessarily still alive; it is highly likely that a number of them have been killed by larger crocodiles. On the survey of the night of November 6, a (7-8') crocodile was sighted at km 45.9 (the breeding area) with a rear leg freshly torn off--obviously done by a larger crocodile.

The number of hatchlings sighted during the June survey was 51, whereas on the November survey it was 56. During the course of the latter survey it was noted that many of the hatchlings were very small, and hence a number of late nests had hatched since the June survey. No creches were seen.

The distribution along the Cadell River of small crocodiles changed between the June and November surveys. Whereas only 5S were spotted on the km 41.5-48.8 portion of the river in June, this number had risen to 12S for the November survey. The number of small crocodiles sighted on the km 19.1-29.1 section fell from 38 to 30, thus indicating that the small crocodiles were being forced upstream from the mouth sections of the river, perhaps by the remaining large crocodiles there.

2. Blyth River Sidecreeks (Table 4)

The number of both small and large C. porosus sighted on the sidecreeks of the Blyth mainstream decreased from the June to the November 1982 survey (Table 4). The number of small animals decreased from 14 to 9, and the number of large animals sighted decreased from 6 to 3. Though the number of animals sighted on the sidecreeks was small, the general decrease was indicative of the results found for the overall Blyth-Cadell Rivers System. It is interesting to note that the main decrease in small animals occurred on Creek B at km 3.5, near the mouth of the Blyth River where the concentration of large animals was greatest during the June 1982 survey. The decrease of three large animals in the sidecreeks also occurred near the mouth of the Blyth on Creeks B and C.

3. Blyth River Mainstream (Table 4)

The number of hatchlings sighted on the Blyth mainstream decreased from 84 for the June survey to 55 for the November 1982 one (Table 4). However the loss of hatchlings between June and November was greater than that implied by the difference between the two figures, for a number of very small hatchlings were sighted during the November survey, indicating that there had been an input of hatchlings since the June survey from late nest(s).

Though the number of small C. porosus sighted on the Blyth mainstream during the November survey (116) was essentially the same as on the June survey (118, see Table 4), their distribution along the stream had changed considerably. For instance on the km 0-10 mouth section, 19 small crocodiles were sighted during the June survey, whereas in November only 9 small animals were sighted. Small crocodiles excluded from the sidecreeks of the Blyth and from its downstream sections moved to what appears to always have been the most desirable sections of the mainstream, namely the brackish km 25-40 sections (Monograph 1, p. 334).

The extreme upstream sections of the Blyth mainstream which were surveyed in October 1980 (Monograph 1, p. 446) and June 1982 were resurveyed again November 1982. These are not included in our standard monitoring sections. Interestingly, on the km 49.8-59 section the number of small animals sighted had increased between June and November from one to seven and the number of large from three to four. Three large crocodiles were also sighted in the two billabongs between km 59-64.6. There is thus additional evidence that sub-adults are probably being excluded by the larger animals from the breeding sections of the waterway --especially during the breeding season.

The number of large animals sighted during the November 1982 survey had dropped to 26 from the 41 sighted in June 1982 and the decrease

occurred almost exclusively on the km 0-15 mouth section of the river--precisely on the same section where one of the major increases in large animals was observed between the October 1981 and June 1982 surveys. There is thus ever increasing evidence that substantial numbers of large animals enter and leave the Blyth-Cadell Rivers System via the mouth of the Blyth River.

4. Overall Blyth-Cadell Rivers System (Tables 1, 2, 3, and 4)

The 111 hatchlings sighted on the Blyth-Cadell Rivers in November 1982 can be expected to yield an input of some 80 (2-3') animals for the June 1983 survey. One might thus expect a major increase of this order in the number of 3-6' crocodiles sighted during future surveys. However, as may be readily seen from Tables 2, 3, and 4, this is not likely because of the continuing major losses (60-70 percent) of the sub-adults. It is difficult to believe that in October 1974 and again in November 1975 some 290 small C. porosus were sighted in the rivers system (Table 2), and furthermore that since that date there has been an input of some 800 hatchlings, and yet in November 1982 we sighted only 197 small (of which 154 were in the 3-6' size classes) and 39 large crocodiles!

The density and number of non-hatchling C. porosus sighted on the Blyth-Cadell Rivers System in November 1982 were smaller than on any other survey since they were begun in 1974. In fact, the number of non-hatchlings sighted in November 1982 was some 20 percent less than in October 1974. However, the data are readily understood in terms of our model of the dynamics of C. porosus populations given in Chapter 6 of Monograph 1. In fact, on the basis of this model, following the June 1982 survey, we predicted in our paper to the 6th Working Meeting of the SSC/IUCN Crocodile Specialist Group:

"The October 1982 survey of the Blyth System may well reveal considerable readjustment between the increased number of small and large animals sighted on the mouth sections of both the Blyth and Cadell Rivers and show not only a small decrease in the number of large animals sighted on the overall Blyth-Cadell System but perhaps a further decrease in the number of small animals sighted as well. However, it is difficult to believe that the number of small C. porosus could decrease much further on the System, and it appears that a stage is being reached where the number of small animals sighted will commence increasing, but with the number of large animals increasing faster, thus yielding a decreasing, but fairly fluctuating ratio of small to large C. porosus."

As already discussed, a major readjustment did take place at the mouths of both the Blyth and Cadell Rivers which resulted in the redistribution of both large and small crocodiles along the two waterways and the loss of only 8 small but 28 large animals. The 72 percent increase from 39 large animals sighted in October 1981 to 67 in June 1982 had disappeared by November 1982 when only 39 large animals were sighted. Where did the animals come from and go to?

There is now little doubt that a major exclusion (including killing) and redistribution of both small and large C. porosus occurs during the breeding season which appears to commence around September-October (we do not know how long it lasts, perhaps right over the wet season), and it is during this period that the heavy losses of sub-adults largely occur. Some of the missing animals from the Blyth-Cadell System appear to leave it via the mouth of the Blyth River; others take up territory in less suitable habitat such as the extreme upstream sections of the Blyth and Cadell mainstreams. These "surviving missing animals" overall probably constitute some 15-20 percent of the non-hatchling population and apparently usually re-enter the main river system during the wet or early dry season, for it is usually the June-July surveys which reveal an influx, if any, of small and large animals. The remainder of the missing non-hatchlings from the normal annual recruitment simply must be presumed dead, and evidence is accumulating that mature C. porosus and sharks are probably responsible. The "missing, presumed dead" constitute some 60-70 percent of the non-hatchling population overall.

MONITORED MAJOR WATERWAYS IN THE MANINGRIDA AREA

In Table 7 we have assembled a summary of our survey results for the major tidal waterways monitored in the Maningrida area since 1975 in order to emphasize overall changes in the non-hatchling C. porosus population for a broad geographical area containing TYPE 1 to TYPE 3 systems. Comparing the results in the Totals column for 1976, 1979, and 1982, one immediately sees that the number of small crocodiles sighted has essentially remained constant, and that there appears to be a slow and small increase in the number of large animals sighted. Thus the ratio of small/large animals appears to be decreasing, but the fluctuations are substantial.

There is little evidence--other than in the changing size structure of the crocodile population--for a sustained recovery, and no evidence whatsoever for a major increase in the number of non-hatchling animals. From our model for the dynamics of a population of C. porosus we may predict--and the data support the model--that a major sustained increase in non-hatchling numbers must be measured in decades.

The results in Table 7 also show that the crocodiles missing from one large system are not necessarily compensated for by an equal increase in another large system nearby. For instance, the 28 large crocodiles missing from the Blyth-Cadell System in October 1982 did not result in an increase of 28 large animals in the Liverpool-Tomkinson System. Furthermore, as discussed elsewhere in these notes, there was no sign of an increase in the number of large animals sighted on either Crab, Anamayirra, or Beach Creeks which lie between the mouths of the Blyth and Liverpool Rivers. Where then can the missing 28 large crocodiles be? We can only guess: some already have been killed by larger crocodiles and/or sharks, and some may have migrated temporarily to the Milingimbi Complex, to the east of the Blyth River mouth. If this is so, then over the next few years we can again expect an influx of large crocodiles to the Liverpool-Tomkinson System and at the Blyth River mouth. It is still not clear what triggered the influx of large animals into the Blyth-Cadell and Liverpool-Tomkinson Systems in 1979 and 1982; however, the evidence is now strong that it was the 'dry wet' seasons preceding the surveys of those years.

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Surveys of Tidal River Systems in the Northern Territory of Australia and Their Crocodile Populations

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CROCODILES IN THE REPUBLIC OF THE PHILIPPINES

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Crocodile habitat was never extensive in the Philippine Islands. Nowhere in the archipelago were the expanses of marsh or river habitats found in New Guinea or the southeastern United States duplicated. Limited crocodilian habitat coupled with an industrious human population, aggressively manipulating lowland habitats for basic agricultural necessities, has led to the virtual extinction of the endemic Philippine crocodile (Crocodylus mindorensis) and threatened the continued existence of the Indo-Pacific crocodile (Crocodylus porosus) throughout the Philippine Islands.

In 1980, the Smithsonian Institution/World Wildlife Fund Philippine Crocodile Project was initiated to determine the distribution, status, and conservation potential for the Philippine crocodile. Coincidental observations on the Indo-Pacific crocodile also were made. Funds for the SI/WWF project were exhausted early in 1982 and a final report on activities and findings was submitted to the IUCN/WWF in February 1982. The following is a summary of that report.

Distribution of the Philippine Crocodile

It now is not possible to determine the original distribution of the Philippine crocodile, owing to confusion between the two species of naturally occurring crocodiles and insufficient knowledge of their preferred or required habitats. Researchers cannot rely on early published accounts, verbal reports, or even recent reports, which are not verifiable now by museum specimens, artifacts, or photographs. That C. mindorensis is commonly called the "freshwater crocodile" and C. porosus the "estuarine or saltwater crocodile" has added confusion to this situation. Local languages do not differentiate between the two species with any certainty and even veteran crocodile hunters or crocodile skin dealers in some cases recognize more than two species. It is apparent that the habitat preferences inferred by the common names of these crocodiles have biased identifications in the past.

Distribution records suggest that the Philippine crocodile was widespread in the Philippine Islands. It is known to have occurred in

northeastern and central Luzon, Samar, Masbate, Mindoro, Negros, Busuanga, Jolo, and Mindanao Islands.

Few extant populations are known. Two individuals persist in the wild at the Pagatban River of southern Negros. These crocodiles are threatened by the activities of the local human population and by indiscriminant dumping of mine tailings into the river by a large copper mining operation. Another population known to have existed in the Kabankalan region of Negros Occidental is now extinct.

Three populations are known to still exist in Mindanao. These are in Zamboanga City, the Nabunturan area of Davao del Norte, and the Linguasan Marsh of Maguindanao and North Cotabato Provinces. In Oriental Mindoro, a juvenile crocodile was killed in 1981, but day and night surveys conducted in the area produced evidence of only C. porosus. It is probable that isolated disjunct populations or individuals still exist in northeastern Luzon and Samar. However, field work in these areas was limited owing to civil unrest.

Distribution of the Indo-Pacific Crocodile

The Indo-Pacific crocodile has been reported from Palawan, Cebu Province, northeastern Luzon, Mindoro, Catanduanes, and Mindanao. Field work indicates that C. porosus still exists in the Cagayan River drainage of northeastern Luzon (unverified report), Mindoro Oriental, Catanduanes, northern and southern Palawan, and Zamboanga del Sur, North Cotobato, Maguindanao, Agusan del Sur, Surigao del Sur, Surigao del Norte, and Bukidnon Provinces of Mindanao.

It is likely that C. porosus was more widespread than records indicate. Most extant populations are in freshwater palustrine habitats. If one assumes that this species utilized coastal habitats in the past, then its distribution in the Philippine Islands has diminished drastically.

Comments on Crocodile Distribution

In addition to previously mentioned areas, numerous other areas were surveyed either under the SI/WWF project or by the herpetological collection teams fielded by Silliman University, Dumaguete City, from 1958 to the present. Many of the smaller islands and islets as well as the larger Visayan Islands and Palawan were investigated. No crocodile populations were reported.

There is no evidence that C. mindorensis ever existed on Palawan. Many specimens of C. porosus from Palawan were examined, and veteran crocodile hunters active in Palawan in the 1950's report taking only the one species in the past. Crocodylus mindorensis undoubtably existed on some islands for which there are no records. Several islands surveyed under the SI/WWF project had habitat that would have been suitable for C.

mindorensis prior to agricultural improvements over the past 20 to 50 years, in particular the Visayan islands of Panay, Bohol, and Leyte.

Some areas that were surveyed where only C. porosus were visible may harbor undetected populations of C. mindorensis. In particular, the Agusan River drainage of central Mindanao deserves further work. It is known that the river, its tributaries, and the extensive freshwater marshes resulting from the annual flooding of the river are inhabited by C. porosus. However, some of the smaller marshy areas that have not been developed for agriculture at this time, and were not accessible to the SI/WWF project, may still have C. mindorensis. It is difficult to know which areas have crocodiles and impossible to prove which areas do not.

Natural History of the Philippine Crocodile

The largest C. mindorensis examined was a 3.5 m captive individual from Negros Occidental. The species matures at a small size. A 2.1 m, 47 kg male and a 1.3 m, 15 kg female C. mindorensis were observed to copulate, and the female subsequently laid eggs.

Crocodylus mindorensis has been observed to build a mound nest of vegetation and debris. Nesting occurs during the dry season, but varies according to locality. On Negros Island nesting occurs between March and July. Crocodylus mindorensis has been observed to guard its nest by lunging at human intruders and hissing. The species utilizes burrows.

The trail of a Trichosomoid nematode was observed on the ventral scales of a captive C. mindorensis.

Commercial Crocodilian Utilization

Little commercial utilization of native crocodilians occurs because local populations are depleted. Native crocodiles are still being hunted for skins in two localities in Mindanao: Tambulig District, Zamboanga del Sur, and the Linguasan Marsh area of North Cotabato and Maguindanao Provinces.

In Tambulig District, skins of C. porosus and live juvenile C. porosus are collected for export through the Sulu Archipelago to Sabah. In Cotabato City, skins of both species are collected and shipped to Manila for processing. In both areas coarse salt is used for preservation, and the skins regularly showed signs of putrefaction. The skins were poorly cut and the legs were not cut to maximize usable surface area. All skins had holes from careless skinning and were "3rd grade" by European standards.

The skins from Tambulig District were purchased by belly width. In Cotabato City skins were purchased by total length and the buyer paid hunters $US 7.75 per foot length. The skins were resold in Manila at $US 10.90 per foot length. The Cotabato City supplier/dealer estimates he

receives from 2 to 5 skins per month. In Tambulig District it is likely that more skins were traded per month, but no statistics were available as the dealer was reluctant to talk with us.

Processed skins and articles of both native crocodile species were seen in tourist shops and a tannery in Manila. The quality of tanning and manufacture of native crocodile goods is poor. Several tanned but whole skins of C. porosus were examined and several approximately 1 m skins of C. mindorensis were examined. We could not determine precise origin of these skins. Belts, shoes, and bags of both species can be purchased in tourist oriented shops for up to $US 90.00. Most of these items are reported sold to Australian and Japanese tourists.

In 1981, stuffed C. mindorensis were sold to Australian tourists for $US 100.00. Crocodile teeth, which are used for necklaces, were for sale in shops in Davao City, Cotabato City, and Manila. All were from small crocodiles; species identification could not be made.

A small trade in live C. porosus exists in Tambulig District. These live crocodiles were reportedly sold to dealers from the Sulu Archipelago through Zimboanga City and thence to Sabah through the "barter trade" routes.

Imported crocodilian goods are for sale to affluent Filipinos and tourists at some department stores and duty free shops in Manila. Articles manufactured from Alligator mississippiensis, Caiman crocodilus, Crocodylus porosus, and the southern New Guinea population of Crocodylus novaeguineae were identified.

Crocodile Farming

There has been interest in crocodile farming or crocodile "culture" for commerical purposes in the Philippines since early in the 1970's. The first crocodile farm of which we are aware was established in North Cotabato Province and reportedly housed nearly 500 crocodiles. These crocodiles were reported to have been slaughtered by the Philippine military around 1972. Since that time, the Soldana House of Reptiles has expressed interest in crocodile farming, but only recently has received a permit from the Ministry of Natural Resources for this purpose.

Over the past few years interest in crocodile farming has increased. The Forest Research Institute in Los Banos constructed a crocodile pen in Quezon Province, Luzon. They acquired a juvenile C. mindorensis from Mindoro Oriental which subsequently died from wounds received during capture. The pen was later dismantled.

A researcher from the Ministry of Natural Resources was sent to the United States for several months during 1980 to examine crocodilian farms. However, he apparently failed to make contact with any North American crocodilian researchers. The Ministry has since expressed a desire to establish a crocodile farm/sanctuary at Lake Naujan National Park, Mindoro Oriental. Crocodylus porosus still occurs in the area and a site adjacent to the lake that could be protected and serve as a crocodile ranch was recommended by the SI/WWF project to the Ministry.

The Japan Reptile Skin and Leather Association investigated the potential for large-scale commercial crocodile farming in the Philippines. A report on the Distribution and Breeding of Crocodiles in Southeast Asia was prepared by Mr. Koji Hara (Ueno Zoo) and presented to the government. However, negotiations between the Japanese and Philippine governments for the funding of a crocodile research facility and farm appear to have stalled. In part this may be due to the ratification of CITES by the Philippine government without a reservation allowing the trade in skins of C. porosus.

A crocodile survey of the Linguasan Marsh area of southern Mindanao was funded by the government. The survey was conducted by the Silliman University Environmental Center with technical aid from the SI/WWF project. Its purpose was to determine the identity and status of crocodiles occurring in the area and the potential for crocodile utilization for national livelihood programs. The conclusion of the Silliman University study was that "a crocodile industry based solely on collection of wild crocodiles for rearing and eventual slaughter for skins is not feasible" in southern Mindanao owing to a scarcity of crocodiles.

Silliman University started a crocodile breeding project with aid from the SI/WWF project and financial support from WWF in 1980. The first known nesting of C. mindorensis in captivity took place during 1981. All but two eggs were infertile and no young survived. Fourteen C. mindorensis were successfully hatched in 1982. The university now has three adult C. mindorensis, and a single C. porosus.

Crocodile Conservation

Three supposedly protected areas have extant crocodile populations; however, actual protection of crocodiles does not occur. They are Lake Naujan National Park, Mindoro Oriental; Linguasan Game Reserve, North Cotabato and Maguindanao Provinces; and the province of Palawan.

At Lake Naujan, fishermen catch young C. porosus on fishing lines and large animals are killed in nets. Crocodiles occur only in the restricted zone of the park, and in theory should be under protection. However, the government has neither the required personnel nor equipment to effectively patrol the area. Fishing is intense and crocodiles continue to be killed. There is a conflict between preserving the national park for wildlife and development of the area for commercial and subsistence level activities by the local residents.

The Linguasan Game Reserve is by law a protected area. Over the past decade there has been little law and order in the area. It is highly

dangerous for government personnel to enter. The continuing civil unrest has effectively preserved the marsh lands and some crocodiles, although it is evident that rice lands are steadily encroaching crocodile habitat. For many years there has been a plan to drain the swamp for agricultural expansion. But civil unrest caused this to be postponed.

The entire province of Palawan has been declared a protected area. However, like Lake Naujan and the Linguasan marsh, the crocodiles receive no protection.

Sumalig Island of Tambulig District, Zamboanga del Sur, has been proposed as a crocodile sanctuary by government agencies. Inhabitants of the area previously sold skins and live juvenile C. porosus. However, there is no longer a village on the island and the crocodiles are effectively protected for the time being.

The largest crocodile population remaining in the Republic of the Philippines is in the Agusan River drainage of Agusan del Sur near the Davao border. This area is sparsely populated by people due to the extensive annual flooding of the Agusan River. Although influenced by political dissidents, the region is still relatively peaceful. Because of natural phenomena and conflicts between the government and militants the area cannot be effectively protected as a national park. The area could act as a sanctuary for C. porosus if local inhabitants and militants were convinced that they could ranch or crop crocodiles on a sustained yield basis. At present, any crocodile encountered is killed, and if it is a nesting female the eggs are destroyed. There appears to be no commercial utilization of skins at present.

Silliman University plans to release captive propagated C. mindorensis into sanctuary areas. However, no suitable areas have been identified and the captive breeding program is still embryonic.

There is little future for crocodiles in either existing or proposed sanctuary areas. Agricultural pressure on crocodile habitat is intense, and with the exception of Palawan, areas with remaining crocodile populations have civil peace and order problems. If sanctuary areas are relied upon for the conservation of crocodiles, both C. porosus and C. mindorensis will become extinct in the Philippines. Until such a time as public sentiment and awareness for wildlife preservation permit reintroduction of the species into secure sanctuary areas, the Silliman University crocodile breeding project is the only hope for preserving C. mindorensis. Commercial exploitation of C. porosus may prolong its survival in the wild in some parts of central Mindanao.

CONCLUSION

Conservation of non-essential natural resources is not a high priority of the Republic of the Philippines. The Philippines is a rapidly developing country that, through an active government policy and owing to the industrious nature of her people, is rapidly modifying or utilizing all accessible natural resources for socio-economic improvement. The government is aware of the value of natural resource conservation. Several large government sponsored or run programs are now in existence trying to develop criteria for the rational utilization of mangrove, water shed, and forested areas. However, when the conservation of natural areas or preserves, or in this case a wild species, interferes or has the potential to conflict with high priority government goals dealing with human settlements or livelihood programs, the socio-economic improvements of the local human population will have priority. This is particularly true when dealing with wildlife species, such as crocodiles, which elicit little sympathy and are feared as a predator of man and his domestic animals. How do we integrate a policy of preservation of an animal which is potentially dangerous, disliked, and lives in areas suitable for fish ponds and rice paddies? The government of the Philippines is interested in how crocodiles can benefit the people, not conservation of a non-commercial natural resource. The future for crocodiles in the Philippines, and probably the remainder of southeastern Asia, is bleak.

STATUS OF THE CHINESE ALLIGATOR IN THE PEOPLE'S REPUBLIC OF CHINA

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The Chinese alligator population is plummetting toward extinction, a victim of human population pressure and man's prejudices. Once widespread throughout the eastern portion of the Yangzi River basin, the alligator is now limited to approximately one-tenth of its former range, a mere 25,000 km^2 (Fig. 1).

In 1981, under the auspices of the Chinese Academy of Sciences and the U.S. National Academy of Sciences Committee on Scholarly Communication with the People's Republic of China, we began a joint Chinese-U.S. study of the ecology, behavior, and distribution of the Chinese alligator. In 1982, this study was continued by Mr. Huang and Prof. Shi Yingxian of Institute of Developmental Biology, Chinese Academy of Sciences.

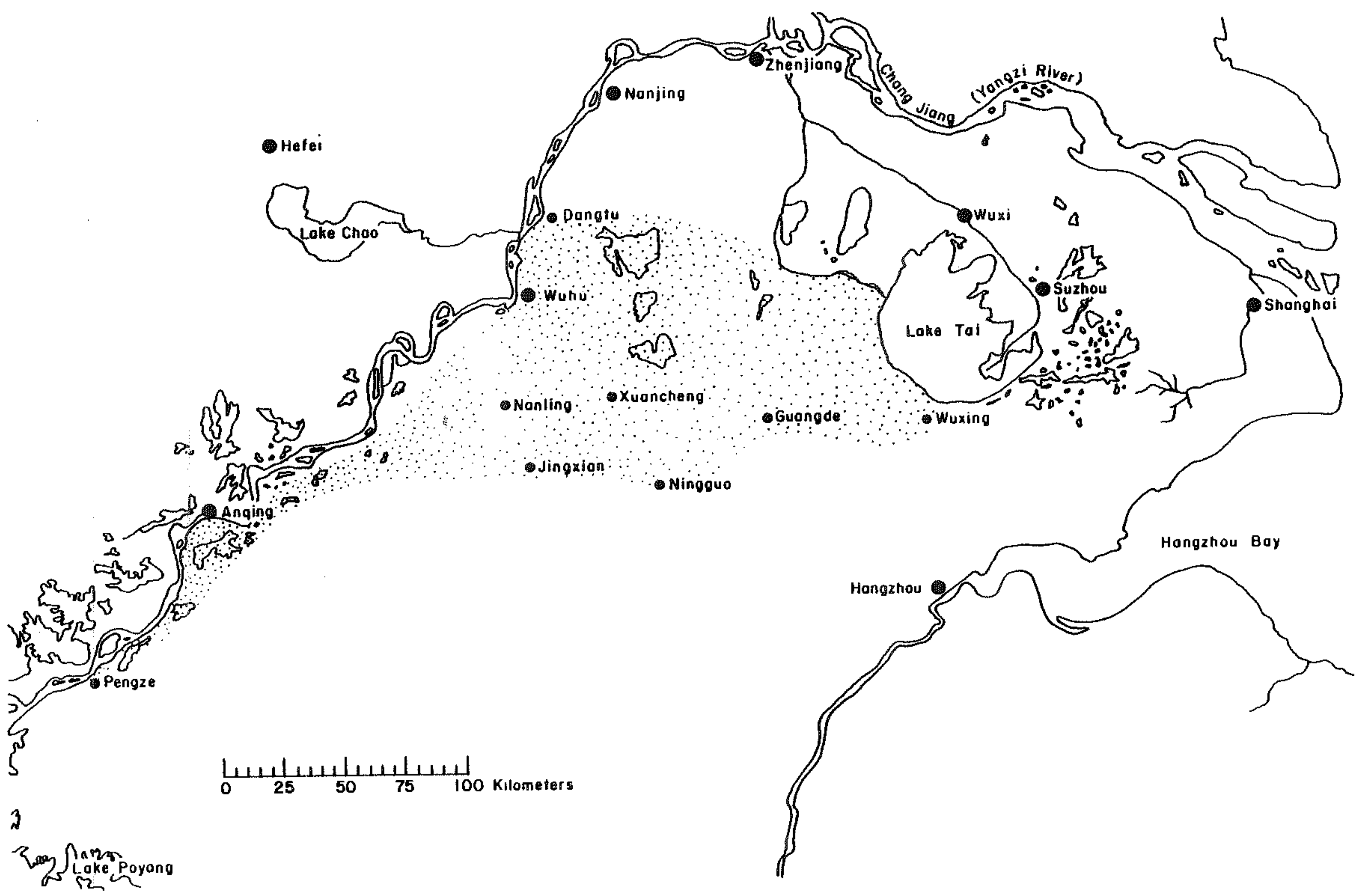
The area visited in 1981 encompassed a wedge-shaped region approximately 60 km on the long axes and extending from Jingxian County to the border of Ningguo County with the city of Xuancheng (118°45'E 30°57'N) at the apex, a total area of approximately 2,800 km^2 or 11 percent of the current range of the Chinese alligator.

Ecology of the Alligator

The alligator is active from late April or early May through October, hibernating in its underground den the rest of the year (Huang 1978, 1981, 1982; Groombridge 1982). Animals commence basking in the spring, a behavior that is frequently interrupted by man's activities. When children are out of school during lunch hours and on Sundays, they throw projectiles at basking animals. Water buffalo and their riders indulging in afternoon swims near basking sites also disturb the alligators. Thus frightened, the alligators return to their dens or hide under overhanging vegetation.

Figure 1. Current habitat of the Chinese alligator (stippled).

Regions visited for this study included Xuancheng, Nanling, and Jingxian.



Alligator activity centers around the den. Not only do animals remain hidden from view when disturbed, but they remain in their dens on cool (less than 25°C), very hot (near 40°C), windy, or rainy days. Although males wander away from the dens during breeding season in search of mates, females and their young of several age classes remain sufficiently near to flee to the dens' relative safety and stable temperature. Earlier studies (Chu 1957; Chen and Li 1979) showed two den types: simple and complex. Simple dens have one or two rooms, one of which may have an underground pool. Complex dens may be made up of many rooms. One den complex continued for more than 50 meters and included both above-ground and underground pools. Dens may be readily located due to the presence of numerous airholes that are excavated from the den chambers up to the substrate surface. Although it has been suggested that complex dens are inhabited by more than one animal, and the size and structure of the den is determined by the age and sex of the inhabitants (Chu 1957; Chen and Li 1979), there are few data to support these contentions. As simple dens were seen in farmed areas, and complex dens in "wilder" areas, it is possible that den structure may be related to amount of space available, to substrate type, or to the length of time it has been actively occupied. This needs further investigation.

Courtship and mating occur from early to mid-June. Bellowing may signify locations, sizes, and sexes of animals and may aid potential mates in locating each other.

Courtship consists of snout-touching, "chuffing" vocalizations, and, if not broken off in the early stages, submerging and resurfacing, often followed by snout lifting. Mounting ensues. Successful mounts are characterized by the male positioned slightly laterally on the female's dorsum, his tail wrapped around and under the female's tail so that the vents may meet. These mounts last for approximately 15 minutes.

Nesting occurs in mid-July, one month after copulation. Nests are typical crocodilian mound nests of scraped-together vegetation, predominantly bamboo. Between 10 and 40 (Huang 1982; Groombridge 1982) eggs are laid in the nest.

There is evidence that the female guards the nest, but not diligently enough to deter children from overrunning nests and destroying the eggs within.

Eggs hatch in late September approximately 70 days after oviposition, just in time for hibernation to begin.

Habitat

On-site investigations indicate the Chinese alligator occurs in three categories of habitat: (1) riverine and swampy areas, (2) sea level or nearly sea level agricultural communes, and (3) tree farm communes with reservoirs up to 100 m above sea level. Habitat types may

be further subdivided based on studies of remote sensing imagery for that region (Watanabe and Huang 1982; Watanabe, Walker, and Huang 1982).

Riverine and swampy habitats historically were similar to those regions inhabited by the Chinese alligator's nearest relative, the American alligator, *Alligator mississippiensis*. These were typical crocodilian-inhabited wetlands. The swamps, such as the Yunmeng Swamp (Huang 1982) in Hubei Province have been drained and reclaimed for agricultural use and are no longer suitable for alligators. Rivers are heavily polluted and silted. Most of the remaining riverine alligators were drowned in their dens during severe floods in 1957. Thus, what should be prime habitat is essentially devoid of alligators. In heavily agricultural regions, animals reside in dens built into the banks of irrigation streams, often adjacent to cultivated fields or even behind houses. Some animals even live in narrow earthen dikes between flooded rice fields. This agricultural habitat is less than prime. The human population is very dense and interactions between humans and alligators are frequent. Commune members know where each alligator lives and the habits of each animal. Unfortunately, this renders the animals vulnerable, and, periodically, local people dig one of these alligators out of its den. The hapless animal may be killed, its body left to rot or chopped up for duck feed, or sold to dealers for unscrupulous zoos. Although there are rumors that hides have entered into the international market, these rumors are, to date, unfounded.

The third habitat type, higher than sea level tree farm communes, is home to Chinese alligators solely because of the presence of reservoirs which are adjacent to underground water supplies. During drought, the animals leave their reservoirs in search of water, but they have no place to go. Heading uphill would lead them to cooler mountainous regions in which they could not survive. Downhill will lead them into less than prime, heavily populated human habitat. Thus, the higher altitude reservoir habitat is the last refuge of the Chinese alligator.

Even here, the alligator is not safe from man. We found dens only days after they had been destroyed by local people who had removed the resident animals. While searching for dens we were followed by peasants, some anxious for information on den locations.

Conservation Measures

Officially, the Chinese alligator is classified as a "number one category endangered species" (Huang 1978, 1981, 1982), the same classification as the giant panda. On paper, the communes in southern Anhui Province have been set aside as alligator preserves, but heavily populated working agricultural communes have neither the staffs nor the resources to protect the alligators from harassment, removal, or killing by the local inhabitants. Protection is minimal. It is illegal to capture and kill animals, but there is no enforcement.

On only one commune visited in 1981 was there a sign declaring the Chinese alligator to be a protected species. A poster exhorting people to protect the animal was seen at Anhui University in Hefei, the provincial capital, which is outside the range of the alligator. Posters were seen on none of the communes in southern Anhui. Although local officials spoke of the possibility of education campaigns among the local citizens, such campaigns are expensive with results slow in coming, and so have not been initiated.

The Xiadu Alligator Farm was established several years ago in Xuancheng County in Southern Anhui Province, under the auspices of the Prefectural Forestry Bureau. Nine adult animals were maintained there until the first pools and buildings were completed in May 1981. Since then, the farm has affected the local alligator population negatively. Local people, hearing that the farm would pay for animals, caught wild alligators in their dens and carried them to the farm for sale. Reportedly, the farm offered Y100 (U.S. = approx. $66) for any animal over 40 jin (= approx. 0.5 kg) in weight. A wild animal of that weight would measure close to the species' maximum of two meters in length. Some communes, holding recently captured animals of close to, but under 40 jin requested more than Y100. When the farm refused to pay them that amount, the communes refused to transport the alligators to the farm. Presumably, these animals were left to die. By late July 1981, the farm population had increased to 89 alligators, all but one of which were adults. On 13 July, when the farm had 80 animals, only 16 were male. By summer 1982, the farm housed between 130 and 140 alligators. The farm was not designed to handle so many animals. As of 1981, it had three large pools: two wedge-shaped, concrete and stone lined pools approximately 10 m by 10 m on the straight axes and 15 m on the rounded edge, connected by a filtration system, and a larger doughnut-shaped pool. In the wedge-shaped pool, maximum water depth was one meter.

One pool had a door with a double sheet of glass in it so that the activity in the pool could be viewed from an adjacent concrete room. The room itself was to be used to maintain some animals during winter hibernation. Water inflow was via a bamboo pole. Water was pumped from an uphill reservoir by a portable gasoline engine. The drain was a small grate in the wall slightly above floor level. It was readily clogged by dead fish, live ducklings, or debris.

The doughnut-shaped pool was designed as a display and breeding pool. It was approximately 30 m in diameter, with an approximately 20 m in diameter island in the center. Surrounding the island were concrete conduit pipes. Some animals immediately established their territories in the pipes. The remaining animals (more then 60 were in the pool in July 1981) hid in rock crevices or congregated under a temporary bridge the workers used to travel back and forth to the island. The sides of the pool were of concrete and rock; the bottom of mud. Maximum water depth was two meters. Water inflow, as in the other two pools, was through a bamboo pole. The outflow was one small circular drain placed in the side

wall. A *Chinemys reevesi* turtle became stuck in the drain and prevented all water outflow.

Plans for the farm included planting the center island with bamboo and erecting a two-story laboratory building above the filter system between the two wedge-shaped ponds.

Immediately after the first animals were placed in the wedge-shaped pools, farm officials were informed of the abrasive properties of concrete on crocodilian skin, especially concrete made from construction sand (Potter, Bacon, and Watanabe ms.). By early July, many of these animals had concrete-induced lesions. Farm personnel then resurfaced the pools with smoother concrete.

In 1981, the farm had two additional structures: a dormitory and kitchen building and a second dormitory building that also included a meeting room and a guest room.

Two "semi-natural" ponds were dug in an area fed by an underground stream. Both pens were irregularly shaped and very small, the pool of one measuring about five meters by three or four meters with several meters of dry land adjacent. As many as seven gravid females successfully escaped from one pond and only one of these females was located by late July. As the farm supports no natural alligator habitat, and is several kilometers uphill from the Xuancheng River, which, during the dry season is made up of disconnected puddles, animals escaping from the farm would not be likely to reenter the wild population. The semi-natural ponds were on the main pathway and adjacent to the waterhole that was the only source of water for human use at the farm. Thus, the animals were disturbed at all hours of the day and night.

In 1981, one female at the farm laid eggs. She released them in the water in one of the semi-natural ponds, and they were not found until several days after oviposition. A second female was induced to lay one egg by injection of oxytocin.

The farm was not equipped to incubate eggs. However, local people brought eggs in shoulder-slung baskets or in their pockets for sale to the farm, which paid them Y1.00 (U.S. $.66) per egg. Banded eggs, unbanded eggs, and eggs that had been rotated were purchased. Eggs were set up in straw baskets, or crockery or rubber basins on the concrete floor of the guest room. Protocols for care of eggs during incubation were given to farm personnel, but they were not followed. Of more than 200 eggs incubated at the farm in 1981, approximately 40 young hatched and 24 survived until hibernation. Eighteen of these young came out of hibernation in the spring, but all died before summer. Chen Bihui (pers. comm.) reported an 86 percent hatchling success rate at the farm in 1982 but he did not report numerical data.

The farm has no facilities for young animals.

The farm is run by the director of the Prefectural Forestry Bureau. Several wildlife technicians are on the staff. Only one staff member has any wildlife management background. He is a graduate of the local agricultural college.

The farm was designed and built without assistance or input from any person or organization experienced in crocodilian farming. No one from the farm visited the Swatow Crocodile Farm in Southern China, which was established with the assistance of Utai Yangprapakorn, proprietor of the Sumatprakan Crocodile Farm in Thailand and who is known to Chinese authorities as Mr. Yang.

The staff had no training or experience in the operation of an alligator farm. Animals were fed fresh fish and ducklings several times per week, but food quantities were not monitored and food not consumed was allowed to rot in the pools. Pools were overstocked and rarely cleaned. Although animals were tail-clipped and data on length, weight, sex, and location of capture were maintained, pools were stocked haphazardly with no consideration for the animals' sexes or sizes.

Eggs were weighed, measured, and marked, with the width of the white band clearly delineated, but eggs were not kept moist, and incubation temperatures and band width changes were not monitored.

Problems were further compounded by the lack of technology. Simple items such as thermometers, plastic bags, wax pencil or permanent ink markers, and insulated styrofoam boxes are unavailable. No one at the farm could read any language other than Chinese, so instructional and scientific materials must first be translated.

Farm personnel are responsible for enforcement and guarding the habitat at communes within the prefecture. Donghe Commune in Nanling County had more than 28 alligators, many of which were badly harassed by people. From the time we left Anhui in late July 1981 until July 1982, when one of us (CCH) returned to the commune, Donghe had not been visited by farm personnel. In the past, every two years at least one nest at the commune hatched successfully. In 1981, all eggs were removed and sold to the alligator farm. Thus, the farm was serving as a stimulus to remove animals and eggs from the remaining habitat, and was maintaining the animals in a captive environment where husbandry was less than adequate and where there was little chance for reproduction. Recent articles in the Chinese press accused the farm of becoming an "alligator crematorium" (Anon., 1982).

Mr. Chen Bihui of Anhui Teacher's University in Wuhu is scientific advisor to the farm, though he spends only a few days per year there.

If given a properly trained staff and some small amounts of technology, it is possible that the situation at the Xiadu Farm could be changed. There is sufficient area (89 hectares now, to be expanded to

3,335 hectares) and enough manpower to run an effective farming operation. But without aggressive lobbying of the Central Chinese Government from outside conservationists, and, especially, agitation to allow continuation of collaboration with experts knowledgeable in crocodilian farming procedures, the farm and, unfortunately, the entire alligator population of southern Anhui Province are doomed. The Central Government is genuinely interested in conservation of the alligator but the Xiadu Farm is under local control.

Fortunately, two captive breeding facilities are being established in Zhejiang Province with the full cooperation of the Zhejiang Provincial Forestry Bureau and with the professional assistance of one of the authors (CCH) and Prof. Shi, an embryologist.

Although several Chinese zoos have Chinese alligators, only the Shanghai Zoo has successfully bred the animal in captivity. In spring and summer, alligators are maintained in a semi-natural pond outside of the public areas. In 1980, twelve young were hatched and in 1981, seven young were hatched.

The Beijing Zoo has about 34 Chinese alligators in an indoor enclosure suitable for less than a third of that number. In 1981, one egg was found, but it did not develop. They plan to build an outdoor quasi-natural breeding pond. The Reptile House staff at the Beijing Zoo is extremely well experienced and competent and is anxious to give the animals the best situation possible. One of the authors (CCH) and Prof. Shi are advisors to the Beijing Zoo on this project.

SUMMARY

The picture for wild populations of the Chinese alligator is bleak. Based on the number of animals known to us in the Xuancheng region--63--and the increase in the farm population from nine to 89 individuals, all but one of which were adults and only one or two of which were counted among the 63 animals we knew of, within two months, we estimate that the alligator population of the Xuancheng region must be in the range of 300-500 animals. Most of the animals we knew of were juveniles, and we suspect the population is heavily skewed toward younger age groups. No area in the Xuancheng region is "wild." All are heavily influenced by humans. Alligator inhabited regions in Zhejiang and Jiangsu Provinces supposedly support smaller populations than Xuancheng. Thus, we estimate China's total alligator population, including animals at farms but excluding animals at zoos, to be, at most 1500-2000 individuals. Refined censusing techniques are necessary for more accurate figures.

Continued capture and killing will further reduce the population. Unless husbandry procedures are drastically revised, capture of animals and collection of eggs for sale to the Xiadu Alligator Farm will ensure that there will be little successful reproduction, and the mature animals will be subjected to improper care.

Natural phenomena, such as floods, may be expected eventually to destroy the entire wild population living in the human modified habitat on sea level communes. Drought could destroy the remaining alligators in all habitats.

Barring any extremes in natural conditions, we hypothesize that the Chinese alligator will be extinct in the wild by the early 1990's.

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THE U.S. TRADE IN CROCODILIAN HIDES AND PRODUCTS, A CURRENT PERSPECTIVE

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ABSTRACT: With the deregulation of the American alligator in 1979, and subsequent changes in state regulations, a promotion to re-introduce the "alligator look" was initiated. Untanned hides were exported out of the U.S., primarily to France and Italy. The fashion appeal was short-lived and has been largely replaced by quality leather of domestic species.

The crocodile leather and products industry in the United States has gone through a significant metamorphosis over the past ten years. Products made from the hides of the American alligator (*Alligator mississippiensis*) and exotic species such as the Nile crocodile (*Crocodylus niloticus*) carried with them a mark of distinction and affluence, while hides of caiman were used to produce stuffed trinkets, cheap belts, shoes, and watchbands. By 1970, many of those species most prized for their hides had suffered from over-exploitation and experienced dramatically declining populations.

A campaign to protect crocodilians was launched in an atmosphere of genuine concern for the environment. It was well received by governments, wildlife organizations, and the general public. The phrase "Endangered Species" came into everyday use. In 1973, the Convention on International Trade in Endangered Species afforded some protection for nearly all species of crocodilians, although the countries that processed most of the crocodilian hides for the world market either refused to sign the agreement or took exception to the inclusion of the crocodilian species they utilized. The U.S. Endangered Species Act was also passed, and for some forms, such as *Caiman crocodilus yacare*, provided total protection, although CITES listed the species on Appendix II. Many states followed and adopted the Federal and International lists into local wildlife regulations. New York State had already taken the lead with the passage of the Mason Bill in 1971. It totally prohibited the sale or possession for sale of all crocodilians and their products. This measure was enacted only after a lengthy battle with representatives of the crocodilian leather industry.

New York law was significant, in that more than 80 percent of the U.S. commerce in crocodilians passed through the Port of New York City.

New York City is also the nation's financial center, the center for the fabrication and distribution of crocodilian products, and the home of many fashion designers, advertising agencies, and fashion magazines. The effect was dramatic, and crocodilian products all but disappeared from the nation's boutiques and shops. Highly specialized reptile tanneries perished, while fabricators turned to other materials. The U.S. had been importing and exporting exotic hides and products to many countries. Japan, for example, depended on the U.S. for 16.3 percent of its crocodilian products in 1970. This figure had fallen to zero percent by 1978 (Duplaix, 1979).

French, German, Italian, and Spanish markets continued uninterrupted, although not without feeling the loss of the U.S. industry. France alone emerged as the world's leading producer of quality crocodilian leather, and by 1981 accounted for 96 percent of the traffic in endangered crocodilian species (TRAFFIC [USA], 1982b).

Under the protection of independent governments, and international agreement, some species began to recover. Others, such as the black caiman (Melanosuchus niger), remain at the brink of extinction and continue to be exploited after years of nearly total protection. In contrast, the American alligator (A. mississippiensis), under total effective protection for almost ten years, recovered remarkably. The species was to become the vehicle for the United States' re-entry into the world crocodilian products market.

In order to achieve the goal of re-vitalizing the U.S. crocodilian trade industry with the American alligator as its basis, Federal and state regulations had to be changed to allow the transport, fabrication, and sale of what was touted as the "uniquely American product." The American consumer also had to be "re-educated" after years of indoctrination that crocodilians were endangered and commerce was bad for animals. Proponents for utilization were told that the world was hungry for the finest of all crocodilian leathers. In a period of economic depression, leather merchants, tanners, and fabricators in New York and around the nation pressed legislators for the necessary regulatory changes. In New York City, the repeal of the ban on trade in crocodilian leather was heralded with the announcement that 13 new fabricating factories would provide 1000 new jobs for the unemployed (Mathews, 1980). Concerns that the re-introduction of the American alligator into the market, estimated to be between 10,000 and 20,000 hides a year, would stimulate further utilization of other endangered species, were put aside as unfounded (Ashley, 1980).

A major stumbling block to the millions of dollars which could be infused into the U.S. economy was the fact that conservationists had saved the alligator and protected the crocodilians of the world, but had killed the U.S. industry. Only three U.S. tanneries had survived the lean years. European crocodilian product experts advised that these tanneries could neither process the annual volume nor produce a quality

product that could compete on the world market with European tanners. Representatives of the leading French tanners appeared to have had the solution. U.S. alligator hunters and farmers would realize the maximum prices for their raw hides if the export of untanned American alligator skins were allowed (Ashley, pers. comm.).

The newly formed (1978) National Alligator Association, representing hunters, farmers, buyers, and dealers in hides and skins, initiated a campaign that was supported by the Louisiana State legislature to legalize alligator hide export. Funds to form a lobby to secure the export legislation were supplemented by $3,000 in "seed money" and a promise of $1.25 per skin purchased, as dues, from the leading French tanning company (Ashley, in litt.). On 12 October 1979, the Federal regulations were changed to allow the export of the raw untanned skins of the American alligator. The fate of the U.S. tanning industry, and ultimately the crocodilian products market, was practically sealed. U.S. tanners would never be capable of competing with the larger foreign companies, already geared for large volume production. Nor would there be any foreign incentive to infuse expertise or technology into the U.S. industry or utilize U.S. labor. Proposals to limit alligator exports to those countries that had signed the CITES agreement or had not taken exception to the ban on utilizing endangered species were not enacted. To do so would have precluded the export of skins to countries that were to provide the greatest market, including France.

The 1979 harvest of 15,000 American alligator hides from Louisiana was the first to be exported (T. Joanen, pers. comm.). A major fashion promotion was launched, aimed at the U.S. consumer and directed at the 1980-1981 fashion season. Similar European promotions were also underway. U.S. fashion magazines declared "alligators are back," "crocodile look is in," and alligator leather was the fashion of the season. The title "alligator" was indiscriminately placed on products made from the hides of caiman and black caiman.

The effect on the utilization of other species of crocodilians is difficult to determine. However, excluding the hides of American alligator, U.S. imports of crocodilian hides and products rose from 10,303 pieces in December of 1979, to 44,790 between July and September of 1980, and to 60,601 pieces in January to March of 1981 (TRAFFIC [USA], 1982c). Shipments of reptile imports through the Port of New York, including all crocodilian hides and products rose from 236 shipments in March of 1980 to 416 in November 1980, 619 in June 1981, and 998 in October of 1981 (D. Mack, TRAFFIC [USA], pers. comm.). Examinations by the U.S. Fish and Wildlife Service showed significant inclusions of Crocodylus niloticus, Melanosuchus niger, Caiman latirostris, and Caiman c. yacare. Surprisingly, handbags fabricated from the hornback of Tomistoma schlegelli and Crocodylus johnsoni were also represented.

In 1981, 29,598 raw alligator hides were exported from the U.S., primarily to France and Italy. Hunters received an average of $119 per skin (T. Joanen, pers. comm.). The skins averaged 2 m in length and 56 cm in belly width. These hides were exported at a declared value of $157.45 per hide and were composed of 1980 and 1981 harvests. In 1981, 13,744 hides were imported into the United States from France and Italy in nearly equal numbers (N. Roeper, TRAFFIC [USA], pers. comm.). These hides, now tanned and finished, were declared to be valued at an average of $131.53 per skin. Presuming these comprised the 1979 harvests, averaging $97.50 paid to the hunter and experiencing the same dealer/exporter mark-up of an average of $38.45, then the value of these skins should have been at least $135.95, had they still been raw skins. Tanned and finished, these appear to be valued at $4.42 per skin less than their value in their raw state. United States' fabricators did not benefit from such savings and paid approximatately $16.00 per belly inch. Based on an average 2 m long hide with a belly width of about 56 cm, the average hide cost fabricators $352. Manufacturing, wholesaling, and distribution costs may double prices at each change of hands. Finally, at the retail level, the product is offered to the consumer at an additional one to three-fold mark-up. A ladies' purse or handbag, depending on the reputation of the manufacturer, the quality of the fittings and linings, and the selection of portions of hides used, commands prices ranging from $1100 to $4000. A pair of men's shoes could cost $500 to $900, and a billfold $150 to $250. Prices for crocodile products closely parallel those for American alligator.

Designers and merchandisers reported that for any fashion to be successful the product should have a three level market appeal. The top of the line should be superbly made goods of high quality, commanding high prices, and appealing to the affluent trend-setting consumer. The second tier would be a good quality line of goods with appeal to the consumer of taste, willing to spend a moderate sum. The third tier would be composed of a line of products of poor to fair quality, cheaply manufactured at a low price, with appeal to the general public with modest means. The lattermost category had historically been filled by cheap products made from the flanks of Caiman crocodilus. But in the shadow of the "alligator look" caiman hides and products were offered at nearly the same prices as alligator products to the retailers. A pair of men's shoes composed of pieced-together caiman flanks carried price tags of from $450 to $550.

With the demand for the "crocodile look," there was an increase in the numbers of caiman shipments imported from Paraguay and Bolivia (U.S. Fish and Wildlife Service, pers. comm.). Irregularities in shipping documents, CITES permits, and difficulties identifying the hides and flanks of non-endangered species from those of Yacare caiman led the U.S. Fish and Wildlife Service to refuse to allow entry to those species from Bolivia and Paraguay in August 1981 (TRAFFIC [USA], 1982a). The ban continues, and precludes the U.S. industry from participating in a large part of the fabrication of products.

Many importers and fabricators, assured by their European suppliers that the hides and products shipped to them were "legal," lost hundreds of thousands of dollars worth of hides and products seized on Endangered Species violations. In November 1981, the U.S. Lacey Act was amended and penalties increased to $20,000 and five years in prison on felony charges for trade in violation of state or foreign laws. Defense fees, loss of business because of the inability to meet orders, and a sense of confusion led many to turn away from crocodilian products.

The American consumers played the most significant role. In the 60's and 70's, they had rallied to save species of wildlife they would never see, and had hardly heard of. The slaughter of whales brought international condemnation. The public spent millions of dollars, and many individuals risked arrest and prison to protect the environment from nuclear waste. These were also the people the industry expected to crave the killing of alligators in order to wear them on their feet and carry them as purses and key chains. The high cost of living had left the consumer with little money to spend on the luxury of a $2000 purse. The industry appeared again to have miscalculated; the consumer was not buying.

In order to assess the current state of the crocodilian products markets and evaluate the prospects for the near future, more than 30 shops, boutiques, department stores, fabricators, fashion designers, and merchandisers were surveyed in July and August 1982 in New York State, New York City, and Washington, D.C. In all but one shop, crocodilian products were offered at some discount, but were not selling. A $425 pair of caiman shoes might be discounted 10 to 15 percent, but further discounts generally were not possible because of the high prices paid by the retailer for the product. Alligator, crocodile, and caiman attache cases, discounted to $1900, had remained on the shelves for over a year. All merchandisers reported low inventories that they wished they could dispose of, without the loss of investments. None indicated they intended to renew inventories of anything but the very minimum levels needed to remain competitive.

Of the three U.S. tanneries that survived the interruption to the hide industry, none experienced the benefits of a vital new market. One tannery was destroyed by fire in 1980, and a second is rumored to be contemplating discontinuing the tanning of crocodilian hides. The third continues to produce mediocre quality American alligator hides in small quantities. In New York City, no new factories were opened, and, in fact, several which were in operation at the start of the "alligator look" have closed. The prospect of increased job opportunities never materialized. Reptile hide and product imports through the Port of New York (imports of reptile products and hides through the Port of New York make up approximately 85 percent of the U.S. imports), including crocodilians, began to fall. In June 1982, 407 reptile shipments arrived, compared to 619 in June of 1981, and this figure remained at 402 for July-August 1982. These shipments were composed largely of snake and lizard skins and fabricated items (U.S. Fish and Wildlife Service, pers. comm.).

French supporters have also changed position, refusing to pay $15,000 in dues to the National Alligator Association (D. Ashley, in litt.). Additionally they did not bid on hides harvested in Florida in 1981 (T. Joanen, pers. comm.). However, when compared to their American counterparts, it appears that foreign tanners have benefitted the most from the short life of the "alligator look."

A little more than a year ago, fashion magazines ran numerous advertisements for crocodilian products. Times have changed! Of 28 leather shoe advertisements featured in the July 1982 issue of Vogue magazine, the nation's leading fashion forecaster, only two promoted reptile leather--and snake skin at that! The fashion look for the 1983 season? It would be polished calfskin. The wane can be summarily attributed to several major factors: lack of consumer interest, high product cost limiting its appeal, the difficulties importers experience in complying with wildlife regulations, and perhaps most importantly, the international economic recession.

Crocodilian products will not disappear entirely from U.S. shops. But, the time for the "alligator look" is past. Perhaps in a few years fashion designers will again turn to quality reptile products for "that new and exciting look."

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PROBLEMS IN THE IDENTIFICATION OF COMMERCIAL CROCODILIAN HIDES AND PRODUCTS, AND THE EFFECT ON LAW ENFORCEMENT

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ABSTRACT: Most processed crocodilian hides and products enter the market devoid of identifying characteristics and traceable marks or tags. The ability of customs agents and wildlife inspectors to determine the presence of endangered species or confirm documentation is limited. The state of the art is discussed.

With the signing of the Convention on International Trade in Endangered Species (CITES) agreement in 1973, customs and wildlife agencies around the world were faced with the problem of identifying rare and endangered species, including crocodilians, from raw skins, processed hides, and a wide variety of manufactured products. Most of the available literature on the identification of reptile leather had been published by processing and tanning technicians, and dealt primarily with the problems of tanning, finishing, and tanning chemistry (Fuchs, 1974).

The commercial identification of crocodilian species had long been based on general characteristics which tended to lump hides of similar forms and quality together. These hides were given colloquial names to describe them. The names were often based on the common name in use in the region from which most of a particular type of skin came, or simply a shipping point. Terms such as "Singapore," "Java," or "Thailand small scale" all referred to Crocodylus porosus skins. The term "Tinga" meant any member of the genus Caiman, from anywhere in tropical America. Caiman latirostris could be referred to separately as "Overo," or any one of four other names. Additionally, local people often sold the skins of Crocodylus acutus, Crocodylus intermedius, and Crocodylus rhombifer as "Cayman."

The commercial sorting and subsequent marketing of tanned hides by broadly similar characteristics is not uncommon. Belly hides with "squiggle"-like scale patterns from the Orinoco River would be combined with all skins bearing the same patterns from different origins. The patterns are actually the trails of a parasitic nematode genus Paratrichosoma (Ashford and Muller, 1978), and are

found on the ventral scales of at least four species of crocodilians from completely different parts of the world. Combined, all may be marketed as "Orinoco Crocodile" (King and Brazaitis, 1971).

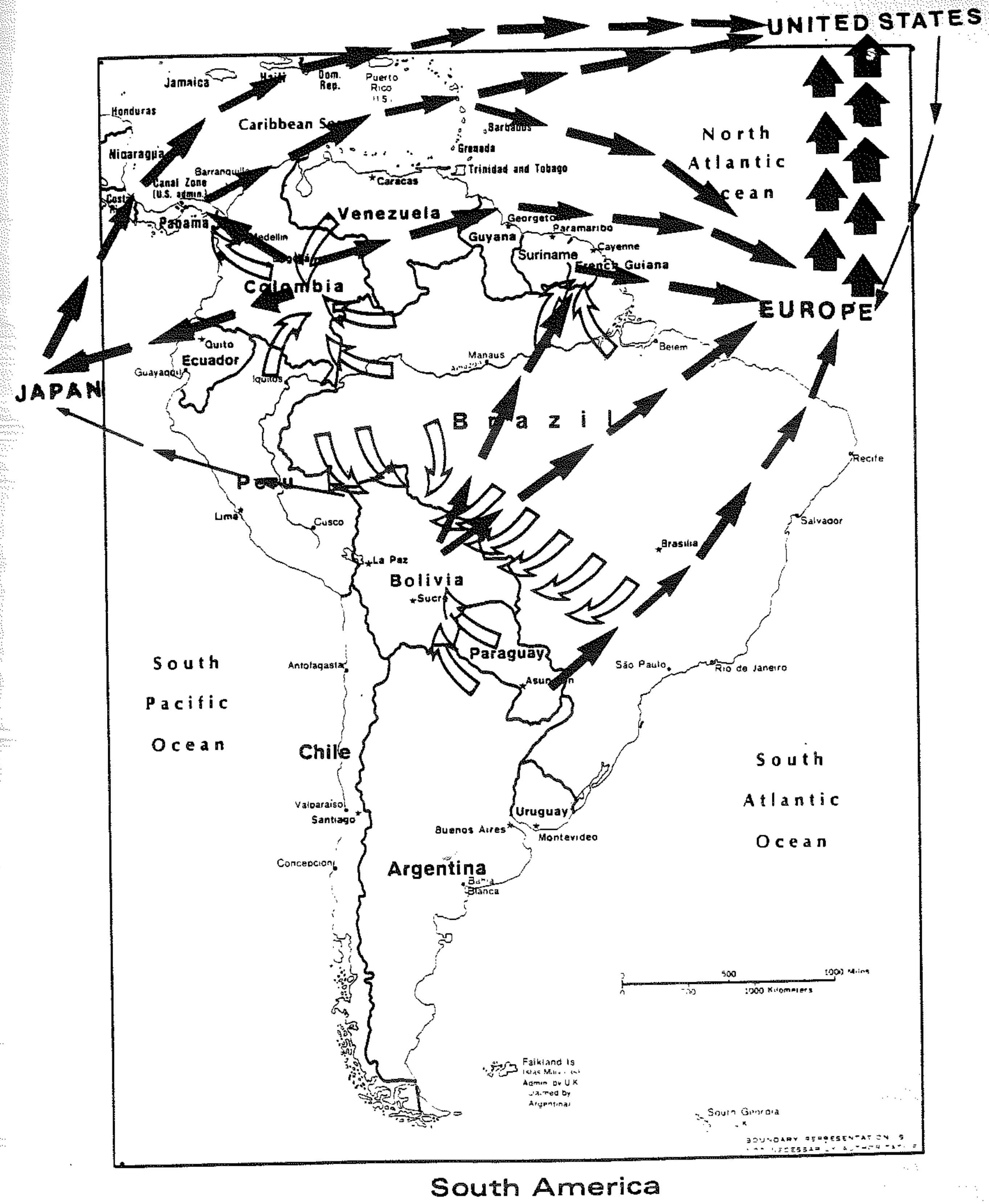
Raw skins are collected through a network of local hunters, foraging far into the field, with little regard for political boundaries. The possibility of encountering a wildlife officer is remote. It is usually at the place of export that collected skins are given a cursory examination, usually for the purpose of collecting duties rather than species identification. Even at this time, Tinga skins may only be represented by flank skins and tails. Skins from various collection sites may then be combined with other skins, of the same type but not necessarily the same species (Fig. 1). These are then processed together at the tannery, provided they require the same treatments. Final sorting for market is based on commercial type. All Tinga skins would be processed together. Other sorting categories would include belly width, dyed color, and grade. Grade I designates a perfect hide, free of holes and major blemishes; grade II with some small holes, and so on, depending on the degree of damage.

Hide documentation is a significant problem. Several hundred or thousand Tinga skins or flanks may be placed in a tanning container together, representing caiman skins from several countries, and more than one race. Once finished and sorted, they may be shipped with documents indicating the origin of a sample of those hides, but not necessarily the same hides shipped. As the skins were unmarked and are not traceable, the validity of the documentation cannot be substantiated. Tinga hides, invoiced as Caiman crocodilus crocodilus with documentation indicating the country of origin as Paraguay, may be seized upon entry as an endangered species violation. Caiman c. yacare, a U.S. listed endangered species, is the only caiman endemic to Paraguay. Similar confounded documentation involving unmarked and non-traceable caiman skins from Bolivia has led the U.S. Fish and Wildlife Service to refuse entry to shipments from that country and Paraguay effective August 1981 until the problem can be resolved. On the other hand, C. crocodilus may be acceptable with Colombian documentation, although they may have been taken illegally in Brazil.

The wildlife or customs inspector has no way of corroborating the documentation of unmarked skins, and often cannot identify the species involved; nor can an importing fabricator of crocodilian products. Manuals for the identification of crocodilian hides and products pose differing views on speciation. Industry manuals tend to arbitrarily assign hide types to different distributions, without scientific foundation, or taxonomic review. The hides illustrated are often indistinguishable from each other (Fuchs, 1974). Such manuals are widely used and duplicated within the industry. Importers who may rely on these manuals and the taxa they describe

FIGURE 1. Trade routes for South American crocodilian skins.

Open arrows indicate direction of transportation from areas of origin to South American tanning centers or major points of export. Dark arrows indicate direction of shipment out of South American to Japan, Europe, and indirectly, the United States. Heavy black arrows indicate direction of movement of the bulk of finished caiman skins from Europe to the U.S.



may experience delays and seizures of goods. The wildlife officer, utilizing manuals based on established biological taxa, may discover that few tanned incomplete hides, or products, can be readily identified without a strong background in crocodilian morphology and classification (King and Brazaitis, 1971). With limited time, and the knowledge that the hides are often untraceable, the inspector has little choice in many instances but to accept the documentation at face value.

Ports of entry of wildlife are often understaffed. Large numbers of shipments are processed, contain many individual items, and arrive in short periods of time. Agents and inspectors are called upon to complete volumes of paper work to support seizures and violation charges, in addition to enforcing local wildlife regulations, answering queries from the general public, and inspecting export shipments.

In 1981, 7,186 reptile shipments entered through the Port of New York. TRAFFIC (U.S.A.) reported that 117,506 crocodilian products, and 93,679 skins entered the U.S. through the Port of New York in 1981 (Roeper and Hemley, this volume), excluding those of American alligator. The figure represents 85 percent of all of the crocodilian imports into the United States during that period. The port was staffed by six agents, a trainee, and seven inspectors, including supervisors. The inspectors would have had to have examined about 40 reptile shipments per person per day plus individually shipped items. Crocodilian shipments were given priority, and nearly all shipments were given some scrutiny. Seventy-eight shipments alone were referred to one independent forensic examiner for corroborative identification.

Nearly all commercial crocodilian products lack skulls, complete body scutellation, and documented collecting data. The examiner is usually presented with an incomplete, unmarked processed hide or raw skin, pieces of hide, or a finished product composed of a number of pieces of hide. The pieces may represent one or more animals and species. The examiner may not damage or dismantle the product to establish the identity of its components. In order to maintain the examiner's objectivity, he/she is deprived of all knowledge of the item's origins, and the name of the species cited in the documentation.

The examiner's first step is to establish that the product is composed of genuine hide, rather than embossed crocodile pattern on domestic leather, or plastic. Artifical skin is distinguished by the repetition of scalation, lack of seams as the scales of one type blend with other scales from a different body region, and the loss of natural variation and detail in the creases and folds of the fine skin. Careful examination can save the examiner considerable embarrassment in court at a later date. Next in importance is to

determine the part of the crocodilian's body from which the sample was derived in order to determine which definitive characteristics of identification may apply. Not every part of every crocodilian bears identifiable characteristics. Many characteristics are evident on those body parts which are most often used in the manufacture of products, such as the ventral tail, ventral belly and osteoderms, and flanks. It is often necessary to examine numerous samples before one is found which bears an identifiable characteristic.

Sensory pits are found on the ventral and flank scales of all crocodylids and gavialids, and are absent from the scales of all alligatorids. Crocodylus siamensis has midventral tail inclusions and Crocodylus moreleti has transverse ventral tail inclusions in addition to sensory pits. Osteolaemus tetraspis and Crocodylus johnsoni both have additional ventral osteoderms, and unique flank and nuchal patterns often utilized in products. Crocodylus niloticus and Crocodylus cataphractus bear somewhat reduced osteoderms in the gular, pectoral, and midventral regions respectively. Among the alligatorids which lack body sensory pits, Alligator mississippiensis frequently has reduced single osteoderms in the gular and pectoral scales, while Melanosuchus niger and Caiman have compound ventral osteoderms and variations in surface skin pitting after tanning. Lateral or flank scales vary considerably between species, but the races of C. crocodilus are virtually impossible to identify as cut pieces incorporated into a manufactured product. Most manufactured products do not display specific single characteristics by which the species of the crocodilian involved can be determined by simple morphological examination (King and Brazaitis, 1971; Brazaitis, 1973).

In order to deal with the problems more effectively, the U.S. Fish and Wildlife Service has proposed the development of a forensic laboratory as part of its recently formed division of Forensic Science. The laboratory will deal with the identification of all forms of wildlife, and would make forensic services available to state and local wildlife authorities.

The international traffic in millions of completely unmarked crocodilian hides and products poses one of the greatest obstacles to the effective enforcement of national and international endangered species regulations. Hides and skins frequently cannot be traced to their source or country of origin. Legally harvested or farmed animals cannot readily be distinguished from those clandestinely exported from illegal sources. Tariffs may be lost when export quotas are exceeded without controls, or are not substantiated by adequate records.

Of the 19 species and subspecies of crocodilians regularly utilized by the leather industry, only the hide of the American alligator bears a tag of identification, placed on it at the time the animal is killed, and maintained intact until the hide is manufactured into a product. As mandated by CITES, it is the only species of crocodilian where the origin and date of harvest, size, and passage from hunter to manufacturer can be substantiated through a system of numbered, color-coded tags. The reptile leather industry has resisted such markings as too costly, cumbersome, and ineffective. Yet, the system is working, and tags placed at the time of capture are still intact after processing and transport overseas and back. The use of dyes, roll marking, and infusion of detectable chemical tracers has yet to be fully explored.

A critical need exists to develop internationally acceptable methods of marking individual hides and products, in conjunction with a comprehensive monitoring and data retrieval system. In the meantime, countries which take exception or refuse to abide by the CITES agreement will continue to profit from the taking of endangered species. The traffic in illegal crocodilian hides and products will continue as long as law enforcement agencies lack the tools and means to execute their responsibilities. It is not enough to hope that the fashion world will change its interests.

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REPORT ON THE STATUS OF THE CAPTIVE BREEDING PROGRAM FOR THE CHINESE ALLIGATOR *Alligator sinensis* IN THE UNITED STATES

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In 1975, the New York Zoological Society joined with the National Zoological Park and the Louisiana Department of Wildlife and Fisheries, Rockefeller Wildlife Refuge, and established the first captive Chinese alligator, *Alligator sinensis*, breeding program (Behler, Brazaitis, and Joanen, 1982). Other contributing or cooperating institutions have since included the Beijing and Guangzhou Zoos of the People's Republic of China; the Munich, Stuttgart, and Budapest zoological parks; and the San Diego and Houston Zoos in the United States. An official captive breeding studbook, the first for a reptile species, was established in May 1982, naming John Behler, Curator of Reptiles at the New York Zoological Park, Studbook Keeper and Program Coordinator.

Breeding facilities were established at the Rockefeller Wildlife Refuge, Grand Chenier, Louisiana, under the management of Ted Joanen, and at the New York Zoological Park, where adults are maintained. The program was expanded in 1980 to include the Houston Zoo as a potential additional breeding facility.

Chinese alligator breeding groups presently include a pair of young adults from the Guangzhou Zoo and a 1.2 m female from Munich, of undetermined age, which are maintained at the New York Zoological Park. The Rockefeller group consists of an original pair of animals from the New York Zoological Park, now in excess of 40 years of age, a young male from the Beijing Zoo, and an older female from the Budapest Zoo. The Rockefeller group also had included an original pair from the National Zoo, also believed to be in excess of 40 years of age, which have since expired.

To date, only the eldest 40 year old+ New York and National Zoo (Davenport, 1982) animals have bred, and only at the Rockefeller Refuge. Breeding occurred in 1977, the spring following their initial liberation into spacious outdoor breeding facilities, and in 1978, 1979, and 1980 (Behler and Joanen, 1982). No offspring were produced in 1981, 1982, or 1983. The breeding took place prior to the aquisition of and introduction into the program of the European and Chinese specimens in 1983. The present living offspring include three males hatched in 1979 (including one dwarfed animal that will not play a role in future breeding programs), and 18 juveniles hatched in 1980 (Fig. 1). Of the 18, 14 are being reared at the Reptile House at the New York Zoological Park, which is the primary rearing facility for the program. Four additional animals reside in temporary quarters at the Houston Zoo.

The 17 juvenile animals at the New York Zoological Park (except for the dwarf of 1979) are now maintained in an exhibit area approximately 5 m long and 3 m wide, of which approximately 2/3 consists of an 80 cm deep pool heated by continuously running water at 28 to 30°C. Food consists of freshly killed mice, small chicks, and an abundance of live freshwater fish, offered two to three times weekly. Although no supplementary vitamins are administered, the animals are fed only whole, unfrozen, live, or freshly killed foods. In addition, the young alligators have been reared under ultraviolet light, in the 310 to 400 nm range. All individuals display well developed teeth and bones with good physical conformation, and average approximately 1 m in length as of early 1984.

Figure 1 shows the group of 1980 animals soon after hatching in September of that year. The coloration is basically black with yellow-white crossbands with some orange-yellow highlights. Each animal bears a characteristic "X" shaped marking on the snout. Markings are crisp and well defined. Figure 2 shows the typical coloration of a one year-old juvenile at about 50 cm in total length. Numerous light spots have appeared which have begun to diffuse the hatchling patterns. The characteristic "X" on the snout is nearly obliterated. By three years of age, the animals had become almost uniform gray in coloration with some lighter crossbanding remaining, primarily on the sides of the body and tail.

Preliminary sexing indicates that most of the 1980 hatchlings are females while those hatched in 1979 are males. Some 1979 and 1980 individuals began to respond to adult vocalizations in 1984, and engage in courtship activities such as pre-copulatory mounting.

Losses have included some of the animals which had been maintained in zoological collections for many years and which were estimated to be between 30 and 40 or more years of age upon acquisition and introduction into the breeding groups. These include the original pair acquired from the National Zoo, a single female from Stuttgart, and a female from Budapest. Losses among hatchlings included one animal which expired soon after hatching in November 1980 at the New York Zoological Park and two 1980 animals at the Houston Zoo in April and June 1981.

Figure 1. 1980 hatchlings, Alligator sinensis

Figure 2. Yearling Alligator sinensis

The future breeding potential for the Chinese alligator in the United States is promising. Both the New York Zoological Society and the Louisiana Department of Wildlife and Fisheries, in concert with other participating institutions, continue to maintain a longterm commitment to the preservation of the species through captive management programs. Additional breeding facilities are currently under consideration. Many other zoological institutions have expressed a willingness to join in the effort. A worldwide survey is underway to identify potential recruits to add to the breeding program.

The captive reproductive potential for the species has increased with the addition of young breeding stock from the People's Republic of China, and the maturing of juveniles hatched in 1979 and 1980 within the next several years. New and intensive captive efforts within the People's Republic of China will also serve to insure the survivorship of the species. The Chinese alligator breeding program is a model of cooperation upon which other programs involving seriously endangered species of crocodilians can benefit.

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CROCODILE AND ALLIGATOR TRADE BY THE UNITED STATES 1981

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INTRODUCTION

The order Crocodylia contains 21 species of alligators, caimans, crocodiles, and gavials, and includes the largest living reptiles. Possessing thick, durable hides, crocodilians are in great demand by the leather industry for the production of shoes, handbags, and other leather products. There is also some demand for baby caimans for the pet trade. All crocodilians currently receive some degree of protection. For example, all three families in the order are listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)--trade is allowed if a permit has been obtained from the exporting country. Fifteen species and an additional two subspecies are listed on CITES Appendix I (see Appendix A)--commercial trade of these species is prohibited. Thirteen species and another seven subspecies are protected by the U.S. Endangered Species Act, which also prohibits commercial trade.

As the market for crocodilian products grows and suitable habitat decreases, the pressure on remaining crocodilian populations increases. In 1981 alone, the value of crocodilian skins, products, and live animals imported to the U.S. was over US $9 million. More stringent controls may be required if present population levels are to be maintained.

This report summarizes the quantities, value, and origin of crocodile and American alligator skins, products, and live animals commercially traded by the U.S. during 1981, and discusses country of origin and species discrepancies.

U.S. Imports of Live Crocodilians, excluding American Alligators

In 1981, the United States imported 15,553 live crocodilians in 17 shipments. In comparison, over 112,000 and 137,000 were imported in 1970 and 1971, respectively, illustrating nearly a ten-fold decline in just over a decade (Table 1).

It is also apparent that both the number of species and the number of countries supplying live crocodilians has decreased since 1970 (Tables 1 and 2). Nine species were imported in 1970 and ten were imported in

Table 1. U.S. live crocodilian imports 1970, 1971, 1979-1981, arranged by country of origin.

Country of origin	Year: 1970	1971	1979	1980	1981
Argentina	4				
Brazil	1				
Cameroon		28			
Canada	2				
Colombia	105,982	136,665		5,280	15,521
Costa Rica		3			
Curacao	6,020			4,700	
Dahomey	1	10			
Egypt	1				
Guyana	276	64		590	
El Salvador				60	
Haiti		5			
Ghana	2	7			
Guatemala			780	10,012	
Japan				275	
Indonesia		10	50		
Liberia		7			
Malaysia	8	2			
Netherlands		1			
Nicaragua	10	190			
pakistan		4			
Panama		32	50,588		
Paraguay		72			
Poland	1				
Singapore	52	73			
Sri Lanka	5	3			
Suriname					20
Thailand	33	25	1		
Trinidad		1			
United Kingdom		1			
Unknown					12
TOTAL	112,398	137,203	51,419	20,917	15,553

Sources:
1970, 1971 - Busack, 1974.
1979 - U.S. CITES Annual Report.
1980, 1981 - TRAFFIC (U.S.A.) analysis of 3-177 Declaration of Importation/Exportation forms, Law Enforcement Division, Fish & Wildlife Service, U.S. Department of the Interior.

1971, compared to only two in 1979 and three in 1981 (Table 2). The U.S. received crocodilians from 15 countries in 1970, 20 in 1981, but from only four in 1979, six in 1980, and two in 1981 (Table 1).

The data in Table 2 suggest that the spectacled caiman, *Caiman crocodilus*, has been the major species imported by the U.S. over the last 12 years. In 1981, *Caiman crocodilus crocodilus* from Colombia accounted for 99.9% of all crocodilian imports. The major source of live caimans in 1980 was Guatemala (10,012 specimens or 47.9%), although Colombia and Curacao* each provided approximately 5,000 caimans. In 1979, Panama was the source of nearly all live caimans imported by the U.S., supplying 98.3% of the total for that year (Table 1).

The decrease in the number of live crocodilians imported by the U.S. is probably due to export restrictions implemented by many countries over the last decade. For example, Panama, the major exporter of caimans to the U.S. in 1979, banned the export of all wildlife and wildlife products in January 1980 (Resolution DIR. 002-80). Consequently, the U.S. did not import any caimans with Panama declared as the country of origin in 1980 or 1981. Guatemala, the major exporter of caimans in 1980, is currently enforcing existing export regulations (Swift, in press). As a result, no live crocodilians entered the U.S. in 1981 with Guatemala as the declared country of origin. Colombia provided over 100,000 live caimans to the U.S. in 1970 and again in 1971. The number of caimans exported to the U.S. has declined since then because of a 1974 Colombian ban on the export of most live animals, including crocodilians (Donadio, 1982). This law has not been adequately enforced, however, as evidenced by all the shipments of live caimans imported by the U.S. between 1979 and 1981 accompanied by Colombian permits.

U.S. Imports of Crocodilian Skins and Manufactured Products, Excluding American Alligators

a. Declared Origins

In 1981, the U.S. imported 107,179 crocodilian skins and 143,727 crocodilian products in 1,129 shipments. The largest number of raw skins originating from a single country were derived from Bolivian caimans (31.4%). Skins of Paraguayan and Colombian caimans made up an additional 29.6% and 16.5% of the trade respectively (Table 3).

Import figures demonstrate a change in the countries supplying the majority of caimans over the last three years. Most of the skins imported in 1980 were of Panamanian (56.5%), Paraguayan (12.9%), and Colombian (12.8%) origin (TRAFFIC [USA], unpubl. data). In 1979, most skins were of Paraguayan (61.3%) or unknown (35.2%) origin (1979 U.S. CITES report).

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* Caimans do not occur in Curacao (Groombridge, 1981).

Table 2. U.S. live crocodilian imports, 1970, 1971, 1979, 1981, arranged by species.

Species	Year 1970	1971	1979	1981
Alligator sinensis		1		
Caiman crocodilus	112,212	136,996	55,571	15,531
Caiman spp.	1			
Melanosuchus niger		8		
Paleosuchus trigonatus	32	2		14
P. palpebrosus				8
Crocodylus acutus	52	21		
C. moreletti	2			
C. niloticus	1	7		
C. porosus	13	24	51	
C. siamensis	39	48		
Crocodylus spp.	3			
Osteolaemus tetraspis	3	46		
Tomistoma schlegelii	44	46		
TOTAL	112,402	137,199	55,622	15,553

Sources:
1970, 1971 - Busack, 1974.
1979 - 1979 U.S. CITES Annual Report.
1980, 1981 - TRAFFIC(U.S.A.) analysis of 3-177 Declaration of Importation/Exportation forms, Law Enforcement Division, Fish & Wildlife Service, U.S. Department of the Interior.

Table 3. 1981 U.S. imports of crocodilian skins, products and live animals, arranged by country of origin and country of export.

Declared Country of Origin	Country of Export	Live	Raw or Tanned Skin	Manufactured Products	Declared Value (US $)
Argentina	France		2	22	933
	Italy		10	118	6,700
	Spain			189	2,307
	West Germany			105	3,235
	SUBTOTAL		12	434	13,175
Bolivia	Bolivia		33,611		263,646
	France			2,074	26,626
	Greece			946	20,141
	Hong Kong			2,702	50,750
	Italy			2,432	83,880
	Korea			30	643
	Switzerland			10	78
	United Kingdom			115	1,970
	West Germany			85	17,429
	SUBTOTAL		33,611	8,394	465,163
Brazil	Austria			117	2,934
	France			208	19,492
	Italy			15	2,280
	Japan		4		138
	Switzerland			5,709	49,647
	West Germany			88	8,065
	SUBTOTAL		4	6,137	82,556
British West Indies	France		1,500	1,561	39,709
	Switzerland			16,659	49,553
	SUBTOTAL		1,500	18,220	89,262
Colombia	Austria			20,893	127,968
	Colombia	15,521	9,864	9,744	193,032
	France			3,908	73,255
	Italy		7,753	32,472	1,180,485
	Japan			252	11,189
	Netherlands			399	1,567
	Spain			1,470	25,733
	Switzerland			619	2,358
	West Germany		18	536	49,301
	Unknown			30	2,475
	SUBTOTAL	15,521	17,635	70,323	1,667,363

Table 3. (continued)

Declared Country of Origin	Country of Export	Live	Raw or Tanned Skin	Manufactured Products	Declared Value (US $)
Costa Rica	Unknown			4	210
	SUBTOTAL			4	210
France	France		50		13,325
	West Germany	12			2,400
	SUBTOTAL	12	50		15,725
French Guiana	France		9,599	365	285,104
	Italy			419	85,261
	Spain			5,292	151,087
	United Kingdom			2	77
	SUBTOTAL		9,599	6,078	521,529
Guyana	France			200	16,783
	SUBTOTAL			200	16,783
Hong Kong	Hong Kong			601	13,530
	SUBTOTAL			601	13,530
India	Unknown			6	595
	SUBTOTAL			6	595
Indonesia	France		1,729	1	385,924
	Italy			72	14,760
	West Germany			1	874
	SUBTOTAL		1,729	74	401,558
Italy	Italy			133	3,868
	Spain			26	574
	SUBTOTAL			159	4,442
Madagascar	France			24	5,937
	SUBTOTAL			24	5,937
Malaysia	Italy			4	1,983
	West Germany			35	12,403
	SUBTOTAL			39	14,386
Nigeria	Italy			147	4,546
	Nigeria			13	120
	SUBTOTAL			160	4,666

Table 3. (continued)

Declared Country of Origin	Country of Export	Live	Raw or Tanned Skin	Manufactured Products	Declared Value (US $)
Panama	Italy			1,833	170,148
	Panama			725	8,732
	Switzerland			120	8,381
	SUBTOTAL			2,678	187,261
Papua New Guinea	Austria			9	1,596
	France		10,633	2,072	3,150,790
	Italy			5,069	798,004
	Japan		12	4	1,625
	Mexico		2		819
	Spain			249	57,096
	Switzerland			3,769	52,004
	United Kingdom			39	8,657
	West Germany			393	40,354
	SUBTOTAL		10,647	11,604	4,110,945
Paraguay	Austria			19	488
	Canada			1,151	7,842
	France		6,823	47	192,278
	Italy		14	8,142	419,196
	Japan		174	45	9,253
	Paraguay		24,689		40,117
	Spain			417	24,941
	Switzerland			30	62
	United Kingdom		20		811
	Uruguay			50	1,137
	West Germany			62	14,558
	SUBTOTAL		31,720	9,963	710,683
Peru	France			8	8,700
	Switzerland			4,856	343,407
	SUBTOTAL			4,864	352,107
Senegal	Senegal			2	6
	SUBTOTAL			2	6
Singapore	France			25	20,031
	Greece			284	4,686
	Italy			1	456
	Singapore		33	851	17,696
	West Germany		138	186	14,743
	SUBTOTAL		171	1,347	57,612

Table 3. (continued)

Declared Country of Origin	Country of Export	Live	Raw or Tanned Skin	Manufactured Products	Declared Value (US $)
South Africa	Italy			9	3,789
	Unknown			12	
	SUBTOTAL			21	3,789
Suriname	Italy			1,294	87,713
	Suriname	20			1,698
	SUBTOTAL	20		1,294	89,411
Thailand	Thailand		1		263
	SUBTOTAL		1		263
Venezuela	Italy			140	28,350
	Spain			324	2,241
	SUBTOTAL			464	30,591
Unknown	France			178	33,469
	Italy		500	52	7,794
	Mexico			4	100
	South Africa			2	25
	Switzerland			331	101,905
	Thailand			3	180
	Unknown			27	2,900
	SUBTOTAL			597	144,947
United States	France			40	8,782
	SUBTOTAL			40	8,782
				401	113,767
	GRAND TOTAL	15,553	107,17	143,727	9,014,703

Source: TRAFFIC (USA) analysis of 3-177 Declaration of Importation/Exportation forms, Law Enforcement Division, Fish & Wildlife Service, U.S. Department of the Interior.

Over 60% (68,165) of the skins imported by the U.S. in 1981 came directly from the declared country of origin, rather than from re-exporting countries. Bolivia supplied over 33,000 skins, 49.3% of the total skins imported directly (Table 4). The final destination of these skins is unknown, as U.S. companies probably could not process them all (68,165)* and most of these skins did not appear as 1981 U.S. re-exports.

In 1981, products made of Colombian caiman skins were imported in the greatest numbers (70,323) and constituted 48.9% of all crocodilian products imported. Lesser quantities were manufactured from skins of British West Indies+ caimans (12.7%) and Papua New Guinea crocodiles (8.1%; Table 4).

It is difficult to detect any shifts in the product trade in 1981 compared to the two previous years because in past years, many shipments of crocodilians were imported with no country of origin declared. In 1981, only 0.4% of the crocodilian manufactured products were imported with no declared country of origin. By contrast, in 1980 most of the manufactured products were of unknown (60.3%), Bolivian (20.7%) or Colombian (8.5%) origin (TRAFFIC [USA], unpubl. data). In 1979, most manufactured products were from unknown countries of origin (80.2%) and Mexico (10.8%)(1979 U.S. CITES report).

b. Species in Trade

Hides of the spectacled caiman, *Caiman crocodilus*, accounted for 89.1% of the skins and 89.7% of the manufactured products imported to the U.S. in 1981 (Table 5). Brazaitis (1973) has taxonomically divided the spectacled caiman into four subspecies, three of which appeared in trade in 1981. The most frequently imported subspecies was declared as *Caiman c. crocodilus*; over 95,000 raw or tanned skins and more than 122,000 products entered the U.S. in 1981 (Table 5). Much smaller quantities of both skins and products declared as the brown caiman, *C. c. fuscus*, and the yacare caiman, *C. c. yacare*, were imported.

The New Guinea crocodile, *Crocodylus novaeguineae*, was the next most commonly declared species, making up 10.6% of the crocodilian skins and 7.4% of the manufactured products in trade. Minor quantities of seven other species were also imported (Table 5).

Declared Value of Crocodilian Imports--Excluding American Alligators

The declared value of all crocodilian skins, manufactured products and live animals imported to the U.S. in 1981 was over US $9 million

*The U.S. has a very limited capacity to process crocodilian hides (Brazaitis, pers. comm.).

+Caimans do not occur in the British West Indies (Groombridge, 1981).

Table 4. 1981 U.S. direct imports of crocodilian skins, products, and live animals, arranged by country of origin.

Country of Origin*	Live	Manufactured Products	Raw Skins	Value (US $)
Bolivia			33,611	263,646
Colombia	15,521	9,744	9,864	193,032
Nigeria		13		120
Panama		725		8,732
Paraguay			24,689	40,117
Senegal		2		6
Suriname	20			1,698
Thailand			1	263
TOTAL	15,541	10,484	68,165	$507,614

*These figures do not include crocodilians imported with declared countries of origin of France, Hong Kong, Italy, and Singapore where crocodilians are not known to occur in the wild.

Source: TRAFFIC (U.S.A.) analysis of 3-177 Declaration of Importation/Exportation forms, Law Enforcement Division, Fish & Wildlife Service, U.S. Department of the Interior.

Table 5. 1981 U.S. imports of crocodilian skins and products--arranged by species and country of origin.

Species	Declared Country of Origin	Skins	Manufactured Products
Caiman crocodilus crocodilus (Spectacled caiman)	*Argentina	12	226
	Bolivia	33,611	7,960
	Brazil	4	6,109
	*British West Indies	1,500	18,220
	Colombia	17,575	67,426
	French Guiana	9,599	6,078
	Guyana		200
	*Hong Kong		600
	*Indonesia	500	
	*Italy		133
	*Nigeria		51
	*Panama		845
	Papua New Guinea	513	192
	*Paraguay	31,432	9,403
	Peru		4,864
	*Singapore	33	851
	Suriname		1,294
	*U.S.A.		40
	Venezuela		140
	South America		8
	Unknown	500	186
	SUBTOTAL	95,279	124,826
Caiman crocodilus fuscus (Brown caiman)	*Argentina		208
	*Bolivia		2
	Colombia	60	2,581
	Panama		1,793
	*Paraguay		115
	Venezuela		324
	SUBTOTAL	60	5,023
Caiman crocodilus yacare (Yacare caiman)	Bolivia		127
	*Colombia		6
	*Italy		26
	*Nigeria		96
	Paraguay	174	192
	SUBTOTAL	174	447
Caiman crocodilus (Spectacled caimans)	Bolivia		300
	Colombia		312
	Costa Rica		4
	*Malaysia		4
	Paraguay		210
	SUBTOTAL		761

Table 5. (Continued)

Species	Declared Country of Origin	Skins	Manufactured Products
Paleosuchus sp. (Smooth-fronted caimans)	*Paraguay		40
	Colombia		98
	SUBTOTAL		138
Crocodylus acutus (American crocodile)	Papua New Guinea		1
	*Paraguay		3
	SUBTOTAL		4
Crocodylus niloticus (Nile crocodile)	Senegal		2
	South Africa		6
	SUBTOTAL		8
Crocodylus novaeguineae (New Guinea crocodile)	*Bolivia		5
	*Brazil		28
	*France	50	
	*Hong Kong		1
	Indonesia	1,229	62
	*Madagascar		24
	*Malaysia		35
	*Panama		40
	Papua New Guinea	10,130	9,871
	*Singapore		490
	Unknown		77
	SUBTOTAL	11,409	10,633
Crocodylus porosus (Salt-water crocodile)	Indonesia		12
	Papua New Guinea	4	1,540
	*Singapore		6
	SUBTOTAL	4	1,558
Crocodylus siamensis (Siamese crocodile)	Thailand	1	
Osteolaemus tetraspis (West African dwarf crocodile)	Nigeria		7
	*South Africa		6
	Africa		6
	SUBTOTAL		19
Crocodylus spp. (Crocodile)	Nigeria		6
	South Africa		9
	Unknown		289
	SUBTOTAL		304

Table 5. (Continued)

Species	Declared Country of Origin	Skins	Manufactured Products
<u>Gavialus gangeticus</u> (Gavial)	India		6
	TOTAL	107,179	143,727

*Species not found in this country (Brazaitis, pers. comm.; Groombridge, 1981).

<u>Source</u>: TRAFFIC (U.S.A.) analysis of 3-177 Declaration of Importation/ Exportation forms, Law Enforcement Division, Fish & Wildlife Service, U.S. Department of the Interior.

(Table 4). Crocodilian skins and products re-exported from France to the U.S. accounted for over US $4 million, and those from Italy were valued at nearly US $3 million.

Skins of Papua New Guinea crocodiles were the most valuable; the average declared value was US $261 per skin. These skins represented only 4.0% of all crocodilian items imported, but 30.8% of the total value of all imported items. The value of these skins is reflected in the declared value of products manufactured from Papua New Guinea crocodiles. The average declared value of US $115 per product was more than the value of products made from any other country's crocodilians. The total value of all skins and products of Papua New Guinea crocodiles was over US $4 million.

Skins, products, and live animals of Colombian origin accounted for the second highest total declared value of all crocodilian items imported in 1981. This amounted to over US $1.5 million, representing 18.5% of the total value of all crocodilian imports.

Trade Routes

Seventeen countries re-exported crocodilian skins and products to the U.S. in 1981. France re-exported the largest number of skins (30,336), and Italy supplied the largest quantity of manufactured products (52,352; Table 6). Italy was the only other major re-exporter of skins. Other significant re-exporters of products include Switzerland, Austria, and France.

Based on declared origins on import documents, the major supply routes in 1981 for all crocodilian items from the source, to the processing country, to the U.S. were:

1) Colombia-- Italy-- U.S.
2) Colombia-- Austria-- U.S.
3) British West Indies-- France-- Switzerland-- U.S.

Many crocodilian skins passed through at least two European countries before reaching the U.S. as manufactured products (Table 7). Switzerland, for example, often imports crocodilian products from other European countries before exporting them to the U.S. The routing of crocodilian skins and products through so many countries before reaching the U.S. may, in part, explain the large volumes of imports with country of origin discrepancies.

Ports of Entry

The majority of both crocodilian skins (87.4%) and products (81.5%) entered through the Port of New York. The only other port of significance was Miami, where 9.1% of the products, 9.2% of the skins, and 100% of the live animals entered the U.S. Between 2% and 3% of the

Table 6. 1981 U.S. imports of crocodilian skins, products, and live animals, arranged by country of export.

Declared Country of Export	Live	Raw or Tanned Skin	Manufactured Products	Declared Value (U.S.$)
Austria			21,038	132,986
Bolivia		33,611		263,646
Canada			1,151	7,842
Colombia	15,521	9,864	9,744	193,032
France		30,336	10,733	4,280,425
Greece			1,230	24,827
Hong Kong			3,303	64,280
Italy		8,277	52,352	2,898,500
Japan		190	301	22,205
Korea			30	643
Mexico		2	4	919
Netherlands			399	1,567
Nigeria			13	120
Panama			725	8,732
Paraguay		24,689		40,117
Senegal			2	6
Singapore		33	851	17,696
South Africa			2	25
Spain			7,967	263,405
Suriname	20			1,698
Switzerland			32,103	607,395

Table 6. (continued)

Declared Country of Export	Live	Raw or Tanned Skin	Manufactured Products	Declared Value (U.S.$)
Thailand		1	3	443
United Kingdom		20	156	11,515
Uruguay			50	1,137
West Germany	12	156	1,491	163,362
Unknown			79	8,180
TOTAL	15,553	107,179	143,727	9,014,703

Source: TRAFFIC (U.S.A.) analysis of 3-177 Declaration of Importation forms, Law Enforcement Division, Fish & Wildlife Service, U.S. Department of the Interior.

Table 7. 1981 U.S. imports of crocodilian products, arranged by country of origin, source country*, and country of re-export.

Country of Origin	Source* Country	Country of Re-export	Quantity
Bolivia	France	W. Germany	51
	Italy	W. Germany	34
	Italy	Switzerland	3
	U.S.	Greece	338
Brazil	France	Switzerland	4,768
British West Indies	France	Switzerland	11,614
Colombia	France	Switzerland	619
	France	W. Germany	29
	Italy	W. Germany	74
Malaysia	France	W. Germany	28
Papua New Guinea	France	Switzerland	2,343
	France	Italy	28
	France	W. Germany	5
	Switzerland	W. Germany	41
	Singapore	France	55
	U.S.	France	3
Paraguay	Italy	Switzerland	24
	France	W. Germany	39
Peru	Italy	Switzerland	2,466
	France	Switzerland	1,042
Singapore	France	W. Germany	162
	Italy	W. Germany	2
TOTAL			38,521

*Source Country - the country that supplied the skins or products to the re-exporting country.

Source: TRAFFIC (U.S.A.) analysis of 3-177 Declaration of Importation/Exportation forms, Law Enforcement Division, Fish & Wildlife Service, U.S. Department of the Interior.

skins and products passed through each of the ports of Chicago, Honolulu, and Los Angeles (Table 8).

Declared Country of Origin and Species Discrepancies

Many crocodilian shipments entered the U.S. with declared countries of origin that are not within the reported range of the species declared. It cannot be determined whether the countries of origin or the species names were incorrectly listed. For example, the spectacled caiman, *Caiman crocodilus crocodilus*, occurs in only nine South American countries and Trinidad and Tobago (Brazaitis, pers. comm.). Eleven countries where these caimans do not occur, however, also appeared on the 3-177 forms as the country of origin (Table 5). Imports from these countries accounted for 30,561 manufactured items, or 21.3% of all crocodilian manufactured products imported.

More than 65,000 skins and over 17,000 manufactured items of *C. c. crocodilus* were declared as Bolivian or Paraguayan in origin. *C. c. crocodilus* does not occur in Paraguay and, according to caiman specialists, is not found in large enough quantities to be commercially exploited in Bolivia (Brazaitis, pers. comm.). The items were most likely *C. c. crocodilus* illegally taken in Brazil (Brazaitis, pers. comm.) or yacare caimans, *C. c. yacare*, a subspecies found in both Bolivia and Paraguay. *Caiman c. yacare* is listed on the U.S. Endangered Species Act and is prohibited from import into the U.S. Pending further investigation of the current ranges of all *C. crocodilus* subspecies, the U.S. stopped accepting shipments of *C. c. crocodilus* skins and products of Bolivian and Paraguayan origin in August 1981.

The British West Indies and Argentina were also declared as countries of origin for imports of *C. c. crocodilus* skins and products. The American crocodile, *Crocodylus acutus*, an endangered species, is the only species known to occur in the British West Indies (Groombridge, 1981). *C. c. yacare* and the broad-nosed caiman, *C. c. latirostris* are the only crocodilians known to occur in Argentina (Brazaitis, pers. comm.). Both are prohibited from import by the U.S. Endangered Species Act. Additionally, domestic legislation in Argentina prohibits the export of crocodilians (TRAFFIC [USA], 1982).

Crocodilian Shipments Denied Entry

Thirty-four commercial shipments consisting of 1,607 manufactured and 296 raw crocodilian items were denied entry in 1981. Most seizures were of crocodilians declared to be spectacled caimans, but seven other species and eleven countries of origin were also involved (Table 9). The shipments usually lacked proper CITES documents, but many *Caiman crocodilus* were denied entry because they were believed to be *C. c. yacare*, a subspecies banned from import by the U.S. Endangered Species Act.

Table 8. 1981 U.S. imports of live crocodilians, skins, and products, arranged by port of entry.

Port of Entry	Live	Raw or Tanned Skins	Manufactured Products
Boston			308
Chicago		500	3,043
Dallas/Ft. Worth		930	1,048
El Paso		2	
Honolulu			3,359
Houston			6
Laredo			4
Los Angeles			3,162
Miami	15,553	9,864	12,921
Minneapolis			5
New Orleans			330
New York		93,679	117,506
San Francisco			655
Seattle			96
Other		2,204	1,284
TOTAL	15,553	107,179	143,727

Source: TRAFFIC (U.S.A.) analysis of 3-177 Declaration of Importation/Exportation forms, Law Enforcement Division, Fish & Wildlife Service, U.S. Department of the Interior.

Table 9. Crocodilian skins and products denied entry into the U.S. in 1981, arranged by species, country of origin, and country of export.

Declared Species	Declared Country of Origin	Country of Export	Quantity	Type
Caiman crocodilus crocodilus	Argentina	France	20	manuf
	Bolivia	France	91	manuf
	Nigeria	Italy	3	manuf
	Paraguay	Austria	19	manuf
		Italy	107	manuf
		Switzerland	30	manuf
	Singapore	Singapore	499	manuf
		Singapore	21	raw
Caiman c. yacare	Bolivia	Italy	127	manuf
	Nigeria	Italy	96	manuf
	Paraguay	Japan	174	raw
		Spain	108	manuf
		Uruguay	50	manuf
		Unknown	100	raw
Caiman crocodilus	Costa Rica	Unknown	4	manuf
	Malaysia	Italy	4	manuf
	Paraguay	Spain	210	manuf
	Unknown	South Africa	2	manuf
		Switzerland	24	manuf
Crocodylus acutus	Paraguay	Italy	3	manuf
Crocodylus niloticus	Senegal	Senegal	2	manuf
	South Africa	Unknown	6	manuf
Crocodylus novaeguineae	Papua New Guinea	France	8	manuf
		Italy	3	manuf
		Switzerland	1	manuf
Crocodylus porosus	Indonesia	Italy	12	manuf
	Singapore	France	5	manuf
Crocodylus siamensis	Thailand	Thailand	1	raw
Osteolaemus tetraspis	Nigeria	Unknown	7	manuf
	South Africa	Unknown	6	manuf
	Africa	Africa	6	manuf
Gavialus gangeticus	India	Unknown	6	manuf

Table 9. (continued)

Declared Species	Declared Country of Origin	Country of Export	Quantity	Type
Crocodile	Nigeria	Unknown	6	manuf
	Unknown	France	66	manuf
		Mexico	4	manuf
		Switzerland	72	manuf
TOTAL			1,903	

Source: TRAFFIC (U.S.A.) analysis of 3-177 Declaration of Importation/Exportation forms, Law Enforcement Division, Fish & Wildlife Service, U.S. Department of the Interior.

American Alligator Trade

The American alligator, Alligator mississippiensis, is one of two crocodilians indigenous to the U.S. and is the only U.S. species that may be commercially exploited for the skin trade. Because of declining populations in past years as a result of excessive hunting and poaching, the American alligator was classified as Endangered throughout its range in 1967 under the U.S. Endangered Species Act. Effective management and enforcement of laws resulted in the partial or complete recovery of many alligator populations. Subsequently, the species was reclassified over a period of five years (1975-1979) to "Threatened" or "Threatened by Similarity of Appearance" status in some areas (Fed. Reg., 1979, 1981). In 1979, the American alligator was transferred from CITES Appendix I to Appendix II at the second meeting of the Parties. As a result, American alligator skins could again enter international trade.

The export of American alligator skins resumed in 1979, when a total of 5,404 skins were shipped from the U.S. (Table 10). The number of skins exported climbed to 29,449 in 1981 with France maintaining its status as the primary receiver of skins for the third consecutive year. France was the sole importer of American alligator skins in 1979. In 1981, France received over 16,000 skins, while Italy and Japan imported 9,684 and 3,186 skins, respectively. Other countries importing alligator skins directly from the U.S. in 1981 included the United Kingdom, Hong Kong, and West Germany. The 1981 total declared value of American alligator skin exports amounted to US $4,660,258 (Table 10).

A large portion of all American alligator skins are tanned in France and Italy, and many skins are then re-imported by the U.S. for the manufacture of leather goods. The U.S. re-imported 7,451 tanned skins from France and 6,290 from Italy in 1981. The number of skins imported amounted to almost half as many as were exported during the year and had a declared value of US $1,807,752 (Table 11).

While trade in American alligator skins is substantial, few manufactured products are exported or re-imported by the U.S. The total U.S. trade of American alligator products amounts to less than 5% of total imports and exports of raw or tanned skins. Still, the quality of the skin makes A. mississippiensis one of the most valuable reptiles to the leather industry worldwide.

SUMMARY

U.S. imports of live crocodilians decreased from over 112,000 in 1970 to about 15,000 in 1981. Imports of crocodilian skins and manufactured products, however, have increased over the last two years. The most frequently exploited species in 1981 was the spectacled caiman, Caiman crocodilus; it accounted for over 99% of the live animals and nearly 90% of both the skins and manufactured products imported. Colombia directly exported to the U.S. almost all of the live

Table 10. Exports of American alligator skins in 1979 and 1981, arranged by country of import.

Country of Import	Number of Skins 1979	Number of Skins 1981	Declared Value (US $; 1981 only)
France	5,404	16,290 (+ 3,895 lbs.)	2,799,693
Hong Kong		38	10,450
Italy		9,684	1,412,532
Japan		3,196	407,650
United Kingdom		246	29,462
West Germany		5	471
Total	5,404	29,449 (+ 3,895 lbs.)	4,660,258

Table 11. Imports of tanned American alligator skins in 1981, arranged by country of re-export.

Country of Re-export	Number of Skins	Declared Value (US $)
France	7,451	1,518,318
Italy	6,290	289,434
TOTAL	13,741	1,807,752

Source: TRAFFIC (U.S.A.) analysis of 3-177 Declaration of Importation/Exportation forms, Law Enforcement Division, Fish & Wildlife Service, U.S. Department of the Interior.

crocodilians imported in 1981, and was the country of origin of nearly 50% of the products imported. Bolivia was the country of origin of most of the raw skins imported. Italy and France were the largest exporters of skins and products to the U.S. in terms of both the total number of items and the total value of all goods imported. Most items entered the U.S. through the Port of New York. Approximately one third of the caimans arrived with declared countries of origin outside the natural range of the species. This may be a serious problem, since these declarations may be concealing the importation of endangered species. The American alligator entered international trade again in 1979, after a series of changes in its legal status. Almost 30,000 skins were exported from the U.S. in 1981.

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Appendix A. Status of all Crocodilian Species listed on the U.S. Endangered Species Act (ESA), the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), and the IUCN Red Data Book (RDB).

Species	ESA	APP.	RDB
FAMILY: Alligatoridae			
Alligator mississippiensis American alligator	E/T/ T(S/A)*	II	O
Alligator sinensis Chinese alligator	E	I	E
Caiman crocodilus apaporiensis Rio Apaporis caiman	E	I	E
Caiman crocodilus crocodilus Spectacled caiman		II	E
Caiman c. yacare Yacare caiman	E	II	E
Caiman c. fuscus Brown caiman		II	E
Caiman latirostris Broad-nosed caiman	E	I	I
Melanosuchus niger Black caiman	E	I	E
Paleosuchus palpebrosus Dwarf caiman		II	V
Paleosuchus trigonatus Schneider's smooth-fronted caiman		II	V
FAMILY: Crocodylidae			
Crocodylus acutus American crocodile	E	I	E
Crocodylus cataphractus African sharp-nosed crocodile	E	I	E
Crocodylus intermedius Orinoco crocodile	E	I	E
Crocodylus johnsoni Johnson's crocodile		II	V
Crocodylus moreletii Morelet's crocodile	E	I	E
Crocodylus niloticus Nile crocodile	E	I	V
Crocodylus novaeguineae mindorensis Philippines crocodile	E	I	I
Crocodylus n. novaeguineae New Guinea crocodile		II	V
Crocodylus palustris kimbula Ceylon mugger crocodile	E	I	V
Crocodylus porosus Salt-water crocodile	E**	I**	V
Crocodylus rhombifer Cuban crocodile	E	I	E
Crocodylus siamensis Siamese crocodile	E	I	E
Osteolaemus tetraspis West African dwarf crocodile		I	E
Tomistoma schlegelii False gavial	E	I	E
FAMILY: Gavialidae			
Gavialis gangeticus Gavial	E	I	E

KEY TO SYMBOLS

ESA

E = Endangered
T = Threatened
T(S/A) = Threatened by Similarity of Appearance

RDB

E = Endangered
T = Threatened
V = Vulnerable
I = Indeterminate
O = Out of Danger

CITES

I = Appendix I listing
II = Appendix II listing

* Different populations of the American alligator are listed on the U.S. Endangered Species Act as Endangered, Threatened, or Threatened by Similarity of Appearance.

**Populations of Papua New Guinea are not included in these listings. Salt-water crocodiles from Papua New Guinea are listed on CITES Appendix II.

CROCODILE MANAGEMENT AND HUSBANDRY
IN PAPUA NEW GUINEA

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INTRODUCTION

The National Crocodile Project in Papua New Guinea was initiated in direct response to dwindling exports of crocodile skins reflecting a decline in the population following hunting pressure by expatriates in the 1950s and 1960s (Whitaker, 1980).

Policies were formulated (Downes, 1968, 1971, 1974), the main objectives of which were:

a) To assist the people of Papua New Guinea living in remote areas that are unsuitable for most types of conventional forms of agricultural practice;

b) To increase foreign exchange earnings on exported skins;

c) To evaluate and monitor the effects of cropping on the wild population with a view towards the goal of maximum sustained yield cropping.

d) To encourage local participation in decision making about management utilization of the local wildlife resource.

The strategy which seemed most appropriate to the Papua New Guinea situation, as stated by Downes (1971), was based on the procurement of young crocodiles from the wild. They would then be reared in a network of village holding pens and technically sophisticated farms (see Fig. 1). Essentially the policy recognized (Bolton, 1979):

a) The existing wastage and inevitable downhill trend of skin hunting with its emphasis on killing wild survivors;

b) The high natural mortality of young crocodiles;

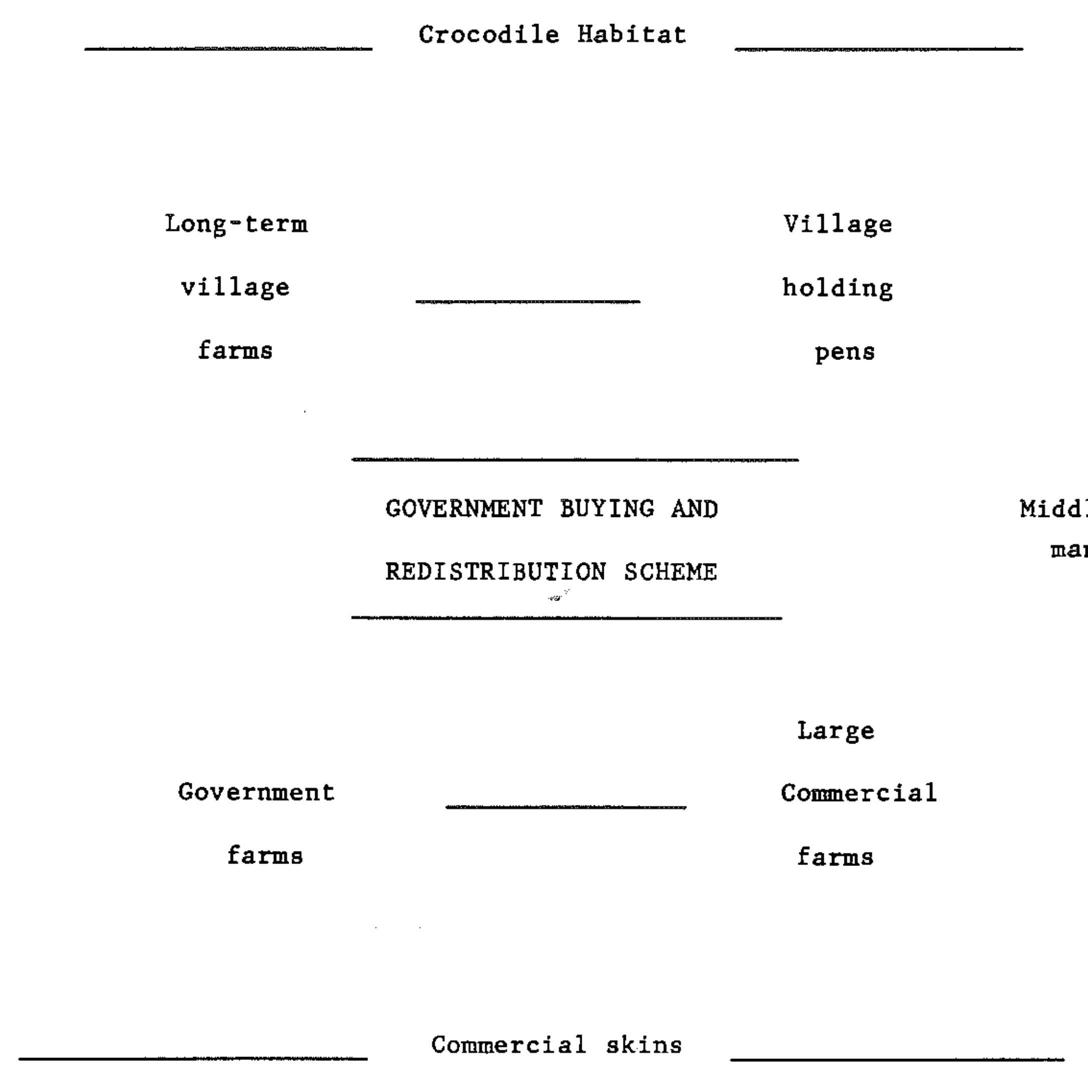
c) The ultimate replacement of skin hunting with pen rearing of young wild crocodiles.

FIGURE 1

A SCHEMATIC DIAGRAM

SHOWING

THE CROCODILE NETWORK IN P.N.G
(after De Vos, March 1979)



This policy met with the approval of the Papua New Guinea Government, FAO/UNDP, CITES, and members of IUCN SSC Crocodile Specialist Group (Pooley, 1977; Medem, 1977).

In 1977 with the assistance of FAO/UNDP (PNG/74/029) the policy was implemented. During the life of the project progress has been monitored in six monthly reports by each regional wildlife manager. These have been the working papers upon which management decisions, resulting in change in emphasis, were placed.

PROGRESS TO DATE

Management

Between 1977 and 1979 the main drive was towards establishing the village rearing system. This was carried out by means of extension work and the improvement and establishment of government demonstration farms. During this period three FAO/UNDP experts were contracted, and eight United Nations Volunteers plus the corresponding number of national counterpart staff were involved in extension work. Demonstration farms were situated at Lake Murray and Balimo in Western Province, Pagwi, and Angoram in East Sepik Province, and Kikori in Gulf Province.

The role of the extension worker was to assist and advise villagers in basic crocodile husbandry and help overcome other problems associated with crocodile farming, i.e., business management. By the end of 1979 over 180 farms had been established, but very few of these could be considered successful (extrapolated from Progress Reports, 1977 to 1979, Bolton and Balson). A review (Burgin, 1980) showed that the stock numbers on these farms had shown a decline indicating a lack of interest in farming. In most areas the majority of skins were still coming from wild caught specimens, and even by 1981 under 1,000 crocodiles had been grown to culling size on village farms (Whitaker, 1981).

The reasons for the decline can be attributed to the following:

a) Seasonal and regional shortages of food and water supplies.

b) People found it hard to abandon subsistance agriculture in in favor of relatively modern farming methods.

c) Villagers tended to become apathetic in the face of the long term nature of crocodile rearing, i.e., cash reward is not available on a day to day basis. This results in the neglect of stock, and when this happens growth rates are slowed and the problem compounded.

d) In Gulf and Western Provinces villagers were initially encouraged to form large business groups (a criteria for Development Bank loans). This meant that any returns would be spread over large numbers of people, most of whom were unproductive (Rose, 1980). In the Sepik the reverse was true. The independent nature of villagers tended to prevent them pooling their resources in an attempt to overcome food and water shortages (Bolton, 1979).

It became apparent that in order to achieve the major objectives of the project a more appropriate strategy had to be put into effect. This was carried out by placing more emphasis on the commercial rearing rather than the village farming of crocodiles. Integral to this was the expansion of the crocodile buying and redistribution service. By early 1980 the methods of packing and transporting crocodiles had been successfully worked out, and the system became fully operational. It should be noted that a successful purchase network had been established by a commercial farm operating out of Lae.

To date the scheme has been a success. Figure 2 shows that there has been an increase in the numbers of crocodiles passing through the buying scheme with a subsequent increase in total captive stock. The scheme is advantageous in that (a) there is less wastage of the crocodile resource, (b) a cash reward (averaging $8 US per crocodile) is spread over a wider population, i.e., those persons who were excluded from crocodile rearing due to lack of a suitable site can now be involved, (c) it relieves the villagers of the responsibilities of maintaining stock, and (d) it puts Papua New Guinea in a better position to respond to market requirements.

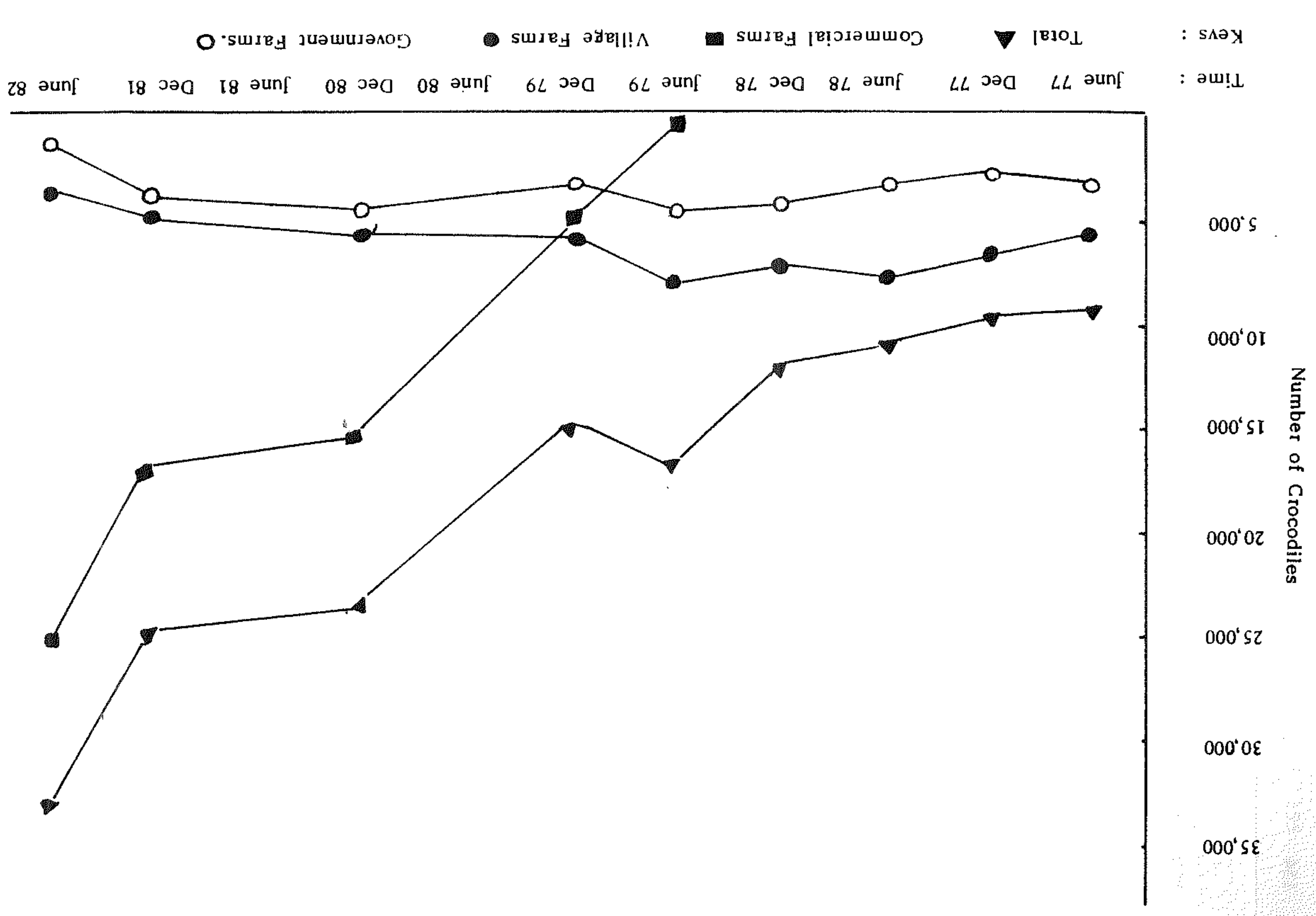
Husbandry

A comprehensive account of crocodile husbandry to date in Papua New Guinea has been prepared (Bolton, 1981). The purpose of this section is to summarize some of the more important aspects of that report and supplement it with additional information from other sources where applicable.

1. Pen Design and Construction

This varies according to local conditions, requirements, and resources, i.e., types of materials available and finance. At the village level a 10 m by 10 m pen with a U-shaped pond 1 m deep has been found to be the most successful unit. The U-shaped pond appears to give the optimum water to land ratio and gives more bank area (the area most utilized by crocodiles) than the conventional round-shaped pond. This is thought to reduce stress amongst young crocodiles (Lever and Balson, 1978) and reduces fighting among 4th year crocodiles (Bolton, 1981). Fencing materials normally consist of roughly cut posts bound together with split cane. The most successful post (pers. obs.) being the rosewood (Terecarpus indicus). After cutting and placement, this species continues to grow and therefore needs little maintenance, only periodic pruning. Water channels are not normally lined, except in some cases where drought and leaching are a problem. Most farms, however, are built either in tidal areas or where there is a continuous water supply, such as small creeks.

FIGURE 2. A Graph to Show the Distribution of Captive Crocodile and Total Stock Figures from July 1977 - June 1982.



In large farms, such as government redistribution stations, a similar pen design is used, but normally the pens are larger to hold more stock. Burrowing in unlined water channels has been found to cause problems (Bolton, 1981) both in regard to maintenance and mortalities. The problem has been partly solved by the placing of split timber or large stones along the channel walls. Neither has proved very effective. The use of Reno mattresses is currently being investigated.

In commercial farms pen design is also based on the U-shaped water channel, and here again pens are normally larger (30 x 30 m) and fencing constructed from more permanent materials, such as wire or concrete. All water channels are lined with waterproof cement. Provision of shade has been found to be paramount to successful rearing and is normally in the form of permanent vegetation. Although food plants such as bananas and cassava have the advantage of being easy and quick to grow as well as providing food for the owner, they also have distinct disadvantages, i.e. bananas have a tendency to fall over after fruiting, facilitating escapes, and cassava radiates from the base, making it difficult to catch stock. Here again rosewood has proved successful both in providing a fast growing canopy and a discrete base.

2. Segregation

Segregation by size is thought to be an important factor in successful pen rearing (Bolton, 1981; Balson, 1981; Bolton and Laufa, 1982). Although it has not been scientifically proved, it is thought to relieve the stress and malnutrition caused by competition for food.

Trials conducted at Moitaka to determine whether growth of subadult *Crocodylus novaeguineae* was affected by the presence of *C. porosus* showed that segregation of species held no advantages as growth rates of each species were not altered. However, Burgin (1981), working on hatchlings, showed that dietary requirements between species differed, therefore indicating that it would be advantageous to segregate species at this level. Further research is needed to establish whether segregation would enhance the growth rates of each species from hatchling to culling size.

3. Stocking densities

Due to the variability of conditions existing from farm to farm and within farms, no firm guide to densities has been found (Bolton, 1981; Gaudie, pers. comm.). In those farms that have a varied feed supply, good size segregation, and adequate shade, density figures shown in Table 1 have proved successful.

4. Growth and Diet

Although growth is dependent on many factors, such as those mentioned above, diet can be regarded as one of the most important. During the history of the project feed trials were carried out at Moitaka Crocodile Farm to determine the optimum available diet, the criterion for success

Table 1. Table shows successful stocking densities

Belly width cm	Total Length cm	Area m^2 per crocodile
10 - 20	43 - 94	0.66
21 - 25	95 - 111	1.00
26 - 36	112 - 166	1.13

being improved growth rates. Bolton (1981) concluded that despite the superiority of fish and fish mixed with poultry, poultry showed perfectly satisfactory growth rates. The food supplement Trivim was later added to the fish diet, but no significant improvements in growth were recorded. Obviously there is room for more experimentation with other food items before optimum diet can be realized. Such trials are currently being undertaken at Mainland Holdings at Lae.

Differential growth rates have been attributed to individual variation, sex, size, and species. Individual growth rates have been seen to be enormous, and these may override variability due to species and sex (Bolton, 1981; Gaudie, pers. comm.). In animals with comparable growth rates, males have been found to grow faster than females and *C. porosus* faster than *C. novaeguineae*. Quantification of the former in sub-adults has been found to be difficult due to problems in sexing individuals.

As with most other animals, captive crocodiles in Papua New Guinea show a decrease in growth rate with increasing size. Table 2 data shows average rate of growth for both species and sex.

Decrease in growth rate is important when considering the commercial turnoff point, i.e., when the highest rate of return is exceeded. Although these would vary from farm to farm due to growth rates and fixed costs such as labor, food, etc., information so far indicates that it would be in the range of 35-41 cm belly width. This could be altered depending on market requirements abroad.

5. Mortality

Mortality rates vary with standards of management and size distribution of stock found on individual farms. Table 3 shows the agregation mortality rates for two government farms in the Sepik. At the time of writing no data for commercial farms is available but indications are that mortality is lower. This would be expected as the major of crocodiles reaching commercial farms are settled stock, all the weak having been eliminated at government redistribution farms. As can be seen in Table 3, a significant proportion of fatalities occur in stock 10 cm belly width or under. Although difficult to prove, it is felt by project staff that this is due to stress. Bolton (1981) reports that stress in crocodiles leads to anorexia and then to eventual death. He recommended the use of parenteral glucose and/or isolation of affected animals in carefully managed sick pens, depending on the stage of sickness, i.e., in the early stages of health attribution the latter method may prove to be all that is required.

In order to alleviate stress, the government farm at Kikori (Gulf Province) uses an introductory pen system. Newly purchased crocodiles are placed in a 30 x 30 m heavily vegetated pen, where they are allowed to acclimate to captive conditions before being placed with other stock. To date, this has resulted in a significant reduction of the mortality rate. It has been recommended that other farms in PNG adopt a similar system.

Table 2. Average rearing periods from hatchling to 50 cm belly width (after Bolton, 1981)

Species	Males	Females
C. porosus	3 years 11 months	4 years 4 months
C. novaeguineae	5 years 10 months	6 years 4 months

Table 3. Mortality rates and size related distribution on two Government Farms in the Sepik (After Whitam, 1981).

Belly width Size (cm)	Number of Deaths	Mortality over 6 month period (%)
Under 10	180	20
10 - 11	59	10
12 - 14	7	4
15 - 16	3	2
Total	249	

6. Breeding

Due to the Government's restrictions on possessing crocodiles over 51 cm belly width, breeding research has been carried out only at Moitaka Government Farm. Crocodiles at Moitaka are housed in enclosures of varying sizes (all constructed from galvanized wire) ranging from 9 m x 15 m (containing one pair of crocodiles) to 56 m x 66 m (housing 20 crocodiles at a sex ratio of 4:)1 (Callis, 1981). Ponds occupy approximately 35 percent of total area with an average depth of 1.5 m. None of the pools are lined and shade is provided by natural vegetation. Diet consists mainly of trash fish and is supplemented (subject to availability) by mixed offal and lamb flaps. Each crocodile receives an average of 2.5 kg of food per week (Callis, 1981).

To date results have been disappointing. Although breeding has occurred regularly for a number of years, success rates have been low. Last season 26 adult female C. porosus and 21 female C. novaeguineae produced only 409 and 38 hatchlings respectively (Hollands, pers. comm.). These figures of 9.7 and 1.2 hatchlings per adult per year clearly show that the present stock, under prevailing conditions, is not commercially viable. In addition it appears that 55 percent of C. porosus eggs were found to be infertile.

It has also been observed that in these small colonies territorial behavior prevented smaller females from entering ponds for mating (Callis, 1981). However the inclusion of one small pond per female has eased the problem. The poor reproduction rate demonstrated at Moitaka could be a result of stress imposed by captive conditions (Burgin, 1981), an unknown dietary deficiency (Bolton, 1981), or a combination of both.

7. Incubation of Eggs

The methods of incubating crocodilian eggs that have been used elsewhere include:

a) Removal of eggs immediately following laying and subsequent incubation carried out in controlled environment chambers (Joanen and McNease, 1975);

b) Removal of eggs from natural nests prior to the termination of development. These are then placed in incubators;

c) Transference of eggs to artificial nests (Pooley, 1971).

The merits and disadvantages of each method were discussed by Bolton (1981). In the absence of environmentally controlled chambers, the method used at Moitaka has been a compromise between methods (b) and (c). Eggs are transferred from natural nests 75 days after laying; average natural incubation periods being C. porosus 95 days (Moitaka records) and C. novaeguineae 87 days (Hall, 1982). These eggs are then placed in incubators complete with natural nesting materials. Recent research (Fergusson, 1981) demonstrated that natural nesting material is essential to successful hatching of young crocodilians.

8. Rearing of hatchlings.

Investigations into factors affecting hatchling growth were carried out by Burgin (1981) over the period 1978-1980 and Bolton (1981) to the present date. Criteria used to measure progress were survival and weight.

9. Conditions

Initial hatchling enclosures consisted of 1 m x 2 m pens. These were found to be unsatisfactory (Burgin, 1981) and were later modified to 2 m x 2 m pens. Each pen was constructed from thermolite blocks faced with mortar. Pools containing water were approximately 5 cm deep and occupied 36 percent of the total area. Pens were furnished with a small raised wooden board to provide cover. The whole area was shaded by chicken wire covered with hessian.

These enclosures were open to daily fluctuations in ambient temperature. Early in 1981, brooders were introduced. Results proved to be inconclusive, and Bolton (1981) recommended an improved design.

After three months, crocodiles which have shown good growth are moved to a 3 m x 3 m pen which has a circular pool 25 cm in depth, occupying 47 percent of the total area, an earth floor, and natural vegetation.

10. Investigations and Results

Burgin (1981) investigated the effects of diet, stocking density, and handling. She concluded that of the diets tested, chopped marine fish produced the best results for C. novaeguineae but the least successful for C. porosus, and that a mixture of fish and chicken proved successful for C. novaeguineae. Comparison of C. novaeguineae fed on marine fish for six months to those started on freshwater fingerlings for three months and thence marine fish for the remaining three months showed the latter diet to enhance survival but did not reveal significant differences in weight. The use of vitamins and insects as food supplements were also studied. The former revealed that no advantages (at the dosage administered) could be found, and that the use of insect traps proved detrimental to survival. High density (0.2 m^2 per animal) stocking and regular resorting into size categories also proved to be detrimental to hatchling production.

During this study unacceptably high mortalities were incurred (up to 90 percent in some trials). Burgin attributed this to low hygienic conditions, poor stock quantity, and density housing.

However, subsequent trials using only C. porosus under similar housing conditions and densities as Burgin, but only feeding coarsely

minced Talapia have been encouraging. The trials experienced less than 10 percent mortality and growth increments averaging 25.1 percent of total weight per month. 1982 results showed mortalities to be higher: 16 percent for C. porosus and 29 percent for C. novaeguineae. However average growth increments are 34.6 percent and 27 percent of total weight for C. novaeguineae and C. porosus respectively. Although rearing techniques appear satisfactory, it is felt that production could be improved by feeding small crustaceans such as prawns and small crabs. Evidence from the wild (Taylor, 1977; Ross, 1977) shows that small crustaceans make up a major proportion of the diet of young crocodiles.

It has also been observed in the Sepik (Bolton and Laufa, 1982) and in Gulf Province (pers. obs.) that villagers have successfully reared C. novaeguineae feeding only freshwater prawns (Macrobrachium spp.). Even under extremely poor housing conditions (normally an oil drum) and in high densities (up to 0.025 per m^2 per animal) with maximum disturbance, all animals appeared to be extremely healthy. Thus it would appear that hatchlings fed on this diet can overcome factors assumed in other captive conditions to cause stress with its subsequent lowering of growth rates and high mortalities. At present project staff are investigating a reliable cheap source of prawns to test this hypothesis.

Legislation

Until 1966 there were no laws in Papua New Guinea relating to the crocodile industry. In 1966 the Crocodile Trade Production Act came into force. This required all dealers to be licensed. It also protected all adult crocodiles over 51 cm belly width (approximately 2 m total length) but was only adopted in the Papuan region. Only in 1975 was it ratified by the entire country. In 1974 a new act was put before Parliament but was not enacted until late February 1980. This was amended and became split into the following categories.

a) Crocodile Traders' License--this is restricted to skin traders only;

b) Company Crocodile Buyers License--for persons employed by the company. This enables them to buy both live crocodiles and their skins. The licensee cannot buy crocodiles for anybody else but the company which employs him.

c) Crocodile Export License--is granted to companies on condition that only export skins that have been bought through its company buyers' license and that all skins are tagged before leaving the country.

Under the new law, the upper size limit of 51 cm remained the same but a lower limit was introduced preventing any person from dealing in skins of less than 18 cm belly width. All crocodile farms with stocks of over 200 crocodiles must now be registered, and six monthly stock reports sent to the Conservator of Fauna. In addition, a scientific worker wishing to collect, kill, or keep crocodiles may only do so after receiving a permit from the Conservator.

Summary and Future Management

To date progress with regard to husbandry techniques and the goal of replacing skin hunting with captive rearing has been slower than expected. The main reason for this is that most of the initial effort was put into village level farming. As shown in the text and elsewhere (Burgin, 1980), this has proved unsuccessful. However, despite this significant progress has been made, as indicated by this paper and others (Whitaker and Kemp, 1980; Hollands, 1982; Bolton and Laufa, 1983). A summary is shown below:

a) Extension work by field officers has led to improved skinning and preservation techniques yielding higher average skin grades.

b) Extension work both by government and commercial farms has established a live crocodile purchase network.

c) Extension workers in some areas have effectively encouraged the protection of adult crocodiles and their nests.

d) The project represents a form of crocodile management which provides a sustainable cash crop in areas where other forms do not exist.

e) There now exists a crop of trained crocodile officers.

f) Some progress towards successful breeding and rearing of hatchlings.

g) The establishment of protected areas and restocking schemes.

h) The establishment of a monitoring and research program.

i) The establishment of a legislative framework on which the industry can be based.

j) Direct marketing to Europe and Japan instead of through Singapore has increased revenue.

Following the Government's budget, released later in 1981, the Crocodile Project, with the exception of the Monitoring component, has been in effect decentralized, i.e., each province is now responsible for its crocodile resource. This means that the management is in danger of becoming uncoordinated and fragmented. In order to prevent this from happening, the establishment of a Crocodile Management Board has been proposed.

The purpose of this board would be to provide a forum where management decisions pertaining to the resource could be discussed and future policies formulated as well as raising money to fund the monitoring program. It is hoped that such a board would bring about unanimous agreement and provide a united front on such matters as monitoring legislation and marketing. A meeting of all parties concerned was held in May of this year with encouraging results, and a further meeting has been scheduled for November. The feasibility and financing of such a board is currently being investigated by project staff.

ACKNOWLEDGEMENTS

Due to the restrictive nature of this type of paper, it can hardly do credit to the hard work put into this project by FAO and Government staff (too numerous to mention), often in extremely trying conditions, over the past five years. My special thanks go to Melvin Bolton, ex-Project Manager, for information and help; Martin Hollands, Senior Ecologist, for critically reading part of the manuscript; and Caroline Jackson for typing this document on extremely short notice.

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SITUATION REPORT: INDIA
CENTRAL CROCODILE BREEDING AND MANAGEMENT PROJECT

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Beginning of the Project

The Central Crocodile Breeding and Management Project of the Government of India was started in 1975 with assistance from U.N.D.P./F.A.O. Several sub-projects were started at different state levels where crocodilians or their potential habitats occurred. These projects were managed by the different State Forest Departments directly or through their Wildlife wings.

The objectives of the Project have been to (1) protect remaining natural populations, (2) maximize natural recruitment through a "grow and release technique," (3) introduce crocodilians into areas where they once occurred and which still have suitable habitat, (4) promote captive breeding, (5) commence research on the different aspects of the biology and management of the Indian crocodilians, and (6) establish a multi-level program for training personnel.

Progress

1. Protection: This has been possible because of protection given to all Indian crocodilian species through (a) an act preventing export of crocodilian leathers, (b) the Wildlife (Protection) Act of India, 1972, (c) the creation of 11 special crocodile sanctuaries (Appendix I), and (d) public education.

2. Releases: The "grow and release technique" involved (a) collection of eggs from the wild, (b) artificial incubation of the eggs in a hatchery at 30 $\pm$ 2°C while maintaining a 7-10 percent moisture content by weight, (c) rearing hatchlings under simulated natural conditions to a length of about 1.2 m, (d) release of the hatchlings in sanctuaries, and (e) protection of the released crocodilians.

The total releases made through summer 1982 are: mugger, 490; gharial, 855; and saltwater crocodile, 278. The details of these releases are given in Appendix I. A list of the different rehabilitation projects is given in Appendix II.

3. Breeding by released crocodilians: Only the released muggers have commenced breeding in Ethipothala since 1981 within the Nagarjunasagar-Srisailam Sanctuary in Andhra Pradesh.

4. Captive breeding: Gharials began breeding in captivity at the Nandankanan Biological Park in 1980. A special breeding pool holding 2.7 million liters of water, with a maximum depth of 10 m, has been constructed for the purpose.

Muggers successfully bred under the project at Nehru Zoological Park (Hyderabad) since 1981, Nandankanan Biological Park (Orissa) since 1982, and the Gharial Research and Conservation Unit, Tikerpada (Orissa) since 1981.

Saltwater crocodiles have not commenced captive breeding as yet. A breeding pool is near completion at the Nandankanan Biological Park, Orissa.

5. Research: Emphases in the past have centered on perfecting the approaches in the "grow and release techniques." Some of the important aspects covered are: (a) interpretations of the various types of data collected during surveys and censuses, (b) incubation of the eggs in simulated natural nests, including egg collection and transportation, (c) husbandry of the young crocodilians, including food requirement and food conversion with growth studies, and (d) behavioral biology, including reproduction, thermoregulation, feeding, orientation, and locomotion.

6. Training: Training has been offered at two different levels. Infra-level staff have been given husbandry training on site at the different husbandry units. The Central Crocodile Breeding and Management Training Institute was started in 1978 to provide training to forest officers in crocodilian management and biology, as well as sanctuary management, during a course covering a period of nine months. A total of 46 officers have been trained, including one foreign candidate from Bhutan and a private Indian candidate.

7. Farming: Under the existing law, commercial farming of crocodilians is not permissible in India. However, on 1 July 1982 the Indian Board for Wildlife authorized experimental "closed-circuit farming" of muggers in Tamil Nadu, as a scientific research project.

APPENDIX I

Crocodile Sanctuaries and Number of Crocodilians Released in Them

		Number of crocodilians released (up to 1982)			
Name of Sanctuary	Area in km	Gharial	Estuarine crocodile	Mugger	State
Chambal National	12,568	635			U.P./M.P./Rajasthan
Katerniaghat (Girwa)	approx. 400	58			Uttar Pradesh
Bhitarkanika	650		210		Orissa
Satkoshia Gorge	796	150			Orissa
*Corbett N.P.		12			U.P.
*Kinnersani	635.4			33	Andhra Pradesh
Hadgarh	191				Orissa
*Krishnagiri	?			130	Tamil Nadu
Coringa	236		3		Andhra Pradesh
Papikonda	591				-do-
Lanjumadugu	20				-do-
Manjira	20				-do-
Pakhal	860			15	-do-
Nagarjunasagar-Srisailam (Krishna)	3,568			154	-do-
*Mudumallai	?			6	Tamil Nadu
*Hoggenakal	?			46	Tamil Nadu
*Mundanthorai	?			21	Tamil Nadu
*Sivpuri National Park	156			25	Madhya Pradesh
*Gir National Park	1,412.12				Gujarat
*Simlipal Tiger Reserve	2,300			60	Orissa
*Sunderbans Tiger Reserve	2,585		65		West Bengal
*Perambiculum W.L.S.	270				Kerala
*Neyyar W.L.S.	128				Kerala
	TOTAL	855	278	490	

*Not created specifically for crocodiles

APPENDIX II

Crocodile Rehabilitation (rearing) Centers in India
(as existing in 1982)

1. Gharial Research and Conservation Unit,	Gharial, Mugger	Satkashia Gorge Sanctuary	Orissa
2. Gharial Rehabilitation Center	Gharial, Mugger	Katerniaghat Sanctuary	Utter Pradesh
3. Gharial Rehabilitation Center	Gharial, Mugger	Kukrail, Lucknow	Utter Pradesh
4. Gharial Rehabilitation Center	Gharial	Deori, Morena	Madhy Pradesh
5. Saltwater Crocodile Research & Conservation Unit, Dangmal	Saltwater crocodile	Bhitarkanika Sanctuary	Orissa
6. Crocodile Rehabilitation Center, Bhagbatpur	-do-	Sunderbans	West Bengal
7. Madras Crocodile Bank*	Mugger	Vadanamalai, Madras	Tamil Nadu
8. Crocodile Scheme, Sathanur	Mugger	Sathanur	Tamil Nadu
9. Crocodile Scheme, Hogenakal	Mugger	Hogenakal	Tamil Nadu
10. Crocodile Scheme, Sasan Gir	Mugger	Gir National Park	Gujarat
11. Crocodile Scheme, Ramtirth	Mugger	Jashipur (Simlipal Tiger Reserve)	Orissa
12. Crocodile Scheme, Bannerghata	Mugger	Bangalore	Karnataka
13. Crocodile Scheme, Neyyar	Mugger	Neyyar	Kerala
14. Crocodile Scheme, Perambikulam	Mugger	Perambikulam	Kerala

* A non-government trust

APPENDIX II Continued

15. Crocodile Scheme, Ranchi	Mugger	Ranchi	Bihar
16. Crocodile Breeding Project	All Three Species	Nehru Zoological Park Hyderabad	Andhra Pradesh
17. Crocodile Captive Breeding Project	All Three Species	Nandankanan Biological Park	Orissa

Present Crocodilian Stock in Different State Projects
(as before 1982 hatching season)

State	Below 2 Years	Above 2 Years	Adults	Total
Orissa				
Gharial	198	72	7	277
Mugger	4	6	6	16
Saltwater Crocodile	201	297	2	500
Andhra Pradesh				
Gharial	--	28	--	28
Mugger	46	43	40	129
Saltwater Crocodile	--	12		12
Tamil Nadu				
Mugger	698	532	657	1,887
Saltwater Crocodile	--	11	--	11
West Bengal				
Saltwater Crocodile	71	62	1	134
Kerala				
Mugger	49	4	8	61

APPENDIX II Continued

State	Below 2 Years	Above 2 Years	Adults	Total
Uttar Pradesh				
Gharial	Total 569			569
Mugger	Total 99			99
Saltwater Crocodile	Total 2			2
Madhya Pradesh				
Gharial	22	--	--	22
Gujarat				
Mugger	419	87	513	1,019

Grand Totals:

Gharial	--	896
Mugger	--	3,211
Saltwater crocodile	--	659

A REVIEW OF THE GROWTH OF *Crocodylus porosus* IN NORTHERN AUSTRALIA

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ABSTRACT: We review the results of three major experiments on the growth of *Crocodylus porosus* in northern Australia and incorporate some new data. After examining embryonic growth rates we examine growth for the first four months after hatching and see that in some cases this can match the pre-hatching growth rate. The effect of wet and dry season on this growth rate is discussed, and in Part 2 we re-examine the whole question of wet and dry season growth rates for *C. porosus*. Wet season growth rates appear to be consistently higher than those for the dry season.

In this paper we are particularly interested in any indications of different growth rates on different rivers. In Part 3 we examine growth over the first year and see that, in line with our earlier Blyth-Cadell results, there are strong indications of different growth rates on different rivers.

In Part 4 we examine growth of small crocodiles and see again strong indications of differences, especially between the Blyth-Cadell Rivers System and the Liverpool-Tomkinson Rivers System. Such differences may well be associated with a better food supply.

In Part 5 we examine growth of large specimens, incorporating valuable new data. Throughout, where possible, comparisons are made with growth of other crocodilian species, but mainly with *C. niloticus*. Results indicate that there can be a substantial variation in growth rates, not only within a river system but between river systems, at all stages of growth and that care must be exercised when comparing data.

INTRODUCTION

The main data on growth in the wild of *Crocodylus porosus* in this paper come from three extended experiments within the Sydney University-Northern Territory Government Joint Crocodile Research Project. All three have been reported on previously, but our aim in this review is to look at the data as a whole, and re-analyze them to obtain the most information possible on aspects of growth of *C. porosus*. Additional recently obtained recapture data are also incorporated. The first experiment involved a capture-recapture study of 254 individuals on the Liverpool-Tomkinson River System (Monograph 7); a multiple regression model was fitted to this data (Webb et al., 1978) to derive growth curves and to examine variables affecting growth. The second experiment was carried out by Magnusson (Ph.D. Thesis, Sydney University, 1978, and several papers), who studied by capture-recapture techniques the growth of C. porosus up to 133 days old, again by fitting growth curves. The third experiment (Chapter 8, Monograph 1) involved the capture of hatchlings on the Blyth-Cadell River System (some 30 km to the east of the Liverpool-Tomkinson System) in 1978 and recaptures in following years.

Throughout this paper we shall be referring to Monograph 1, which is but one of a series of 17 published by Pergamon Press between 1979 and 1982 reporting on the lengthy C. porosus studies by Messel and his collaborators.

In seeking to understand the growth rates presented in this paper, we are unfortunately lacking quantitative data on an important piece of information--food availability (or at least, the relative food availability) on the rivers at different times of the year, in different years, and any differences in food availability on different rivers. The ability of crocodiles to survive in a very low growth situation may be illustrated by an example given by Deraniyagala (1939). He quoted the case of two hatchling C. porosus (hatching total length around 30 cm), one of which was kept in a tub and the other in a small natural pond (with access to a wild diet). The animal in the tub died after two years at a length of only 35 cm, whereas the one in the pond had attained a length of about a meter after only 10 months. An example of the effect of feeding on growth may be taken from our own data. A hatchling captured at SVL 16.4 cm on the downstream Liverpool was recaptured after 3 months, on the Tomkinson. Its SVL had changed by only 0.3 cm and weight by only 5 gm, which is essentially no growth over the period. This animal had a skewed jaw which presumably interfered considerably with its ability to catch food items; it was very thin on second capture. Other examples of very low growth over 3 months of the dry season were seen on the upstream Blyth (see Part 1). The differences in growth between Deraniyagala's two animals were probably due to a number of factors, the availability of a proper diet possibly being a major one. However, given that the animals can survive for so long in an essentially no-growth situation, it is clear that attempts to interpret variations of growth amongst wild populations are fraught with difficulties, especially when so much necessary data are either unavailable or very difficult to obtain. The results in this paper obtained from recaptures over lengthy periods can be suggestive only, and there is need for smaller scale experiments to examine particular points.

To avoid constant repetition, all growth rates referred to in this paper are snout-vent length (abbreviated SVL) rates. Units of growth, if not explicitly stated, are cm/day. For conversion between head length (HL) and snout-vent length (SVL) we have used the same equations as used by Webb et al. (1978) (see their page 388). Other conversions (e.g., SVL to total length, TL) may be obtained from Webb and Messel (1978). Unfortunately there are some errors in this latter paper; they are described in Appendix 1. All uncertainties quoted are standard deviations (n-1 method). Differences between means are tested for using the t-test.

PART 1: EMBRYONIC GROWTH AND POST-HATCHING GROWTH UP TO 133 DAYS

1.1 Embryonic Growth

Estimates of growth rates for embryonic C. porosus may be obtained from data given by Deraniyagala (1939) for animals in Sri Lanka and by Magnusson and Taylor (1980) for animals in Arnhem Land, northern Australia. The data are inadequate, but we have tried to look at them in a number of ways. The results are not claimed to be any more than indications of embryonic growth rates. The egg sizes reported by Deraniyagala are consistent with the egg sizes reported by Webb et al. (1977), who reported for 22 nests mean egg lengths ranging from 7.2 cm to 8.1 cm. Deraniyagala's nests I, II, and III had mean egg lengths 7.4 cm, 7.9 cm, and 8.3 cm. The sizes of hatchlings were also consistent (see Table 1.1). In fact, the mean HL of 17 animals in Table LVIII of Deraniyagala is 4.8 ± 0.2 cm, to be compared with 4.6 cm (no error limit given) as the mean for five nests given by Webb et al. (1978). (However, there can apparently be great variation in egg and hatchling sizes; results from Edward River crocodile farm in north Queensland, Australia, appear to show that small females yield small eggs and small hatchlings [Gordon Grigg, personal communication].)

We shall now examine the available data on embryonic growth and derive some estimates for their growth rates. These can only be indications, however, because the length of incubation can vary greatly from some 80 to 120 days. Nests laid late in the dry season develop more slowly because of the cooler temperatures, and there are indications from field observations that some late nests may not hatch at all. Detailed studies are required on embryonic growth under different temperature regimes in the field.

Deraniyagala gave the following records for embryos from Nest II (days are estimated days after laying, allowing 97 days for incubation; he suggested, however, that the incubation was by no means normal).

Days	37	48	60	97
Total length	8.1	11.9	17.0	29.4 ± 0.5
	n = 1	n = 1	n = 1	n = 4

Table 1.1. Table of examples of sizes on hatching of C. porosus from Arnhem Land, Northern Australia (Liverpool-Tomkinson Rivers System) and Sri Lanka (Deraniyagala, 1939). Also shown are sizes for C. niloticus (Pooley, 1962). The description "artificial nest" means that the eggs were removed from a natural nest and incubated in an artificial nest.

Nest	Sample	SVL	Length	Weight	Age Processed
Myeeli 1 Removed from nest after hatching 4.3.76	48	14.1 ± 0.3	30.0 ± 0.7	83.0 ± 3.4	∿2 days
Myeeli 2 Removed from nest after hatching 16.2.76	46	13.6 ± 0.5	29.6 ± 0.6	74.5 ± 4.1	∿2 days
Myeeli 3 Removed from nest after hatching 18.4.76	50	13.8 ± 0.3	29.9 ± 0.5 (49 anmls)	69.6 ± 3.5	∿2 days
Liverpool km 47.5 Artificial nest 17.3.76	15	13.7 ± 0.7 (14 anmls)	29.6 ± 1.2	81.2 ± 5.7	∿2 days
Atlas Creek Artificial nest hatched 15.2.77	26	14.9 ± 0.3	32.0 ± 0.7	82.8 ± 2.7	∿6 days
Billabong Morngarrie Creek Removed from nest after hatching 13.4.76	11	13.4 ± 0.5	28.8 ± 1.1	59.2 ± 6.0	∿1 day
Liverpool B22 Artificial nest hatched 30.4.76	26	14.1 ± 0.4	29.9 ± 0.6	63.2 ± 7.6	11-13 days
Tomkinson B48 Artificial nest hatched 30.4.76-10.5.76	8	13.6 ± 0.3	29.1 ± 0.5	59.8 ± 6.5	1-10 days
Tomkinson km 68.5 Artificial nest hatched 19.2.77	9	14.4 ± 0.3	30.8 ± 0.7	73.1 ± 1.5	∿7 days
T12 Tomkinson km 53.9 between 4-9.6.74	29	14.9 ± 0.2	31.7 ± 0.5	92.7 ± 4.2	∿7 days
T13 Tomkinson km 59.7 between 4-9.6.74	14	14.0 ± 0.3	29.9 ± 0.5	87.4 ± 4.5	∿7 days
T14 Tomkinson km 65.1 between 21-28.6.74	9	14.5 ± 0.2	31.0 ± 0.5	82.8 ± 2.8	∿7 days
Deraniyagala Nest 1 Artificial	11	-	30.1 ± 1.0	90.2 ± 6.1	0
Deraniyagala Nest II Artificial	4	-	29.4 ± 0.5	78.8 ± 6.3	0
Deraniyagala Nest IV Artificial	5	14.6 ± 0.2	30.4 ± 0.3	79.4 ± 3.6	0
Liverpool 1975 hatched May 4. Artificial	23	13.5 ± 0.6	28.3 ± 1.4	64.7 ± 4.8	7 days
C. niloticus Clutch A Artificial nest	10	-	30.4 ± 1.5	-	0
Clutch B Artificial nest	14	-	31.5 ± 0.6	84.0 ± 2.5	0
Animals in Table 5 Artificial nest	10	13.7 ± 0.9	30.5 ± 1.4	0	0

This shows a TL growth rate for the 37 days before hatching of 0.34 cm/day, or an SVL rate of 0.17 cm/day (using an approximate conversion factor of 2); Nest III gave 0.15 cm/day for 37 days before hatching. Deraniyagala stated that his animals were incubated at temperatures which fluctuated daily between 27 and 30°C.

From Table I of Magnusson and Taylor (1980) we may also obtain some estimates for embryonic growth rates. They gave measurements for a series of embryos taken from two different nests; the Series I nest was incubated at a mean 2.5°C lower than that of Series II (28.5°C against 31.0°C). The Series I animals, from the 51st to 86th day, grew 0.15 cm/day (SVL) and the Series II animals grew, from the 49th to 86th day, 0.155 cm/day (SVL). To obtain these results we used a conversion factor of 4.01 between snout-vent and head length rates obtained from a regression of the four pairs of snout-vent and head length values in Table I of Magnusson and Taylor (SVL = 4.01, HL = 3.7, r = 0.991). If we regress the total length against head length for all the animals in Table LVIII of Deraniyagala we obtain TL = 8.37 and HL = 10.53 (r = 0.97). If we use the conversion factor 0.48 given in Appendix 1 of Webb and Messel (1978) for converting between the snout-vent length and total length (for their smallest class of animals; they do not consider embryos), then we obtain a conversion factor between snout-vent length growth rate and head length growth rate of 4.02.

When comparing Deraniyagala's results with Magnusson's and Taylor's, one must bear in mind possible variations in incubation period discussed already and differences in temperature.

Magnusson and Taylor gave an HL (Series II) of 3.74 cm at 86 days whereas Deraniyigala (using his ages) had animals of 80 days with an HL of 4.2 cm. Plotting of Deraniyigala's head length measurements against age for Nest II gives a good fit to a straight line between 26 and 81 days, (8 points, r = 0.99) with an SVL growth rate of 0.20 cm/day (using 4.01 to convert) compared with 0.155 cm/day for the Series II animals. If the Series I head lengths are plotted against age, a good fit to a straight line is again obtained between 9 and 86 days (8 points, r = 0.995; the 28-day value is omitted) with an average SVL growth of 0.17 cm/day. Taking the Nest II and III growths over the last 37 days, one obtains from the head lengths an SVL rate of 0.13 cm/day (somewhat less than that obtained from the total length change), indicating that there may have been a slowdown in growth near hatching time for these two nests (though the data is perhaps too limited to draw such a conclusion).

If one looks at Nest I and calculates the average SVL growth over the last 25 days, it is 0.15 cm/day, comparable with Nest II and Nest III rates over the last 37 days. Thus, an SVL growth rate of between 0.15 and 0.20 cm/day covers the range of results, with the various uncertainties mentioned previously, for the 80 or so days before hatching occurs.

Pooley (1962) presented an excellent and detailed study of pre-hatching and post-hatching growth of penned C. niloticus which allows interesting comparisons with the results for C. porosus. For embryonic growth over 29 days before hatching he had a rate (his Table 4) of 0.33 cm/day for total length, which is very close to that of Deraniyigala (previously given). For a 49-day period going roughly from 80 to 30 days before hatching, the total length growth rate is 0.29 cm/day. The mean skull length on hatching (his Table 5, 10 animals) was 4.1 cm, to be compared with 4.6 cm for C. porosus. The mean total length for these same animals was 30.5 cm, very comparable to C. porosus (Table 1.1). From Pooley's results the mean TL growth rate of these 10 animals over their first month was 0.27 $\pm$ 0.04 cm/day, not much less than over the month prior to hatching. It must be remembered that Pooley provided food as required, so these growth rates are presumably an optimum with respect to food supply.

1.2 Hatchling Growth Up to 133 Days

Magnusson (1978) carried out a study on hatchling growth up to an age of 133 days by means of capture-recapture methods. He has presented (Magnusson and Taylor 1981) a mean growth rate for these animals during the wet season for their first 80 days, obtaining an SVL rate of 0.09 cm/day. Since each animal in his study was individually marked and some were captured up to five times, much might be learned by examining the individual growth records. This will also allow examination of variations of initial growth between animals from different nests. Nests are identified in Table 1.1.

In Table 1.2 we give the individual growth records for the three animals that were captured four or more times; all came from the Myeeli I nest. We also present in records A to H (Table 1.3) SVL growth records over different periods for animals from various nests. The identification numbers of each crocodile are given so that progress of particular crocodiles can be followed. The best record is for the animals from the Myeeli I swamp (records A, F, G). Comparison of the growth from 0 to 37 days and from 0 to 96 days shows little difference in average rate, despite the 0-96 day period including 40 days of dry season growth (of course, very early in the dry season; there is no sharp transition from wet season to dry season conditions). The 0-65 day average is higher than the shorter and longer period average, as is also shown for the three individuals in Table 1.2, all of whom show an increased rate of growth from their 37th to their 65th day. Animal 1403 also shows a slightly higher rate of growth from 0 to 65 days than from 0 to 35 days.

The highest rates of growth (record C) are the 0-53 day growths of animals hatched at the research base and released at km 23.4 on the Tomkinson River. The average growth rate is 0.126 $\pm$ 0.021, with the highest rate being that of No. 1415 at 0.158 cm/day, almost double the rate of the slowest growing animal in this group. This high growth

Table 1.2. Capture histories of three hatchlings from the Liverpool-Tomkinson Rivers System. All hatched from a natural nest on March 4, 1976.

Animal 1360											
Age (days)	0		37		65		96				
SVL (cm)	13.8		16/5		19.1		21.0				
Rate (cm/day)		0.073		0.093		0.061					
Animal 1370											
Age	0		19		37		65		96		131
SVL	14.1		15.3		17.2		20.5		21.9		22.5
Rate		0.063		0.106		0.118		0.045		0.017	
Animal 1394											
Age	0		35		65		94				
SVL	14.7		17.5		20.1		21.0				
Rate		0.080		0.087		0.031					

Table 1.3. SVL growth rates of animals from some of the nests in Table 1.1 for various periods measured in days after hatching.

Record Animal	Growth Rate	Record Animal	Growth Rate
Record A	0-(35-37) days Myeeli 1 Nest	Record C	0-53 days Liverpool km 47.5 Nest Released on Tomkinson
1360	0.073	1404	0.126
1362	0.071	1405	0.125
1367	0.074	1406	0.132
13.70	0.084	1407	0.109
1389	0.083	1410	0.138
1394	0.080	1414	0.081
1403	0.094	1415	0.158
Mean	0.080 ± 0.008	1416	0.132
All wet season growth		1418	0.134
Record B	0-(37-39) days Myeeli 2 Nest	Mean	0.126 ± 0.021
		Almost all wet season growth	
1316	0.085	Record D	13-52 days Liverpool B22 Nest
1344	0.095	1486	0.029
1348	0.122	1492	0.047
Mean	0.100 ± 0.019	1506	0.026
All wet season growth		1510	0.053
		1514	0.028
		1517	0.053
		Mean	0.039 ± 0.013
		All dry season growth	

Table 1.3. (continued)

Record Animal	Growth Rate	Record Animal	Growth Rate
Record E	53-82 days Liverpool km 47.5 Nest Released on Tomkinson	Record G	0-65 days Myeeli 1 Nest
1404	0.083	1358	0.080
1406	0.072	1360	0.0815
1407	0.041	1370	0.098
1413	0.038	1394	0.083
Mean	0.058 ± 0.022	1396	0.102
All dry season growth		1403	0.098
		Mean	0.090 ± 0.010
		Almost all wet season growth	
Record F	0-96 days Myeeli 1 Nest	Record H	0-82 days Liverpool km 47.5 Nest Released on Tomkinson
1360	0.075	1404	0.111
1364	0.074	1406	0.111
1370	0.081	1407	0.085
1391	0.083	Mean	0.102 ± 0.015
1394	0.067	Almost all wet season growth	
Mean	0.076 ± 0.006		
40 days are dry season			

occurred at the end of the wet season. Record E shows growth rates for these animals from their 53rd to 82nd day, and the rates for Nos. 1404, 1406, and 1407 have dropped considerably. The growth over this period was all in the dry season.

The lowest average rates of growth are from a group of animals that were raised at the base and then released into the Liverpool River at km 47.3. The growth record D, is from mid-May to mid-June and so is an all-dry-season growth rate. These animals may be compared with those in record C, whose wet season growth over a corresponding age span was up to four times higher.

Webb et al. (1977) gave results from three nests (T12, T13, T14) on the Tomkinson River, all of which hatched in June, 1974. The initial sizes for the surviving hatchlings from these nests are given in Table 1.1. (It should be noted that all the standard errors in this reference were calculated incorrectly and are generally too small.) Mean daily SVL growth rates of the hatchlings from these nests were 0.06, 0.05, and 0.05 cm/day respectively, for periods of 69, 63, and 52 days. These growth rates were all in the dry season (all periods ending mid-August) and may be compared with records C, D, and F. The dry season growth rate over the same age interval was again considerably less than the wet season one. Magnusson and Taylor (1981) also compared the wet season growth rates of hatchlings with these dry season rates and found that they were significantly higher.

Additional information on early growth may be obtained from data on recaptures of some of the animals from the Liverpool 1975 Nest (see Table 1.1). Five of these animals were recaught after spending 18-21 days in the wild and their SVL mean growth was 0.086 ± 0.021 cm/day (period of growth from 6th to 26th day). Three other animals recaught after spending their 6th-70th days in the field showed an average growth rate of 0.058 cm/day. The growth period for these animals began mid-May and was all dry season growth. The initial growth rates up to the 26th day are comparable with the purely wet season early growth rates.

The growth rates of Record C (mean 0.126 cm/day) are not far below those that we have obtained from embryonic growth rates, in agreement with the results of Pooley, and perhaps represent an upper limit to the initial growth rate of C. porosus. Since Pooley's animals were given access to plentiful food, it seems that food availability for the animals in Record C also was not a limiting factor to growth.

1.3 Blyth-Cadell Hatchlings Study

Further information on early growth of C. porosus may be obtained from our capture-recapture study on the Blyth-Cadell Rivers System. A large number of hatchlings of various ages were captured in mid-June 1978 and recaptured in late September 1978. The results (Monograph 1, Chapter 8) show that the mean rate of growth of all hatchlings over the 3 months period (all dry season) was 0.030 ± 0.0.13 cm/day. Because this sample includes hatchlings of various initial ages, care should be exercised when comparing this with the most comparable previous results, those for the Tomkinson T12, T13, and T14 nests of 1974 discussed in the previous section. The reader is referred to Monograph 1, Chapter 8, for a detailed discussion of the results.

In his thesis, Magnusson (1978) fits a curve to records of animals up to 133 days old. He found that a parabola gave a better fit to the data than a straight line and that the growth curve also predicted a rate of 0.031 cm/day at 120 days (well into the dry season).

The largest growth rate over the 3-month dry season period on the Blyth was for an animal that went from 19.0 to 24.7 SVL, a rate of 0.061 cm/day. As described in Chapter 8, growth on the freshwater section of the Blyth was particularly slow. Several animals only gained between 0.4 cm and 0.7 cm in the period, corresponding to growth rates ranging from 0.004 to 0.008 cm/day. Examination of Magnusson's growth records over dry season periods shows that animal 1370 only grew 0.6 cm from mid-June to mid-July (0.017 cm/day).

Record D of Table 1.3 shows a mean dry season growth rate (0.039 cm/day) for young animals consonant with that found on the Blyth-Cadell System (0.03 cm/day). Animal 1370 shows a mean rate from its 65th to 131st day of 0.030 cm/day, and animal 1394 has the same rate from its 65th to 94th day.

To examine further the relationship between growth rate and SVL, the change in SVL over the 3-month dry season period was regressed against the initial SVL for animals (both male and female) that remained on the km 20-35 section of the Blyth River. (We have selected this section to omit the slow growth freshwater sections.) The slope was 0.20 (standard error 0.1), showing a slight upward trend of growth rate with size, but the coefficient of determination was only 0.08, so one should treat the result with care. From Magnusson's results for the wet season one might have expected a clear downward trend in hatchling growth with increasing initial SVL (and hence increasing age), though we did note previously some evidence for an increase in growth with age for some of Magnusson's animals up to 60 days. The possible discrepancy here could perhaps be understandable in the following way. During the wet season food availability is higher than during the dry and is not a restrictive factor on growth. Under the harsher conditions of the dry season, however, food accessibility may be greater for larger animals. In this way animals that are larger at the start of the dry season may be able to cope better in terms of food sources and so grow faster.

PART 2 COMPARISON OF GROWTH IN THE WET AND DRY SEASON

2.1 Introduction

In northern Australia the year is divided into distinct wet and dry seasons (Monograph 1, Chapter 3). As has already been stated by several authors (Webb *et al.*, 1978; Monograph 1, Chapter 8; Magnusson, 1978) there are considerable differences between the growth rates of *C. porosus* over the wet season and over the dry season. It was suggested in Section 8.5.4 of Monograph 1 and by Webb *et al.* (1978) that increased abundance of food sources is the main reason for higher growth during the wet season, in contrast with the view of Magnusson (1978) who suggested that temperature and/or salinity are the major factors involved.

Our purpose here is to review the previous data and present some further data. The discussion is also necessary as a prelude to later sections. In Parts 1.2 and 1.3 we have already mentioned the influence of wet and dry season on early growth of hatchlings. Ideally one would like to have a continuous series of measurements, at say one monthly intervals, for a series of animals living in the wild over a number of years. Unfortunately such data would be very difficult, if not impossible, to obtain. To work on the rivers during the wet season is very difficult and recapturing animals over successive months would become increasingly difficult due to increasing wariness. For these reasons the main data available comprise capture-recapture records over periods normally involving a mixture of wet and dry season periods.

Another factor to be borne in mind in looking at data which extend over a number of years is that conditions relevant to growth may well vary from year to year. For example, we may have a particularly heavy wet season one year and a particularly dry one the following year. The availability of food could well be different during the two wet seasons and during the following dry seasons. The 1978-1979 wet season was a particularly dry one and growth rates between mid-1978 and mid-1979 obtained on the Blyth-Cadell Rivers System (Monograph 1, Chapter 8) could be less than normal on those rivers. Availability of various food species may also vary over the years and on different rivers in different ways. With all these varying factors affecting interpretation of differences between wet and dry season growth rates of animals in the wild, one must take results on a particular river at a particular period as a guide only. In the following we have attempted to obtain estimates of wet and dry season growth rates by careful examination of capture-recapture records for animals over the period 1973-1980 on the Liverpool-Tomkinson and Blyth-Cadell River Systems.

2.2 Examples from the Liverpool-Tomkinson System

Examples illustrating dry and wet season growth may be gleaned from the capture-recapture records on the Liverpool-Tomkinson System. They are presented in Table 2.1 and we shall discuss some of these.

Table 2.1. Examples of growth on the Liverpool-Tomkinson Rivers System over intervals which are mainly in the dry season. The number of wet season days in the interval is shown in brackets.

Initial Size	Sex	Mean SVL Growth (cm/day)	Interval (days)
1. H	F	0.050	146 (17)
2. 2-3'	M	0.054	152 (51)
3. 3-4'	M	0.0355	124 (30)
4. 3-4'	M	0.0357	225 (145)
5. H	F	0.038	124 (30)
6. 2-3'	M	0.028	118 (30)
7. H	M	0.054	263 (49)
8. 2-3'	M	0.032	174 (41)
9. H	M	0.0527	387 (151)
		0.0552	270 (116)
		0.047	117 (35)

The simplest description of growth over an interval (ΔT, days) involving both wet season (ΔT_W) and dry season (ΔT_D) periods is to assume linear growth (at different rates) over the two periods. Let a (cm/day) and b (cm/day) be the growth rates over the wet and dry season respectively. The change in SVL (ΔSVL, cm) over ΔT is given by $\Delta SVL = a\ \Delta T_W + b\ \Delta T_D$. Such a model has of course a very artificial sharpness in the boundary between the two seasons. Following Webb et al. (1978) we take the wet season as extending from December to April (151 days) and the dry from May to November (214 days). Days 1-120 and 334-365 are wet season and days 121-333 are dry season. The coefficients a and b will also depend on the age of the crocodile. To illustrate this approach we take the example of animal 9 in Table 2.1 that was captured three times on the Liverpool-Tomkinson System over the period of approximately one year. Over a period of 387 days from mid-dry season (day 180) to mid-dry season (day 202) the growth rate was 0.0527 cm/day. From day 85 to day 202 the growth rate was 0.047 cm/day. Use of these results gives a = 0.091 cm/day and b = 0.028 cm/day when substituted into the equation above. This is the only example (besides the animals of Tomkinson nests T12, T13, T14 to be discussed shortly) we have on the Liverpool-Tomkinson System of an animal caught three times within approximately a year and so allowing calculation of a and b as above.

If an assumption is made about the magnitude of b then estimates of a may be made. These estimates can be a rough guide only, especially when one recalls the artificiality of a sharp boundary between the wet and dry season and that the growth rate probably varies over the wet season and over the dry season. However, by assuming various values for b, a range of values for a may be obtained. Consider for example animal 2 from Table 2.1 and taking b = 0.03, we obtain a = 0.10. Any lower value for b would give a higher value for a and vice-versa. Taking b = 0.05 gives a = 0.06. This animal is of 79 cm length initially, in the middle of its second dry season, and a rate of growth of 0.10 cm/day over the initial part of the following wet season would be a rate comparable to that of Magnusson's under 80 day old animals during the wet season (Part 1).

The group of hatchlings from the Tomkinson nests T12, T13, and T14 (see Part 1.2) gives rates of growth over approximately 2 months of the dry season and then over the next year (see Part 3.2). These mean rates are both about 0.06 cm/day. This example is out of line with the rest of the data and the reason is not clear. Possibly there was a higher food supply on the relevant section of the Tomkinson that year than is usual during the dry season.

2.3 The Blyth-Cadell Study

The Blyth-Cadell capture-recapture study initiated in 1978 (Monograph 1, Chapter 8) was specifically designed to throw light on the question of wet and dry season growth rates. Hatchlings were initially captured in June, then again in September (giving a dry season growth rate) and then again in the following June. On the Blyth River the overall average dry season rate was 0.030, from September to the following June it was 0.053, and from June to June 0.048. Calculation of a wet season growth rate as in Part 2.2 gives a rate of 0.073 if we use the June to June rate and 0.070 if we use the September to June rate. Similar calculations for the Cadell results lead to rates of 0.084 in both cases. In this we have assumed, of course, that the average rate over the dry season period outside the June to September interval is also 0.030 in both the first and second year. If it is in fact lower (as appears likely), then the mean rate over the wet season will be larger.

It had been planned to obtain a growth rate over the animals' second dry season by recapturing in October 1979 but extraordinary circumstances (Monograph 1, Chapter 8) meant that only 4 growth records could be obtained for this. The rates over some 4 months of the second dry season were 0.014, 0.015, 0.005 (males), and 0.008 (female) (Monograph 1, Table 8.5.8), with overall mean 0.010. The sample is so small that it is hard to conclude much but we may perhaps take the figure of 0.010 as an estimate of dry season growth rate in the second year, on the Blyth-Cadell River, indicating decreasing growth rate with age (Monograph 1, Chapter 8). This figure is lower than the 0.03 used in the calculations of wet season rates above. If one uses the 0.010 in the above calculation for all dry season days in the second year, one obtains wet season rates of 0.079 on the Blyth and 0.091 on the Cadell. Given that the growth rate probably declines with the progress of the dry season and with age, we may take the wet season growth rate as being in the range 0.07 to 0.10, which again is comparable with the initial wet season growth of Magnusson's hatchlings.

In October 1980, 11 animals were recaptured on the Cadell River. These will be discussed in more detail in Part 4 (Table 4.4). However, they do throw some further light on differences between wet and dry season growth rates. Nine of the animals were recaptured in June 1979, and so we may calculate for them an average growth rate over a 480-day period that includes 151 days of wet season; all these animals were at least one year old in June 1979. For the 6 males the average growth rate was 0.0195 $\pm$ 0.0042 cm/day (range 0.012-0.023) and for the 3 females it was 0.0137 $\pm$ 0.0021 cm/day (0.012-0.016). For the males, if we allow no growth at all over the dry season component of the 480 day interval, we obtain a wet season growth rate of 0.064 cm/day. If we take the figure of 0.010 cm/day that we have just obtained from the June 1979-October 1979 captures, the wet season growth rate becomes 0.042 cm/day. For the females, the same calculations give rates of 0.045 and 0.023 cm/day. The sample size is of course small, but the results appear to indicate, especially if we allow a second and third dry season growth rate of 0.01 cm/day, that the growth rate for both males and females over their second complete wet season is considerably less than over their first complete wet season. Further discussion of wet and dry season growth rates occurs in Parts 3 and 4.

2.4 The Multiple Regression Model

In Webb et al. (1978) a multiple regression model was developed to quantify the influence of some variables on growth rates obtained by capture-recapture on the Liverpool-Tomkinson System. Among the variables was the percentage of dry season in the interval over which the growth rate was obtained. In the sample used the percentage of dry season varied between 35 and 90 percent. From the regression equations given one may calculate mean growth rates over the dry season and over the wet season for males and females (after substituting appropriate mean temperatures) and for different mean snout-vent lengths. In Table 2.2 we have done this for a succession of mean snout-vent lengths that are roughly appropriate for successive dry and wet seasons in the life of an animal. The results for males are in agreement with our previous discussion. The results for female growth rates over the dry season appear to be too high. This not only conflicts with the examples we have given of female growth rates over the dry season (especially on the Blyth-Cadell System), but also would raise the question of how females could differ so much from males in their dry season growth rates. It is not clear why the predictions for female growth over the dry season are in such apparent error. In substituting values of 0 percent and 100 percent for percentage dry season to obtain wet and dry season rates we are exceeding the range of values occurring in the data put into the model, but one would expect that if the coefficients have much meaning then they would give sensible estimates for these two extreme cases.

As we shall see, the mean yearly growth rates predicted from the model are in good agreement with more direct calculation of such rates. However, some points may be made in relation to the model. It is stated as an assumption of the model that in the period between captures, deviations between the real growth curve and an assumed linear growth are negligible. Of the growth records used, however, approximately 75 percent involved intervals of between 300 and 399 days, and over 90 percent involved intervals of greater than 200 days. Intervals over 200 days must include a mixture of dry and wet season, and we have seen (and the model itself predicts this) that there are considerable differences in growth rate between the wet and the dry season. These differences appear to be in conflict with the assumption just stated and this possibly casts some uncertainty on the interpretation of the model. The coefficient in the multiple regression equation which gives the size of the dependence on the percentage dry season is β_2. For males this is -0.236 and for females it is -0.062; the two values thus differing by a factor of almost 4. (The coefficient β_7 on page 389 of Webb et al. [1978] is incorrectly given as -0.0174; it should be -0.174.) Again it would be hard to understand, if these results were to be correct, how males and females could differ so much in their response to the dry season.

We shall now give a brief discussion of the mathematical basis of the regression model. For simplicity we shall take one sex only and neglect any influence of temperature. The equation for growth thus becomes:

Table 2.2. Mean dry season and wet season SVL growth rates for males and females of different sizes calculated from the multiple regression model of Webb et al. (1978).

Mean SVL	Dry Season Rate	Mean SVL	Wet Season Rate
	Males		
20.0	0.033	30.0	0.108
40.0	0.017	50.0	0.096
60.0	0.0006	70.0	0.085
80.0	negative	90.0	0.074
	Females		
20.0	0.054	30.0	0.067
40.0	0.036	50.0	0.054
60.0	0.018	70.0	0.041
80.0	0.0008	90.0	0.028

Wet season: $$\frac{dy}{dt} = a - by$$

Dry season: $$\frac{dy}{dt} = a - by - \alpha.$$

where y is SVL, say, and α is a positive constant giving the difference between dry and wet season growth rate. It will be seen that we have assumed that this difference is independent of the size of the animal. Suppose now that we have measurements (y_1 and y_3) of SVL at the beginning and end of a period going from T_1 to T_3; T_1 to T_2 being dry season and T_2 to T_3 being wet season. Then we have:

$$\Delta y = a(T_3-T_1)-b\int_{T_1}^{T_2} y \; dt - b\int_{T_2}^{T_3} y \; dt - \alpha(T_2-T_1)$$

The mean rate Y over the interval ΔT ($\Delta T = T_3-T_1$) is thus given by:

$$Y = \Delta y/\Delta T = a - b\,\bar{y} - \alpha(T_2-T_1)/\Delta T$$

$(T_2-T_1)/\Delta T$ is just the fraction of dry season occurring in the period ΔT.

The assumption made in the growth paper is that it is permissible to replace $\bar{y}$ [$= \int y \; dt/\Delta T$] by 1/2 (y_1+y_3). This is only true if y depends linearly on t during the interval ΔT. If this assumption is made, then we arrive at the form of equation given in the growth paper. As we have already commented, most of the intervals occurring in the data used to derive the model included significant mixtures of wet and dry season growth, and so the growth is definitely not linear over the whole interval but only over parts of it.

If one had enough data to warrant the analysis, more realistic models than the above suggest themselves. The sharp distinction between wet and dry season is highly artifical, and a more realistic approach might be to have an equation of the form:

$$\frac{dy}{dt} = a - by - \alpha \sin \omega t$$

where the sinusoid has a period of one year, with growth reaching a peak somewhere around the middle of the wet season and a minimum around the middle of the dry season. Further, the assumption that the difference between wet and dry season growth rate is independent of the size of the animal is also open to doubt. One might expect the difference to be greater for small animals, given that their major diet foods of insects and crustaceans are much more plentiful during the wet season, whereas larger animals depend more on fish, birds, and mammals whose abundance (at least for fish amd mammals) might not be so dependent on the different seasons. These are matters for further investigation, the available data being insufficient to enable much to be said.

2.5 Results for C. niloticus

Pooley's (1962) results for penned, juvenile *C. niloticus* show that growth decreases and virtually halts during the South African winter and spring. Over the first two months of life (in autumn) the growth is 12.1 cm (total length). Over the next six months it is 3.7 cm, a drop in the daily snout-vent length rate from 0.1 cm/day to 0.010 cm/day (obtained by dividing length by 2). It then rises again to 0.086 cm/day over summer, 0.054 cm/day over autumn, and then 0.018 cm/day over the next winter/spring. The dependence on season of juvenile *C. niloticus* thus appears to be greater than that of *C. porosus*, probably principally due to much cooler temperatures prevalent in comparison to northern Australia. Availability of food was not a factor, as these penned animals were provided with ample food.

PART 3: GROWTH OF *C. porosus* OVER THE FIRST YEAR

In order to allow comparison of growth rates on different rivers over the first year of life we have calculated growth rates for animals that remained on the Liverpool River and those that remained on the Tomkinson River over their first year. This will also allow comparison with the rates (Monograph 1, Chapter 8) already obtained for the Blyth and Cadell Rivers. These rates may also be compared with those given by the growth curve (Table 3.1) and obtained in a much less direct fashion (Webb *et al*., 1978).

3.1 Liverpool Hatchlings

Twenty-three hatchlings (including 12 males and 11 females) were captured in the mid-dry season of 1973 and recaught one year later. The overall mean growth rate for these animals was 0.054 ± 0.006 (range 0.043-0.069). For the males it was 0.056 ± 0.006 (range 0.047-0.069), for the females 0.050 ± 0.005 (range 0.043-0.058). Nine hatchlings were similarly recaptured over the 1974-1975 period. The overall average for these animals was 0.054 ± 0.008 (6 males, 3 females). The mean growth rates over the two periods are identical. The largest growth rate for an animal in the later period was for a male whose rate was 0.074, the snout-vent length increasing from 20.1 to 46.4 cm. The lowest growth was for a female, 0.045 cm/day, its snout-vent length changing from 20.5 to 37.3 cm. Taking all 32 animals, the growth rate was 0.054 ± 0.007 cm/day (0.056 ± 0.007 for males, 0.050 ± 0.005 for females). The interval between recaptures ranged between 340 and 370 days with most being within the range of 350-365 days.

To investigate whether there were any differences in growth rates along the river (salinity gradient), the animals were grouped into various intervals between km 20 and km 60 (non-freshwater section). The sample is admittedly small, but there was no indication of any differences in the hatchling mean growth over a year dependent on their position on the brackish section of the river. Most of the animals were recaught within a kilometer or so of their first capture positions and

Table 3.1. Sizes of male and female crocodiles at various ages as predicted by equations (5) and (6) of Webb *et al*. (1978). HL denotes head length, SVL denotes snout-vent length, and TL denotes total length. The total length was calculated from the snout-vent length using equations from Appendix 2 of Webb and Messel (1978). The annual growth rates are also shown. For consistency with Webb *et al*. (1978) we have in this Table taken 13.2 cm as the SVL on hatching rather than 13.9 cm which was used in Part 3.4. The figure of 13.2 cm is obtained from HL using the equations on page 388 of Webb *et al*. (1978), as are all SVLs in this Table.

	Age (years)	HL (cm)	SVL (cm)	TL (cm)	In Feet	Annual Rate (SVL; cm/day)
Males	0	4.6	13.2	28.0	11"	
	0.5	8.0	25.8	52.9	1' 9"	0.062
	1.0	11.0	36.0	75.0	2' 6"	
	1.5	13.7	45.3	94.1	3' 1"	0.048
	2.0	16.0	53.6	111.1	3' 8"	
	2.5	18.1	60.9	126.1	4' 2"	0.038
	3.0	19.9	67.3	139.2	4' 7"	
	3.5	21.5	72.9	150.7	4'11"	0.029
	4.0	22.9	77.8	160.7	5' 3"	
Females	0	4.6	13.2	28.0	11"	
	0.5	7.8	24.6	51.5	1' 8"	0.058
	1.0	10.6	34.5	71.9	2' 4"	
	1.5	13.0	43.1	90.0	2'11"	0.044
	2.0	15.2	50.5	104.9	3' 5"	
	2.5	17.0	57.0	118.0	3'10"	0.033
	3.0	18.6	62.5	129.0	4' 3"	
	3.5	19.9	67.4	138.9	4' 7"	0.025
	4.0	21.1	71.6	147.3	4'10"	

one may assume that they spent most of the year along the same stretch of river. These results are consistent with those of Webb et al. (1978), who found position along the brackish sections of the river to be an unimportant variable. The results are also consistent with those obtained for the Blyth River, where there appeared to be no difference in growth over the full year between the brackish and freshwater sections (though there was over the three months of dry season growth). Magnusson (1978) and Magnusson and Taylor (1981) also found no dependence of growth on salinity in a somewhat limited salinity regime.

3.2 Tomkinson Hatchlings

In Part 1.2 we referred to the initial growth rates of animals from the three nests (T12, T13, T14) on the Tomkinson in June 1974. Twenty-two of these animals were recaught in July 1975, and their average growth rate over a period of some 340 days from mid-August of 1974 was 0.060 ± 0.005. This rate is about the same as their initial growth rate over some two months in the 1974 dry season, and does not show the usual decline from the initial growth rate that was observed with animals which spent their initial growth period in the wet season. Of this sample, 12 were males (0.061 ± 0.005; range 0.054-0.074) and 10 were females (0.0585 ± 0.0040; range 0.052-0.063), and there thus was no significant difference in the male-female growth rates, though the female rate was, as usual, lower. The mean interval between captures was some 340 days.

Twenty-one other animals were captured in mid-dry season of 1973 and recaptured some 340 days later in 1974. The average growth rate was 0.054 ± 0.009 cm/day (8 males, 0.063 ± 0.007, range 0.052-0.071; 13 females, 0.049 ± 0.005, range 0.038-0.056). The female growth rates of the 1973-1974 season are lower than those of the 1974-1975 season. This difference is in fact significant at the 0.01 percent level. Since the male rates over the same two years are much the same, it is hard to understand this difference.

The growth rates for hatchlings on the Liverpool-Tomkinson System calculated in this direct fashion are in good agreement with those predicted by the growth curve (Table 3.1).

3.3 Growth Over the First Year on Different Rivers

In Chapter 8 of Monograph 1 it was shown that growth over the first year was somewhat higher on the Cadell River than on the Blyth River, into which it runs about 20 km from the mouth of the Blyth. The sample on the Cadell was small however. The Liverpool-Tomkinson Rivers System lies some 30 km to the west of the Blyth-Cadell Rivers System and the Tomkinson runs into the Liverpool about 20 km from its mouth (Monograph 15). By the end of the dry season the Cadell is slightly brackish at the upstream limit of navigation by survey boat, whereas the Blyth is fresh; likewise the Tomkinson is slightly brackish, whereas the Liverpool is fresh at the upstream limit (see Monographs 1 and 7 for full details on

the salinity regimes of these rivers). The two river systems are thus somewhat similar, the Blyth corresponding to the Liverpool and the Cadell to the Tomkinson. Now that we have obtained separate growth rates for the Liverpool and Tomkinson we can make some comparisons of growth rates.

Because most of the intervals for the Tomkinson recaptures are about 340 days compared with 350-360 days for the Liverpool and Blyth-Cadell recaptures, there is a slight upward bias (due to a higher percentage of wet season) in the Tomkinson rates. This may be corrected for by using the two-rate model discussed in Part 2. Taking a dry season growth rate of 0.030 cm/day, one finds that the Tomkinson rates for 360 days are some 2 percent lower than the rates over 340 days given in Part 3.2. It is these corrected rates for the Tomkinson that we use in our comparisons.

Because of the small sample size for the growth over the first year on the Cadell, we shall not include the Cadell in the comparisons here; as we have already said, the rates of growth on the Cadell were higher than on the Blyth. The mean yearly rates on the Blyth were 0.050 ± 0.005 (n = 33) for males and 0.043 ± 0.008 (n = 13) for females (Monograph 1, Table 8.5.7). The various rates are collected in Table 3.2.

The male growth rates on the Liverpool and Tomkinson Rivers are not significantly different. The female rates are significantly different (at 0.1 percent level) if we use the 1973-1974 results for the Tomkinson, but are not different if we use the 1974-1975 results for the Tomkinson.

Comparisons of the male rates on the Tomkinson with those on the Blyth give results that are highly significant (at 0.0001 percent level). Comparison of the rates for females on the Blyth and Tomkinson shows that the 1974-1975 rates are highly significantly different (at the 0.01 percent level), but the 1973-1974 rates are not.

Comparisons of male rates on the Liverpool with those on the Blyth show the difference to be significant at the 0.1 percent level. The female rates also differ significantly at the 1 percent level.

The results clearly indicate higher growth in the first year on the Liverpool and Tomkinson Rivers than on the Blyth; in fact the largest growth rate on the Blyth was 0.060 cm/day for a male, which is about the mean male growth rate on the Tomkinson (the rates on the Liverpool-Tomkinson System are also mostly higher than on the Cadell, though the numbers in the Cadell sample are only small). There is also a strong indication that males grow better on the Tomkinson than on the Liverpool; for females the picture is complicated by the disparity between the 1973-1974 and 1974-1975 growth rates.

3.4 Range of Sizes and Ambiguities Amongst Hatchling Captures

Besides the capture-recapture records, we also have available many hundreds of single captures, and thus, much may be learned from the size structure of the population at a given time of year. In this section we

Table 3.2. Mean SVL growth rates of hatchlings for the period from June 1978 to June 1979 on the Blyth, Cadell, and Blyth-Cadell Rivers. Abstracted from Table 8.5.7, Monograph 1.

	Blyth		Cadell		Blyth-Cadell	
	Rate	n	Rate	n	Rate	n
All hatchlings	0.0483 ± 0.0065	46	0.0530 ± 0.0033	9	0.0484 ± 0.0063	61
Males	0.0502 ± 0.0046	33	0.0530 ± 0.0059	3	0.0495 ± 0.0052	41
Females	0.0432 ± 0.0079	13	0.0530 ± 0.0017	6	0.0461 ± 0.0079	20

Table 3.3. Possible SVL (cm) of hatchling hatched on February 1 for two different sets of growth rates (see text, Part 3.4).

	Feb 1	Mar 21	Apr 30	Jun 9	Jul 19	Aug 28	Oct 7	Nov 16
Day Number	32	80	120	160	200	240	280	320
Upper Rate	13.9	18.7	22.7	24.7	26.7	28.7	30.7	32.7
Lower Rate	13.9	16.8	19.2	20.4	21.6	22.8	24.0	25.8

shall use all available information to consider the range of size that a hatchling may assume during its first dry season. Because of the possibility of errors in measurement, we only take examples of size and growth that are paralleled by at least one other animal. These sizes may then be correlated with the growth rates we have been considering and the possible times of hatching.

Nesting of C. porosus in northern Australia (Webb et al., 1977; Magnusson, 1978) is stated to take place between November and May, during the wet season. Incubation periods vary between 80 and 100 days, normally, though during the dry season hatching can take much longer (or as mentioned in Part 1.1 it may not even occur at all) because the temperature is lower. If a nest is laid on the earliest possible date, say November 1, then the eggs could be expected to hatch around February 1. If laid at the end of May, they would probably hatch no sooner than September 1. R. Jenkins (personal communication) has found a riverside nest in the Alligator River region which was laid down in August. This is exceptionally early (or late), and we will use the November date in our discussions. It is unknown whether any eggs from such an August nest would hatch.

We first consider animals hatching early in the year. Animal 1406 (record H, Table 1.3) hatched on March 19 with an SVL of 14.5 cm and by June 9 had an SVL of 23.6 cm. If we assume that an animal with comparably high growth rate had hatched on February 1 with an SVL of 13.9 cm, we may make some calculations of the range of maximum sizes possible over the year. The figure of 13.9 has been adopted for the SVL on hatching, since the mean of the means in Table 1.1 for hatchlings ≤ 2 days old is 13.9 ± 0.43. Considering first the upper range of growth, we take a mean growth to the end of the wet season (April 30) of 0.1 cm/day. One hatchling, captured on day 205 (July 24) and recaptured on day 351 (December 17), had a mean growth of 0.05 cm/day (the SVL going from 23.0 to 30.3 cm). We may thus take 0.05 cm/day as a possible rate over the dry season, leading to the predicted lengths shown in Table 3.3. Taking a lower rate for growth during the wet season of 0.06 cm/day and during the dry of 0.03 cm/day, we obtain the lower growth rate shown in Table 3.3.

Examination of our capture-recapture records reveals the following examples. An animal (Blyth River) caught on June 22 (day 173) had an SVL of 25.1 cm. A group of animals was captured on the Blyth River around the end of October (day 300) with SVLs ranging from 29 to 31.5 cm, in agreement with the upper size suggested for an animal born near February 1. Animals were caught on the Goromuru River in 1975, around day 280, with an SVL of 31.1 and 31.5 cm. In late September (day 269) 1978 an animal was caught on the Cadell River with an SVL of 28.0 cm; an animal with the same SVL was caught in late August on the Tomkinson River. Another animal with an SVL of 18.5 cm on day 112 (late April) had an SVL of 32.7 cm by day 10 of the next year. If we allow an initial growth rate of 0.1 cm/day, then this animal hatched in early March. With this same sort of growth and a hatching in early February, it seems we could have an animal with an SVL of 33 cm by the end of November. After examining late hatchling growth we shall look again at the question of maximum hatchling sizes late in the dry season.

We now consider the lower size range of hatchlings later in the dry season and attempt to relate this to the latest possible times of hatching. Amongst the Blyth-Cadell captures of late October 1974 (around day 300), there were three hatchlings captured on the upstream Blyth River (around km 42) with SVLs of 16.0, 16.5, and 16.5 cm. Some other animals in the range 17.0-18.5 cm were also captured on the upstream Blyth River (around km 42) with SVLs of 16.0, 16.5, and 16.5 cm. Some other animals in the range 17.0-18.5 cm were also captured at this time. During the September 1978 captures on the same river system, the smallest animal caught had an SVL of 17.1 cm. So in 1974 one had animals 1 cm (SVL) shorter one month later. As we have discussed earlier, some very low growth rates occurred over the June-September period on the upstream Blyth in 1978 (see Monograph 1, Chapter 8). If we assume that the mean initial rate of growth of the late October 1974 hatchlings was 0.06 cm/day (i.e., the same as the initial rate of the Tomkinson T12, T13, and T14 nests) and that their initial SVL was 14.0 cm, then a 16.5 cm SVL corresponds to an age of about 40 days, and with a normal incubation period of 90 days we obtain a date of mid-June for the laying of the nest, which would be a late nest. A longer than normal incubation period (as would be highly likely during the colder dry season months) and a lower growth rate would of course push the date further back. Pushing laying back to the end of April (the end of the wet season) and assuming 90 day incubation, we would obtain an age of 90 days for the 16.0 cm hatchling, corresponding to a mean growth rate of 0.02 cm/day, a growth rate that seems possible after examination of the Blyth-Cadell capture-recapture data.

An animal that had an SVL of 16.0 cm in late October and grew at the average rate of 0.05 cm/day over the next year would by the following October have an SVL of 34.3 cm; at a rate of 0.04 cm/day it would have an SVL of 30.6 cm. Thus there could be an overlap in sizes in the late dry season of animals born early that same year or born late in the dry season of the previous year. It is possible that in our assignment of animals to the hatchling class for calculating the Liverpool and Tomkinson growth rates we have erred, in that the animal is actually in its second dry season. Such cases, and there would only be a few, would have the effect of lowering the mean growth rate, since growth over the second year of life is slower (see later).

Another way of comparing growth on the two river systems is to compare the sizes of the animals in the second year, in mid-dry season. On the Blyth-Cadell System the largest recapture had an SVL of 42.0 cm, with several others over 40 cm. Examination of the Liverpool-Tomkinson data reveals several animals in mid-July with snout-vent lengths around 46 cm, and numbers between 42 cm and 46 cm. It is also interesting to note that one of the Blyth October 1979 captures, No. 1753, which had an SVL of 41.8 cm in June, had only 42.5 cm in October. These observations again indicate a higher growth rate on the Liverpool-Tomkinson System.

3.5 Other Species of Crocodile

From Pooley's (1962) results we can calculate mean growth rates for penned *C. niloticus* over the first year. From his Table 5 we can calculate a mean snout-vent length growth rate over the first year of 0.052 cm/day (range 0.035-0.061). This growth is thus very comparable to that of *C. porosus*. A specimen in natural conditions (Cott, 1961, p. 245) grew at a rate of 0.038 cm/day.

Whitaker and Whitaker (1977) presented similar data for *C. palustris*. The animals were in pens with access to plentiful food. The mean growth rate (converting from length to snout-vent length by dividing by 2) over the first year was 0.074 cm/day (range possibly 0.04-0.1). Compared to wild *C. porosus* and penned *C. niloticus* the rates of growth of these animals are very high, and it is difficult to say whether they reflect an inherently faster growth rate for juvenile *C. palustris*, or whether under equally favorable conditions *C. porosus* and *C. niloticus* could match this growth. There appears to be no reason why not. Some growths given by Deraniyagala (1939) for a captive specimen of *C. palustris* are considerably less than those of Whitaker and Whitaker. After 20 months Deraniyagala's specimen was only 49.7 cm in total length, after hatching at 25.5 cm. This is smaller than any of Whitaker and Whitaker's animals after 12 months.

PART 4: GROWTH OF SMALL (3-6', 0.9-1.8 m) *C. porosus*

In this part we re-examine the growth records for animals after their first year on the river and up to the fourth year. This main purpose again is to look for differences between different rivers. For animals larger than 2-3' (0.6-0.9 m) it is impossible in some cases to be certain of an animal's age, and this uncertainty increases with age. However, amongst the capture-recapture records on the Liverpool-Tomkinson System there are a number of triple captures where animals were caught in three successive years, and in these cases we know much more about the age of the animal. These triple captures of animals in the wild provide very valuable data, and we have tried to make full use of them.

4.1 Growth from Second to Third Year on the Liverpool-Tomkinson System

The capture-recapture records show 13 animals that spent their second year on the Liverpool River. The SVL growth rates for these initially 2-3' animals from mid-dry season to mid-dry season are:

All animals:	0.038 ± 0.007	(n = 13, range 0.029-0.050)
Males:	0.039 ± 0.007	(n = 7, range 0.031-0.050)
Females:	0.036 ± 0.006	(n = 6, range 0.029-0.044)

As expected the growth rate for males is higher than that for females, though not significantly.

There were 34 animals that spent their second year on the Tomkinson River from mid-dry season to mid-dry season and were initially 2-3' animals. The growth rates for these animals were:

All animals	0.045 ± 0.006	(n = 34, range 0.034-0.059)
Males:	0.045 ± 0.007	(n = 8, range 0.038-0.054)
Females:	0.045 ± 0.006	(n = 26, range 0.034-0.059)

Interestingly, the male and female rates on the Tomkinson are identical. The hatchling growth rates for males and females over the one year period 1974-1975 were also very close.

The average time interval between these Tomkinson recaptures is only 340 days, somewhat short of the average full year interval between the Liverpool recaptures. To enable a comparison of these rates, we may correct the Tomkinson rates by assuming a two rate growth over the year (see Part 2.2). If we assume a rate of growth of 0.02 cm/day (the mean of 0.03 for the first dry season and 0.01 for the second dry season, see Part 2.3) during the dry season component then we can calculate that the rate 0.045, over 340 days, represents a rate of 0.043 over 365 days. We may take then the corrected Tomkinson annual rates as:

All animals:	0.043 ± 0.006	(n = 34)
Males:	0.044 ± 0.007	(n = 8)
Females:	0.043 ± 0.006	(n = 26)

The male rates are not significantly different between the Liverpool and the Tomkinson; the female rates are significantly different at almost the 1 percent level. From the equations in the growth paper (see caption of Table 3.1) we can calculate the mean rate of growth of animals from 1.5 to 2.5 years to compare with the directly calculated rates above: 0.043 (males) and 0.038 (females).

4.2 Growth from the Third to Fourth Year on the Liverpool-Tomkinson System

Examination of the capture-recapture records reveals 21 cases of animals that are likely to be going from their third year to their fourth year (mid-dry season to mid-dry season). Some are definite cases because they are triple captures; in a few cases the initial sizes may be a little large (the two largest animals we have included had SVLs of 58.8 cm and 60 cm). The mean SVL growth rates were:

All animals:	0.0316 ± 0.0072	(n = 21, range 0.018-0.047)
Males:	0.0337 ± 0.0049	(n = 5, range 0.026-0.038)
Females:	0.0309 ± 0.0078	(n = 16, range 0.018-0.047)

The time interval for these rates is 365 ± 25 days.

Six of the females on the Tomkinson included above are triple captures that we know are going definitely from their third to fourth year. The mean rate for these (over approximately 340 days) is 0.028 ± 0.010 (range 0.018-0.047). Thus the male growth rate is higher, but not significantly.

Unfortunately the numbers of animals which spent the year on one particular river are insufficient to allow any comparison of the Liverpool and Tomkinson growth rates. The equations from Webb et al. (1978) predict the following values for growth rates from 2.5 to 3.5 years: 0.033 (males) and 0.028 (females).

4.3 Two Year Growth Rates from First to Third Year on the Liverpool-Tomkinson System

By selecting from triple captures and 2 year spaced captures we can obtain a mean SVL rate of growth from the hatchling to the 3-4' (0.9-1.2 m) stage over a two year period from mid-dry season to mid-dry season. There are 19 such cases from the whole Liverpool-Tomkinson System, with the interval between recaptures varying between 675 and 740 days. The mean growth rates over the approximately two year interval are:

All animals:	0.044 ± 0.007	(n = 19, range 0.034-0.056)
Males:	0.046 ± 0.006	(n = 11, range 0.034-0.056)
Females:	0.042 ± 0.007	(n = 8, range 0.034-0.052)

These rates may be compared with those calculated using the equations of Webb et al. (1978), calculating from age 0.5 to 2.5 years: 0.049 cm/day for males and 0.044 cm/day for females. The rates predicted are in good agreement with the directly calculated rates. In Table 4.1 we give the individual records of growth of the 11 triple captures included in the above. It will be seen that the growth rate over the second year is on average only 60 percent of that over the first year.

From the 19 two-year spaced captures we can abstract some information on relative growths on the Liverpool and Tomkinson Rivers. The samples are very small unfortunately but the results are in support of earlier results indicating a higher growth rate on the Tomkinson. For male animals on the Liverpool, the mean growth rate was 0.0434 ± 0.0021 (n = 5, range 0.041-0.046). On the Tomkinson there were two males with a mean of 0.0528 (0.0499, 0.0557). For females on the Liverpool, the mean rate

Table 4.1. Capture histories of animals caught on the Liverpool-Tomkinson System in their first year and recaptured in their second and third years. The rates of SVL growth are also given (the intervals between captures vary between 337 and 371 days.

Number	Sex	Initial SVL	1st Year Rate	SVL	2nd Year Rate	Final SVL
15	M	25.4	0.047	42.4	0.022	50.7
30	M	25.0	0.059	46.0	0.027	56.1
94	M	23.0	0.062	44.5	0.031	55.9
95	F	21.0	0.054	40.0	0.017	46.2
98	F	24.0	0.043	39.0	0.034	51.6
103	M	22.5	0.053	41.0	0.032	53.0
184	M	23.0	0.059	43.2	0.042	57.7
232	F	20.0	0.053	38.2	0.042	52.7
270	M	22.0	0.061	42.9	0.039	56.3
349	F	29.0	0.056	48.1	0.038	60.9
351	M	21.5	0.070	45.1	0.042	59.1

was 0.0362 ± 0.0018 (n = 4, range 0.0343-0.0384). On the Tomkinson it was 0.0489 ± 0.0026 (n = 3, range 0.0473-0.0519). Interpretation of these differences is complicated by the fact that the Liverpool capture intervals ranged from 718 to 739 days, whereas the Tomkinson intervals ranged from 675 to 703 days. As we shall now show, even when this is compensated for, the strong indication is still that the growth rate is higher on the Tomkinson. We again use the simple model from Part 2.2. We take a two year growth, allowing 0.08 over the wet season and 0.02 over the dry season. Over 730 days (302 wet, 428 dry) this gives a mean rate of 0.045. Over 675 days, with 55 fewer dry season days, we get a rate of 0.047, so the shorter interval has little effect on the average.

4.4 Growth from Second to Fourth Year on the Liverpool-Tomkinson System

By selecting from triple captures and two year spaced captures we can obtain a mean SVL rate of growth from the 2-3' (0.6-0.9 m) stage on the Liverpool-Tomkinson System. The interval between captures varies from 666 days to 730 days with the majority of intervals being around 680 days. The mean growth rates are:

All animals:	0.0368 ± 0.0063	(n = 21, range 0.025-0.047)
Males:	0.0380 ± 0.0076	(n = 9, range 0.025-0.047)
Females:	0.0358 ± 0.0053	(n = 12, range 0.028-0.046)

Unfortunately the samples are too small to permit any conclusions about differences between Liverpool and Tomkinson growth rates, the majority of the animals being from the Tomkinson River.

In Table 4.2 we give the individual histories of the triple captures included in the above animals. The equations in Webb et al. (1978) give rates of 0.038 for males and 0.033 for females for growth from 1.5 to 3.5 years. The male-female differences are not significant, though as usual the male rate is higher.

4.5 Growth Rates of Animals up to 6' (1.8 m)--Liverpool-Tomkinson System

In Table 4.3 we present some interesting growth records for animals up to 6' (1.8 m) in length. The ages of most of these animals are uncertain to within a year. We shall now comment on some of these growth records.

Animal 37 exhibited a very high growth rate for a non-hatchling over a two year period, going from a total length of 1.0 m to 1.81 m over the period. Because of a toe abnormality noted on both captures there is no question that this is the same animal both times. Its mean growth rate over two years matches that of many hatchlings in their first year. This animal could conceivably have been 1.5 years old on first capture and so

Table 4.2. Capture histories of animals caught on the Liverpool-Tomkinson System in their second year and recaptured in their third and fourth years. The rates of SVL growth are also given (the intervals between captures average around 340 days, with 378 the longest interval and 335 the shortest).

Number	Sex	Initial SVL	1st Year Rate	SVL	2nd Year Rate	Final SVL
35	M	42.5	0.0431	58.8	0.0264	68.2
40	F	39.0	0.0368	52.1	0.0195	59.3
92	F	36.0	0.0429	51.0	0.0249	60.2
262	F	36.0	0.0436	50.9	0.0252	59.4
301	M	39.0	0.0376	52.0	0.0338	63.5
317	F	37.5	0.040	50.9	0.0251	59.5
318	F	36.0	0.0418	50.0	0.0240	58.2
321	F	36.5	0.0445	51.4	0.0466	67.4
322	F	31.0	0.0533	48.9	0.0297	59.0
355	F	36.5	0.0524	54.2	0.0184	60.4

Table 4.3. Growth records for animals up to 6' (1.8 m) in length on their final capture. All animals are from the Liverpool-Tomkinson System.

Number	Sex	Initial SVL	Final SVL	Rate	Period (days)
37	M	49.0	87.1	0.0518	736
110	F	52.0	77.5	0.0351	727
124	M	55.0	80.7	0.0365	704
165	M	64.0	77.4	0.0388	345
176	M	58.0	82.8	0.0345	696
177	M	56.0	81.3	0.0364	696
195	M	48.0	74.4	0.0380	695
291	M	46.5	78.6	0.0467	687
451	M	65.0	75.3	0.0300	343
517	M	72.5	82.1	0.0291	330

had reached 1.8 m (6') at age 3.5 years. Animal 291 exhibited a growth rate that is not much lower. The two males 451 and 517 exhibited a mean growth of 0.030 cm/day over what is probably their fourth year of growth (from age 3.5 to 4.5). Animals 124, 176, 177, and 195 had very similar mean growth rates of around 0.036 cm/day over a two year period, which possibly was from their third to fifth year on the river (age 2.5 to 4.5). So, at 4.5 years they have an SVL of 80 cm which is in agreement with the growth curve.

From Pooley's (1962) results we can calculate mean growth rates for penned C. niloticus over the second year. From his Table 5 we can calculate a mean growth rate of 0.038 cm/day over the second year (range 0.022-0.053). Again the growth is very comparable to C. porosus, with the mean growth being somewhat lower for C. niloticus. The mean rate over the two years from hatching is 0.040 cm/day.

Whitaker and Whitaker (1977) obtained for their penned animals, C. palustris, a mean rate of 0.066 cm/day (approximate range 0.045-0.090) over the second year, with the largest animal being 1.70 m in length at the end of its second year and the smallest 0.9 m. Average growth over the first two years of life was 0.070 cm/day. These are very high growth rates; recall that similar remarks applied to the comparison for first year growths (Part 3.5). Again, would C. porosus or C. niloticus under ideal conditions grow at such rates?

4.6 Blyth October 1980 Recaptures

In October 1980, 11 animals (7 males, 4 females) were recaptured of the original animals of 1978; the animals were very difficult to approach and they were all that could be caught in the time available. Summary histories of the animals are given in Table 4.4. Since all these animals had been captured in September 1978, we can calculate two year SVL growth rates. For all animals it is 0.032 ± 0.005 cm/day; for the males, 0.033 ± 0.004 cm/day and for the females, 0.029 ± 0.06 cm/day. The largest rate was 0.040 cm/day for a male and the lowest 0.022 cm/day for a female. These rates may be compared with those for animals for which we calculated two year growth rates in Section 4.3. The rates are less than those on the Liverpool-Tomkinson System. The male rates differ at the 0.01 percent level and the female rates at the 1 percent level.

Though the sample of animals on the Blyth-Cadell is much smaller than for the Liverpool-Tomkinson, it is interesting, by looking at individual examples, to compare the extremes of growth on the Liverpool-Tomkinson and Blyth-Cadell River Systems. The largest animals captured (numbers 1617 and 1817) on the Blyth-Cadell System in October 1980 had an SVL of 50 cm. With a month or so accuracy, their ages may be estimated at 32 months. Two very comparable animals from the Liverpool-Tomkinson System (1 male, 1 female) of similar age had SVLs of around 63 cm, and there are many examples of animals of the same age with SVLs between 57 and 60 cm. The smallest male captured (#1631) on the Blyth-Cadell System had an SVL

Table 4.4. Growth and movement histories of 11 hatchlings first captured in June or September 1978 and recaptured in October 1980, on the Blyth-Cadell Rivers System. Position shows the distance in km upstream at which the crocodile was captured on either the Blyth (B) or Cadell (C) River. Rates are cm/day.

	SVL	Position	Capture
1617 Male			
	23.1	24.9 B	June 78
	26.2	26.4 B	Sept 78
Change	3.1		93
Rate	0.033		
	26.2	26.4 B	Sept 78
	38.8	25.6 B	June 79
Change	12.6		264
Rate	0.048		
	38.8	25.6 B	June 79
	50.0	11.5 B	Oct 80
Change	11.2		481
Rate	0.023		
1626 Female			
	21.0	24.2 B	June 78
	25.2	24.2 B	Sept 78
Change	4.2		94
Rate	0.045		
	25.2	24.2 B	Sept 78
	41.5	20.3 C	Oct 80
Change	16.3		745
Rate	0.022		
1687 Male			
	20.0	31.7 B	June 78
	23.2	31.4 B	Sept 78
Change	3.2		94
Rate	0.034		
	23.2	31.4 B	Sept 78
	45.0	16.0 B	Oct 80
Change	21.8		743
Rate	0.029		
1758 Female			
	19.5	42.4 C	June 78
	21.7	42.1 C	Sept 78
Change	2.2		93
Rate	0.024		
	21.7	42.1 C	Sept 78
	39.0	42.0 C	June 79
Change	17.3		262
Rate	0.0066		
	39.0	42.0 C	June 79
	45.0	42.2 C	Oct 80
Change	6.0		479
Rate	0.012		

Table 4.4 (Continued)

	SVL	Position	Capture		SVL	Position	Capture
1631 Male				1773 Female			
	20.1	22.5 B	June 78		18.4	42.3 C	June 78
	21.2	23.0 B	Sept 78		20.3	42.2 C	Sept 78
Change	1.1		93	Change	1.9		93
Rate	0.012			Rate	0.020		
	21.2	23.0 B	Sept 78		20.3	42.2 C	Sept 78
	34.0	25.7 C	June 79		38.2	41.8C	June 79
Change	12.8		267	Change	17.9		262
Rate	0.048			Rate	0.068		
	34.0	25.7 C	June 79		38.2	41.8 C	June 79
	43.0	27.0 C	Oct 80		46.0	42.5 C	Oct 80
Change	9.0		479	Change	7.8		479
Rate	0.019			Rate	0.016		
1644 Male				1816 Male			
	17.4	44.5 B	June 78		17.1	31.9 C	Sept 78
	18.0	30.6 B	Sept 78		37.2	31.7 C	June 79
Change	0.6		95	Change	20.1		261
Rate	0.006			Rate	0.077		
	18.0	30.6 B	Sept 78		37.2	31.7 C	June 79
	37.0	31.0 B	June 79		43.0	31.0 C	Oct 80
Change	19.0		263	Change	5.8		480
Rate	0.072			Rate	0.012		

	37.0	31.0 B	June 79	1817 Male			
	48.0	21.3 C	Oct 80				
Change	11.0		481		26.5	31.2 C	Sept 78
Rate	0.023				41.5	31.0 C	June 79
					Change	15.0	
264							
1656 Male					Rate	0.057	
	18.7	36.1 B	June 78		41.5	31.0 C	June 79
	20.2	36.5 B	Sept 78		50.0	30.2 C	Oct 80
Change	1.5		94	Change	8.5		477
Rate	0.016			Rate	0.018		
	20.2	36.5 B	Sept 78	1818 Female			
	35.4	36.8 B	June 79				
Change	15.2		267		24.8	31.4 C	Sept 78
Rate	0.057				39.0	39.2 C	June 79
					Change	14.2	
263							
	35.4	36.8 B	June 79	Rate	0.054		
	46.0	10.5 B	Oct 80				
Change	10.6		477		39.0	39.2 C	June 79
Rate	0.022				45.0	31.5 C	Oct 80
					Change	6.0	
478							
					Rate	0.013	

of 43 cm and total length of 87 cm, so it has not reached the 3-4' category yet. This animal is at least 28 months old and may be compared with an animal from the 1974 Tomkinson Nest T14 which had the same SVL at some 13 months (both animals were hatched around June-July). Again we see that the growth rate, on average, appears to be greater on the Liverpool-Tomkinson System than on the Blyth-Cadell System and that, as we have already discussed, the confident attribution of an age to a given animal more than a year old is impossible, especially if the animals are from different systems. In October 1981 we managed to recapture one of the 1978 hatchlings, a female, and at the age of at least 42 months, its SVL was only 49 cm. Use of the growth curve (Fig. 3) in Webb et al. (1978) would give an SVL of 67 cm at 42 months. Some discussion of these animals recaptured on the Blyth-Cadell in October 1980 has already been given in Part 2.3.

PART 5: GROWTH OF LARGE ANIMALS

In October-November of 1980 and 1981 a number of animals caught originally between 1973 and 1976 on the Liverpool-Tomkinson Rivers System were recaptured, providing valuable information on the growth of C. porosus after the third year, i.e., for the ages where the data were very limited before. In Table 5.1 we give the capture histories of these animals and also the average rate of SVL growth between first and last capture. In Table 5.2 we give the size at the end of each year calculated using the growth curves in Webb et al. (1978). For large animals we have used the 65 cm maximum head length curve for males and the 51 cm maximum head length curves for females. We have also calculated the yearly growth rates.

It may be seen in Table 5.1 that for males, 0.025 cm/day seems to be about the average growth rate over the first seven or so years of life (Nos. 491, 382, 454, 1418, 1059). From Table 5.2 and assuming an initial SVL of 13.9 cm (see Part 3.4) we see that the growth curve of Webb et al. (1978) predicts, over the first seven years, an average SVL growth rate of 0.037 cm/day: a figure which is too high when compared with the specific examples. Both animals 491 and 454 are from the June 1974 Tomkinson nests and so are known to be 7.2 years old. Use of the growth curve for large males (the 65 cm case) would predict that their SVL should be around 110 cm which is much higher than these two examples and also than that of No. 382, about a year younger.

Animal 251 merits attention. Between its first two captures, about a year apart, its growth rate was 0.030 cm/day. Over the next six years, between the 1975 and the 1981 captures, it averaged 0.021 cm/day. According to the growth curve, an animal with an SVL of 65 cm should be some 3 years old, and so by October 1981 animal 251 should be some 10 years old, with an SVL of 126 cm (53 cm case) or 131 cm (65 cm) case instead of the 122.0 cm found. The 65 cm case also predicts, between the 4th and 10th year, an average growth rate of 0.024 cm/day, which is fairly close to the observed value of 0.021 cm/day.

Table 5.1. Capture histories of animals recaught on the Liverpool-Tomkinson Rivers System in October 1980 and October 1981. The rate shown is that between the initial and final captures.

Animal	Sex	Capture Date	SVL (cm)	Capture Date	SVL (cm)	Capture Date	SVL (cm)	Rate (cm/day)
491	M	17/ 8/74	15.5	26/ 7/75	38.3	23/10/81	82.0	0.025
251	M	16/ 8/74	65.0	25/ 7/75	75.3	13/10/81	122.0	0.022
382	M	29/ 6/74	18.4	21/ 5/75	38.8	1/11/80	86.0	0.029
438	F	2/ 8/74	22.4	1/11/80	77.4	-	-	0.024
454	M	16/ 8/74	18.9	24/ 7/75	39.6	6/10/81	90.9	0.028
1418	M	17/ 3/76	14.9	11/ 5/76	22.0	8/10/81	69.2	0.027
148	F	20/ 8/73	60.0	27/ 8/74	72.1	22/10/81	110.0	0.017
1059	M	23/ 7/75	20.5	8/10/81	77.5	-	-	0.025

Table 5.2. Growth of large crocodiles calculated using the equations of Table 1 of Webb et al. (1978). For males we have taken the 65 cm maximum head length case; for females the 51 cm case. The annual growth rate (SVL, cm/day) is also shown. See Table 3.1 for symbols.

Age (years)	HL (cm)	SVL (cm)	TL (cm)	TL (feet)	Growth Rate
Males					
4.0	23.1	78.5	162.2	5' 4"	
					0.028
5.0	26.0	88.8	183.3	6' 0"	
					0.026
6.0	28.7	98.4	203.0	6' 8"	
					0.0245
7.0	31.2	107.3	221.2	7' 3"	
					0.023
8.0	33.6	115.7	238.4	7'10"	
					0.021
9.0	35.8	123.4	254.2	8' 4"	
					0.020
10.0	37.8	130.6	269.0	8'10"	
					0.018
11.0	39.7	137.3	282.7	9' 3"	
Females					
4.0	21.1	71.6	147.3	4'10"	
					0.0215
5.0	23.4	79.5	163.2	5' 4"	
					0.020
6.0	25.4	86.8	177.9	5'10"	
					0.018
7.0	27.3	93.5	191.3	6' 3"	
					0.017
8.0	29.1	99.7	203.8	6' 8"	
					0.016
9.0	30.7	105.5	215.5	7' 1"	
					0.015
10.0	32.2	110.8	226.1	7' 5"	
					0.014
11.0	33.6	115.8	236.2	7' 9"	

The two females recaptured in 1980 and 1981 (Nos. 438 and 148) also deserve comment. Animal 438 had an SVL of 77.4 cm at an age of some 6.5 years, again somewhat less than that predicted by the growth curves. Animal 148 may be taken as approximately 2.5 years old on first capture (according to the growth curve) and so has an SVL of 110 cm at age approximately 10 years in good agreement with the 51 cm curve for females.

Animal 1418, one of Magnusson's 1976 hatchlings, at 5.5 years has an SVL of 69 cm, which by the growth curve should be the SVL of a three year old. However, as we have seen in Part 4.3, there are examples of animals that show growths up to their third year in line with that predicted by the growth curve.

Animals 176 and 177 (see Table 4.3), both males from the Liverpool, had SVLs of about 58 cm in July 1973 and about 83 cm in June 1975. It is easily within reason that these animals hatched in June 1971, and thus at the age of 48 months had SVLs slightly larger than that of No. 491 which was some 88 months old. (One wonders if possibly 1978-1981 was not such a good period for growth.) Since we are comparing the Blyth-Cadell and Liverpool-Tomkinson Systems for different years, it is possible the years on the Blyth-Cadell were bad ones for growth. However, the comparisons of the Liverpool and the Tomkinson in Parts 3 and 4 are over the same years and there are differences.

Some other individual growth records for larger animals over the period 1973-1976 may also be examined. One female (#359) changed from an SVL of 80.0 to 107.0 cm over a 22 month period, giving the high average rate of 0.040 cm/day. (Calculation from the head length change gives an SVL rate of 0.037 cm/day.) This is a very high rate for a large animal, especially a female. Another female (#1070) over a 460 day period grew from an SVL of 103 to 114 cm (0.024 cm/day); another (No. 401) grew from 107 to 114 cm over a year (0.019 cm/day). The growth of two large males (called A and B) has already been detailed in Webb et al. (1978). Another record of a large male is that of No. 365, which changed in SVL from 149 to 160 cm over a 282 day period, giving a rate of 0.039 cm/day (however calculation from the head length change gives an SVL rate of 0.027 cm/day and shows that care must be taken in interpreting SVLs derived from HLs, especially for big animals).

Worrell (1964) presented information about a large C. porosus kept in a zoo. The animal was approximately 2 m originally and for 6 years grew at an SVL rate of 0.040 cm/day (at apparently a uniform rate) and then slowed, averaging only 0.010 cm/day over the following 16 years. The latter growth rate is hard to interpret as the animal may have stopped growing at some stage. However the rate of 0.040 cm/day from approximately its fifth to eleventh year is high. The animal of course is in a state of captivity and is presumably always well fed; however, the figure indicates a possible rate of growth for a large animal, one that is larger than most of our observations in the wild. At age $\sim$ 27 years the animal was about 4.9 m in length. Animal 251 is 2.4 m, with an age of probably 10 years, in comparison with this captive animal which was 3.7 m at about 12 years.

Some information is available on growth of large specimens of another crocodilian species, C. niloticus. Stoneman (1969; Table 1) presented data for some penned, well-fed animals kept over a period of some 9 years. Measurements were made in 1965, 1966, and 1969, and for the animals initially over 1.7 m in length, the growth rate over 1966-1969 is down by a factor varying from 5 to 12 of that over 1965-1966. Average SVL growth rates over the four year period from 1965 to 1969 vary from 0.006 to 0.014 cm/day for these animals (rates obtained by halving total length rate). These rates may be compared with the 6 year growth of our specimen 251M (initially 1.5 m), averaging 0.021 cm/day, and it may also be noted that the reduction in growth rate over the year prior to the 6 year period is only 30 percent (from 0.030 to 0.021), differing considerably from the large drops noted above. The ages of Stoneman's specimens were uncertain, but they were known to lie between 9 and 12 years. The largest animal had a total length of 2.24 m, which may be compared with 2.44 m for animal 251, which had a minimum age of 9 years but could be 10 or 11 years old. Cott (1961) presented a number of measurements of C. niloticus of known age from zoos and had one animal at 2.34 m after 8 years (kept at Cairo under fairly natural conditions of climate and environment) and two at 1.85 m after 4.5 years. The growths of the zoo animals were generally similar to that of an animal observed under natural conditions over 22 years (Cott, 1961). The growth rate of C niloticus from Cott's data, over the first 7 years, averaged 0.035 cm/day, which is somewhat higher than that for C. porosus in our sample (Table 5.1). Again it is interesting to note that the wild specimen observed over 22 years exhibited roughly linear growth up to 7 years (at 0.036 cm/day) and then also very uniform growth at a rate of 0.005 cm/day over the next fifteen years. We see again, as with Stoneman's examples, a sharp drop in rate. The C. porosus specimen quoted by Worrell also showed this sharp decline in growth rate, but after the twelfth year. Our only really comparable animals for growth rate of large C. porosus were the cases A and B of Webb et al. (1978), one of which showed no appreciable growth over 3.3 years and another (B) which averaged 0.011 cm/day over 2.3 years (very similar to Worrell's rate over 16 years). This animal (of total length 4.0 m, 13 feet) was estimated as 20-24 years old.

In Webb et al. (1978), there was a discussion of typical maximum sizes reached by C. porosus on different rivers. For males, they estimated (from hunters' reports) 4.2-5.0 m and for females, 3.2-3.7 m (though some male specimens are known to exceed 6.0 m). Cott (1961), in discussing the maximum size of C. niloticus, quoted (also from shooters' reports) 4.0 to 4.6 m as the average for large crocodiles shot in an area in Central Africa, with specimens up to 6 m. In other areas animals up to 6.5 m have been taken. Webb and Messel (1978) reported a reliable measurement of a C. porosus specimen of at least 6.15 m, and less reliable reports gave lengths over 8 m. The typical maximum sizes

reached by C. niloticus and C. porosus do not appear to be all that different. From his data, Cott took it as evidence that the maximum size attained by C. niloticus differs widely according to locality, in agreement with the general opinion amongst hunters (quoted by Webb et al.(1978) that the typical maximum size of C. porosus males varies in different river systems and regions. This would fit in with our results for early growth, which appear to indicate differences between river systems. However in attempting to draw inferences about differences of growth of larger animals on different rivers, one must always remember that the animals can and do move between river systems.

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APPENDIX 1 ERRATA

There are a number of discrepancies in the tables given in Appendix 1 and Appendix 2 of Webb and Messel (1978).

The major error occurs with the results quoted for the Group IV animals, which are the largest animals, all males, and with snout-vent lengths greater than 126cm. Looking at Appendix 2 in the N column it is seen that the number of Group IV is sometimes given as between 231 and 237 and sometimes as between 9 and 11. The actual number of animals in Group IV is 11 (but not all can be used for each measurement). The coefficients given when N is between 231 and 237 are in fact those appropriate for Group IV + males in Group III. This error occurred due to a logical error in programming and also occurs in Appendix 1

The other major problem occurs for the group 41-126cm snout vent length. In Appendix 1, N is given as 416 for M+F, tail length 45-135. In Appendix 2, N is given as 426 for supposedly the same animals. The discrepancy is due to 10 animals of undetermined sex being included (correctly) in Appendix 2 but omitted (incorrectly) in Appendix 1.

A number of other values of N are correct by 2. In Appendix 2 what is given as the handwidth is actually the footwidth and vice-versa.

There are also some errors in the paper entitled "Movement and dispersal patterns of C. porosus in some rivers of Arnhem Land, northern Australia" by Webb and Messel (Aust. Wildl. Res., 1978, 5, 263-83). The movements shown for 40, 232 and 321 in Fig. 5 are incorrect. No. 40 hardly moved between the three captures but has been given a movement of 21.6km upstream. A paragraph (page 271) is devoted to this erroneous movement. No. 232 also does not move and is given a movement of 16.1km. No. 321 is shown as not moving at all over the three captures when fact it moved 17 km upstream between the second and third capture.

LANDSAT REMOTE SENSING IMAGERY AS A TOOL IN DEFINING THE ENVIRONMENT OF THE CHINESE ALLIGATOR, *Alligator sinensis* FAUVEL

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INTRODUCTION

Landsat Remote Sensing Imagery

The Landsat satellite series provides means of monitoring the Earth's surface from space (U.S. Geological Survey, 1977). The first satellite, initially named ERTS-1, but renamed Landsat-1, was launched in July 1972. Landsat 2 was launched in 1975, and Landsat 3 was launched in 1979. The most recent Landsat launch was that of Landsat 4 in the summer of 1982.

The satellites contain four multispectral scanners (MSS) that operate with one in the green, one in the red, and two in the near infrared portions of the electromagnetic spectrum. For Landsats 1, 2, and 3, these are referred to as bands 4, 5, and 7 respectively. Digital data can be reproduced in the form of single band black-and-white images, false-color composites (FCCs) (generally a combination of 3 bands), or computer-compatible tapes (CCTs). The MSS sensors have the resolution of approximately 0.45 hectares. The image is composed of individual picture elements, called pixels, which cover approximately 79-by-79 m of ground. Landsat frames provide extensive (34,000 km^2 per image), repetitive coverage of the Earth's surface at a uniform scale and in a uniform format.

Landsat data may be manipulated digitally prior to being reproduced in an image format. The raw data may be corrected for sun-angle differences and for atmospheric interference. The images may be enhanced by contrast stretching or filtering. In contrast stretching, the range of brightness values of the pixels is increased to spread over the entire available dynamic range of the film rather than the smaller range imaged by the sensor. In filtering, the brightness of the pixel is changed to a

different brightness value on the basis of its relationship to the surrounding pixels. Filtering may be used to smooth the data (low-pass filtering), amplify the detail (high-pass filtering), or emphasize pixels which differ from adjacent pixels (edge enhancement). Computer enhancement of images is expensive, and the individual user must decide if the increase in detail provided by the enhanced image is worth the expense.

Images may also be optically enhanced by optically filtering, stretching, and combining the four Landsat bands. Many of the resulting enhancements are less costly than digital enhancements and the results are similar to computer enhancement.

Images may be purchased as single band black-and-white images or as false color composites. Standard false color composites are produced by combining band 4 in blue light, band 5 in green light, and band 7 in red light. This image resembles an infrared photograph with vegetation represented in red. The spectral reflection of an object varies with wavelength. Hence, different bands of Landsat imagery emphasize different features of a scene. Water and the water/land contrast are best visualized in band 7. Siltation is best imaged in bands 4 and 5.

Use of Landsat Data to Map Alligator Habitat

Landsat satellites furnish excellent data for use in determining alligator habitat. Site visits give basic topographic information to a qualified researcher; however, use of Landsat images may help refine classifications. General information on the habitat of the Chinese alligator is contained in Watanabe and Huang (this volume). Site visits in Xuancheng County, Anhui Province, P.R.C., indicated three definite habitat types based on suitability for the Chinese alligator: (1) swamps and flood plains, formerly prime habitat but now devoid of alligators due to pesticide, herbicide, and industrial pollution, heavy silting, flooding, and, in the case of swamps, drainage of water for agricultural use; (2) heavily agricultural communes with dense human populations; and (3) tree farm communes with small reservoirs at elevations less than 100 m above sea level. A standard false color composite image may allow the observer to extend the classification developed for an area with ground information to regions not visited but which appear similar on the images. However, because seasonal or annual changes in vegetation and agricultural products sometimes are not apparent on Landsat images, this method may be misleading. Black-and-white Landsat transparencies may be projected with a color-additive viewer which allows variation in light intensities and different colored filters in order to enhance selected features on the image.

In order to emphasize silting of deeper bodies of water, the image may be projected with band 4 in blue light, band 5 in white light, and band 6 in green light. Terrain is emphasized with band 5 in white light and bands 6 and 7 in blue light. Water-land contrast is emphasized with band 4 in green light, band 5 in blue light, and band 7 in white light.

We wished to differentiate the higher altitude tree farm regions from other regions in order to learn how extensive this habitat type might be. One good color and light combination for this determination was band 4 and band 5 in blue light, band 6 in white light with low light intensity, and band 7 in red light. This is very striking but hard on the eyes. We, therefore, used band 5 in blue light, band 6 in green light, and band 7 in red light. This new color image emphasized striking topographic differences. For example, with these colors, the slightly higher elevation agricultural regions appeared whiter than sea level agricultural areas, flood plain regions took on a golden brown coloration, and foothills were light brown regions surrounding the bright yellow mountains. These colorations more clearly delineated the areas than the colors on the standard false color composite. This color selection allowed us to further subdivide the area into six distinct regions: (1) rivers and swamps; (2) urban areas (which may be seen on the image as dark smudges); (3) flat, sea-level agricultural areas, such as at Donghe Commune in Nanling County; (4) slightly higher elevation, drier agricultural areas such as at Hanting Commune in Xuancheng County; (5) foothill regions with small reservoirs; and (6) mountainous regions. Areas 1 and 2 are essentially devoid of alligators. The higher altitudes and lower temperatures of area 6 function as a barrier to the alligator.

During ground inspection, areas 3 and 5 appeared identical, and only on color-enhanced Landsat images were the differences apparent. Donghe Commune in area 3 supported a minimum of 22 alligators, while at Hanting Commune in area 4 only five animals were found. We were told by local residents that several years ago Hanting Commune had supported a sizable alligator population, and the alligator population at Donghe Commune had been much greater than at present. The communes are near each other and, on inspection, do not appear dissimilar. An unknown environmental factor may be responsible for the increased (and near total) extermination of alligators at Hanting Commune, but we must consider the higher, drier habitat type as a possible cause. Soil maps made with Landsat imagery (Yan et al., 1981) show differences in soil type between the two areas, to be expected in regions of different altitudes.

Examination of Landsat images from different years and seasons shows changes in land use patterns. Three large lakes several kilometers from Xuancheng appear to be good alligator habitat. In fact, large tracts on their western and southern shores are drained for agriculture and thus are inhospitable to denning alligators. Chen Bihui (pers. comm., 1981) claims that the southernmost lake, Nanyi Hu, once contained many alligators but is now reported to have none.

Landsat image analysis techniques that are more sophisticated than color additive viewing are available; however, for a study of this nature, the cost may be prohibitive. For example, Landsat computer compatible tapes now cost $650 each. Using a computerized enhancement technique on digitally enhanced imagery, the researcher can select pixels based on on-site inspection and imagery characteristics which have specific factors one wishes to enhance. For example, vegetation quality

in a specific area may be compared over several years. In an on-site area frame survey regions that appear similar on the Landsat imagery, such as all the regions that appear to be higher altitude tree farm/reservoir habitat types, may be randomly site visited (Paul and Mascarenhas, 1981). For the Chinese alligator, a study of this kind may yield sufficient information on the viability of the total population.

Landsat imagery itself is an invaluable tool to determine possible habitat for a rapidly decreasing population that has clear environmental requirements.

Landsat remote sensing data are available for purchase in either digital or image format from the EROS Data Center, Sioux Falls, South Dakota 57198. Price lists and forms for requesting data bank searches for acquisition of images of particular latitudinal and longitudinal areas are also available from EROS.

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IUCN/Species Survival Commission

The Species Survival Commission (SSC) is one of six volunteer commissions of IUCN - The World Conservation Union, a union of sovereign states, government agencies and non-governmental organizations. IUCN has three basic conservation objectives: to secure the conservation of nature, and especially biological diversity, as an essential foundation for the future; to ensure that where the earth's natural resources are used this is done in a wise, equitable and sustainable way; and to guide the development of human communities towards ways of life that are both of good quality and in enduring harmony with other components of the biosphere.

The SSC's mission is to conserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats. A volunteer network comprised of nearly 7,000 scientists, field researchers, government officials and conservation leaders from 188 countries, the SSC membership is an unmatched source of information about biological diversity and its conservation. As such, SSC members provide technical and scientific counsel for conservation projects throughout the world and serve as resources to governments, international conventions and conservation organizations.

IUCN/SSC also publishes an Action Plan series that assesses the conservation status of species and their habitats, and specifies conservation priorities. The series is one of the world's most authoritative sources of species conservation information available to nature resource managers, conservationists and government official around the world.

The Crocodile Specialist Group (CSG) is a worldwide network of biologists, wildlife managers, government officials, independent researchers, non-governmental organization representatives, farmers, traders, tanners, manufacturers and private companies actively involved in the conservation of crocodilians (Crocodiles, Alligators, Caimans and Gharials). The Group operates under the auspices of the Species Survival Commission of IUCN. The CSG provides a network of experts to assess conservation priorities, develop plans for research and conservation, conduct surveys, estimate populations, provide technical information and training, and to draft conservation programs and policy. CSG also assists monitoring international trade and identifying products. The CSG works closely with CITES to promote sustainable use and international trade that benefits the conservation of crocodilians. The Group is headed by its chairman, Professor Harry Messel, and maintains offices in Gainesville, FL USA. Working Meetings are held every two years.

Many of the Proceedings of these meetings are have been long out-of-print and are available again for the first time since they were published.

Species Survival Commission

The World Conservation Union