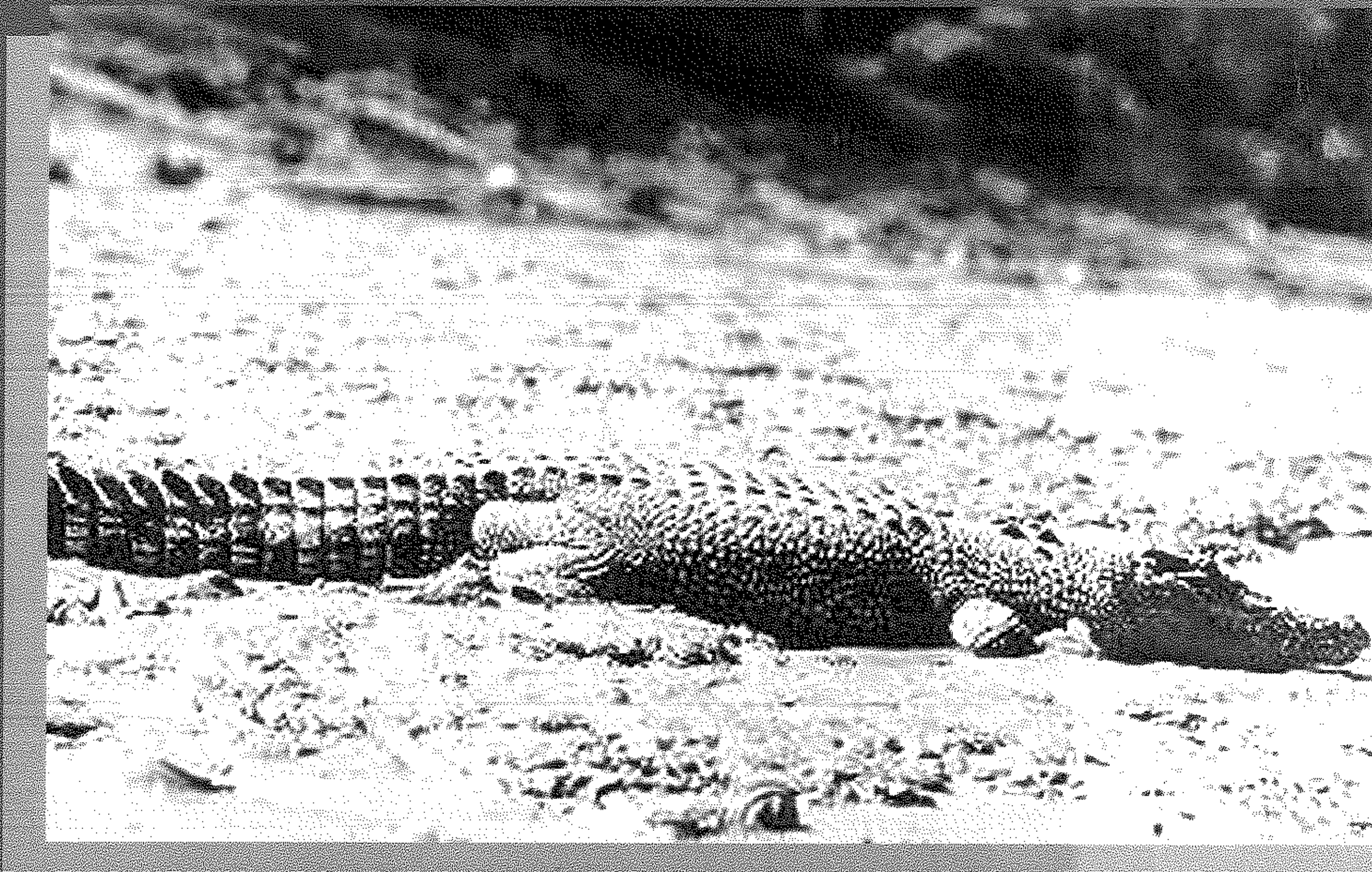
Crocodile Specialist Group, Species Survival Commission

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

6th Meeting 1982

**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
St Lucia Estuary, South Africa
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Species Survival Commission

CROCODILES

6th Meeting
1982

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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.

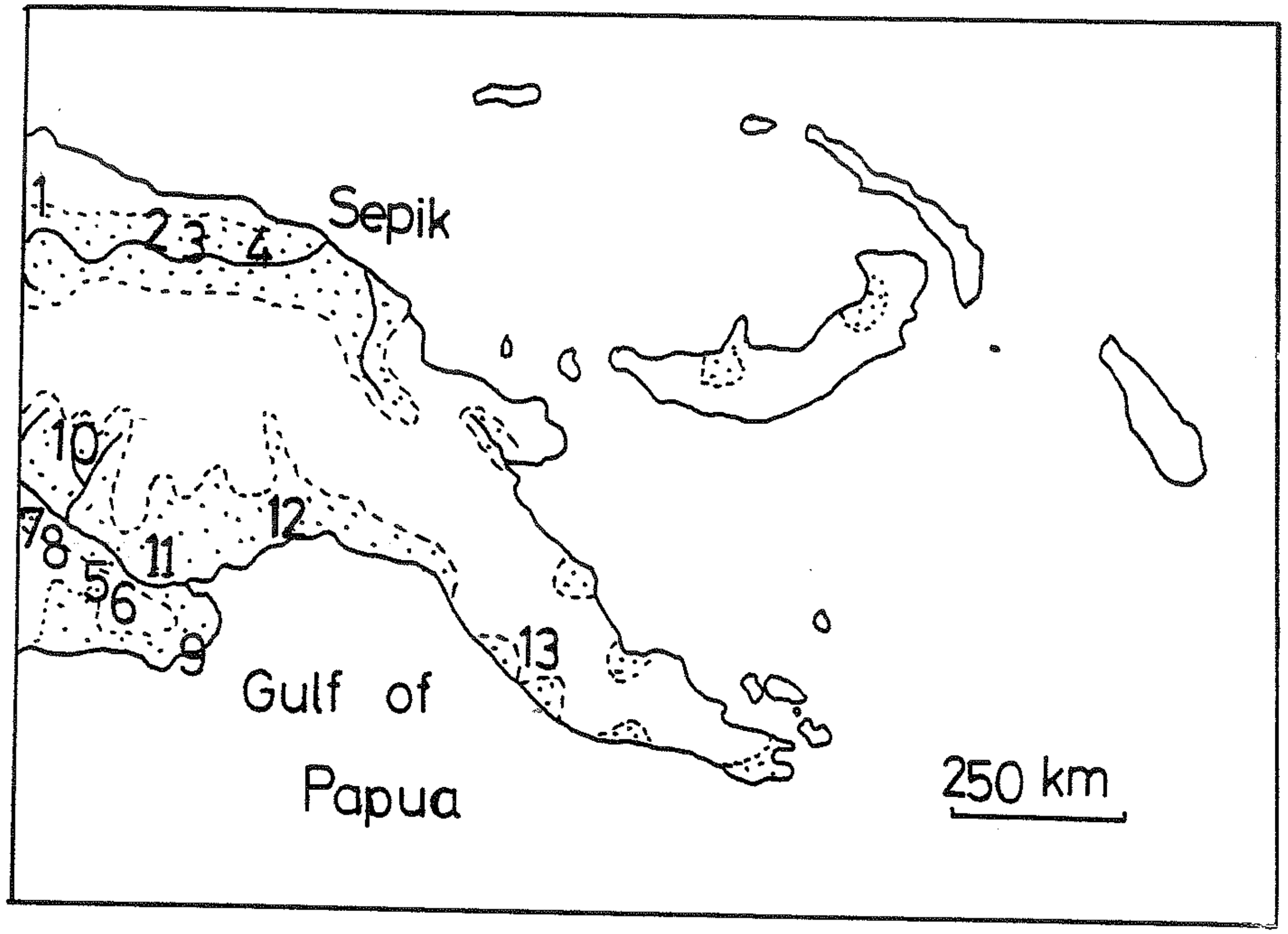
SUITABLE CROCODILE HABITAT

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

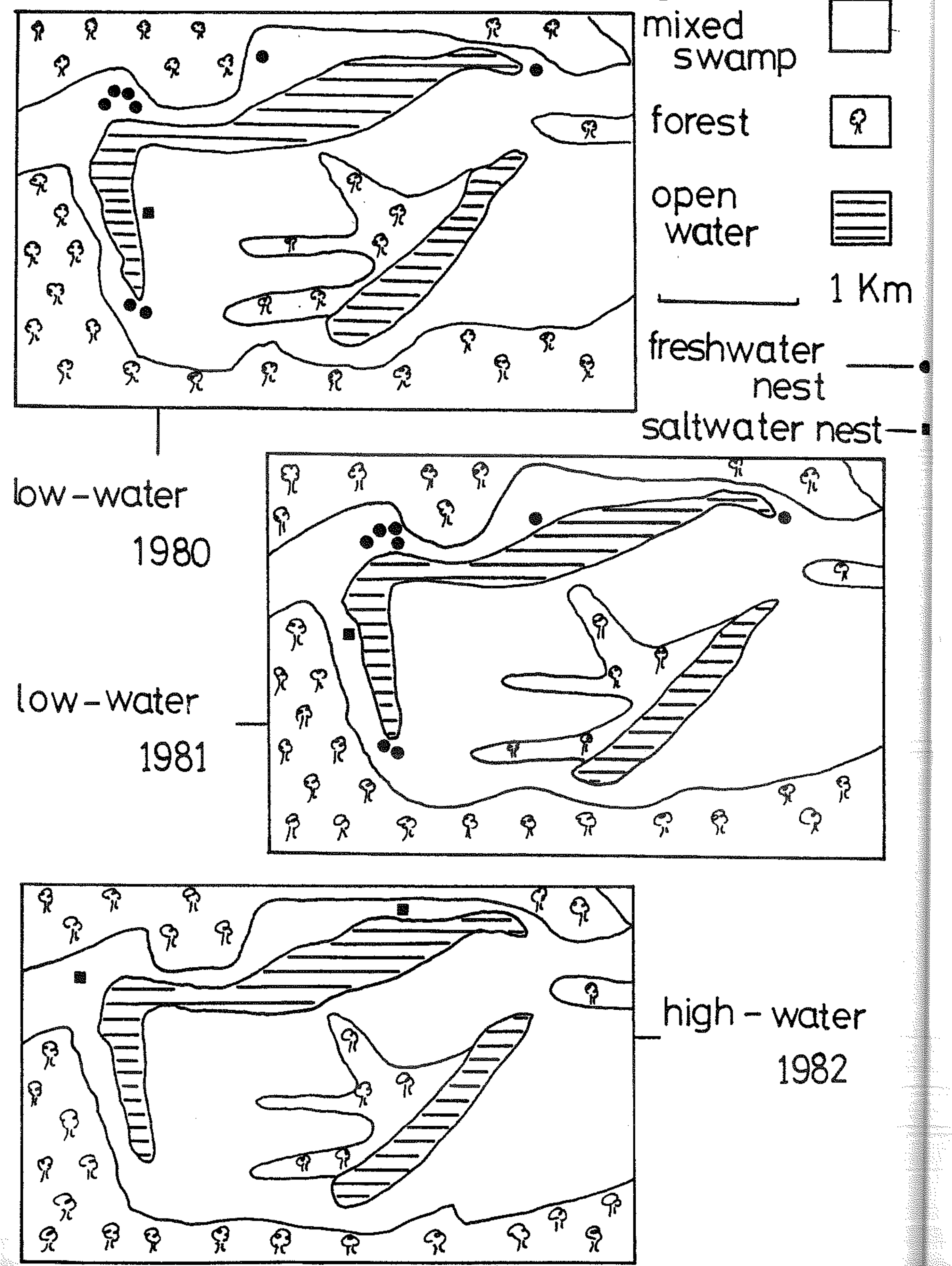


Fig 3

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

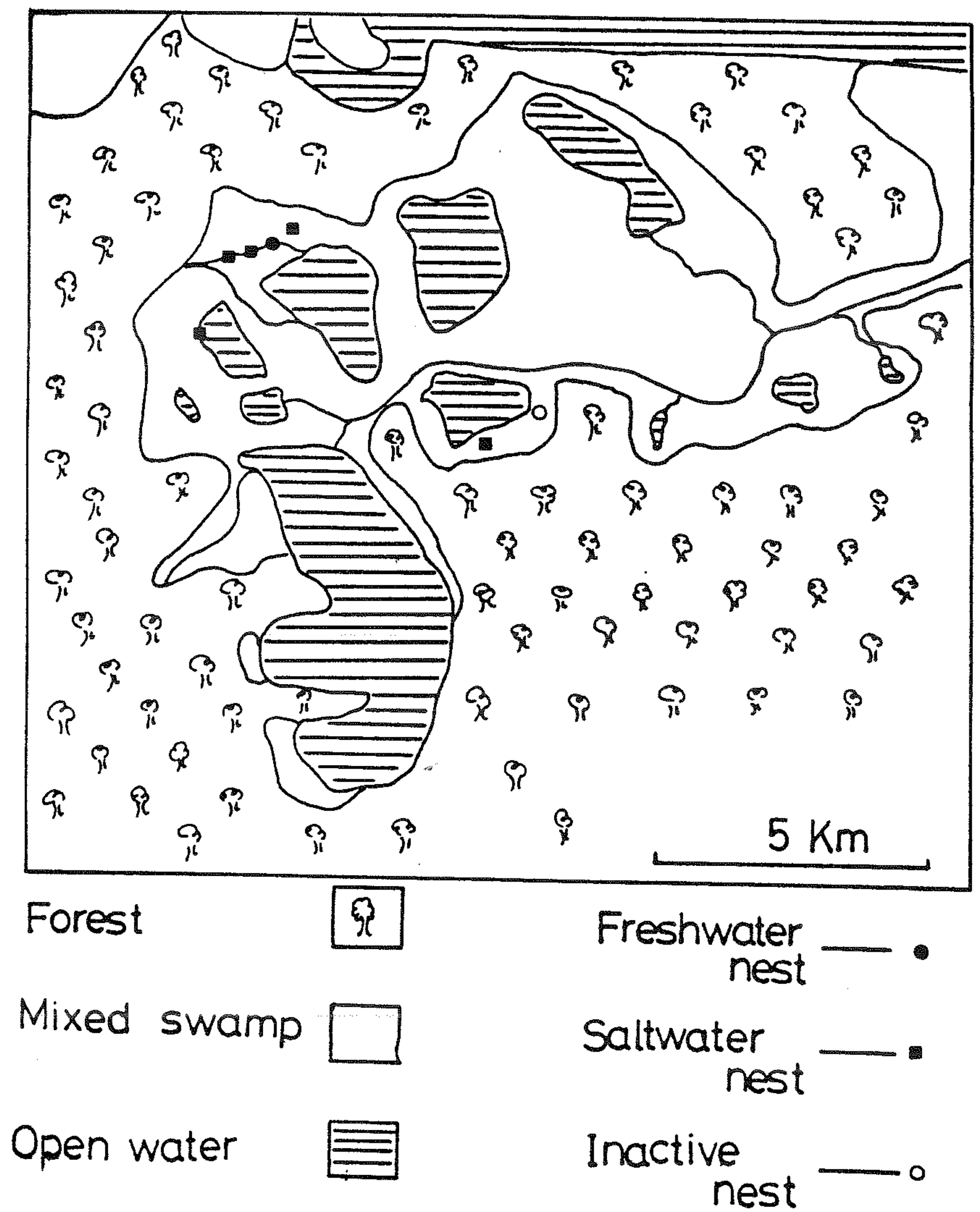
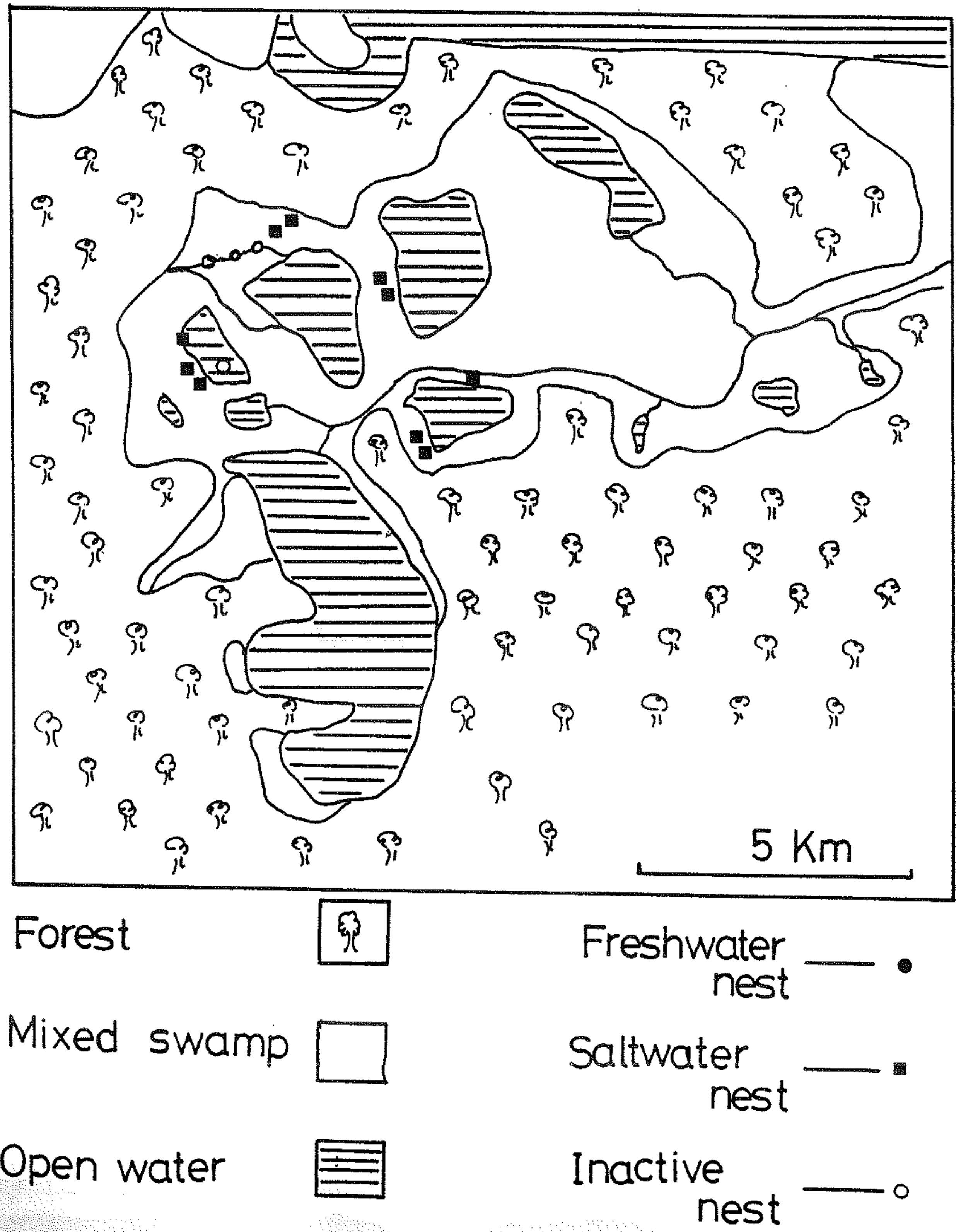


Fig 4

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.

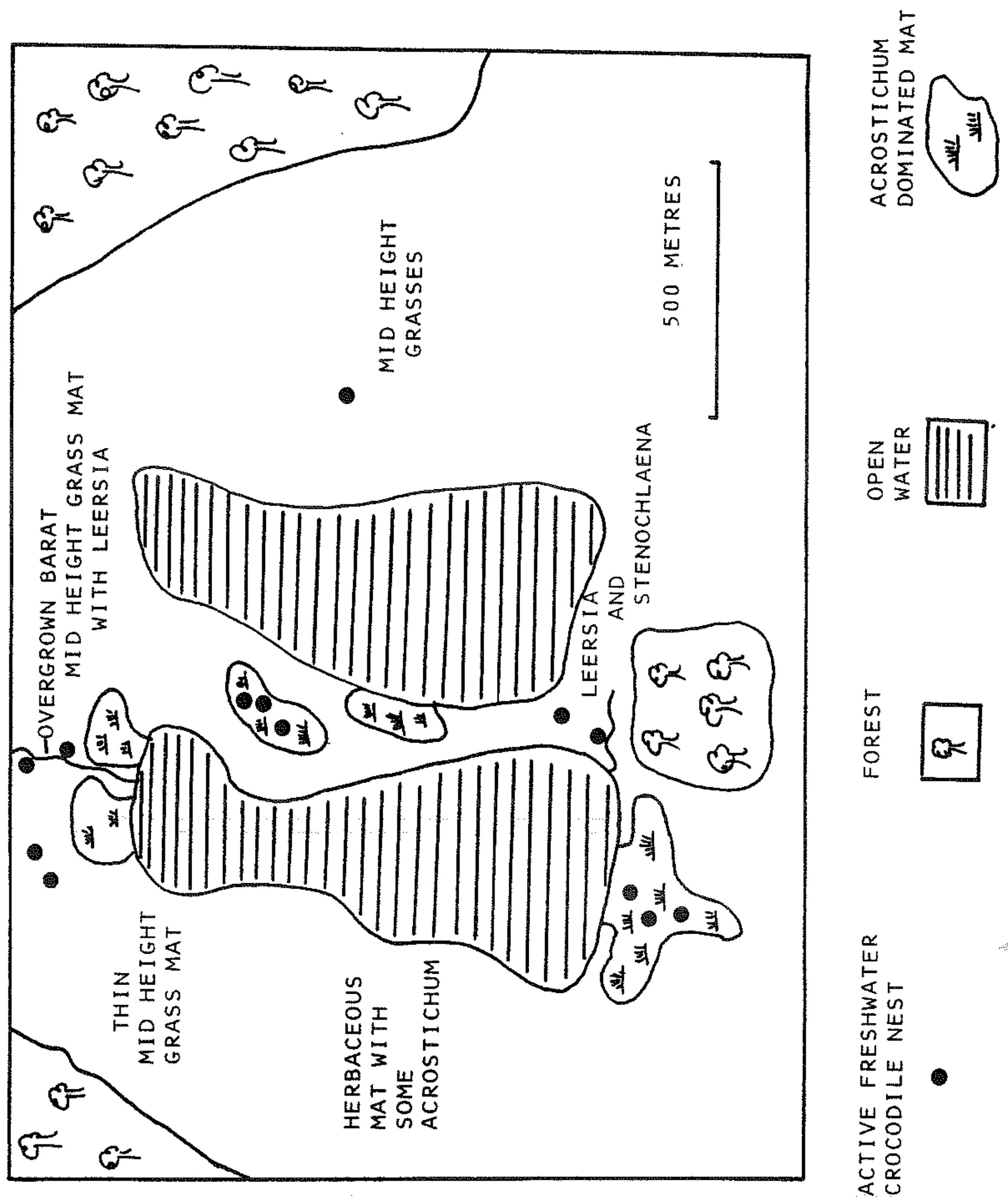


Fig 5

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

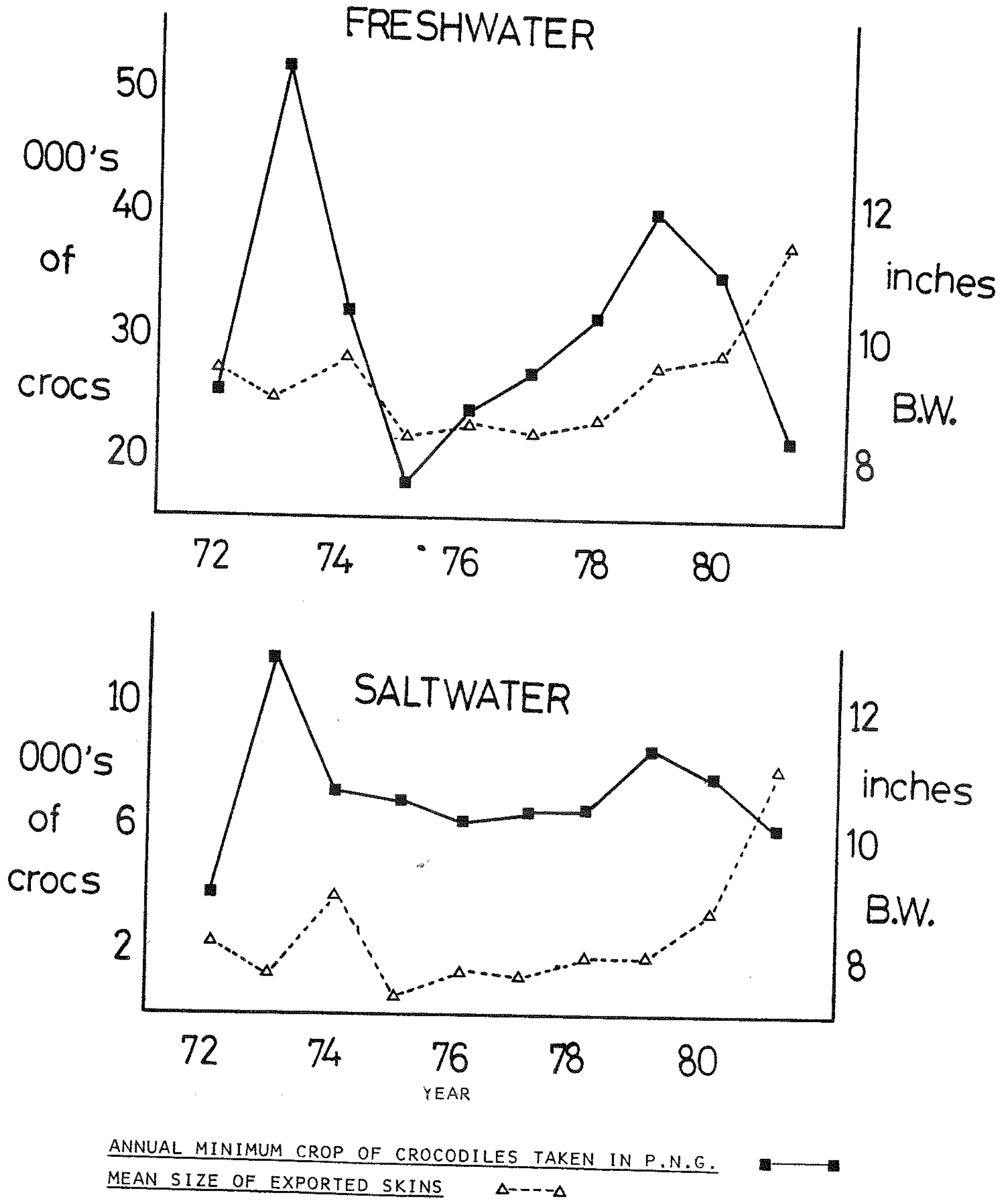
There are some areas in Gulf Province, particularly the mangrove swamps, where both aerial surveys and ground visits are extremely difficult. In these areas two pilot schemes are being conducted to monitor population changes by examining the catch of a selected group of hunters obtained over a known 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



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 <u>Salvinia</u> and barramundi fishing. The <u>Salvinia</u> 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

This paper would not have been possible without the work of all the staff, both government and UNDP/FAO, who have been involved with the crocodile project over the years. Particular thanks must go to the hard working Monitoring Field Staff: Jack Cox, Benny Guap, and Thomas Willie (Sepik), Phil Hall, Aviok Kawuk, and Kowokat Kurumop (Western Province), and Sawaku Kawi and Mavaira Ubuam (Gulf). Mark Rose (Papuan Regional Manager) also supplied valuable information on Gulf Province. Alistair Graham, Melvin Bolton, and Miro Laufa were all involved in establishing a monitoring program for Papua New Guinea. I would like to thank M. Bolton, J. Cox, M. Laufa, G. Malynicz, and M. Rose for critically reviewing the draft. Finally thanks to Caroline Jackson for typing the document for us at short notice, and Sue Hollands for preparing a number of the figures.

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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 ≥(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 (~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 (≥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.

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 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	

Systems	Total	H	2-3	3-4	4-5	5-6	6-7	≥7	EO	km surveyed	Density (crocs/km)	95% levels	TYPE
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	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	

(Size Class Numbers: H, 2-3, 3-4, 4-5, 5-6, 6-7, ≥7, EO)

*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