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C R O C O D I L E S

Proceedings of the 5th 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 the Florida State Museum

Gainesville, Florida, U.S.A.

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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) have 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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F O R E W O R D

This report on the work of the IUCN/SSC Crocodile Specialist Group is dedicated to H.W. Campbell and to S.J. Maness, both dedicated crocodile conservationists, valued colleagues, and contributors to this volume. Both have died since the 5th Working Meeting of the Crocodile Specialist Group was held in Gainesville, Florida, in August 1980.

H.W. Campbell was Senior Zoologist at the Gainesville, Florida, U.S.A. field station of the National Fish and Wildlife Laboratory, U.S. Fish and Wildlife Service. Although his duties involved him in a variety of wildlife studies ranging from Sirenia to phosphate mining to crocodiles, it was on the latter species that Duke focused much of his personal attention during the last decade. He served as chairman of the federal/ state Recovery Team for the American crocodile populations in the United States, but his interests reached far beyond North America. The U.S. Fish and Wildlife Service involved Duke in international projects in Latin America and the Caribbean, in Australia and Papua New Guinea, and in southern Asia. He quickly won friends in each of these places. He clearly understood the diplomacy needed to achieve conservation and usually waa able to find a middle course between uncontrolled exploitation and total prohibition, a course that conserved the wild resource while permitting its sustained utilization. Duke first became a member of the IUCN/SSC Crocodile Specialist Group in 1974, and served as its Chairman from 1979 until his death from cancer on 10 December 1981.

Scott Maness was a Biological Technician on the staff of the Merritt Island National Wildlife Refuge of the U.S. Fish and Wildlife Service, in Florida, U.S.A. Scott served as a U.S. Peace Corps volunteer in Venezuela from 1973 through 1976, and it was there that he first became involved with conservation of Orinoco and American crocodiles and the various caimans in northern South America. His enthusiasm won him the support of many governmental agencies and non-governmental organizations in the continuing fight to prevent the loss of these reptiles. Scott briefly joined the research staff of the National Zoological Park, Smithsonian Institution, Washington, D.C., and returned to Venezuela in 1977 to continue his studies on the crocodilians of that nation. Scott died on 8 June 1981 from burns suffered fighting a wildfire on the Merritt Island National Wildlife Refuge.

This issue of the Proceedings records our sense of loss at the passing of these two colleagues.

F. Wayne King
Chairman

IUCN/SSC Crocodile Specialist Group

INTRODUCTION

The 5th Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of the International Union for Conservation of Nature and Natural Resources was convened from 12 to 16 August 1980 at the Florida State Museum, Gainesville, Florida, U.S.A. The sessions were open to anyone involved in crocodilian conservation.

During the four day meeting, a total of 38 papers were presented by Group members and other participanta. Several of the papers were never submitted for publication and a few had to be dropped, even so the 26 papers contained in this volume are so long that it was not possible to include the usual summary of the meeting and the 1980 list of priority projects for crocodilian conservation.

David Dietz and F. Wayne King were scientific editors for the volume; Rhoda J. Bryant was managing editor.

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INVESTIGATIONS INTO THE STATUS OF MORELET'S CROCODILE (*CROCODYLUS MORELETII*) IN BELIZE, 1980.

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ABSTRACT: In this paper we present a report of our investigations into the status of Morelet's Crocodile (*Crocodylus moreletii*) in Belize, Central America. The research was carried out in May and June 1980 under the sponsorship of the World Wildlife fund. Assistance was also received from the Fauna Preservation Society (London), as well as from numerous private individuals in Belize, especially Bader Hassan and Mary Ann Boggess (Orange Walk Town).

The report is divided into three sections. The first deals with crocodile populations *per se*, the second discusses the dynamics of Belizean crocodile exploitation, and the third lists our recommendations for the conservation of *C. moreletii*. There is also an appendix.

INTRODUCTION

General impressions.-- Over the past three years we have observed crocodiles at 17 different locations in Belize. We believe that their distribution is country-wide, and we have seen them in a variety of habitats ranging from brackish mangrove lagoons to swiftly flowing mountain streams. Morelet's crocodiles are difficult to find near areas of human settlement and large animals (2 m) have become very scarce in all but the most remote parts of Belize. On the other hand, individuals between 0.5 and 1.5 m are reasonably common (in densities ranging from 2 to 10 animals/km of shoreline) in shallow freshwater lagoons with even partial protection from human exploitation.

Areas examined.-- On previous trips to Belize (summers of 1978 and 1979) we visited four locations of reasonable crocodile abundance which we wished to examine once more. These were Laguna Seca, Rio Bravo, Cox Lagoon, and some swampy ponds near Kate's Lagoon (for approximate locations, see Fig. 1). There were, in addition, several new areas which local informants had suggested we check. Finally, personnel in the Belizean Forest Office had requested that, if possible, we survey a portion of the upper Macal River which an FAO report had suggested as one possible site for a crocodile refuge.

STUDY AREAS

Laguna Seca (Location 1).-- This is a large, shallow lagoon in the western interior of Belize. As the name indicates, a considerable part of the lagoon may dry into flat savanna; during the wet season, however, a large area (approximately 3.5 km^2 with perhaps 15 km of shoreline) floods completely, and even during some "dry" seasons, the greater part of the lagoon may remain under water. Although crocodiles in Laguna Seca have been hunted occasionally for years, they have long been protected from frequent exploitation by the remoteness of the lagoon. In the summers of 1978 and 1979 we were able to survey only a small portion of the lagoon, in which, nevertheless, we saw 14 and 9 animals in the respectivly. In 1980 we examined a much larger area and saw only three animals. This apparent scarcity may be attributed in part to the greater flooding of the lagoon (and consequent dispersal of its crocodiles). However, we believe it is largely due to greatly increased hunting pressure. During our stay at this lagoon, we saw numerous hunters, and we also found the remains of four recently killed crocodiles. The rapid improvement of road access to Laguna Seca was also very much in evidence. On our way in we forded the Rio Bravo; on our way out we were able to cross a brand-new bridge. While a few crocodiles will survive here for quite some time, we do not believe Laguna Seca will long maintain a really important population of *C. moreletii*.

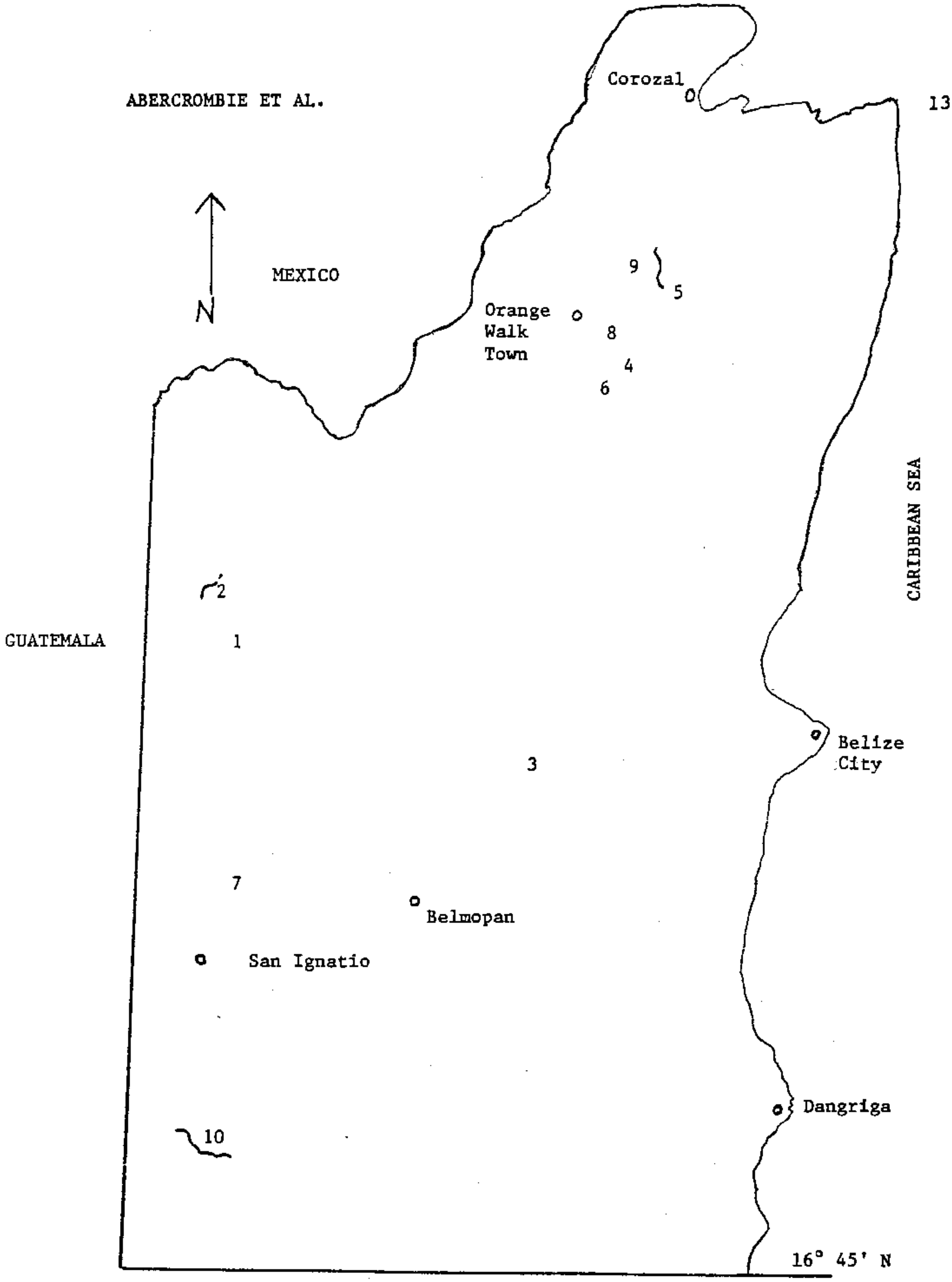


Figure 1. Southern Limit of 1980 Investigations.

Rio Bravo (Location 2).-- Again, this is a location we examined during three successive summers. In 1980 improved road access allowed us to survey a larger portion of the river (ca. 3 km) than before, and again we found crocodiles less in evidence--presumably due to hunting. We do not, however, expect the crocodile populations of Rio Bravo to suffer so much as those of Laguna Seca. First, the Morelet's crocodile populations in rivers are obviously less dense than those of lagoons, and river hunting is consequently less rewarding economically. Second, the Rio Bravo is frequently broken with stretches of long, shallow rapids. Combined with the great weight of native boats, such rapids render crocodile hunting on the Bravo quite difficult. We expect that all animals on river stretches with road or trail access will be extirpated; others will probably survive. The question we cannot presently answer is how many new roads and trails will reach Rio Bravo.

Cox Lagoon (Location 3).-- This is a long, narrow lagoon (0.6 km^2 in area with approximately 8 km of shoreline) about 50 km west of Belize City. We surveyed this lagoon in the summers of 1978, 1979, and 1980, and observed 27, 60, and 38 crocodiles respectively. Most of these animals are in the 0.5-1.5 m size range, but we saw at least three adult individuals in the summer of 1980. We believe Cox Lagoon is seldom exploited; indeed, although local hunters consider it something of a promised land, they realize the lagoon is property of Big Falls Ranch (a rice-producing farm) and generally respect the "posted" signs (see Recommendations).

Kate's Lagoon swamps (Location 4).-- Kate's Lagoon itself is a large, very shallow body of water about 20 km south of Orange Walk Town. It is a pleasant place, with cow pastures and large shade trees along its eastern border, and large numbers of Belizeans swim in it and picnic along its banks. As one would expect, the lagoon is not running over with crocodiles; the locals, in fact, have told us it harbors none at all. In the swamps extending roughly from the western part of the lagoon (Location 6), there are a number of small ponds, very shallow and heavily choked with sawgrass. We surveyed this area in 1979 and 1980. Our first visit disclosed approximately a dozen crocodiles (the labyrinthine nature of the swampy area makes is extremely difficult to know how many times one may be counting the same individual), and a similar number were found in 1980. We know this location is frequently hunted, but cover is so heavy and so well placed that it will be very difficult to extirpate its populations entirely. Indeed, we have even seen large adult animals in this area.

In addition to these old, familiar areas, in the summer of 1980 we also examined six new locations, including two lagoons, two small, swampy ponds, and two river sections. We found at least a few crocodiles in all these sites. In the two swampy ponds (Locations 5 and 6) we found one and two animals respectively. The two lagoons (Aquacate Lagoon, Location 7, and Kate's Lagoon, Location 4) had easy human access, and we could discover only one Morelet's in each. The two rivers, on the other hand, deserve more extensive comment. The first (Location 9) is an approximately 5.5 km section of Freshwater Creek. The stream itself is broad and swampy, almost devoid of current. The northern and southern ends of the section we paddled are closed by mangrove swamps. On this section we observed 26 animals, all in the 0.5-1.5 m size range. The area "enjoys" easy human access, and local informants indicated that it is hunted rather frequently. We confirmed this by finding the partial skeleton of a Morelet's crocodile; extrapolation from skull size indicated it was a juvenile of about 0.75 m long. (The taking of so small an animal clearly suggests extremely heavy hunting pressure.) Furthermore, we saw no adult crocodiles, though one informant suspected at least two might still inhabit the area. We believe it unlikely that significant crocodile populations will long survive on such stretches of river unless action is taken to ensure their conservation.

Macal River (Location 10). As indicated above, a report by the United Nations' FAO suggested that the upper reaches of the Macal River might provide an appropriate area for the establishment of a crocodile refuge. In the summer of 1980, we talked with personnel in the Belizean Forest Office (see The Crocodile Hide Business in Belize) who indicated some interest in this project, but who said they first needed some survey data on how many crocodiles the area might actually contain. And indeed some difficulties do attend any survey of the upper Macal. The only available access is at the Guacamallo Bridge (ca. 14 km south of Augustine), and in that vicinity there are a number of significant rapids. We spent five nights in the Guacamallo area, and we managed to explore just over 13 km of the river (approximately 5 km were covered twice). Our technique involved scouting a river section in daylight and then surveying it for crocodiles after nightfall. By this method, a total of 11 animals was observed, and while this may sound like a rather small number, two considerations should be held in mind. First, nine of the animals were adults, and one was very large (approximately 3 m); nowhere else in Belize have we seen so great a density of breeding-size Morelet's. Second, while night survey is an effective method of counting crocodiles, there are two reasons we believe it may seriously underestimate the number of animals on the Macal. To begin with, crocodiles there may reverse the typical Belizean pattern of diurnal secrecy and nocturnal activity. Hunting pressures are minimal, and while daytime temperatures are quite pleasant (about 27° C), the nights in those mountains can be rather cool (about 22° C). We observed three adults in broad daylight (it seems probable that we missed seeing others); we were not always able to locate these same animals after dark. More important, in our night surveys we were able to search effectively only the broad, flat stretches of the river. On the other hand, over half of the crocodiles we saw were near or actually in the poorly searched rapids zones. Although the demands of nighttime white water work precluded extensive observations, we did notice that some of the animals appeared to be searching for food. Specifically, one crocodile (ca. 2 m in length) was located immediately below a long series of rapids. Its head was oriented upstream, and, taking no notice of us, it made repeated sideswipes of its snout into the churning water that flanked the eddy in which it lay. A second animal, slightly smaller, was seen working upstream in the midst of an approximately 10 m stretch of rapids. We agreed that this animal made use of eddies and cross-currents to aid its upstream progress, but we also noticed that it frequently stopped and probed around with its snout. We have noted similar probing behavior (though not in rapid water) among feeding alligators.

We do not know whether the above behavior is a common feeding strategy of *C. moreletii*, and indeed we did not actually see any of the animals catch and eat any prey. In this connection, we hope to make more extended observations in the summer of 1982. Our point for the present, however, is that we quite possibly missed seeing a number of crocodiles in the rapids, and if so, our observations would underestimate the density of crocodiles in the Macal River.

PART I: THE CROCODILE POPULATION OF BELIZE

We attempted to estimate very roughly the total number of crocodiles in the northern half (north of 16° 45' N lat.) of Belize for 31 May 1980 (a time shortly before the emergence of any 1980 hatchlings). We derived our estimates by two independent methods. Both are rather complex and we have therefore relegated the details to a methodological appendix.

Estimate 1.-- We have night survey data on density of crocodiles per unit of certain habitat types. By looking at 1/50,000 topographic maps, we count units of various habitats and estimate 2500 crocs age 9 months.

Estimate 2.-- We have rough data on hide exports for three years. Assuming that hunting effort is constant from year to year and that a constant proportion of the crocodile population is taken per unit effort, we estimate 2200 crocs age 9 months. (We believe that both of the above methods underestimate the total croc population: the first method counts animals observed as total density per unit of habitat; the second method is subject to more complex biases listed in the appendix.)

CONFORMATION AND SIZE OF MORELET'S CROCODILES

Table 1 supplies size data on 17 crocodiles we captured, marked, and released. In conformation, all these animals were quite similar; their color, however, varied noticeably from the black and yellow pattern characteristic of *C. moreletii* to a dull greenish-gray more nearly typical of *C. acutus*. These color differences appeared to be correlated with neither size nor location. Indeed, we have found animals of both color extremes within 100 m of each other.

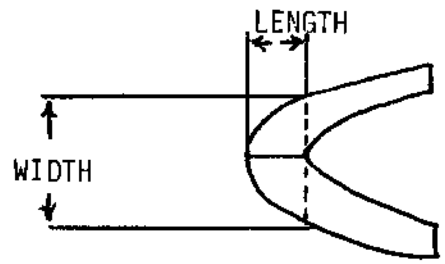
On several occasions we have been asked to estimate the probable lengths of crocodiles from skulls in various collections. For this purpose we have derived a least-squares formula from the data on our crocodiles. If X is taken to represent the length (in mm, from the

TABLE 1. Characteristics of animals captured

ANIMAL NUMBER	TOTAL LENGTH	S-V LENGTH	HEAD LENGTH	HEAD WIDTH	HEAD DEPTH	SNOUT LENGTH	SYMPH. LENGTH	SYMPH. WIDTH	X-8ANDS 8ODY	X-BANDS TAIL	1-CREST WHORLS	2-CREST WHORLS
1	1759	902	273	129	105	174	43	54	?	?	18	16
2	1651	845	232	139	95	152	41	57	4	11	17	17
3	1001	517	150	62	50	93	19	30	?	1D	19	18
4	749	362	111	52	41	66	16	24	5	9	21	17
5	610	286	91	35	30	57	17	19	5	10	20	18
6	590	270	90	33	28	53	14	19	?	8	21	18
7	560	260	87	29	27	51	13	17	6	10	22	17
8	521	253	B1	28	26	46	10	14	5	10	19	18
9	505	241	78	35	24	44	12	16	4	?	22	17
10	489	229	73	27	24	43	15	16	4	9	20	18
11	480	225	80	28	24	45	11	15	?	?	22	17
12	473	235	73	32	26	40	9	15	4	10	21	17
13	466	219	69	31	24	38	10	13	5	10	22	17
14	400	203	7D	32	22	38	13	13	4	9	21	18
15	351	165	60	22	17	32	11	13	?	10	21	17
16	347	165	61	21	19	29	8	11	5	11	20	17
17	541*	265	84	31	27	5D	13	16	?	9	16*	18

* No tail tip

NOTES ON THE TABLE: (A) All sizes are in mm. (B) Snout-vent length runs to anterior margin of vent. (C) Head width is width at the eyes. (D) Head depth is depth immediately posterior to eyes. (E) Snout length is length to anterior margin of eyes. (F) Number of crossbands was not always clear; attempts were made to give a number where possible, even with some guessing. On animals for which it was impossible even to guess, we have indicated "?". (G) Mandibular symphysis lengths and widths were measured as shown in the at right.



Partial diagram of mandibles, ventral view.

anterior of the premaxilla to the posterior of the parietal) of an animal's head and Y represents the estimated total length (mm) of the animal, then the total length is best estimated by the formula

$$Y = -39.8 + 6.89X.$$

The correlation coefficient associated with this equation is, for our sample, $r = 0.996$. It must be remembered that all our data were taken from animals less than 2 m long. Therefore, anyone using the above formula to estimate animal lengths from the size of especially large skulls should carefully note the usual caveats against projecting linear relationships beyond the range of available data. This question of size may be particularly relevant to the problem of protecting Morelet's crocodile. It has somehow entered the literature (*viz.* Schmidt and Inger 1957) that *C. moreletii* is a small crocodile. Therefore, it might erroneously be thought that a policy protecting, say, all crocodiles under 1220 mm would preserve at least a small number of breeding-size animals. (Incidentally, several years ago the Belizean government apparently considered just such a conservation measure--assuming that *C. moreletii* gained sexual maturity "at something less than four feet.") We are convinced, however, that such would not be the case, for *C. moreletii* appears to us to be a rather large beast. Only at about 1750 mm do these Belizean animals begin to attain the heavy girth usually characteristic of breeding-size crocodilians. We have seen animals in the field whose length we estimated at 3 m. We have also examined a skull that we believe came from a crocodile over 2700 mm long. Furthermore the Atlanta (Georgia) Zoo currently maintains a male *C. moreletii* approximately 3 m long, plus 7 other adults averaging 2.25 m.

PART II: THE CROCODILE-HIDE BUSINESS IN BELIZE

In gathering the information contained in this part of our report, we talked with hunters and hide dealers in areas surrounding the towns of San Ignatio, Orange Walk, and Dangriga, with officials of the Forestry Office in Belmopan, and with Audubon Society members in Belize City. We had prior contacts in some of the locations. These contacts were approached first when possible; they provided us with an up-to-date assessment of the situation and often led us to other knowledgeable people. In places where we had not established prior contacts, we asked people we encountered on the road or in other public places for information about "alligators" (the local terminology) and/or those who hunted them. This "snowball sampling" technique usually worked quite well in directing us to informants.

We wished to learn about (1) the social characteristics of those who hunt crocodiles and those who deal in hides and (2) the economic stake each group has in crocodile exploitation. We were also interested in the perceptions of each group regarding the current status of crocodiles in the wild and the desirability of protecting them. Finally, we wanted to examine the relevant laws and possibilities for change.

Hunters

Crocodiles are hunted at night, mostly during the dry season (approximately January-June). They are sought in Belize solely for their hides, although we received several reports that the Guatemalans enjoy eating the tail. There seem to be two basic types of hunter. The "master hunter" spends most of his time during the dry season hunting and fishing. This person is an expert hunter and woodsman. He knows the area and the animals he hunts very well. He often goes out for days or even weeks at a time to very remote areas. On a "successful" trip, he may kill as many as 25 or 30 crocodiles. Although some of these hunters seem to know more about crocodiles than others, they are not known specifically as "crocodile (or 'alligator') hunters," for they also hunt other commercially valuable species (jaguar, ocelot) as well as "food" species (deer, gibnut, turtle, peccary, etc.). These hunters have another occupation (usually farming or some craft) which they practice during the wet season when the usual hunting places are inaccessible. It was our impression that most of the men who match this description are of the older generation. Several of the "master hunters" have retired because of poor health and old age; those still active are in their late fifties and early sixties. Although these men have sometimes passed their skills on to their sons and nephews, members of the younger generaton are less committed to hunting as a way of life and are generally less skilled.

The other type of hunter can be characterized roughly as "part-time." These men continue to work at another job during the dry season and go hunting after work, on holidays, or when their work takes them into wild areas (as in the case of the chicle workers). Like the master hunters, they hunt animals of all types; however, the part-time hunters typically stick to areas close to home (within easy walking or bicycling distance) or to areas easily accessible by road. This type of hunter is much more common than the first type and may include, at one time or another, most of the adult male population of rural Belize. A hunter of this type probably gets a crocodile or two every couple of years.

In addition, people who do not ordinarily hunt are likely to kill any crocodile that ventures near their homes, fields, or ponds. Crocodiles are feared by most people in Belize (although a few Belizeans keep them as pets) and will be shot on sight. A Good Friday incident in which a man was allegedly killed and eaten by a crocodile in a roadside pond near Orange Walk received widespread publicity and has exacerbated anti-crocodile feeling.

On the whole, though, it is probably safe to say that crocodile hunting in Belize is less important today than it was five or six years ago. Although some nonmonetary rewards of hunting remain important, the decision to go after crocodiles is primarily economic: hunters speak wistfully of "$1000 nights" and of avoiding small animals "because they only bring a dollar." Furthermore, the current economic situation in

Belize provides an increasing number of alternatives to hunting. Work is generally available, and it pays well. The sugar cane industry and several road-building projects were specifically mentioned as more lucrative and dependable sources of income than hunting. Several of the young and middle-aged men we talked to said that they had given up crocodile hunting in recent years because (even at $10* a foot--the highest price ever in Belize) it simply didn't pay enough.

It is probably also the case that crocodiles are more difficult to find than they have been in some period of the past. The older hunters acknowledged that crocodiles are scarcer than when they began hunting them in the 1940's. One hunter noted, "You used to get 25 or 30 in a night. Now you get 5, 10, maybe only 2." Overall, however, both hunters and hide dealers felt that there were still plenty of crocodiles left in Belize, especially in its "inaccessible" regions. Some people believe the number of crocodiles has actually increased in recent years due to the decline in hunting. There is little sentiment on the part of the hunters for protection of crocodiles. First of all, they do not feel such protection is necessary since "there are still plenty of alligators." Even if crocodiles were near extinction in the country, the native hunters do not feel that they are animals worthy of protection: "Why should they be protected when they are dangerous, when they kill people"? Many hunters we talked to claimed that they would not take crocodiles under 4 or 5 feet in length. This, however, was less for conservation than for short-term economic reasons; small crocodiles simply did not pay. (Incidentally, the evidence we found at campsites and hide-dealing establishments indicates that small animals are indeed being taken by somebody.)

From our observations, it appears that no hunter in Belize depends exclusively on the hunting of crocodiles to make a living. All the hunters we spoke to or heard about had another occupation which could be practiced year round. The sale of crocodile hides undoubtedly brings appreciated money into some poor Belizean households, but the impression we obtained was that such money was not depended upon for subsistence. It was a good source of "extra" income--to be spent on hunting equipment or new things for the house. Intensive crocodile hunting does not seem to involve many people at the present time. However, this is a situation which could change rather rapidly if Belize experiences an economic recession with resulting unemployment, if the price of crocodile hides goes up, if good roads are built into presently inaccessible hunting areas, or if there are several long, consecutive dry seasons.

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* All prices are given in Belizean currency; at the time of the study $2 Belize was approximately equal to $1 U.S. Note also that crocodile hides in Belize are priced by length, not by width across the belly.

Hide Dealing and Exportation

It is clear that if hides were not commercially valuable, most crocodile hunting in Belize would cease. Thus, any protection programmust at some point or another deal with those who purchase the hides. In Belize, there are quite a number of people who buy crocodile hides from hunters. Nearly every fair-sized community seems to have at least one such person. These hide dealers are most often also storekeepers; they all seem to engage in hide-buying as a sideline; they all also buy cat skins. The local hide dealers have a very loose, informal relationship with one another and also with the exporter in Orange Walk, the one man licensed to ship hides out of Belize. The exporter says he will buy hides from anyone who brings them in--hunter or dealer. In the summer of 1980, he was paying $10 a foot for hides 5 feet or longer.* The local hide buyers set their own prices--in 1980, these ranged from $7 to $10 a foot. We have circumstantial evidence that some hides may be bought and sold several times before reaching the exporter. In such cases, of course, the hunter would receive much less than the price being paid by the exporter.

The hide dealers share the feelings of the hunters regarding crocodile abundance and the foolishness of protection. They are more openly hostile toward, and much more aware of protectionist activities. They feel (and are probably instrumental in passing on such views to the hunters) that to forbid hunting would quickly bring about a surplus of crocodiles, which would invade settled areas and threaten human lives. There is evidence that at least some hide dealers actively encourage hunting by offering to transport hunters to the bush. Hunters with hides are never turned away and, apparently, are not made aware of quotas (see below) and other governmental controls. Hide dealers deny that losing the hide business would have any great economic effect on them. This seems to be a correct assessment; the hide dealers, as a group, are solidly middle-class and have at least one other way of making a living.

The man licensed to export hides is clearly the most important figure in Belize in respect to crocodile exploitation. Like the local hide dealers, this exporter does not depend solely upon the skin business for livelihood. The exporter sees himself as providing a living for many hunters and their families. He once told us that if hide exportation were prohibited, the men he currently buys from would "become involved in drug exportation to make a living." Since our research indicates that most hunters do not in fact depend even primarilly upon the hide trade for their livelihoods, we disagree with the exporter over his conclusion.

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* As far as we could tell, he pays the same price to both hunters and dealers. One dealer claimed he received $14 a foot from the exporter but this man's testimony is disputed on other points and may be on this one.

Crocodile hides from Belize go initially to the Andre Fontaine Company in Belgium.* This arrangement has been in effect for several years; the Belgians have visited Belize three times. The exporter adjusts his prices to hunters so that he can make a profit; from hints he gave us, he has been receiving between $10 and $15/foot recently. The exporter told us that the number of hides exported has decreased year by year since the early 1970's when the government imposed a quota on the exporter. He further told us that the quota had been decreased each year until it currently stands at 1500 total hides and skins (both crocodile and cat).**

Governmental Action

Current laws relevant to wildlife in Belize are contained in the "Wildlife Protection Regulations," written and passed in 1945. Under these regulations, animals may be placed on a protected list by ministerial decree. Animals on the list may not be hunted. Neither the Morelet's crocodile nor the American crocodile (C. acutus) was included on the list we were able to review. In addition to protecting certain animals entirely, the Regulations (1) require a license for hunters, (2) prohibit hunting on Crown lands, and (3) ban the use of artificial lights in hunting. Enforcement of this last provision would reduce the number of crocodiles taken to near zero, since virtually all commercial hunting is done at night with headlamps. (It is also clear that such enforcement would be extremely difficult.) As it is, few of the hunters we talked to admitted any knowledge of the ban on headlamps; licensing requirements and Crown lands regulations were more widely known, but it appears that these provisions too are often violated.

The government has taken several steps recently which indicate a willingness to support wildlife preservation efforts. After the November 1979 elections, the cabinet was reorganized and the Ministry of Forestry

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* According to K. Fuchs (pers. comm.) the hides are not processed in Belgium but are resold to a tannery in Italy. Attempts in Brussels to trace this economic connection were soundly rebuffed.

** The export quota system is not easily interpreted, for one is not able to determine from trade statistics how many exported skins are from crocodiles and how many from spotted cats. It is our belief (and perhaps we are wrong) that actual declines in exports have resulted less from lowered quotas than from a decline in the country's population of crocodiles.

Note also that if we have correctly estimated the prices this exporter receives, then he is being paid significantly less for Morelet's hides than is usually given for American Alligator skins--despite the widely recognized superiority of leather from the former species.

and Minerals (the ministry responsible for wildlife) was removed from the jurisdiction of Trade and Industry and combined with Agriculture and Lands to form a new Ministry of Natural Resources. The government expects to submit new legislation regarding wildlife protection and the establishment of a national parks system to the legislature within the next few months. The proposed legislation is based on a 1978 report of FAO consultant William O. Deshler entitled "Proposals for Wildlife Protection and National Parks System Legislation and the Establishment of National Parks and Related Areas in Belize." Under the proposed legislation, both _C. acutus_ and _C. moreletii_ would be placed on the protected list (the list specifying that "no person shall hunt any of the following species on either government or privately owned lands"), and all commercial dealing in wildlife species or parts thereof would be subject to a seven-year moratorium. As presently written, the legislation does not make any specific provisions for crocodile preserves. Deshler's report suggests but does not formally recommend locations for two such presesrves: (1) the upper reaches of the Raspaculo Branch, Macal River, and (2) the Big Creek-Independence area near the Savannah Forest Station. Neither site was visited by Deshler and future recommendations are dependent on obtaining information about the current status of crocodiles in these areas. The proposed legislation is supported by the current government and by the Audubon Society. The two officials we talked to in Forestry (the chief Forest Officer and his assistant) believed that the legislation had a good chance of being passed.*

In the meantime, several other measures which may affect the crocodile hide business in Belize have been taken. After receiving a letter from the American consulate (dated 5 May 1980) informing them that _C. moreletii_ and _C. acutus_ were endangered species and could no longer be imported into the U. S., officials in the Forestry department informed the exporter that his license for exporting skins (both crocodile and cat) would not be renewed next year. The exporter himself naturally hopes there will be some change in these plans, and it may therefore be a bit early to make any definite pronouncements about the legal status of Morelet's crocodile next year. In the meantime, the government has recently issued two orders which will make exportation more expensive. One order (dated 2 May 1980) raised export taxes on products of wild animals from 5% to 10% _Ad valorem_. A second (also 2 May 1980) increased fees for dealer and hunting licenses.

Belizean Audubon Society

Audubon Society members have been almost solely responsible for whatever wildlife education exists in Belize. They are waiting for

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* Very recent information from Belize indicates that all crocodiles are now legally protected (see Current Plans under Recommendations, below).

passage of the above mentioned legislation before deciding what type of educational campaign to undertake in regard to crocodiles. They recognize that attitudes toward crocodiles will be difficult to change. Meanwhile, some individual members of the Society prepared and presented an educational radio program on crocodiles to counteract the publicity surrounding the Orange Walk incident. In other words, Audubon Society members are willing to help in crocodile protection but would like to have the force of law behind them before they fully commit themselves.

PART III: GENERAL RECOMMENDATIONS.

The Necessity for Eventual Legal Protection

In the past, exploitation of Morelet's crocodile has been greatly slowed by the inaccessibility of much premium habitat. Such conditions should not, however, be expected to persist, and as Belize continues to expand her road network, more and more areas will become easily accessible to crocodile hunters. Our experiences in the summer of 1980 demonstrated that such changes can be very sudden. We are therefore convinced that *C. moreletii* must eventually be given some degree of legal protection in order to ensure the long-term survival of the species in Belize.

Current Plans

As our report indicates (see above) the Belizean government intends to prohibit export of crocodile skins by 1981. We would strongly support this plan--with the added proviso that it should not be necessary permanently to cease all commercial exploitation of the species. FAO (see Deshler 1978) recommended a seven-year moratorium on crocodile hunting; even this might be unnecessarily long. We believe Belize's crocodile populations still possess the capacity for rapid recovery; many of the animals we have observed were 1.0-1.5 m long. If Morelet's growth rate is comparable to that in *Alligator*, we might expect their young to be of breeding size within three to four years. Therefore, if a true moratorium on crocodile hunting had been instituted by the end of 1980, it is possible that *C. moreletii* could withstand a limited, closely monitored harvest program beginning with the dry season (January) of 1986. We are convinced that the long-term survival of Morelet's crocodile depends upon its perception by the Belizean people as a valuable resource. Therefore, it would be politically advisable to stress the temporary nature of any moratorium as well as the economic benefits expected from it.

In the early spring of 1981 we were informed that the Belizean government had indeed declared a moratorium (of indefinite length) upon the taking of any crocodiles. Furthermore, we have more recently learned that this policy has been continued since Independence. Although it does not currently appear that the protection ordinance has been enforced with uniform effectiveness, we are nevertheless encouraged by the overall program of Belize's new government.

If this ban on crocodile hunting can be maintained (and more rigorously enforced) for even a few years, the Belizean Forest Office should be able to develop a reasonable harvest scheme based on the results of experimental programs in New Guinea and Florida. In the meanwhile, of course, efforts should be made to learn as much as possible about the specific population ecology of *C. moreletii*.

Hide Exports

If at some future date crocodile hides are legally exported from Belize once more, the Forest Office should attempt to derive useful data from such commerce. For example, trade statistics should distinguish between crocodile and spotted cat hides. Furthermore, the actual number of animals (as opposed to just the number of hide-pounds), preferably broken down by size, should be reported. Monitoring such data over a number of years could provide the Forest Office with valuable information on the status of their crocodile populations. Finally, and most important, we would strongly urge research to determine how a greater percentage of revenues eventually derived from crocodile hides might be kept in Belize.

Crocodile Refuges

Conversations with Forest Office personnel, as well as with members of the Belizean Audubon Society, indicate the possiblity of establishing one or perhaps more crocodile refuges. We believe such refuges should be established, whether or not nationwide protection becomes a reality. One of the areas suggested for such a refuge includes the upper reaches of the Macal River (see above). We have examined this river rather carefully between coordinates BP901653 and BP817670 (grid zone designation 16Q), and although it provides less than ideal crocodile habitat, we nevertheless consider it a virtually ideal refuge site for several other reasons.

First, it already enjoys considerable protection. Access is limited to the Chiquibul Road, and that road's traffic is controlled by a Forest Office checkpoint. Hunting is prohibited in the area and is limited to occasional poaching by logging crews and sport hunting practiced by British military forces stationed in the area. (Incidentally, Mr. William Locklair, head of the Augustine Forest Station, said that his most serious hunting problems were caused by the British Army. It would seem that proper command supervision could prevent any such problems.)

Second, the area certainly gives shelter to a large number of interesting vertebrae species other than crocodiles. In our five-day stay, we observed such animals as king vultures, Sarcoramphus papa, deer, Dama (Odocoileus) v. yucatanensis, ocellated turkey, Agriocharis ocellata, iguana, Iguana iguana, parrot (we saw only Amazona--though, as the river's name indicates, macaws, Ara macao, are also present), and cougar, Felis c. mayensis, as well as a large number of smaller reptiles and birds. We have been told that jaguar are reasonably common, and tapir, Tapirus bairdii, are everywhere in evidence. We know from Audubon Society members that the area is already quite popular for birding trips, and the natural scenery of the mountains (which includes an extremely high waterfall and an enormous cave) is unsurpassed in Belize. These factors, together with the climate (which is characterized by warm days and cool nights), clearly indicate real possibilities for tourism. A national park, filled with lots of wildlife, might eventually become an economic asset of some importance. Furthermore, the crocodiles of the Macal River do not seem greatly afraid of human beings. We have observed several during daylight, and we therefore suspect that they might become a visible (and therefore tourist-attractive) part of any park's fauna.

Before a park is formally established, it would be desirable to complete a more extensive survey of this river system. However, since the establishment of a refuge might initially require little more than making a proclamation plus posting a few signs, such a survey is probably not imperative.

In addition to any mountain refuge, it may be necessary to guarantee protection in some more nearly ideal crocodile habitat. The Big Creek-Independence area has already been suggested; this or other locations in central Belize might well be appropriate, though a survey should be done prior to formal designation. We have noted that Cox Lagoon is densely populated with crocodiles. Furthermore, it already enjoys some de facto protection under the administration of Big Falls Ranch. We believe it would be appropriate if the Forest Office would encourage (and aid, if possible) the Big Falls administration in maintaining this protection. The same would naturally hold for other privately protected areas.

Conservation Education and Public Relations

As we have said before, we believe the long-term future of crocodile populations in Belize depends upon their perception by the Belizean people as an economically valuable natural resource. Clearly the exportation of hides is one possible source of revenue. We have suggested that, along with other wildlife, crocodiles could help attract some tourist trade to Belize, perhaps especially in the mountains. Finally, data from Africa indicate that the extirpation of crocodiles often results in eventual declines of food-fish populations (see Curry-Lindahl 1972). All these factors might be emphasized in an education program.

We highly commend the Belizean Audubon Society for their long-standing efforts in conservation, and we especially appreciate the work they have done for the less-than-popular crocodiles. We further suggest that any plans the Forest Office makes for crocodile conservation would certainly profit from coordination with the Audubon Society.

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APPENDIX

A. Estimation of total C. moreletii population by habitat.

1. We divided Morelet's habitat into two classes, RIVERS and LAGOONS.

   a. Rivers in turn were further divided into three types. We define them below and also give the crocodile densities we have observed as characteristic for each type:

      1) TYPE 1 RIVERS. These are rivers easily accessible to boat traffic. Except for the Macal River (which, more than 10 km above San Ignatio, is considered Type 3), any stretch of river is coded Type 1 if that stretch is intersected by a road or major trail. Density is 1 croc/10 km.

      2) TYPE 2 RIVERS. These are rivers accessible with moderate difficulty to boat traffic. Any stretch of river is coded Type 2 if it is separated from a Type 1 River by exactly one obstruction marked on a 1/50,000 topographic map. Density is 1 croc/3 km.

      3) TYPE 3 RIVERS. These are rivers accessible only with difficulty to boat traffic. Any stretch of river is coded Type 3 if it is separated from a Type 2 River by one or more obstructions marked on 1/50,000 topographic map, or if the entire river has no road access. In addition, because of Forest Office protection, the entire Macal River more than 10 km above San Ignatio is coded Type 3. Density is 1 croc/km.

   b. Lagoons were also further divided into three types. We define them below and also give the crocodile densities we have observed as characteristic for each type:

      1) TYPE 1 LAGOONS. These are lagoons easily accessible to boat traffic. Any lagoon is coded Type 1 if it is within 0.5 km of a major Type 1 River. Density is 1 croc/2 km shoreline.

      2) TYPE 2 LAGOONS. These are lagoons accessible with moderate difficulty to boat traffic. Any lagoon is coded Type 2 if it is not Type 1 and if it is intersected by a Type 2 River or a marked trail. Density is 3 crocs/km shoreline.

3) TYPE 3 LAGOONS. These are lagoons accessible only with difficulty to boat traffic. Any lagoon is coded Type 3 if it is neither Type 1 nor Type 2. Density is 7 crocs/km shoreline.

2. Additional measuring conventions employed were as follows. For all lagoons, shoreline was measured as (a) the length of any lagoon stretch less than 100 m wide or (b) the total length of both shores of any lagoon stretch 100 m or greater in width. We measured all habitat types on 1/50,000 topographic maps. We considered only portions of Belize north of 16° 45' N latitude. No potential habitat within one kilometer of the sea was considered. (We believe such habitat might be inhabited by *C. acutus*, and we are not sure the two species are sympatric.)

3. We measured the following habitat-type totals and therefore estimate the following numbers of animals:

a.	Type 1 Rivers:	659.9km X 1 croc/10 km	=	66 crocs.
b.	Type 2 Rivers:	149.9km X 1 croc/3 km	=	50 crocs.
c.	Type 3 Rivers:	132.4km X 1 croc/km	=	132 crocs.
d.	Type 1 Lagoons:	197.1km X 1 croc/2 km	=	100 crocs.
e.	Type 2 Lagoons:	388.3km X 3 crocs/km	=	1165 crocs.
f.	Type 3 Lagoons:	147.2km X 7 crocs/km	=	1030 crocs.
	Total number of animals			2543 crocs

B. Estimation of total *C. moreletii* population by unit of hunting effort method.

1. Figures for pounds of hides exported are taken from Belizean trade reports, 1975, 1976, 1977 (all available).

2. Pounds of hides exported are converted to an estimate of total number of animals taken for each year.

3. Population of hunting-size animals is estimated beginning in 1975 by a least-squares method as described by D.B. DeLury (1954).

4. A rate of croc population decline is estimated for 1975-1977 and then projected through 1980. On that basis the current population of hunting-size animals is estimated.

5. The number of hunting-size animals is multiplied by 10 in order to estimate the total number of crocodiles age greater than 9 months.

6. Some of the more important (and more readily challengable) assumptions underlying our estimation procedure are as follows:

a. Approximately 10% of crocodiles are of hunting size in 1980. This assumption is in rough accord with our observations.

b. All animals exported were (1) C. moreletii (2) of Belizean origin from north of 16°45'N. (Note that this assumption tends to overestimate the population.)

c. There was a constant hunting effort for each year, 1975 through 1980. (We actually suspect--see Part II above--that hunting effort has declined over that period. If so, then this assumption tends to underestimate the population.)

d. The pounds of processed skin for each crocodile taken is, on average, equal to the average pounds of skin per animal in a 30-individual sample of Alligator mississippiensis taken in the Florida nuisance alligator program. (Note: We began with a 40-animal sample; 10 animals in that sample, however, were in excess of 9 feet long. Since hide dealers in Belize had told us they seldom dealt with animals of such length, we did not consider those 10 animals in our sample. The mean length of hides in our remaining sample was 6.2 feet; the mean weight of hide per animal was 12.883 lb. We believe this average weight may be slightly excessive for C. moreletii; if so, again we underestimate the population.)

e. The reported export data are correct and the ratio of croc hides to other hides exported to Belgium remain as in 1976 for 1975 and 1977. We have no guesa as to the accuracy of this assumption.

f. The "catchability" of crocodiles remained constant from 1975 to 1980. We suspect that the animals might have become, on average, more difficult to catch over this period. If so, then this assumption underestimates population size.

7. As reported in the body of this paper, we estimate approximately 2200 crocodiles according to this method.

C. A final warning on the accuracy of our estimates. Again we would warn the reader that our estimations are no more than systematic guesses; little stock should be placed in them. For what it is worth, our intuition is that we underestimated considerably the total number of crocodiles in Belize.

THE HABITAT AND DISTRIBUTION OF *PALEOSUCHUS* IN VENEZUELA

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INTRODUCTION

The genus *Paleosuchus* is represented in Venezuela by both species, *P. trigonatus* and *P. palpebrosus*. Locality data are very scarce and other information is virtually nonexistent. Donoso Barros (1966a, 1966b) briefly reported on the genus in Venezuela and published the first photograph of a *Paleosuchus* egg. Medem (1958; King 1973) described the range and status, commenting also on the poorly understood biology. Only four specimens were located in national museums, and only one example appears to be found in collections outside the country (Medem, pers. comm.). Data on *Paleosuchus* collected during surveys for *Crocodylus intermedius* in southern Apure State (Godshalk, this volume) extended the known range in Venezuela.

HABITAT

The large area of distribution covers a variety of habitats. The topography, climate, substrate, vegetation, and qualities of the water differ greatly within the range. The southern portion of Apure State, found in the Llanos region, exhibits two general types of habitat where *Paleosuchus* are found.

First are the large, meandering rivers and smaller tributaries which are bordered by dense gallery forest. These flow slowly across flat, sedimentary plains of Andean origin. Water courses bordered by savanna do not seem to be utilized. This was also found by Medem (1967) in Colombia. The rivers contain water ranging from clear, the Cinaruco River for example, to very turbid with an extremely high sediment load, as in the Meta River.

Depressions occur in some areas of the sandy, aeolian savannas that separate the rivers described above. Percolating water from the saturated soil gives rise to springs that form headwaters for many of the rivers' tributaries. The dense vegetation that forms around these springs and borders along the drainage is dominated by the mauritius palm, *Mauritia minor* Burret (palma moriche in Spanish). These areas, called *morichales*, typically have clear, nutrient-poor water with a low pH. Water flow is usually minimal due to the slow seepage and the very gradual slope. Flooding may occur with the intense precipitation during the wet season. In the dry season some morichales have such reduced surface flow that they remain isolated for several months. Use of this habitat has led to the local name for Paleosuchus in southern Apure State of "morichalero." These areas are found within the Tropical dry forest as classified under the Holdridge System (Ewel and Madriz 1968). The annual precipitation averages from 1800 mm to 2000 mm and falls mostly during the six-month wet season. The annual mean temperatures are 24° to 26°C and are not affected by altitudinal variation which ranges only from 25 m to 100 m above sea level.

Rivers in the area south and east of the Orinoco River flow across the Guayana Shield. This massif of pre-Cambrian origin entirely covers the Amazon Territory (175,750 km^2) and Bolivar State (238,000 km^2), as well aa parts of Colombia, Brazil, and Guayana. Rivers in the lower elevations generally run slowly through a dense forest cover. Upstream they are broken by many waterfalls and rapids as they course the uneven terrain. The forest is often reduced in the upper reaches and may be found only along the water courses that cross large savannas. Here the streams are generally very rocky and have swift currents. Many black water rivers, which contain acidic water with little organic or mineral content, originate on the Guayana Shield. The aquatic life is generally reduced according to the severity of these conditions. In some rivers the primary production is very low.

The greater part of this region is within the Tropical humid forest zone (Ewel and Madriz 1968). At higher elevations (above 500 m) suitable habitat is also found within the very humid premontane forest. Precipitation averages from 2000 mm to 4000 mm and is distributed throughout the year. The annual mean temperatures range from 24° to 26° over most of the area but cooler at higher elevations.

DISTRIBUTION

Paleosuchus is usually typified as inhabiting swift and rocky forest streams. This habitat clearly forms a large part of the range in Venezuela. The rivers of the Guayana Shield are barely penetrated by Crocodylus intermedius or Caiman crocodilus, as these species prefer quieter water. Medem (1958, 1971) found Paleosuchus near rapids and waterfalls in small Colombian streams, as well as the forested rivers. Black water rivers also present a major barrier. Only Paleosuchus is found consistently in these acidic waters in Venezuels.

The genus is also found commonly in other, very different environments. Although the range in Apure State includes only forested watercourses, few can be regarded as swift and none are rocky. The morichales sometimes have little or no surface flow and pass over a sandy substrate. Survey data and additional reports indicate a very successful distribution in this region.

Paleosuchus is often found in close association with Caiman but are separated by subtle habitat differences. Both species of Paleosuchus are also sympatric in some areas of their distribution. The details of the ecological isolation and intraspecific and interspecific relationships are not understood. Caiman is apparently the dominant. In Paleosuchus, one species is more abundant according to the locality (Medem 1971). During our surveys night counts on the Cinaruco River in Apure showed P. palpebrosus to be the dominant where sympatric with P. trigonatus. No information exists for other areas in Venezuela.

LOCALITIES

The following localities are cited for Paleosuchus in Venezuela or in close proximity. Most are taken from the scientific literature. Large portions of the distribution remain unexplored, especially on the Guayana Shield, and therefore no information exists. In the densely forested areas these caimans are overlooked unless searched for specifically. Most Venezuelans do not distinguish between Caiman and Paleosuchus. These factors, compounded by the inaccessibility of the region, has hindered understanding of the genus in Venezuela.

Refer to Figure 1 for the localities listed below. All localities lie within the Orinoco Basin except for the Rio Negro (Area 3) and the San Juan River (Area 5).

Area	Site	Source
		Paleosuchus palpebrosus (Cuvier)
1	- Cinaruco River	Four animals were collectd during surveys on this river. Three are preserved in the Rancho Grande Biological Station Herpetological Collection. One is maintained at the Caricuao Zoo, Caracas.
	- Meta River	A report by Lamar (1978) included a map showing this locality, adjacent to Venezuela, from Medem (1981).
	- Tomo River	Lamar (1978) reported three individuals in the Tuparro Faunal Territory, close to Venezuela.
5	- San Juan River	Donoso Barros (1966a) reported this site from two specimens, only one of which he examined. This river is in the Paria drainage which is separate from the Orinoco system. The nearest P. palpebrosus locality is approximately 500 km SE in Guayana.

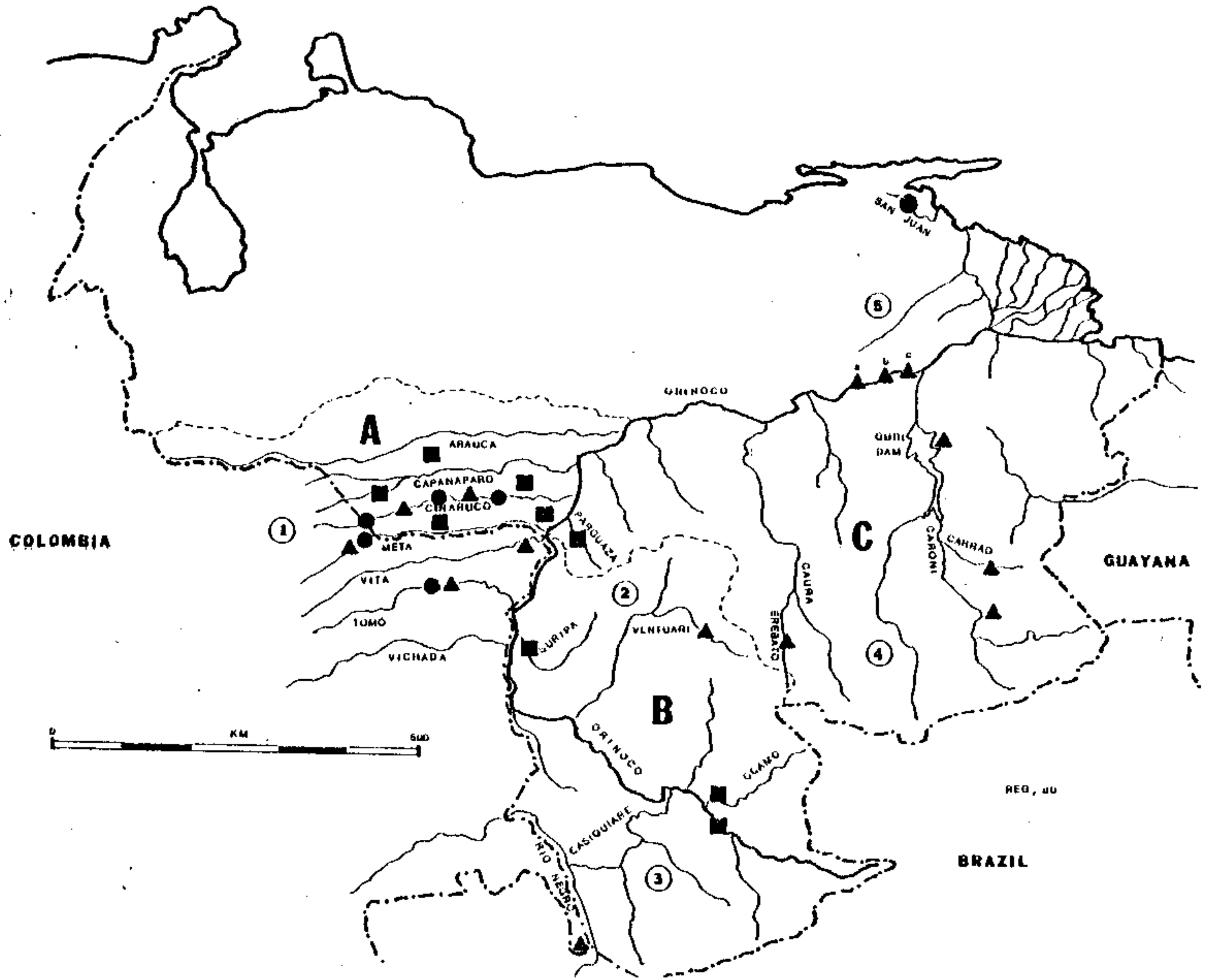

Figure 1.-- The distribution of Paleosuchus in Venezuela. A simplified diagram of the rivers within the known range. Circles = Paleosuchus palpebrosus; triangles = Paleosuchus trigonatus; squares = Paleosuchus sp. Political Areas: A = Apure State; B = Amazon Federal Territory; C = Bolivar State.

Paleosuchus trigoantus (Schneider)

1 - Cinaruco River — Two specimens were collected during our project in Apure. Unfortunate events led to the destruction of the material.

- Meta, Vita, and Tomo rivers — Medem (1978, in press) was cited by Lamar (1978). These Colombian localities are very close to Venezuela and are therefore included.

2 - Venturari River — Donoso Barros (1966a) examined a small series from the upper Ventuari.

3 - Rio Negro — The specimen from Natterer (1841) represents the oldest Venezuelan record for Paleosuchus. The locality is described as being near Cerró Cocuy, a large rock formation that is found in Venezuela close to Brazil and Colombia.

4 - Erebato River — R. Hoogesteijn collected a skull from local Yanomamo Indians which I examined.

- Caroni River — Steyermark (1955) reported "a relative of the cayman" in a small tributary of the upper Caroni and included a photograph of P. trigonatus.

- Carrao River — One specimen was collected during a Central University expedition (Roze 1958). Medem (1974) remarked on an unconfirmed report of P. palpebrosus at the same location. No more information was given and probably represents a confusion with Roze's article.

- Guri Dam — Gorzula (1976) found a specimen here, which is part of the Caroni River.

5 - Orinoco River

(a) Lichtenstein and von Mertens (1856) recorded the first Paleosuchus from the Orinoco drainage.

(b) Donoso Barros (1966a) listed this example only as from "Guayana," a local term for an immense area, and included it on the range map.

(c) This locality was cited by Gorula (1976) for a specimen he collected.

Paleosuchus sp.

1 - Capanaparo, Cinaruco, and Meta rivers	Reliable reports of Paleosuchus in the region were gathered from various Amerindian groups and certain white settlers who were familiar with the animals. The morichales found between the major rivers are commonly utilized.
2 - Parguaza and Suripa rivers	Piaroa Indians reported these caimans to be present here.
3 - Ocamo River	Vareschi (1959), a botaniat, wrote that while on a trip up the Orinoco, "crocodiles" were found in a small, wooded stream near the Ocamo River. A photograph of P. palpebrosus, labelled Crocodylus intermedius, is included with this chapter but origin of the specimen is not given. Adding to the confusion is a photograph on the same page of Caiman crocodilus which was taken in an entirely different area. It is accompanied by a quote from Humbolt that refers to the Orinoco crocodile.
- Orinoco River	"Babillas," a generic term for caimans, were found by Cocco (1972) above the juncture with the Ocamo. This habitat appears suitable only for Paleosuchus.

CONCLUSION

Paleosuchus appears to be more commonly distributed in Venezuela than previously assumed. Our findings in Apure revealed it to be relatively abundant over an immense area in which it was unknown to science. Neither species has been shown to be gregarious, and specimens are usually encountered singly or in pairs. Both the habitat and habits of Paleosuchus have caused the genus to remain obscure. Further research is required to understand the status and biology of these widespread but poorly known caimans.

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STATUS AND CONSERVATION OF CROCODYLUS INTERMEDIUS IN VENEZUELA

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INTRODUCTION

The distribution of *Crocodylus intermedius* is restricted to certain regions within the Orinoco River Basin of Colombia and Venezuela. The area, known as the Llanos, covers approximately 250,000 km^2 in Colombia and 265,000 km^2 in Venezuela. Intermittent commercial hunting, most intense from about 1925 to 1950, nearly eliminated the Orinoco crocodile before any scientific studies on the species had been undertaken. Medem (1955) first noted the declining Colombian populations and called for immediate protection. He began investigations with the species in 1956 and subsequent publications (Medem 1958a, 1958b, 1968a, 1968b) reinforced the need for better legislation and more detailed studies. *C. intermedius* was fully protected in Colombia by Resolution No. 411 (Min. Agric.) in 1968 and Resolution No. 573 (INDERENA) in 1969 (Medem 1971). The critical condition of crocodilians in Colombia (Medem 1970) led to funding by the World Wildlife Fund--International. Status surveys were conducted in Colombia from 1973 to 1975, and only 280 adult crocodiles were located, indicating alarming conditions there.

Information on *C. intermedius* in Venezuela from this century is very limited. The scant references usually report the species as rare or near extinction and give few details. Vila (1953) was perhaps first to comment on the disappearance of crocodiles in the northern part of its range but stated that they were relatively common in the south, especially in Apure State. Later reports (Mondolfi 1957, 1965; Medina 1960; Vila 1965; Donoso Barros 1966a, 1966b; Rivero Blanco 1968, 1970; King 1973; Godshalk and Maness 1976) indicated that the Orinoco crocodile was nearly exterminated throughout its range. In 1969, Prof. Medem advised the IUCN/SSC Crocodile Specialist Group that a status survey for *C. intermedius* was "urgently required" (Bustard 1970). In 1972 Prof. Medem undertook a general survey of Venezuelan crocodilians sponsored by the New York Zoological Society. *C. intermedius* was found to be extinct in large areas and a more detailed study was strongly recommended (Medem pers. comm.). Funds for a survey were secured from the Fundacion para la Defensa de la Naturaleza (FUDENA), the World Wildlife Fund Venezuelan affiliate, in 1977. The Fauna Preservation Society provided additional support through the Oryx Fund.

STATUS

Habitat

Survival of the remaining crocodiles is often due to the complexity of the Orinoco River system. The difficulties to human access in certain regions present a major defense.

Three general habitat types within the study area are described (refer to Figs. 1 and 2):

1) Rivers that flow through the (formerly) continuous deciduous forest of the western portions of Apure and Barinas ststes and the northern portions of Portuguesa, Cojedes, and Guarico states. Some areas are subject to flooding in the rainy season but, in general, the rivers usually remain within their banks even during high water. The rivers are small as they emerge from the Andes or Coastal Range, increasing in size as they proceed towards the Orinoco River. This habitat is utilized from 100 m to 500 m above sea level.

2) Rivers in the area of northern Apure, eastern Barinas and southern Portuguesa, Cojedes, and Cuarico states. These are generally large, meandering rivers that cross vast savannas. Forested areas are reduced to isolated formations, scattered intermittently across the grasslands, and partial cover along some rivers. Immense areas are subject to flooding as the rivers overflow their bands in the rainy season. Due to poor drainage, this may reach up to 80-90% of the surface area in some places, and it greatly increases the habitat utilized by the crocodiles. Numerous interconnections between the rivers are formed, according to the time of year, and provide great mobility within certain areas. The rivers are frequently changing course, with the original bed retaining a reduced flow.

3) Rivers of southern Apure. These convoluted rivers are usually bordered by dense gallery forest which is often several kilometers wide. They flow from Colombia along basically parallel courses across the flat, aeolian plains. General flooding during the wet season exists over much of the savanna, but usually forms only very shallow lakes, and the rivers lack intercommunicating networks. Large oxbow lakes snd elbows, causing the repeatedly changing meanders, are a very common feature.

Distribution historically was continuous throughout these habitat types. The narrow forest streams had lower carrying capacities per kilometer than larger rivers of the plains. These plains rivers (Type 2) held extremely numerous populations of C. intermedius before commercial hunting exterminated them. Factors such as the availability of nest sites and the dry season conditions of a river greatly affected the relative densities.

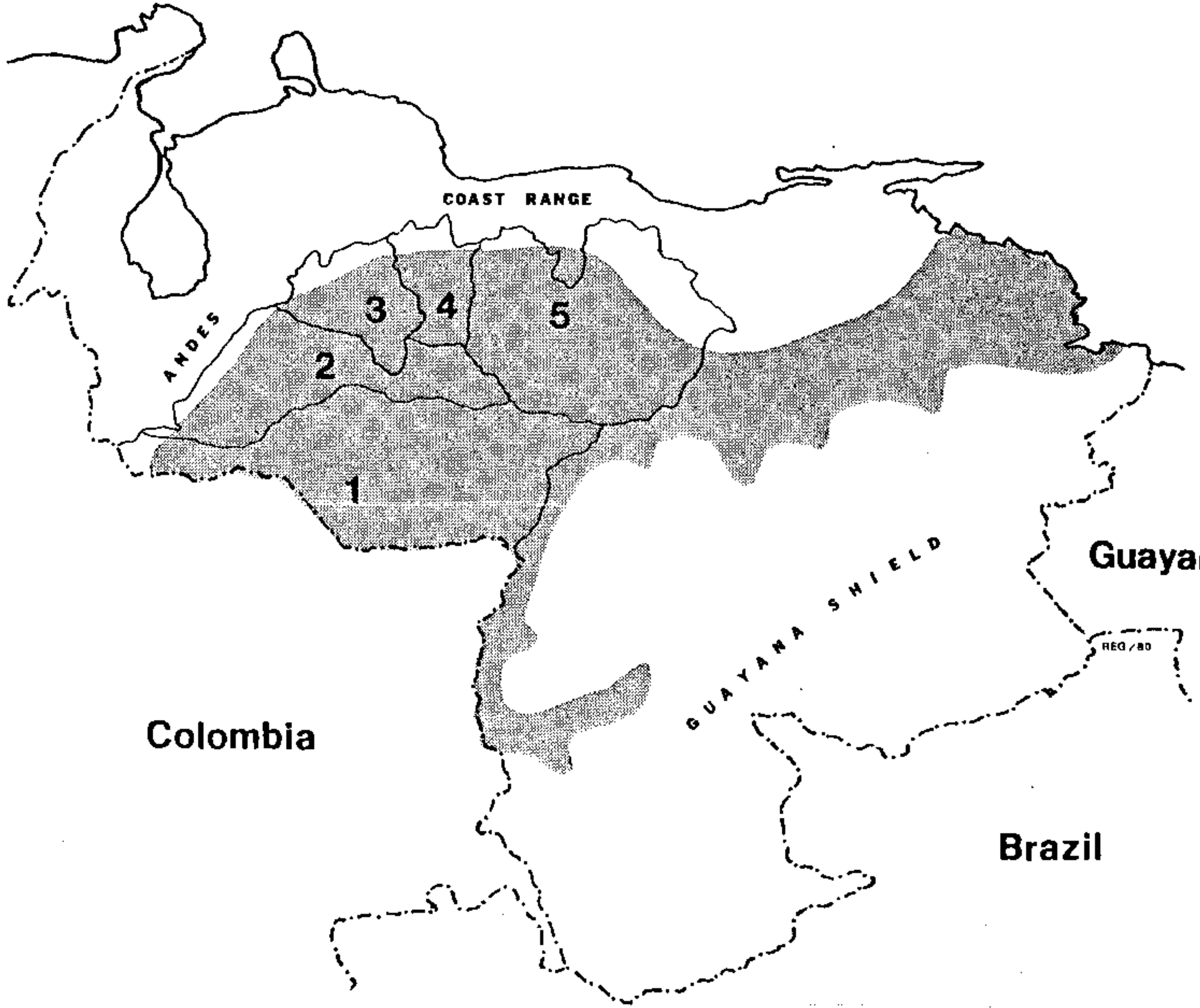

Figure 1.-- The distribution of Crocodylus intermedius in Venezuela. States (area) of the western Llanos region where status surveys were undertaken are as follows: 1 = Apure (76,500 km^2), 2 = Barinas (35,200 km^2), 3 = Portuguesa (15,200 km^2), 4 = Cojedes (14,800 km^2), 5 = Guarico (66,400 km^2).

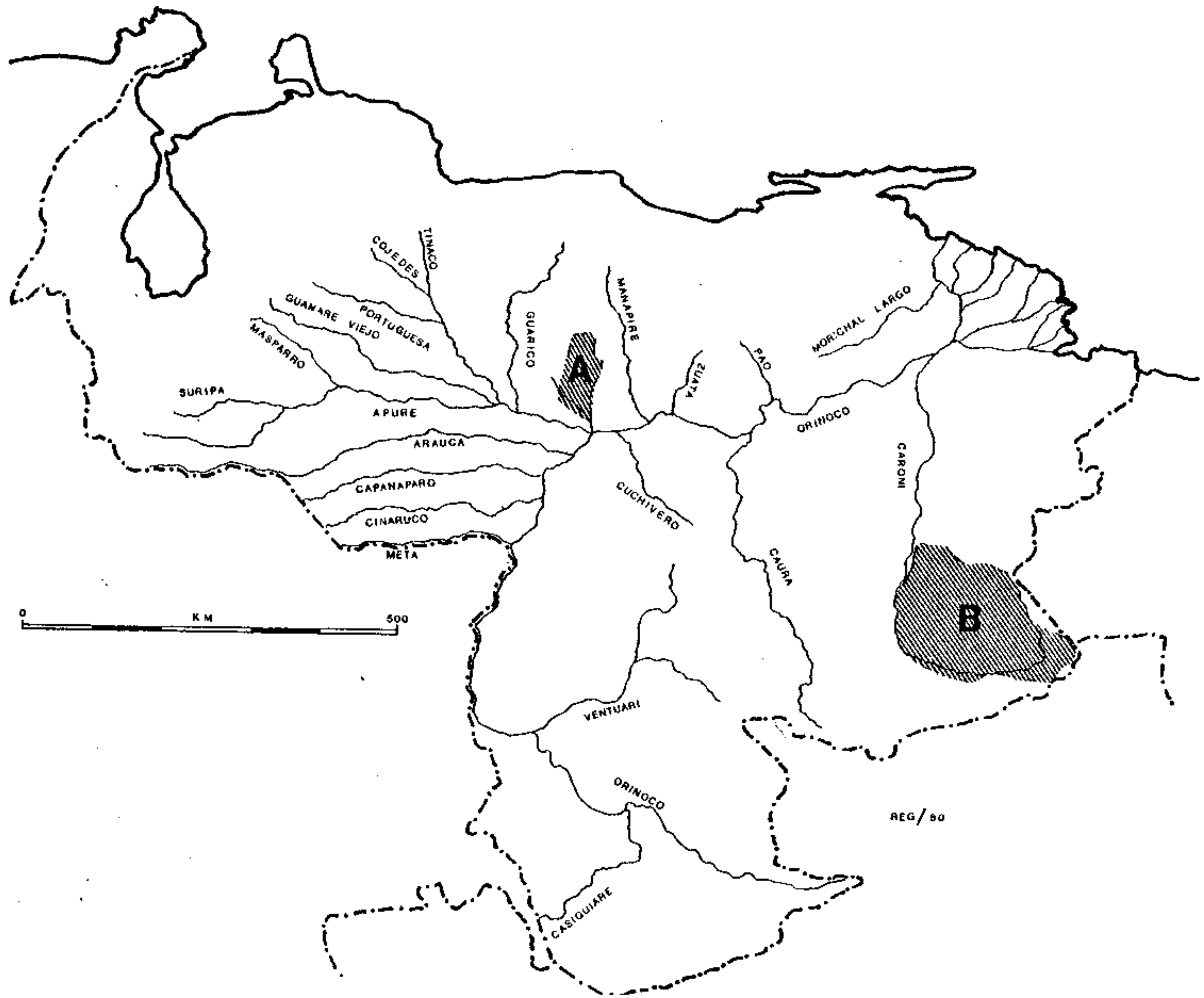

Figure 2.-- Simplified diagram of the Orinoco River system in Venezuela. Diagonally striped areas are national parks (area in hectares) as follows: A = Aguaro-Guaritico (560,000), B = Canaima (3,000,000).

Survey

Field surveys were carried out from January to July 1978. Dr. Evelio Sosa A., DVM, assisted throughout the project and provided valuable knowledge from experience with the species. Surveys were conducted first in the north, moving progressively southward, in order to take advantage of the dry season drainage pattern (Godshalk 1978). This allowed us to travel on waterways where the adjacent flooded areas were reduced or nonexistent. We expected greater success with more limited available habitat. Recent crocodile sightings were incorporated in planning the itinerary. Rivers were also selected to represent various habitats and river sizes (see Fig. 2). Many less important tributaries were also included in the study. The usual strategy involved traveling upriver by day, looking for evidence on the mud banks and sandy beaches. Numerous interviews were also made with the local inhabitants (Llaneros) closely associated with the rivers. Various Amerindian groups were also visited in the south Apure region. Spotlighting at night was done during the downriver travel. The outboard engine noise was thus reduced to increase the possibility of encounters with crocodiles. Paddles were sometimes used downriver to eliminate noise completely. By this method most areas were covered twice, once by day and returning later at night. Competent local guides were always used and they contributed greatly to the project. Transportation in the Llanos has traditionally been by water, and men were found with excellent knowledge of both the rivers and the crocodiles. Three observers were always present and in some cases as many as six.

More than 3500 km were traveled on water during the survey. A total of 273 adult crocodiles were located in the study area and were generally scattered over large expanses. Reproduction was found in several locations but immature crocodiles (less than 2 m) were rarely encountered or reported by the Llaneros. It was not uncommon to find large areas totally devoid of *C. intermedius*. Where they are found, the low numbers of individuals and lack of reproductive success often cause the species to be functionally extinct.

On the basis of our results, the situation must be considered extremely serious. Rivers were usually selected for study according to the possibility of crocodiles being present. The number of animals recorded cannot be regarded as an absolute, as there always remains a certain number uncounted. They do give an indication of the relative abundance, however. In the case of the Cinaruco River, many earlier reports suggested good possibilities for positive results. The habitat appears virtually identical to the nearby Capanaparo River, where a reproductive population exists. The area is remote and few Llaneros or Indians live there, so a main source of disturbance was absent. Yet, with little or no hunting pressure along the river, evidence of crocodiles on the numerous sand beaches was surprisingly rare. Some young animals (< 1 m) were reported but recuperation has been very slow.

TABLE 1.

Major Rivers Traveled:	Km	Crocodiles Seen	Crocs/10 km	Hab. type
Tinaco	55	7	1.30	1
Cojedes	130	76	5.90	1
Portuguesa	170	1	.06	2
Orinoco	120	5	.40	2
Capanaparo	370	78	2.00	3
Cinaruco	485	19	.40	3
Meta	230	67	2.90	3

Recent reports of C. intermedius exist for other rivers which, due to time constraints, were not included in the study project. Observations suggest that similar conditions exist in these areas and the species is very rare throughout its entire distribution.

CONSERVATION

The following are major factors affecting present and future populations of Crocodylus intermedius in Venezuela.

Legal Status

Regulations on hunting crocodilians were first legislated in 1944 (Ley de Pesca) under the jurisdiction of the Departamento de Fisheries, Ministerio de Agricultura y Cria (MAC). Permits were required but generally were issued automatically. Provisions existed for restrictions on the taking of certain species as well as "for their conservation and protection." No biological value was perceived for the crocodiles, which were considered as vermin, and hide hunting was permitted without control until the populations were reduced to extreme levels. Commercialization had brought C. intermedius to the brink of extinction before the existing legal machinery effected any sort of protection. In 1970 the Fauna Law was enacted which placed responsibility for the crocodilians under the Office of Fauna, MAC, and is presently in effect. The clear and comprehensive text presents the groundwork for excellent protection. Some of the relevant provisions are as follows:

Ley de Fauna -

Provisions governing the conservation and management of fauna

Art. 11 - MAC given legislative power:

c) - for establishment of Refuges and Sanctuaries.
d) - for prohibition of hunting of species or collection of eggs to avoid extinction.
f) - for taking the necessary measures for species "conservation, protection, production, and rational utilization."

Art. 18 - for taking measures to preserve, modify or restore habitat.

Art. 26 - for relocation of fauna one place to another for its conservation.

Art. 73 - prohibits hunting on protected ares: National Parks, etc.

Art. 77 - prohibits the killing "in any form, time or place":

4) - rare species.

Provisions governing hunting and commerce of fauna

Art. 81 - Prohibition of hunting:

3) - "with motorized vehicles whether aerial, terrestrial or aquatic."
6) - animals "on their nests, burrows, or together with their young."

Art. 82 - prohibits hunting at night or with artificial light.

Art. 83 - prohibits "collection or destruction of eggs, alteration or damage of nests, burrrows or dens, and of hunting the young."

Art. 84 - prohibits commerce of protected fauna and its products.

Art. 109 - establishes fines for commercial hunting, trade, industry or transport of protected fauna or products from 1000 Bolivares (US$ 230) to 50,000 Bs.(US$11,625) plus confiscation of animals, products and equipment.

In 1974, a four-year nationwide moratorium on all hunting was enacted in order to investigate the faunal resources. The Minister of Environment and Renewable Natural Resources (Ministeria del Ambiente y Recursos Naturales Renovables [MARNR]) was created in 1977 and assumed responsibility for the Department of Fauna. In 1978, the hunting ban was extended for an indefinite period with very limited exceptions. The prohibition has definitely reduced general hunting impact on the wildlife but illegal hunting is a continuing problem in some areas. Although the government will not issue permits required for legal hunting of C. intermedius, more specific and permanent action is required. During a trip I made to Venezuela in November 1979, personnel from the Department of Fauna discussed the formation of a comprehensive National Endangered Species list. I do not know if this has been realized yet.

National Parks

Only one National Park, Aguaro-Guaritico, is found within the distribution of C. intermedius (see Fig. 2). This large Park encompasses 569,000 hectares of the Central Llanos of Guarico State and includes an extensive alluvial network of prime habitat. The crocodile appears to have been eliminated due to extensive and long-term use of the area for hunting and fishing. This occurred before the establishment of the Park in 1974. A few individuals may exist in the southern part but apparently are absent in most areas. The Park presents a logical site for a controlled crocodile release progrsm.

C. intermedius is included in the faunal list for Canaima National Park prepared by the Division of National Parks, although no reliable reports or specimens exist. The great distance from the nearest confirmed locality, plus the altitude and habitat types, make this area very unsuitable.

Captive Programs

Semi-captive breeding began in 1960 at Cachamay Park near Ciudad Bolivar, Bolivar State. Two adult pairs were acquired and successful reproduction followed. Various problems led to the escape or death of most of the subsequent young. A biologist with the Department of Wildlife last reported 32 three-year olds and 3 adults (Dr. S. Gorzula pers. comm.). Information on the current state was not available, but the Park is trying to maintain production with the ultimate goal of restocking areas which have not been designated yet.

T. Blohm has a reproductive pair in semi-captive conditions on his ranch in Aragua State. The first successful hatching took place in May 1980 and produced 14 young (Blohm this volume).

Five crocodiles were born in July 1980 at the Crandon Park Zoo in Miami, Florida, USA. The eggs, which were laid in captivity, were artificially incubated and represent the first zoo births for C. intermedius.

A clutch was collected during our surveys in Cojedes State in 1978. The resulting hatchlings marked the first successful artificial incubation for the species. The 21 surviving young are currently being raised by Dr. Sosa on his ranch in the Llanos of Cojedes.

FUDENA Project No. 28 was designed to gather eggs in certain areas following our results and recommendations. Unfortunately, the investigators arrived at the locations and were not able to find any nests. No following effort was made after hatching nor during the ensuing 1980 season.

At least 20 additional specimens (mostly unsexed) are located privately or in zoos in Venezuela. These are usually not paired, and no other reproductive success has been recorded. The present state of captive production clearly does not provide an adequate base for the species' recuperation.

Hunting

The crocodilian hide industry has been effectively dismantled in Venezuela, and no products of national origin may be manufactured or sold. Near the Colombian border some hunting still exists on a small scale, mainly for *Caiman crocodilus*. These hides are smuggled to the legal Colombian tanneries, and the products often return to Venezuela as "Colombian."

Various large, adult *C. intermedius*, wary survivors of previous hunting pressure, continue to reproduce in the Colombian border area. The resulting inexperienced offspring are occasionally taken by the caiman hunters, principally along the Meta River, and it appears that little or no recruitment into the adult population exists there. These hides, along with those of *Caiman*, are shipped to the tanning facilities in Colombia. No *C. intermedius* hides have arrived at European tanneries in the last few years (Hr. K. Fuchs pers. comm.). The low population levels make widespread commercial hunting impossible. Tighter security at the National Guard checkpoints and more rigid enforcement of the laws have helped to eliminate hunting of the crocodile as a lucrative endeavor.

A passive hunting pressure now proves to be a more important factor. This is the elimination of crocodiles that enter areas adjacent to ranches or towns during seasonal movements. Their presence is not tolerated when people feel themselves or their livestock "threatened." This accounts for a slow but continued removal of adult animals throughout most of the distribution. The single hide value, usually under US$ 50, is not so great for the Llanero and is usually a side benefit, not the main incentive. Sometimes the skin is not taken through fear of legal problems and the difficulties in selling the raw hide.

Crocodile eggs are highly prized by most Llaneros and many Indian groups and are often encountered while they search for Podocnemis nests. They report a decreased tendency for nest guarding, due to human disturbance, which leaves the clutch open to common nest predators such as Procyon and Tupinambis.

Fishing

Commercial fishing is a problem with C. intermedius, as it is with many of the world's riverine crocodilians. Huge gill nets are used and crocodiles are occasionally drowned. The nets are often stretched entirely across a stream and the fauna beaten toward the trap before closing the circle. Large wooden barriers (called tapas), 5 m to 10 m high, are sometimes erected to span small streams. The fish move downstream with the receding waters of the dry season and are swept against the barrier. Llaneros are suspended on platforms at water level and use long gaffs to remove all fish and turtles. Small crocodiles are also taken when encountered. Long fish lines (called espinel), with up to 150 baited hooks, and the use of dynamite account for occasional deaths, as do various other damaging fishing techniques.

Habitat Destruction

Continued deforestation of the headwaters in the north and west accelerate runoff, and some rivers have decreased flow in the late dry season as compared to former years. This also includes certain legally protected units, such as the Ticoporro Forest Reserve, which lost 79,500 hectares (34%) between 1950 and 1975 due to illegal hardwood exploitation (Hamilton et al. 1976). However, most loss is due to slash-and-burn agriculture, the worldwide disintegration of tropical forests.

In large portions of Apure State, the sand beaches are being intensely utilized for cotton production. This seriously reduces the sites suitable for nesting in many areas. Heavy silting from erosion and water control projects are covering beaches at other locations. How great the effects are on reproduction is not known.

Water Management

Dam construction and water diversion cause very adverse effects for fauna in some rivers. The lakes produced by the dams usually present suitable crocodile habitat but close proximity to human populations and increased use for recreation (fishing, boating, etc.) negate this factor. Human consumption and evaporation by the intensified use of irrigation remove great quantities of water from certain systems. The severely reduced flow downstream of the dams has rendered certain stetches of rivers devoid of crocodiles.

Rural Development

Amplification and modernization of the road systems in the Llanos increase the human/crocodile conflicts. The expanded use of land for ranches, farms, and communities, with the increased ease of access, has the same effect. This trend is irreversible.

Public Education

The Venezuelan government has made a major effort to increase public environmental awareness and is among Third World leaders in this respect. Major effectiveness is at the primary school level, and thus a large segment of the population remains resistant or excluded from any reorientation. The traditional characterization of the crocodile as a dangerous predator of livestock and man, with no intrinsic value, is hard to modify. Many of the crocodiles taken recently are hunted as a result of this fear. Extensive coverage of our project by the national news media emphasized the need for public cooperation for the protection of the species. The Orinoco crocodile must be valued as a significant element of Venezuelan heritage and folklore, and, if allowed to recuperate, an important renewable resource and essential component of the Llanos ecosystem. Public education is the most important factor in eliminating the slow attrition of remaining crocodiles.

Other Diverse Problems

- Widespread and indiscriminant use of pesticides and herbicides (including DDT and Dieldrin) is found. Uncontrolled applications have led to resistance in some pests and hence to increased concentrations of the highly poisonous chemicals. This vicious cycle was experienced in the U.S. and Mexico two decades ago. Local inhabitants report huge fish kills when the first rains wash out chemicals that have concentrated in the fields during dry season sprayings. The toxic effects have even led to suspected human death in eastern Colombia (Medem pers. comm.). Though no studies have been undertaken to moniter the problem, there is undoubtedly some biochemical effect on the piscivorous predator at the top of the complex Llanos foodweb. Concentration of the toxins surely occurs at this trophic level.

- The modern outboard engine provides lightweight, rapid, and economical transportation over vast areas where travel is restricted to water. It also represents the Llanos' most destructive technological advancement in terms of its impact on the fauna. Increased range of travel and access to formerly remote areas are the most detrimental aspects.

- Future plans to develop the Orinoco Tar Belt for oil production will undoubtedly cause tremendous effects on the ecology of the central Orinoco region. Impact studies are currently being planned, but the very nature of the exploitation of the petroleum-rich sands will severely degrade the environment, no matter how strict the resulting controls may be.

DISCUSSION

The distribution of Crocodylus intermedius covers an enormous and ecologically complex area. Original populations were very abundant until efficient, concentrated commercial hunting exterminated or severely reduced the crocodiles throughout their entire range. The time limitations of our project necessitated selective surveys in order to gain a general idea of the species' present condition. Reliable reports concerning areas not surveyed reinforced our discouraging findings. Field observations also indicated many important factors that presently affect the Orinoco crocodile.

Our results support the IUCN Red Data Book statement that C. intermedius is "virtually extinct in Colombia and rare in Venezuela" (Honegger 1975). Populations are very low and assistance is needed to insure the species' survival. It is interesting to note that we found no area where the crocodile has recuperated in spite of the hide industry collapse 20 to 30 years ago. At best, only minor recruitment into the population is occurring. Sporadic hunting and factors mentioned above maintain a constant pressure and the result is evident. Although C. intermedius remains one of the world's most endangered crocodilians, it is not too late to save the species. A comprehensive program that protects the remaining wild stock combined with well planned captive projects would provide safeguards for the future and is urgently advised.

RECOMMENDATIONS

1) Urgent, specific legislation in Venezuela to protect C. intermedius as an endangered species. Under this status the existing law is sufficient.

2) Increase enforcement of existing laws, not only those directly concerning the hunting and products of C. intermedius, but also those governing habitat disturbance and destruction.

3) Establish a National Park in western Apure State to include sections of the Capanaparo and Cinaruco rivers. This habitat type is not

represented within any existing Park, and survey results show a relatively abundant, reproductive crocodile population there. The Llanos fauna appears intact and protection would also be afforded to the primitive Amerindians of the region.

4) Establish a Fauna Refuge on the upper portion of the Cojedes River in the State of Cojedes. In approximately 100 km, 89 large crocodiles were found. This was the highest concentration of crocodiles/km encountered and active reproduction was also found.

5) Undertake further surveys, especially in western Apure and Barinas where reports indicate isolated populations. Nothing is known about the delta region (approx. 30,000 km^2) where possible interaction with C. acutus may exist. Results would then be utilized in formation of future sanctuaries, refuges, and/or national parks.

6) Initiate studies into the general ecology and breeding biology of the species. Further knowledge is required for proper conservation and management.

7) Research possibilities for expanded captive breeding and rearing. Existing captives should be sexed, paired, and placed in proper facilities for reproduction. Some areas of prime habitat which are devoid of crocodiles exist in regions of sparse human settlement and may be very suitable for restocking. Aguaro-Guaritico National Park is suggested for the first efforts, provided that adequate and sustained protection is provided to insure success.

8) General public education, utilizing various media, is necessary to explain the situation and to stress the need for national cooperation. A certain level of public awareness will have to be maintained throughout the species' recovery.

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THE ECOLOGY OF THE CHINESE ALLIGATOR AND CHANGES IN ITS GEOGRAPHICAL DISTRIBUTION

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According to historical relics such as inscriptions on bones and ancient bronze objects, Chinese alligators have inhabited the middle and lower reaches of the Huang River and the Chang Jiang (Yangzi) River and in Shaoxing and other areas south of Hangzhou Bay for six or seven thousand years. Literature on the anatomical features, ecology, and geographical distribution of the alligator dates back to the period from the Shang (c. 16th-11 cent. B.C.) and Zhou dynasties (11th cent.-256 B.C.) to the Qin (221-207 B.C.) and Jin (256-420 A.D.) dynasties in ancient China.

Modern scientific research on the Chinese alligator has a history of over one hundred years. Fauvel (1879) first named the Chinese alligator as *Alligator sinensis*. Barbour (1922) and Pope (1932) also wrote about the Chinese alligator. Later Sidney Hsiao (1934-35), a Chinese scholar, studied the life cycle of the Chinese alligator. Chu Cheng-kuan (1959) and Huang Chu-chien (1959, 1978) of the Institute of Zoology, Chinese Academy of Sciences, have conducted research in the same field since the 1950's. In the 1970's and 1980's, Huang Chu-chien and the wildlife survey team of Anhui Province studied the population ecology of the Chinese alligator.

ECOLOGICAL OBSERVATIONS OF THE CHINESE ALLIGATOR

Habitat

Chinese alligators are mainly found in Jingxian, Nanling, Xuancheng, Ningguo, Fanchang, Wuhu, Dangtu, Langqi, and Guangde in Anhui Province. They also live in Yixing in Jiangsu Province and in Xiaofeng, Anji, and Changxing in Zhejiang Province (Fig. 1). In the past, the Chinese alligators were mainly inhabitants of the floodlands of the Chang Jiang River and its tributaries and of lakes and swamps in lowlying areas and marshes in the hilly country. Chinese alligators, however, are now almost extinct in these areas due to the rapid increase in population density and the great changes in natural conditions over the past 20 or 30 years. At present, Chinese alligators are mainly inhabitants of marshes, sandy land, and porous dry riverbeds of the hilly country in

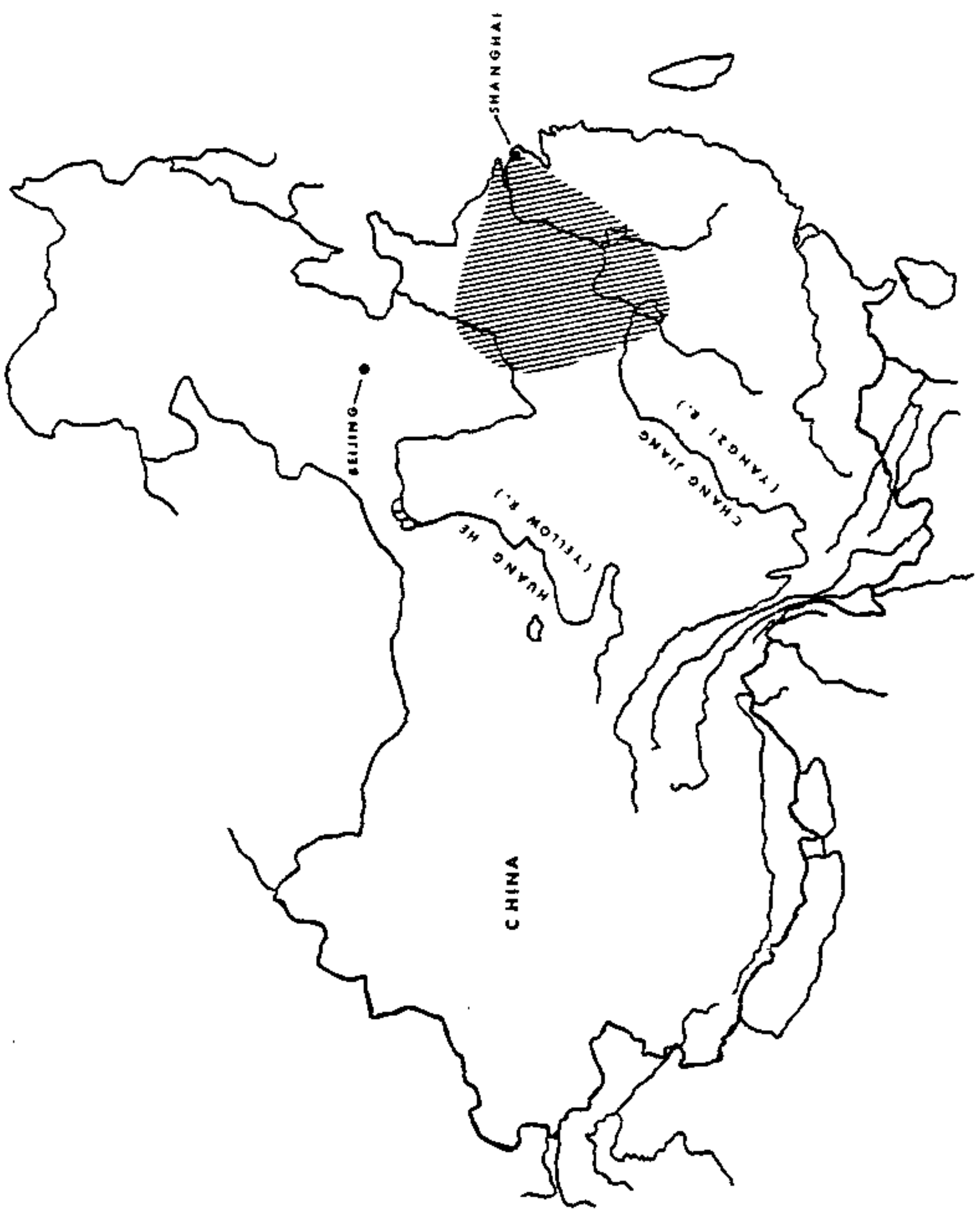

Figure 1.-- Historical distribution of the Chinese alligator in the Peoples Republic of China.

southern Anhui Province. Chinese alligators living in the marshes of the hilly country and in the bamboo groves of the farmers are not threatened by the yearly river floods, but those inhabiting reed marshes are. In order not to be drowned when their burrows are flooded, Chinese alligators often remain near the ventilation holes of their dens where they can swim to the surface of the water for breathing. Sometimes, however, pounded by flooding water, they are forced to desert their dens.

Dens

All dens of Chinese alligators are located close to marshes and swamps. The depth and structural form of their dens are commensurate with the required subterranean temperature and humidity for their hibernation in cold winter. The deepest point of their caves reaches the subterranean water level in winter. Each adult alligator has its own den, but each young alligator shares a den with its mother. The season for digging dens is from May to August. Chinese alligators start digging a burrow by removing the crusty top soil with the claws of their front feet, then shoving the soil aside and boring a hole by forcibly moving their head forward and backward. It takes a long time to complete a den. The den of an old Chinese alligator is generally long and intricate. The male and the female live apart, and their burrows are somewhat different in structure. The young alligator, though sharing a den with its mother, can dig a side den 2 m in length by itself. When a young alligator reaches adulthood, it leaves its mother and lives alone in a separate den.

The den of a male generally has two openings. The distance between the two openings is approximately the same length as the alligator living in the den. The number of perpendicular ventilation holes is in proportion to the length of a den. There are more than 10 ventilation holes in a curved den 20 m in length (Fig. 2). The ventilation holes make it possible not only for the ventilation of air but also for the Chinese alligators to float on the water in their underground pools for breathing in the event of flooding. Chinese alligators living in the marshes of the hilly country are not threatened by floods, and, therefore, their dens do not have any ventilation holes.

The den of a female Chinese alligator is more intricate, with rooms at various layers of the soil. It is divided into the principal and subsidiary chambers to accommodate the young alligator and its mother sharing a den and to adapt to the variation in the water level. The walls of the den are formed by the alligator pressing against them over long periods of time, and are therefore very firm. The curving shape of the den blocks out light and wind.

Figure 2.-- Complex den at Yishan Commune, Xuancheng County, Anhui Province. Each person is standing at an air hole. There are many more airholes than people. Entrance to den is behind man in background. Pool and trail in foreground belong to the den system. Den extends behind photographer; length of entire den system is more than 50 m. Huang Chu-chien (author) at left. (Photo by M. Watanabe.)

In terms of the structure, dens may be simple, intricate, or intermediate. A simple den has only one opening to the perpendicular wall of a stream or river embankment. It generally extends about 10 m, with no branches, and enlarges at the end into an elliptical resting platform which serves to keep the den warm for resting and hibernation.

Intricate dens have two openings to the perpendicular wall of a stream or river embankment. It extends about 20 m in a curve with branches leading to the resting platform or to a pond. It also enlarges at intervals into chambers.

Reproduction

In early May Chinese alligators come out of their dens in daytime to find food or climb up the embankment. Sometimes they float on the water to sun themselves. Beginning in early June, as it gets warmer, they generally come out at night. (The sexes are outwardly different, mainly in that the female cloaca is sunken in shape while the male cloaca is protruding.) Copulation has been seen to take place in the water. A male mounts the back of a female, and his tail bends over the tail of the female for copulation which fertilizes the eggs inside the female's body. In the period between early July and late August, the female selects a secluded spot on a slope facing the sun and not far from the marshes to build a nest. First she digs a trench in the ground with her front feet and snout, fills in the trench with decaying plant material, lays her eggs (over 10-40 eggs to each nest), and then covers them up with decaying plant material in the shape of a mound. The egg is white in color, elongated and elliptical in shape, and symmetrical at either end. Its shell is crusty. Calculations show that one female (92.1 cm in length) laid 20 eggs. Each egg was 59 mm in length, 34 mm in diameter, 110 mm in circumference, and 43 g in weight. The shell of the egg was 3.75 g in weight. Measurements of 46 eggs show averages of 0.6 mm discrepancy in diameter at both ends (0.1-1.6 mm), length of 60.5 mm (56-62.8 mm), and weight of 44.6 g (40.3-48.5 g). (The fertilization rate of eggs is quite high.) Natural hatching of eggs generally takes approximately 70 days. The young alligator pecks the smaller end of the egg with its egg caruncle and breaks the egg. In one nest observed, the young alligators emerged from their eggs at different times without help from the female. It took about one week for all the young to emerge from the 20 or so eggs in that nest. (More time is required if hatching conditions are unfavorable.) The body of the young alligator is striped in beautiful black and yellow. It moves agilely and crawls swiftly. The average body length is 21 cm, and the average weight is 30.2 g.

Hibernation and Awakening

Chinese alligators first appear in the middle of April. They generally begin to be active in early May and enter a state of hibernation in late October. A Chinese alligator, dug out on a bright day at the beginning of its hibernation, has its two eyes wide open but moves slowly and can only let out the sound "puh, puh." In a state of complete hibernation, it eats nothing and is motionless. When its burrow is opened up, we find its two eyes closed, its breath feeble, and its body stiff and prostrate at the bottom of the den.

Before mid-April the subterranean temperature of the upper layers is lower than that of deeper layers. After mid-April the subterranean temperature of the upper layers gradually surpasses that of the deeper layers. In early May, when the temperature reaches approximtely 25.0°C, Chinese alligators come out of their dens mainly in the daytime. In July and August they move about most frequently at night. In late September as the temperature drops, the number of excursions out of their dens decreases. In late October, they enter a state of hibernation at a depth of 160 cm and at a temperature of 22.0°C, and sometimes even at a depth of over 300 cm. The temperature of the dens where they lie in hibernation remains above 10.0°C throughout the whole winter.

Observation and anatomical dissection have shown that the diet of the Chinese alligator consists of 41 percent river snails, 22 percent spiral-shelled snails, and 37 percent clams, fish, and shrimp.

HISTORICAL CHANGES IN GEOGRAPHIC DISTRIBUTION

Just as other species of Crocodylia distributed throughout the world, Chinese alligators are remnants of the evolution of reptiles since the Mesozoic Era. They are inhabitants of swamps and marshes.

In the past six or seven thousand years, Chinese alligators have been found in the area between the Huaihe and the Chang Jiang rivers, in the middle and lower reaches of the Chang Jiang River, and in Shaoxing and other areas. After the middle of the Qing Dynasty (1644-1911) their territories and numbers decreased sharply. Since the end of the Qing Dynasty their territories and numbers further diminished. By the early 20th century the remaining Chinese alligators were found in the border areas between Anhui, Zhejiang, and Jiangsu Provinces (Fig. 3). The alligators' strong adaptability to the environment and food resources and, in particular, their hibernation in burrows during the long and cold winters, were the main natural reasons for this. Another factor was that these areas were thinly populated in ancient times, and no conflicts of interest existed between man and the Chinese alligator. Some people even

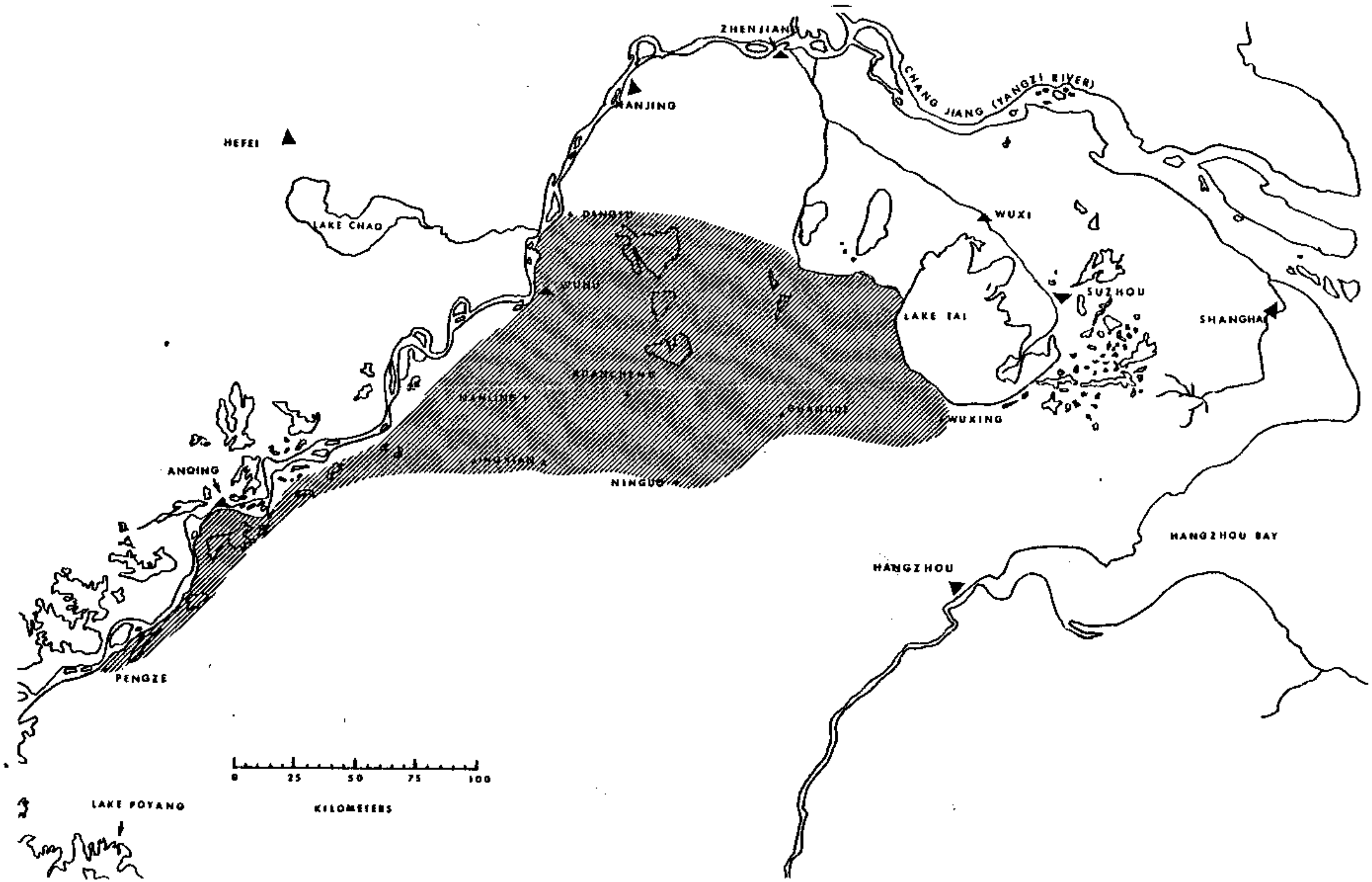

Figure 3. Present distribution of the Chinese alligator in Anhui, Zhejiang, and Jiangsu Provinces.

made Chinese alligators an object of superstitious worship, and, therefore, few were killed, and few inroads were made into their natural habitat. Moreover, the climate around 1450 A.D. was warmer than it is today. All this shows that Chinese alligators in ancient times continually adjusted to the environment mainly in keeping with the balance of ecology.

After the middle of the Qing Dynasty, populations in the abovementioned areas increased greatly. As more and more zoos and museums in China and abroad came to know Chinese alligators as a Chinese specialty, people were keen to catch them or paid high prices to purchase them. Moreover, the farmers saw them as a menace to the raising of fish and ducks. Thus, grave threat existed to the survival of Chinese alligators. In the past few decades, the inroads into their natural habitat have been aggravated because farmers have devoted themselves to growing cash crops to increase agricultural and sideline production, and no effective measures for their protection have been undertaken in the localities. The balance in the ecology of Chinese alligators has thus been disrupted, resulting in a sharp decrease in their numbers and shrinkage in the territory they inhabit.

The Chinese government has now designated the Chinese alligator a precious and rare species that is a valuable gift in the exchanges of animals between countries. The protection and propagation of the Chinese alligator is of important significance to both international academic exchange and the promotion of tourism. Therefore, the Chinese alligator has been placed in the first category of animals under national protection in China. A natural reserve has been set aside in an area inhabited by Chinese alligators in some counties in Xuancheng Prefecture, Anhui Province, where preparations are also being made to establish a farm for the artificial breeding of Chinese alligators, and to produce a color documentary film about the Chinese alligator. I am deeply convinced that the study of the Chinese alligator and this species' propagation will receive the support of scientists throughout the world and will be a contribution to mankind.

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MANAGEMENT PROBLEMS AND OPTIONS FOR AUSTRALIAN CROCODILES

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ABSTRACT: Extensive areas of northern Australia provide suitable habitat for the estuarine crocodile *Crocodylus porosus* and the freshwater crocodile *Crocodylus johnsoni*. Populations of these species are very depleted. The history of crocodile exploitation in Australia is summarized.

The two Australian species are fully protected by legislation, the enforcement of which is promoting recovery of both species. Factors operating against recovery and conservation of crocodiles in Australia are discussed as problems confronting wildlife authorities.

The long-term conservation of crocodiles in Australia depends on integrated management of the resource and its environment. In this respect, controlled commercial utilization and establishment of adequately protected areas are proposed as the only viable options for management of crocodiles. Problems inherent to commercial management of crocodiles are discussed in this context.

BACKGROUND

Suitable habitat for the two Australian species of crocodiles (*Crocodylus porosus* and *Crocodylus johnsoni*) is provided by the many rivers and creeks and their associated wetlands that drain northern Australia and intersect the northern coastlines of Queensland, Weatern Australia, and the Northern Territory (Fig. 1). Crocodiles are believed to have been numerous and widespread prior to European settlement of Australia. This belief is based on the frequent, and often colorful, references to crocodiles in the diaries of early explorers of northern Australia. Following the "opening-up" of northern Australia, individuals with a taste for adventure recognized the variety of resources that could be exploited. Initially, harvesting concentrated on the commercially more attractive *Crocodylus porosus*, but as populations of this species began to decline, the commercially inferior *Crocodylus johnsoni* was harvested also. Early hunters with unsophisticated equipment probably had little impact on crocodile populations, but as boats and firearms improved, the ability of huntera to obtain crocodiles improved dramatically. The demand for crocodile hides stimulated development of an industry, without controls to safeguard against overharvesting.

FRESHWATER CROCODILE
Crocodylus johnsoni

SALTWATER CROCODILE
Crocodylus porosus

Figure 1.-- Distribution of crocodiles in Australia (after Cogger 1979).

The result of such overexploitation became apparent and protective legislation gradually was extended to include crocodiles. Legislation to protect crocodiles was introduced at different times in the state and territories, but both species are now protected throughout Australia. The extent to which populations of each species were exploited varied, and this is reflected in the varying prognoses for recovery of each (Messel et al. 1980, Monographs 1-17; Webb pers. comm.).

TABLE 1.-- History of crocodile protection in Australia.

State	*Crocodylus johnsoni*	*Crocodylus porosus*	Legislation
Western Australia	1962	1970	Fauna Conservation Act 1950, as amended
Northern Territory	1964	~~1972~~ 1971	Wildlife Conservation and Control Ordinance 1962, as amended
Queensland	1974	1974	Fauna Conservation Act 1974

CONSERVATION PROBLEMS

Australia is a Federation of State and Territory Covernments that is responsible for wildlife conservation, while the Commonwealth Government is responsible for regulating international trade. In 1972, as a result of past exploitation, the Commonwealth Government imposed a total ban on the export of crocodile skins and skin products from Australia. Because of differences in the extent of suitable crocodile habitat between Queensland, Northern Territory, and Western Australia, the levels of exploitation vary as does the present conservation status of each species. Consequently each of these Governments does not see crocodile conservation in the same way.

Available data (Cogger pers. comm., Webb pers. comm., Messel et al. 1979-1980) suggest that both species are responding positively to protection in parts of their range. The extent to which hunting reduced different populations varied according to the passage of protective legislation and the availability of suitable habitat in different regions. The recovery of crocodile populations has not been uniform.

For example, although some Northern Territory populations of Crocodylus porosus are recovering, others are not, and C. porosus is now absent or in critically low numbers in many rivers along the east coast of Queensland which formerly contained sizeable populations (Messel et al. 1980). In 1970 the Western Australian Government protected Crocodylus porosus in that State for a period of 10 years, following a recommendation by Bustard (1970). The first comprehensive survey of C. porosua populations in selected rivers of the Kimberley Division of Western Australia was undertaken by Messel et al. (1977). By 1978 both species had been classified under Western Australian legislation as rare fauna and likely to become extinct in that State.

Total protection of crocodiles will probably result in the recovery of both species. A concomitant result of this policy may be adverse public reaction due to the reputation of crocodiles as dangerous animals. The case for crocodile conservation evokes little public sympathy in many areas; some outdoor pursuits taken for granted by citizens of northern Australia are becoming increasingly hazardous as crocodile numbers build up. Public sympathy is a major factor influencing the success or otherwise of programs for the conservation of potentially dangerous wildlife. The general public is unlikely to tolerate the presence of large numbers of a potentially dangerous animal in readily accessible areas unless it is able to benefit materially from that animal's existence. Fortunately, crocodiles occur largely in remote and sparsely populated areas where the likelihood of contact between man and crocodile is much reduced. Nevertheless, some populated centers are situated within the range and greatest concentration of crocodiles in Australia, and in these places the need for crocodile management in terms of public safety is more urgent.

Since their numbers were depleted, crocodiles until recently have not been a noticeable component of the northern wetlands fauna, and Australians residing in areas where crocodiles occur have had limited experience in coexisting with crocodiles. Rivers and billabongs (waterholes) in northern Australia have been relatively free of saltwater crocodiles and have been safe locations in which to swim and fish. Crocodiles that survived hunting have become extremely wary and are rarely seen by the public. By contrast, crocodiles born since protection have not been shot at to any great extent and have not learned to associate man with a potential threat. Loss of human life from crocodile attacks and increased public pressure could result in the removal of protection for crocodiles. Such a decision could erode the results of protective legislation and lead to the decline and eventual extinction of the species. In the Northern Territory protection of C. porosus has been enforced since 1972. Saltwater crocodiles that have survived from the 1972 group of hatchlings are now eight years old and nearing adulthood. Large crocodiles are becoming more numerous and are being seen more frequently in waters close to human population centers, and these animals are relatively fearless of man. The first generation of protected C. porosus, although not yet reproductively mature, is sufficiently large to maim or kill a human.

There exists all the ingredients of a conflict situation between man and crocodile, and between the interests of public safety and wildlife conservation. This conflict was highlighted late in the 1979 Dry Season by the unfortunate death of a person taken by a crocodile in the sea at Nhulunbuy in northeastern Arnhem Land.

The problem now confronting wildlife authorities is to develop not only scientifically based management of the resource, but also (and perhaps more importantly because successful conservation management of crocodiles depends on it) an intensive program of public education of the ecological role of crocodiles and the potential dangers of living with these reptiles. Creating a public awareness of the hazards associated with bathing, boating, and similar activities in areas frequented by crocodiles is fundamental to any conservation program. Such awareness already exists in relation to other potentially dangerous animals, such as stone fish, box jellyfish, and sharks. With time, the number and size of protected crocodiles are going to increase. The problem is not going to disappear; in fact without appropriate measures the situation could worsen. Wildlife authorities responsible for crocodile management must develop credibility regarding their ability to manage "problem" crocodiles which have attacked or have caused concern to members of the public. Crocodile management should include relocation of problem animals; unfortunately attempts to capture large crocodiles often result in the animal's death unless special precautions are taken.

The overall similarity in appearance between C. johnsoni and the larger, more dangerous C. porosus results in the unwarranted persecution of the former.

The buildup of crocodile populations in Australia is hindered by commercial fisheries and the activities of poachers.

A general worldwide decline in the availability of crocodiles has produced an increased demand for crocodile hides. Illegal trafficking in crocodiles skins exists and is not confined to a particular species, although, because of differential exploitation of the two Australian species and the biological characteristics of each, there may be greater reward for effort at present in C. johnsoni poaching. Crocodylus johnsoni has increased its numbers more rapidly than C. porosus (Webb pers. comm.), and the freshwater crocodile is now much more common than the saltwater crocodile. It is a relatively easy operation to net individual waterholes and remove large numbers of animals without expensive equipment. Consequently, populations of freshwater crocodiles inhabiting billalongs are vulnerable to overexploitation, particularly in the late dry season when animals are crowded into remaining waterholes. Entire populations may be removed by netting. While aerial surveillance of the northern coastline has significantly improved law enforcement, the dense canopy of vegetation characteristic of freshwater billabongs, the great number of billabongs, the remote location and general inaccessibility of many areas inhabited by crocodiles, and the limited number of enforcement officers have made it difficult to stop all poaching activities. Law enforcement must be improved if conservation management of crocodiles in Australia is to be successful. State, Territorial, and Commonwealth legislation provide varying penalties for offenses committed. Increased Government awareness in recent years to the importance of wildlife conservation has resulted in increased penalties for breaches against the legislation. The severity of penalties (Table 2) very often reflects the date of the legislation.

Commercial fishing is a multi-million dollar industry in northern Australia. The barramundi, Lates calcarifer, is the principal commercial fish. The intensity of commercial barramundi fishing in some Northern Territory rivers is a major factor working against the survival of mature saltwater crocodiles and the overall recovery of crocodile populations in these areas. Large crocodiles are frequently drowned in fishing nets set in the rivers. At least 100 saltwater crocodiles are drowned annually in commercial barramundi nets set in the Alligator Rivers Region, viz. East, South, and West Alligator rivers, Wildman River, and Murgenella and Cooper creeks (Messel et al. 1979-1980). The problem is compounded by extensive poaching for both crocodiles and barramundi.

Although C. porosus has recovered substantially throughout some parts of its range, its capacity to continue to do so depends on preserving the large reproductive adults. Male crocodiles that were born in the first year of protection are still non-reproductive, and females of this age can be considered as immature reproductives that must yet attain maximum fecundity (Webb et al. 1978). The dynamics of riverine populations of C. porosus are such that individuals within a given population are not confined to a particular river (Messél et al. 1979-1980). Different stages in the life of a saltwater crocodile between hatching and maturity may be spent in different rivers which comprise a complementary ecological suite of adjacent rivers. If this is so, then any impedence (such as fishing nets) to the movement of crocodiles into or out of a river may seriously impair the ability of that population to increase and disperse. Often rivers with high numbers of saltwater crocodiles also produce good commercial catches of barramundi. A relationship may exist between C. porosus and barramundi similar to that suggested by Cott (1961) between Crocodylus niloticus and commercial fisheries in African lakes and rivers. Unless a serious attempt is made to rationalize the use that is currently made of fish resources in the estuarines and along the coastline of northern Australia, saltwater crocodile recovery will not be fully realized.

Another factor operating against the recovery and conservation of crocodiles in Australia is habitat destruction and predation by introduced animals. The rivers that comprise the Alligator Rivers Region and that drain the extensive plains in the Northern Territory to the west of Arnhem Land provide vast areas of suitable nesting habitat for Crocodylus porosus. Conservation of C. porosus in this region is seriously impaired because much of the vegetation fringing the rivers is destroyed by large numbers of introduced water buffalo and feral pig. Concentrations of these animals can, in a very short period, totally

Table 2.-- Penalties for offenses involving protected fauna in Australia.

State	Legislation	Penalty Provisions
Northern Territory	Territory Parks and Wildlife Conservation Act 1980	$2000 or imprisonment for 6 months, or both; and an additional $100 for each animal in respect of which the offense was committed.
Queensland	Fauna Conservation Act	$100-$1000 first offense; $200-$3000 second or subsequent offense; an additional $200 for each animal in respect of which the offense was committed.
Western Australia	Fauna Conservation Act 1950, as amended	$400 maximum for an offense against the Act in respect of protected fauna.
Commonwealth	National Parks and Wildlife Conservation Act 1975, as amended	The legislation provides for a maximum penalty of $5000 and $1000 for each day during which the offense is committed. The Regulations provide for a $2000 maximum penalty.
Commonwealth	Customs Act 1901, as amended	$1000 against the person committing the offense; possible supplementary penalties against the owner/operator of the means of transport.

denude riverside vegetation and promote erosion of the riverbanks. Local eradication and controlled shooting to reduce numbers of water buffalo in order to restore "nesting" vegetation is not easily achieved. Buffalo have become an important source of revenue and protein to both white and Aboriginal Australians. Several privately-operated abbatoirs are currently exporting buffalo meat and provide employment for Aboriginals, and these operations cannot be scaled down overnight.

Crocodile nests which are constructed in freshwater wetlands are more vulnerable to predation by feral pigs than those nests situated on the banks of tidal rivers. Natural predators of crocodile eggs of both species are large monitor lizards, Varanus mertensi and Varanus gouldii, which are sympatric with crocodiles in Australia.

MANAGEMENT OPTIONS

Australian Government agencies are faced with a crocodile resource that at best has begun a recovery brought about by enforcement of legislative protection. For reasons outlined previously, continued enforcement of total protection without formulated management will fail to achieve the desired objective (viz. long-term conservation of crocodiles in Australia).

Intensive hunting in the past and, more recently, poaching and fisheries netting activities have reduced populations of C. porosus in some regions to such an extent that substantial recovery may not occur for a considerable time, if at all. In the absence of quantitative data on C. johnsoni throughout most of its range, its status is uncertain. Consequently most of the following discussion of management options is directed to C. porosus. Artificial "seeding" of rivers with subadult crocodiles may be considered to increase recruitment; however, stocking programs are generally expensive both financially and in terms of effort and should only be undertaken after careful monitoring of natural recovery.

It would be counter-productive to restock habitat situated near human settlements which, because of its proximity to townships, have few to no crocodiles resident in them. There is little benefit in adopting management policies that will aggravate public antagonism to crocodiles. Accordingly, it may be appropriate to designate certain waterways near human population centers as "crocodile free" buffer zones. Active management may be required to maintain designated rivers free of large crocodiles.

Restocking rivers with crocodiles from widely separated geographic locations may result in an unacceptable mixing of isolated gene pools and loss of genetic diversity. A program has been commenced by researchers at the Australian National University, Canberra, to karyotype crocodiles from different regions snd obtain genetic signatures for different populations. This should assist future restocking strategies.

Based on extensive surveys, Messel et al. (1980) provided an explanation of the dynamics of *Crocodylus porosus* populations which inhabit tidal wetlands of northern Australia. Provided this is a correct interpretation, these data are essential for the development of successful restocking strategies. *C. porosus* nesting and age class distribution is largely determined by salinity characteristics of each river. Messel et al. (1980) classified Type 1 tidal rivers as meandering rivers with a continual freshwater input throughout the year. Dry season inflow of fresh water is greatly decreased but sufficient to prevent upstream salinities from exceeding sea water values measured at the mouth. These rivers provide the majority of hatchlings that enter populations in each season. The opposite extreme is the Type 3 rivers which are generally short in length and hypersaline. Freshwater input in such rivers is restricted to the wet season. During the dry season salinities in upstream sections exceed those measured at the mouths. Type 2 rivers are intermediate between Type 1 and Type 3. The suitability of a Type 2 river as nesting habitat will depend on its affinity to either Type 1 or Type 3 rivers. Non-Type 1 rivers are usually poor or non-breeding systems (Messel et al. 1980) and generally contain a higher proportion of subadult *C. porosus* larger than 1.3 m. They serve as rearing grounds for animals until adulthood, at which time crocodiles leave the rivers to return to Type 1 breeding rivers.

Magnusson (1979) has shown that during the first six months, hatchling *C. porosus* are relatively sedentary, remaining near the nest site. Formation of a creche by the maternal female appears to extend the period of sedentary behavior in hatchling *C. porosus* (Jenkins unpubl. data). Dispersal in subadult *C. porosus* in tidal rivers is a function of age (Webb and Messel 1978). Thus, age at which *C. porosus* are restocked might determine the river type into which they are liberated. Crocodiles that are reared for 2-3 years or more would be released into non-Type 1 rivers in order to reduce unnecessary mortality that may result from contact with reproductive adults resident in Type 1 systems. On the other hand, hatchlings would be released into Type 1 breeding rivers. Obviously, movement patterns of captive bred animals might be different. Type 1 rivers selected for restocking should be surveyed, and the hatchlings released where salinities vary between 4 and 20 $^{o}/oo$. It is within this range of salinity that Messel et al. (Mono. 1, 1980) have demonstrated reduced natural mortality of *C. porosus* hatchlings. A restocking program involving the release of subadult crocodiles (other than hatchlings) would require more capital investment and a detailed understanding of the dynamics of non-Type 1 populations of subadult *C. porosus*. Some of the information that would ensure successful restocking is not yet available, and further study, using radiotelemetry, of the movement of subadult *C. porosus* is urgently needed.

If sustained exploitation of crocodiles in Australia proves to be the only viable management option that will ensure the long-term conservation of this resource, management strategies will need to be formulated for this purpose. The populations of both species of crocodile are not yet sufficiently plentiful to sustain even the most limited commercial harvesting directly from the wild. Data to facilitate commercial management of crocodiles in Australia are inadequate. Sustained-yield harvesting of crocodiles depends on an accurate assessment of natural mortality in the subadult age classes. When equilibrium has been reached, this surfeit of crocodiles then is the proportion of the population which can be harvested without adversely affecting the survival of the population. In fully equilibrated populations sufficient numbers of subadult crocodiles survive to reproductive maturity each year to compensate for the loss of reproductive adults. Recovering populations require annual recruitment of reproductives to exceed loss. Excessive commercial exploitation that would seriously impair recruitment potential of a recovering population should not be contemplated.

Following a period of conservative harvest quotas it may be possible to increase the size of annual quotas at a rate equal to the increase in population size until a maximum sustainable harvest level has been achieved. Excessive quotas, determined by non-biological parameters, will ultimately exhaust the crocodilian resource.

Crocodiles are totemic for many communities of Australian Aboriginals. Management of crocodiles in Australia must take into account the traditional relationship between Australian Aboriginals and crocodiles and, in so doing, ensure that adequate safeguards are incorporated into management strategies so the significance of this relationship will be preserved. Accordingly, commercial exploitation of crocodiles on Aboriginal-owned land might be restricted all together or limited to certain districts. Actual harvesting of crocodiles would be undertaken in accordance with a crocodile management program and subject to Government controls. A particular Aboriginal community that owned traditional land rights over a gazetted crocodile commercial zone would have the following options open to it:

- Harvesting of animals undertaken by members of the community.
- Harvesting of animals undertaken by agents operating under contract to the community.
- Harvesting of animals undertaken by licenced operators with payment of a royalty per crocodile taken. Royalities would be determined by a set percentage of the value of each skin.

Adoption of these policies will facilitate greater economic independence of some Aboriginal communities in a manner similar to that which is being achieved in Papua New Guinea. Such policies will provide additional incentive for Aboriginal communities to pursue a traditional life-style and benefit economically from preserving the natural environment.

Ultimately the management of crocodiles in Australia can and should entail the commercial harvesting of animals from selected rivers during a defined open season. Controls established in Louisiana, U.S.A. (Palmisano et al. 1973), for the experimental harvest program of

Alligator mississippiensis in 1972 are directly applicable to any similar such harvest of either Australian species. Controls on commercial exploitation of wild crocodiles in Australia must be uniform between the different political divisions. Duration of the open season may vary from State to State according to the summation of regional quotas in the States. The timing of commercial open seasons should not coincide with breeding and nesting of the two species. This applies particularly to *Crocodylus johnsoni* harvesting more so than to *Crocodylus porosus* harvesting which should be restricted to non-Type 1 river systems. Unlike *C. porosus*, *C. johnsoni* populations do not appear to exhibit similar partitioning between reproductive mature and immature animals.

Size limits, both maximum and minimum for each species, should ensure that marketing (and thereby harvesting) is restricted to legally obtained specimens. Commercial harvesting zones in Australia might be divided into distinct districts with a field center in each district, staffed by Government officers, for certification of skins taken during the season.

Because of the importance, in terms of *C. porosus* recruitment, of retaining Type 1 breeding rivers in an undisturbed condition, every effort should be made to establish the more important of these systems as protected areas. *Crocodylus porosus* harvesting should be restricted to non-Type 1 systems. Figures 2a-c display the geographic distribution of Type 1 breeding rivers in northern Australia (prepared from data obtained by Messel et al. 1979-1980). Conservation management of both crocodile species entails the protection of adequate areas of suitable habitat that will ensure, to the greatest extent possible, unhindered recruitment. Included in Figures 2a-c are boundaries of existing national parks and nature reserves that have been established in areas of suitable crocodile habitat. Aboriginal reserves have not been included because of the often multi-purpose approach to land and resource management which, in some instances, may jeopardize the objective of crocodile conservation.

At present *Crocodylus porosus* is included in Appendix I. Papua New Guinea populations of *C. porosus* have been retained on Appendix II along with *Crocodylus johnsoni*. CITES does not permit commercial international trade in specimens of Appendix I wildlife. However, trade is permitted for products derived from Appendix I species that have been bred in captivity. Such a closed-cycle crocodile farm is being developed by Applied Ecology Pty. Ltd. so as to comply with the provisions of CITES with respect to *C. porosus*. Through the efforts of Applied Ecology Pty. Ltd. the Australian Government is well advanced toward establishing the first closed-cycle crocodile farm. The investigations by Applied Ecology are being sponsored by the Commonwealth Government through the Minister for Aboriginal Affairs and are aimed at assisting Aboriginal communities in attaining some economic independence. In accordance with Government policy the farm will not become fully operational until an Environmental Impact Statement on the proposal has been submitted to and approved by the Commonwealth Minister responsible for environmental matters. The Northern Territory Government recently announced its intention to establish two commercial crocodile farms in that State.

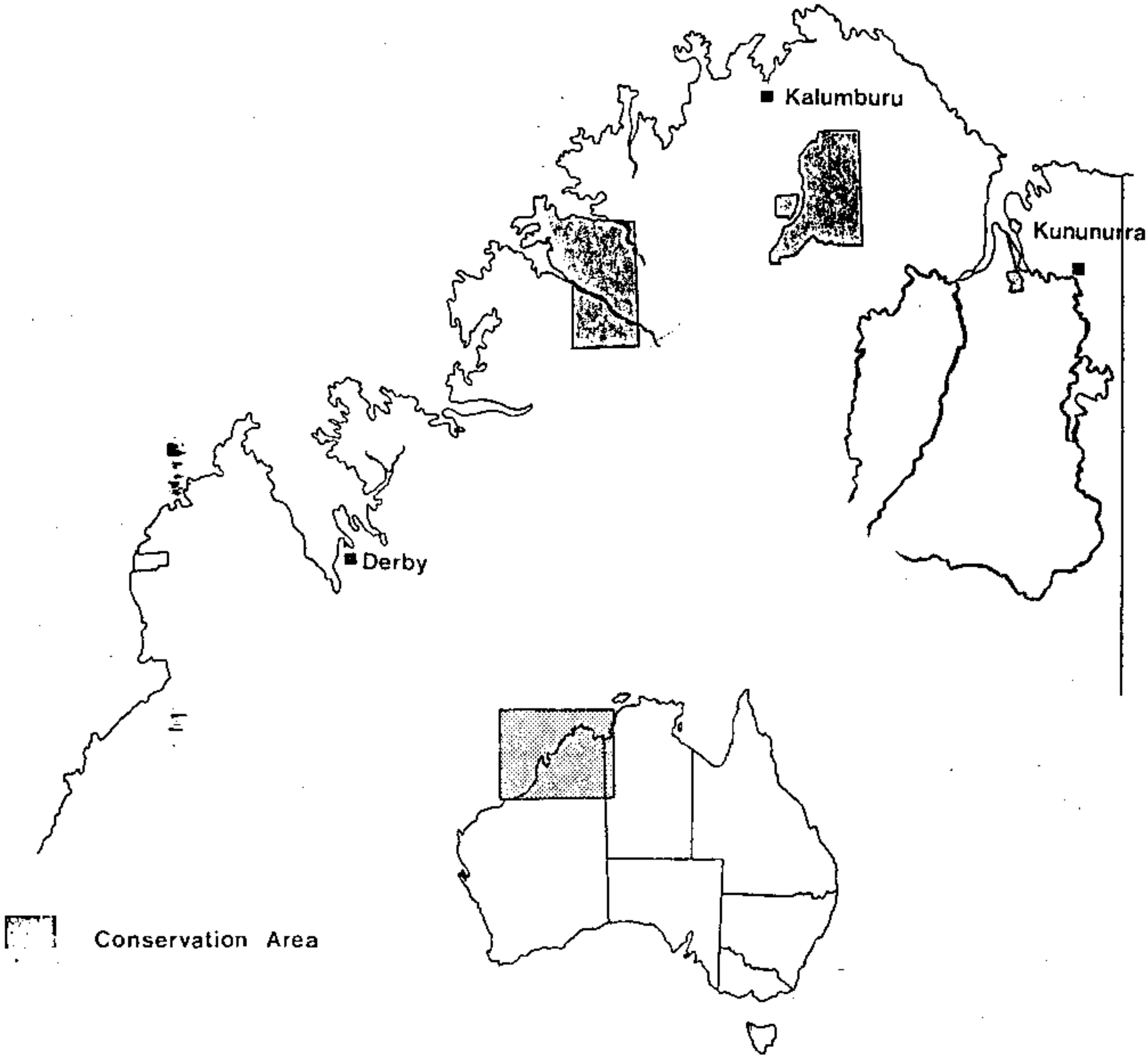

Figure 2a.-- Type 1 Rivers in conservation areas in Western Australia.

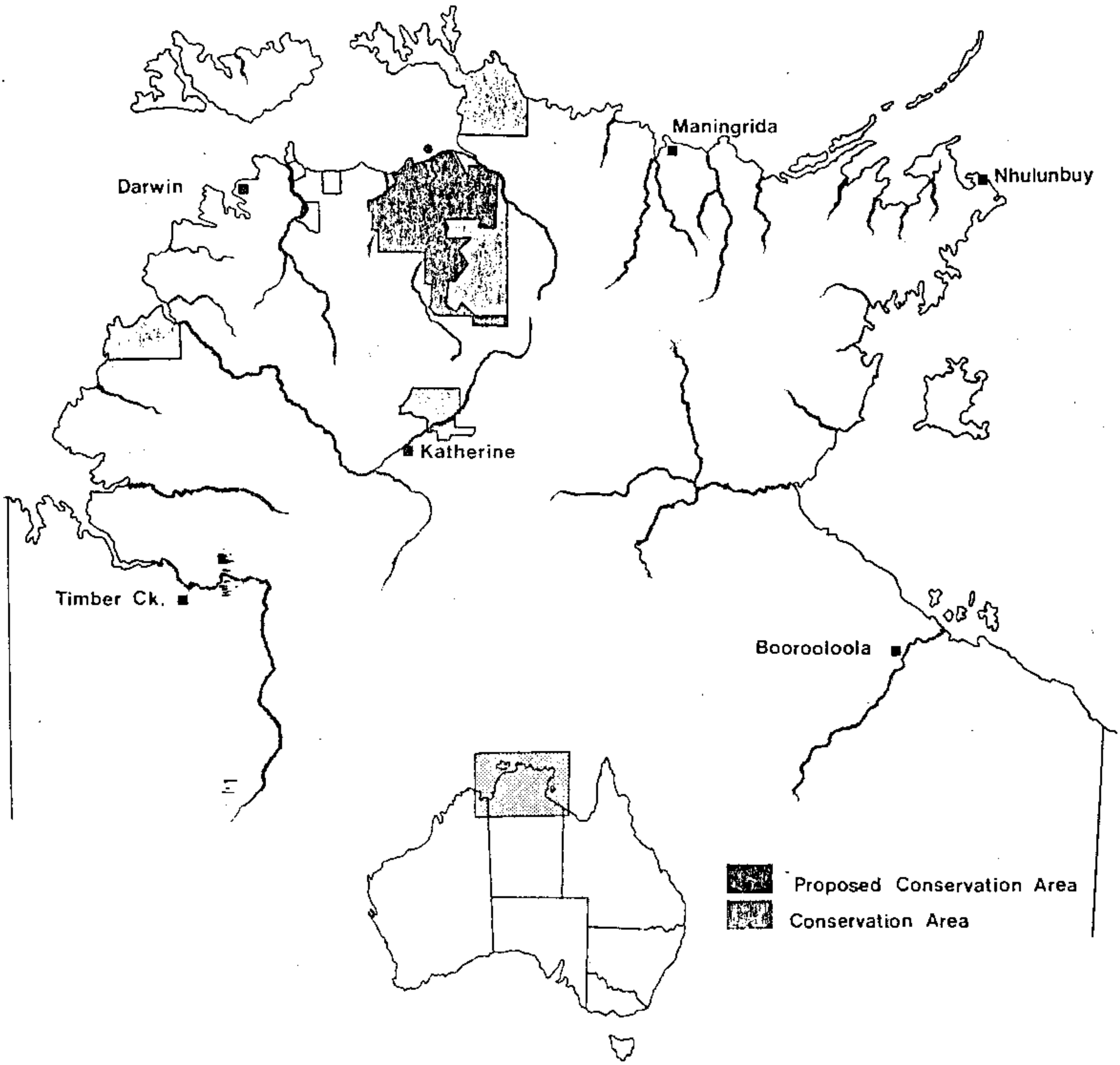

Figure 2b. Type 1 Rivers in conservation areas in Northern Territory.

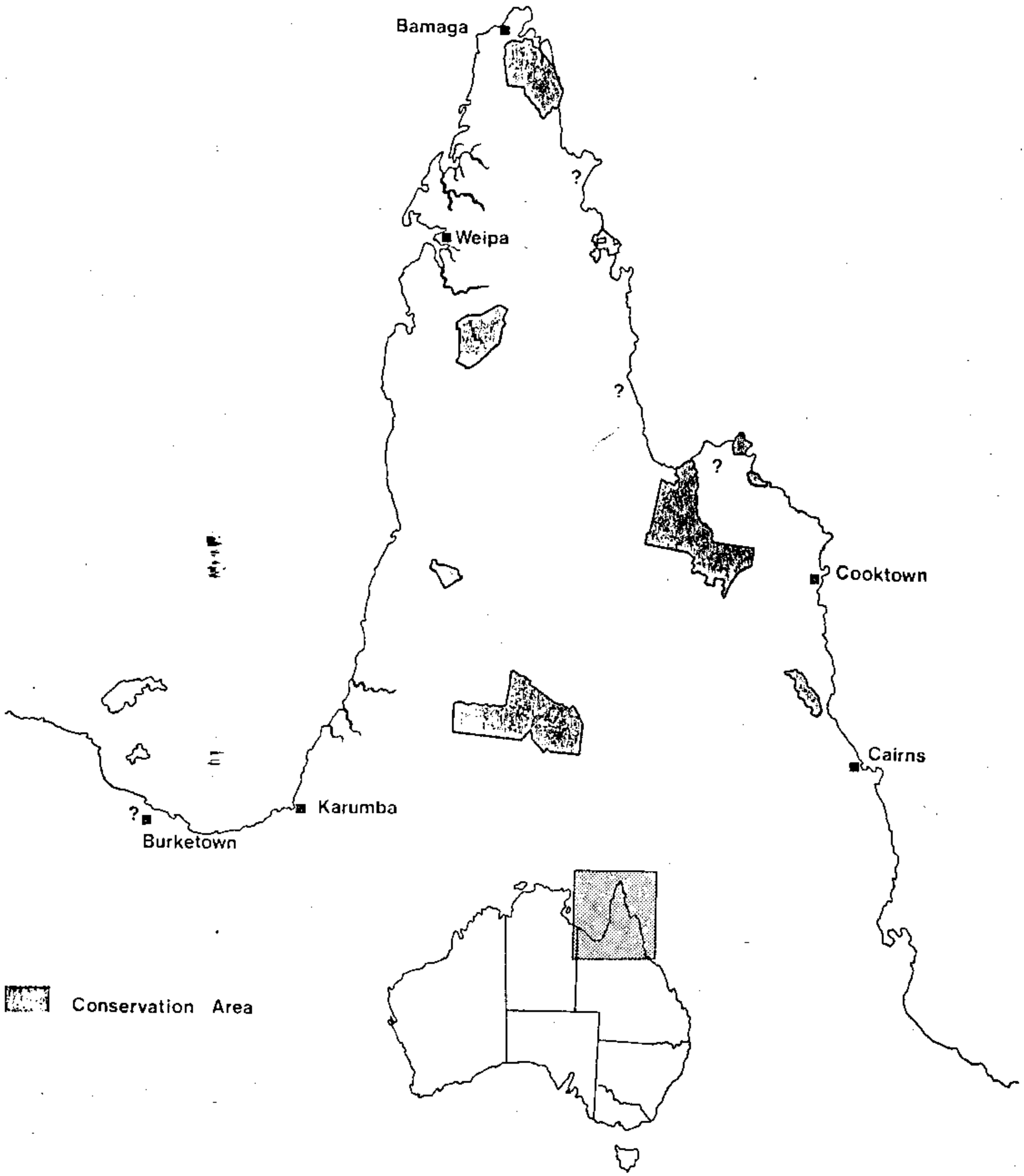

Figure 2c.-- Type 1 Rivers in conservation areas in Queensland.

Marketing of skins derived from captive-bred crocodiles must be effected in such a manner as to prevent export of skins taken illegally. Marketing controls similar to those documented by Palmisano et al. (1973), with the use of sealed, numbered tags and stock registers, are considered sufficient to ensure that export is restricted to farmed skins and that the provisions of CITES are satisfied.

Until it can be demonstrated that *Crocodylus porosus* populations in northern Australia have recovered sufficiently to enable the species to be placed on Appendix II of CITES, legal commercial export of *C. porosus* skins must be restricted to those derived from "farmed" animals. If commercial harvesting becomes a reality, restriction of trade to skins derived from farmed crocodiles would remove pressure on wild populations of crocodiles and facilitate their recovery. An agreed percentage of subadult "farmed" crocodiles may be released at predetermined locations, to further enhance the recovery capacity of wild crocodiles.

Commercial crocodile farms, both Government and privately sponsored, should provide a source of employment for qualified and unskilled members of the workforce. These establishments, if located in easily accessible regions, will be tourist attractions which, in addition to supplementing the income of the farms, will assist in fostering public appreciation of crocodiles.

An alternative marketing policy, if foreign trade relations were not jeopardized, would be to restrict export of crocodile skins to Parties to CITES which had not entered reservations with respect to Appendix I crocodilians. Australia, as a responsible Party to CITES, would be concerned if by allowing crocodile skins to enter the international market it facilitated illegal international trade in crocodile skins. The IUCN/SSC Crocodile Specialist Group and CITES need to develop a World Crocodilian Marketing Policy to ensure that all crocodile skins entering trade do so according to uniform controls on identification, certification, and volume.

ACKNOWLEDGEMENTS

I wish to express my thanks to Professor H. Messel for making available much unpublished data on *Crocodylus porosus*, and for giving freely of his time to discuss implications of these data and the future conservation management generally of crocodiles in Australia. My thanks to Graham Webb for providing unpublished information on *Crocodylus johnsoni* and other valuable comments to this manuscript.

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CLASSIFICATION AND POPULATION STATUS OF THE AMERICAN ALLIGATOR

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The U.S. Fish and Wildlife Service places the alligator (Alligator mississippiensis) in three basic classifications, i.e. endangered, threatened, and threatened S/A, throughout its range in the Southeast United States. These categories simply designate status of the animal in relation to its recovery or rate of recovery. Generally, the endangered status would indicate low populations, whereas the threatened status indicates an increasing population no longer in danger of extinction, and the threatened S/A status indicates a recovered population. Other important factors are also considered in making these determinations, such as habitat evaluations and state research, management, and enforcement programs. Today, alligators in 28% of the U.S. range are classified as threatened, 69% as endangered, and 3% as recovered (Table 1).

Since the IUCN meeting in Madras, India, 3-13 February 1978, the U.S. Fish and Wildlife Service reclassified the biological status of the alligator only in portions of Louisiana. As a result of reclassification, nine additional coastal parishes were classified as threatened S/A. Presently, 12 parishes in Louisiana are classified as threatened S/A.

All the 64 counties in Florida were delisted from endangered to threatened status, allowing a limited experimental harvest beginning in 1977.

Three Louisiana parishes were delisted to threatened S/A in 1974. All or part of 27 parishes were delisted from endangered to threatened in 1977, with 9 of these parishes being further delisted to threatened S/A in 1978; 33 parishes retained endangered status. Texas delisted 14 of 74 counties reporting alligator populations. In South Carolina 5 counties were delisted to threatened, while 23 remained classified as endangered. Alligators in 21 Georgia counties were delisted to the threatened status; 74 counties retained their endangered status. All of Mississippi, Alabama, and North Carolina are considered endangered under the present classification system of the U.S. Fish and Wildlife Service (Joanen and McNease 1978).

Table 1. Alligator classification status by state, 1 July 1980.

State	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	12	33	18	63
Florida			64	64
South Carolina		23	5	28
TOTAL	12	303	122	437
Percent	2.8	69.3	27.9	

At the CITES meeting held in Costa Rica in March 1979, members of the U.S. delegation submitted a proposal to delist the alligator from Appendix I to Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. This proposal was unanimously passed, thus allowing international trafficking in legally taken alligator skins. The U.S. Management Authority, along with the Scientific Authority, implemented the regulations and requirements governing shipment of skins.

CURRENT POPULATION STATUS BY STATE

Ten states reported having alligators present in all or parts of their 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 the high densities characteristic of Gulf coast states.

Louisiana

The coastal marsh population, where nest count indexes were used to calculate population levels, increased approximately 70% from 1977 to 1980. Nest count data indicates an annual increment of approximately 15% 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. Louisiana personnel surveyed 36 different areas of the atate, covering a total distance of some 327 miles. Alligators per mile averaged 3.14 for the 36 transects (Chabreck 1980).

Florida

Population increases are occurring throughout Florida (Hines pers. comm.). One inland lake surveyed by the nest count method increased from 45 nests in 1978 to 90 nests in 1979. Summarizaton of night count data by year demonstrated an average of 5.0 alligators per mile in 1974, 4.6 in 1975, 6.3 in 1976, 9.4 in 1977, 6.8 in 1978, and 7.4 in 1979.

Georgia

A 1980 alligator population survey indicated population increases are occurring in most of Georgia. An analysis of population trends by counties showed that 72 were increasing, and 36 were stable. The statewide population was estimated at approximately 95,000 over a 108-county area, with a 15% increase as compared to the 1977 survey (Odom pers. comm.).

Texas

The 1980 statewide population was estimated at 68,692, a 25% increase since 1977. Listed as having increased populations were 48 counties, 21 showed stable trends, 4 were decreasing, and 23 undetermined. Alligator habitat was estimated at 5735 sq mi in 1977-78. The statewide average density was estimated as 11.79 alligators per sq mi. Seven night count surveys covering some 27 mi averaged 4.5 alligators per mile in Texas (Brownlee pers. comm.).

Alabama

No current population estimates are available for Alabama. However, the 1978 night counts conducted in Mobile and Baldwin counties indicate a 17% increase as compared to the 1977 surveys. Four routes from 20 to 35 miles in length were run in the 2-county area. In 1978, 1039 alligators were observed compared to 891 for the same routes in 1977 (Keeler pers. comm.).

Arkansas

Alligator range is limited in Arkansas. The trend in Arkansas's alligator population since 1977 is considered stable to slightly increasing. Since 1972, the state restocked 2000 alligators from Louisiana in 34 counties lying within the species historic range. Today, 37 counties possess alligators to some degree (Barkley pers. comm.).

South Carolina

Of 28 counties containing alligators in South Carolina, 7 reported increasing populations. Increases were estimated as much as 25%. Nine counties reported stable populations, and the status of 12 counties was unknown (Murphy pers. comm.).

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 (Smithson pers. comm.). North Carolina based this information on several sources:

1) Questionnaire returns from coastal plain hunters and fishermen.

2) Questionnaire returns from North Carolina Wildlife Resources Commission field personnel and other natural resources field workers.

3) A computerized file of alligator sightings maintained by the North Carolina Natural Heritage Program.

4) Night cruise-count surveys conducted by members of a North Carolina State research team during 1979 and 1980.

5) Intensive field work on one study area from 1977 to 1980 and on a second study area from 1979 to 1980.

Mississippi and Oklahoma

No current population estimates are available for these states. Mississippi's night count data for 44.5 miles of survey lines indicated an average of 1.0 alligators per mile (Chabreck 1980). Oklahoma reports alligators occurring in only McCurtain County. This small population is characterized as stable (James pers. comm.).

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REVIEW OF THE STATUS OF THE AMERICAN CROCODILE

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STATUS.-- Endangered.

DISTRIBUTION.-- Historically from Mexico south through Central America to Peru and Venezuela. Also found in Cuba, Hispaniola, Jamaica, and South Florida, U.S.A.

REGIONAL STATUS

BAHAMAS.-- Suitable habitat is found on the west coast of Andros Island, only 110 miles (180 km) north of Cuba and 120 miles (193 km) east of Florida, both of which have populations of *Crocodylus acutus*. However, extensive surveys of the area have failed to reveal the presence of any crocodile (King pers. obs.). Although extinct in the islands today, and not recorded there in historical times, crocodiles once occurred in the Bahamas. The Florida State Museum, U.S.A., has preColumbian fossils of crocodiles from New Providence Island, Bahamas.

BELIZE.-- The distribution of *Crocodylus acutus* relative to *C. moreletii* in Belize is poorly understood. Powell (1971) reported that *C. acutus* was rare on the mainland but somewhat more common on the offshore islands. More recent information indicates that the populations of the islands have been eliminated (Ross and Ross pers. comm.), and a recent survey of the mainland located only *C. moreletii*, no *C. acutus* (Abercrombie et al. this volume; see also Charnock-Wilson 1973, Neill and Allen 1961).

* Deceased.

Crocodiles are still observed inland and occasionally in coastal areas in Belize, but most individuals are C. moreletii (Weyer pers. comm., Abercrombie et al. this vol.). Population levels (Abercrombie 1978) and intense public education efforts (Weyer pers. comm.) have reduced intensive hunting, but crocodiles are still killed as targets of opportunity. However, the Belizean government banned the export of hides in 1981 (Abercrombie pers. comm.).

CAYMAN ISLANDS.-- Although specimens of Crocodylus acutus have been collected on both Little Cayman and Cayman Brac, they may have been vagrants from Cuba or Jamaica, or possibly from a resident breeding population (Garman 1888, Grant 1940).

COLOMBIA.-- Crocodylus acutus occurs along both the Atlantic and Pacific coasts and their drainages in Colombia (Medem 1958, 1962) and is now totally protected (Resolucion No. 411, 16 July 1968, Ministerio de Agricultura; Resolucion No. 573, 24 July 1969, INDERENA).

Hunting for this species began in the late 1920's, and before it was abandoned as an organized activity in the late 1940's due to depletion of the stocks, over 500,000 hides were taken (Medem 1971, 1978). Native hunters continued to kill the remaining crocodiles through the 1960's. Today, populations in some river systems have been totally eliminated. Others are so depleted that they are unlikely to recover without assistance in the form of restocking. Biological survey teams in the Atrato River swamps working on surveys for a new transisthmus ship canal route in the late 1960's seldom reported seeing crocodiles (Campbell pers. comm.). Periodic regional surveys throughout the whole of Colombia during the 1970's have consistently confirmed the loss of this species from most of its former range, and the absolute absence of even moderately abundant populations anywhere (Medem 1978, pers. comm.). The existing protective legislation is not routinely or consistently enforced. The species must be considered endangered in Colombia.

COSTA RICA.-- Historically Crocodylus acutus occurred along both coasts and into the larger rivers. Today, it is seen only sporadically, primarily in Guanacaste Province and in the Tempisque River and major tributaries (Powell 1971). Crocodiles are afforded partial protection in that the hunting season is closed for six months each year in the Pacific drainages and four months in the Atlantic (Powell 1971). However, enforcement of the legislation is difficult in remote areas, with a flourishing traffic in illegal hides across the Nicaraguan border (Powell 1971, Vaughan pers. comm.). Some populations are protected within existing national parks, but outside these sanctuaries the species must be considered severely depleted.

CUBA.-- Crocodylus acutus was once distributed throughout the island in saline habitats, being replaced by C. rhombifer in freshwater habitats. By 1917 C. acutus had been depleted along the shores of Ensenada de Cochinos (Bay of Pigs), and by 1919 the personnel of the U.S. Naval Base had eliminated C. acutus from the rivers and estuaries around Guantanamo Bay in eastern Cuba (Barbour and Ramsden 1919). After the Castro government took power, major habitat alteration programs associated with agricultural expansion were initiated, and all crocodiles that could be captured were placed into "corrales" located near the Zapata Swamp in south coastal Cuba. Both *C. acutus* and *C. rhombifer* were mixed in the corrales, and an intensive husbandry program was initiated, but unfortunately the two species were hybridizing in the corrales. A pure stock of *C. rhombifer* has now been segregated into a separate breeding compound (Varona 1980), but apparently no such facility has been established for *C. acutus*. Scattered aggregations of *C. acutus* still occur on the north coast, west of La Habana, and along the southern coast, including the Isle of Pines, but crocodiles are still persecuted where they occur (Varona *in litt.* to Moler 1980). Some measure of protection is now provided by Resolucion No. 21-79, which prohibits all hunting in several important areas (Varona 1980).

DOMINICAN REPUBLIC.-- Historically crocodiles occurred around the coasts of the country in suitable habitat and inland in large rivers. Today the populations are reduced or eliminated throughout most of the historical range, with small remnant populations in the mangrove swamps of the Rio Montezuma near Monti Cristi in the northwestern corner of the country (Powell 1971), possibly in the Rio Samana west of Samana Bay (Campbell pers. obs.), and a surprisingly large population in the saline Lago Enriquillo in the southweat of the country (Powell 1971, Duval 1977, King pers. obs.). The species is legally protected, but local killing of crocodiles as vermin or for local apothecary use continues (Garrick *in litt.*). The population in Lago Enriquillo, estimated to number between 175 and 250 adults, may be the most locally dense population of this species still extant anywhere. However, it is threatened by land use practices around the lake which have already diverted the majority of the freshwater streams away from the lake for irrigation use. This has increased the hypersalinity of the water to the point that hatchling crocodiles can no longer survive in the lake (Dixon *in litt.*, Inchaustequi pers. comm., King pers. obs.). In addition there has been some increase in local hostility toward crocodiles (Garrick *in litt.*). The species must be considered endangered in the Dominican Republic.

ECUADOR.-- *Crocodylus acutus* was once very abundant along the Pacific coast and larger rivers (La Condamine 1778, Whymper 1882, Wolf 1892, Spillman 1951, Medem 1973a, b) with peak populations numbering in the thousands in the Rio Guayas, Rio Daule, and their tributaries. The lower reaches of the Mataje, Santiago, and Esmeraldas rivers also were reported to support large populations.

Commercial hide hunting began on an organized and systematic basis perhaps 35-40 years ago; Guayaquil and Esmeraldas were the chief export ports for hidea moving to the United States. No statistics on the extent of the hide trade are available (records were apparently not kept).

The American crocodile received official protection in 1977 by Resolucion No. 818, but the species is now apparently extirpated over much of its former range in Ecuador (Medem 1973b). Despite the legislation, *C. acutus* hides are still purchased by Guayaquil dealers whenever possible

(Fritts 1978). Small remnant populations reportedly occur in some of the larger, more inaccessible swamps, such as Laguna de Sade and Estero Vaina, and a few small animals were observed on the Rio Quevedo, a tributary of the Rio Perdido in 1972 (Medem 1973b). A survey of late 1978 found fewer than 10 crocodiles in the Estero Penafiel, Rio Churute, and Rio Guayas (Fritts 1978). That survey also confirmed the widespread belief among knowledgeable Ecuadorian hunters, villagers, and dealers that Crocodylus acutus is extinct throughout most of its former range in Ecuador. The few scattered populations that remain are in imminent danger of extinction.

EL SALVADOR.-- Little historical information on the distribution and abundance of Crocodylus acutus is available for El Salvador, but it is reported to be becoming scarce from hunting and malicious killing (Powell 1971). Populations may still exist in lakes Guija and Jocotsl (Powell 1971).

GUATEMALA.-- Crocodylus acutus has been reduced seriously over its range in the Pacific versant of Guatemala, although some small populations may still exist (Powell 1971, J. Campbell in litt. to Moler 1980).

The distribution of this species in the Caribbean drainage is poorly understood. Reports of crocodiles (generally in eastern Guatemala) in recent years do not specify whether C. acutus or C. moreletii is involved (Dumeril and Dumeril 1951, Neill 1971). Whichever species is involved, it is becoming scarce. Crocodiles are seldom seen in areas like Lago de Izabel where they were once numerous (Popenoe pers. comm.). The species must be considered endangered in Guatemala.

HAITI.-- Crocodiles once occurred around the coasts of Haiti, including the offshore Ille-a-Vache, but are infrequently seen or heard of today (Schwartz and Thomas 1975, Schwartz pers. comm., Thompson pers. comm.). Crutchfield (pers. comm.) reported seeing crocodiles in 1974 on the Tiburon peninsula east and west of Jeremie and was told that fair numbers still occurred in the vicinity of Gonaives on the northwest coast and in inland lakes, especially Etang Saumatre, along the southeastern border with the Dominican Republic. Plans are currently being made to conduct a crocodile survey in Haiti (Ottenwalder pers. comm.).

HONDURAS.-- Crocodylus acutus is distributed in both the Atlantic and Pacific drainages in Honduras, possibly being replaced by C. moreletii in the extreme northwest, at least in inland waters (Neill 1971, Klein in litt. to King 1977). Even though periodically hunted for its hide until the mid-1920's, C. acutus was still abundant in Lago Ticamaya, Lago Yojoa, and at Puerto Cortes, and still occurred in Tio Verdugo (Schmidt 1924). Today, populations are depleted.

JAMAICA.-- Traditionally the range of Crocodylus acutus in Jamaica has been restricted to the southern coasts and associated larger rivers (Grant 1940, Powell 1973). In 1969 the populations were estimated to contain approximately 2000 adults (Hall in litt. to Campbell, Campbell pers. obs.). About that time an attempt was made to attract tourists for crocodile sport-hunting, with the result that the populations were quickly depleted. A government sponsored survey in December 1970 revealed that *C. acutus* still existed in moderate to low numbers in most available habitat,but nowhere was it abundant (Campbell, Patton, and Pritchard 1971). In a 1975 survey, a total of 41 living crocodiles was obtained in virtually all habitat on the south coast (Garrick *in litt.* to King 1975). Today the species appears restricted to isolated populations and occasional individuala scattered throughout the historic range (Campbell pers. obs.), with the greatest numbers remaining in the Black River Morass area (Garrick *in litt.* to Campbell and to King 1975). Unfortunately, the Black River Morass is undergoing severe habitat modifications as part of a government sponsored water diversion and rice cultivation program.

The species is protected from commercial exploitation, including sport-hunting safaris, to an indeterminate degree, but illegal commerce still occurs and crocodiles are killed as vermin wherever encountered (Campbell pers. obs., Garrick *in litt.* to Campbell and to King 1975).

MEXICO.-- Crocodiles range throughout coastal Mexico from central Tamaulipas on the east coast and Sinaloa on the west coast southward into Central America. There is some question on the actual historical distribution of *Crocodylus acutus* relative to *C. moreletii* on the east coast. Records for *C. acutus* exist as far north as La Pesca (Baker and Webb 1966) in Tamaulipas, but these and all other east coast records north of Campeche are unsubstantiated by museum specimens and may be based on misidentified *C. moreletii* (Ross and Ross pers. comm.). The issue is currently unresolved.

Similarly, on the Pacific coast *C. acutus* is well documented as occurring as far north as northern Sinaloa, although Powell (1971), King and Brazaitis (1971), and Brazaitis (1974) indicate that *C. moreletii* occurs in this region. If *C. moreletii* does, in fact, occur on the Pacific coast of Mexico, it is very rare and coexists with *C. acutus*, which is well documented from the Pacific coast.

Present distribution of crocodiles in Mexico is greatly reduced from historic times; today only scattered, localized, and marginal populations exist throughout the historic range of either species (Alvarez del Toro 1972, Campbell 1973, pers. comm., Casas and Guzman 1970).

Casas and Guzman (1970) give documentation of the decline of crocodiles throughout Mexico as a result of excessive hunting and land-use changes. Unfortunately, figures for both species are lumped; no data on *C. acutus* alone are available. These data show the classic pattern of overexploitation which has already resulted in the listing of *C. moreletii* as an endangered species in Mexico and elsewhere throughout its range. Recent field work along the east coast of Mexico confirms the great rarity of crocodiles of any species, but more importantly reveals only very infrequent specimens presumed to be *C. acutus*; the great majority of the specimens observed are *C. moreletii* (Campbell 1973, pers. obs., Ross and Ross pers. comm.).

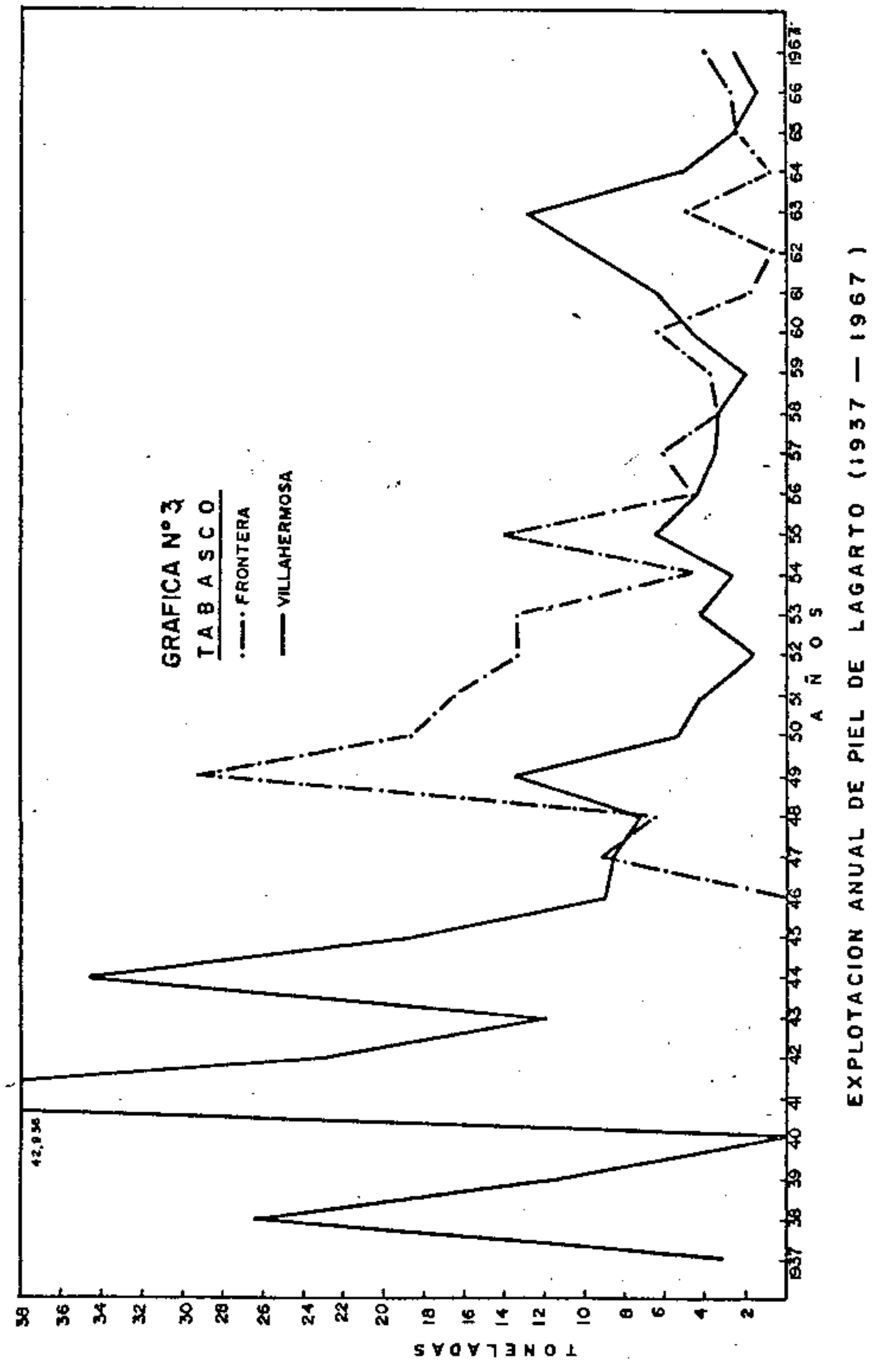

Figure 1
From Casas and Guzman 1970

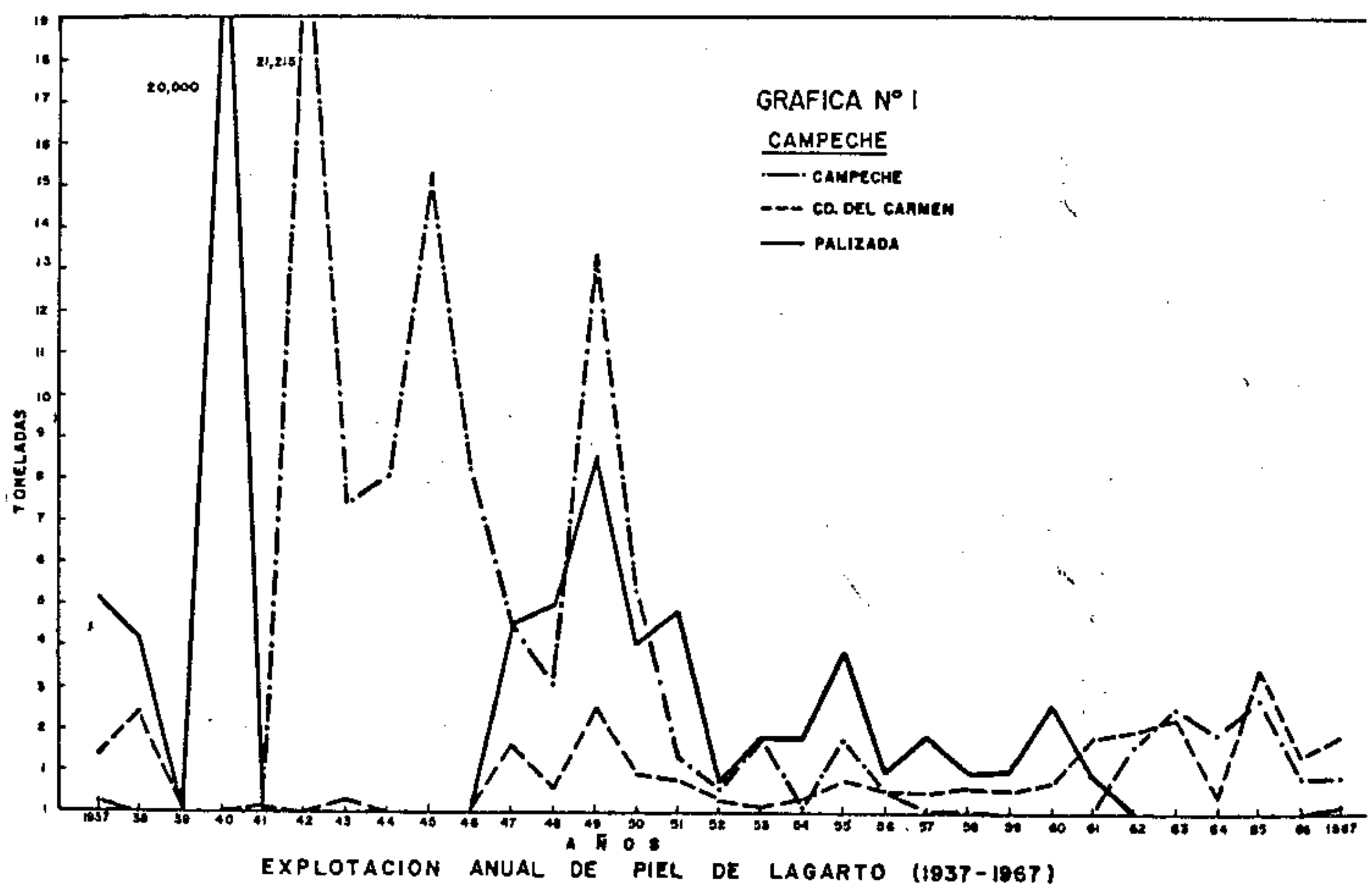

Figure 2

From Casas and Guzman 1970

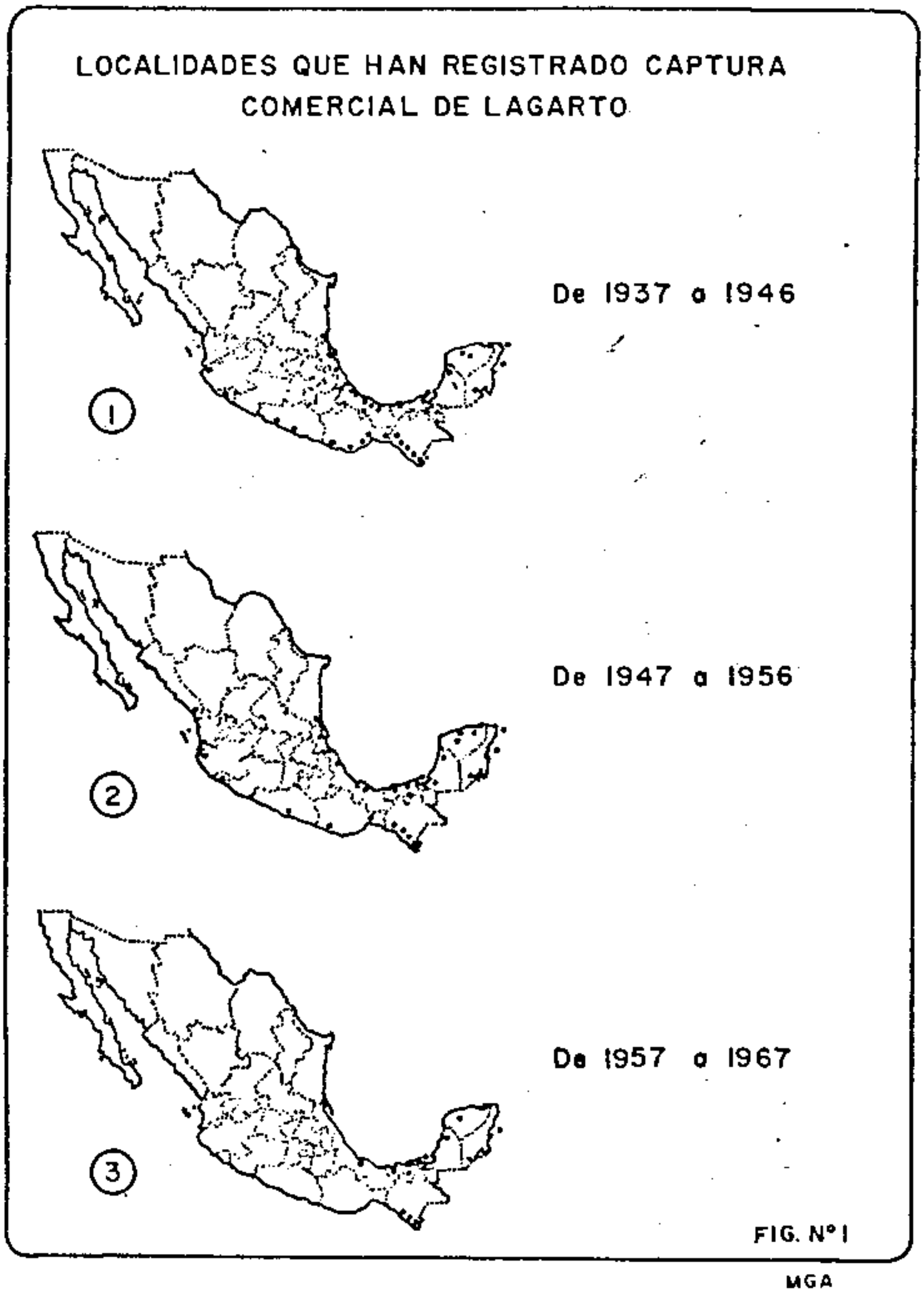

Figure 3

From Casas and Guzman 1970

The accompanying graphs (Figs. 1-3) from Casas and Guzman (1970) and the map showing the decline in commercial hunting are self-explanatory. The decline in commercial hunting areas is especially informative: between 1937 and 1946 there were 37 areas registering commercial crocodile exploitation, between 1947 and 1956 these had declined to 30, and between 1957 and 1966 only 13 localities were involved (note especially the loss of all Pacific coast hunting areas). Between 1967 and 1970 these localities were further reduced to 8. Today commercial hunting of crocodiles is prohibited (data from Casas and Guzman 1970), but excepting a few areas where crocodiles are viewed as a value for the tourist trade, crocodiles are generally killed whenever possible as vermin (Campbell 1973, pers. obs.).

In Mexico Crocodylus acutus must be considered endangered.

NICARAGUA.-- The American crocodile has been seriously reduced throughout its range in Nicaragua (Powell 1971). Herpetological collections in the northeastern regions of the country in 1960 (Campbell and Howell 1965) failed to obtain any specimens, and a medical team surveying for blood parasites and viruses in the vicinity of Bluefields in 1966 saw no specimens in over a month in the field (Campbell pers. comm.). In 1971 one local hide dealer in Bluefields had 2400 salted crocodile and caiman skins on hand awaiting the arrival of an expatriate buyer (Nietschmann 1977). His stock of hides was obtained from hunters, loggers, ranchers, and farmers from many parts of Nicaragua, and even from Costa Rica.

PANAMA.-- The American crocodile once occurred along both coasts and in all the larger rivers in Panama. No organized, systematic hide industry exists, but crocodiles are killed for the novelty trade or as vermin and captured for the pet trade whenever convenient.

The species was still present in small numbers in some areas of suitable habitat, especially Gatun Lake, Chagras River, Canal Zone, and the lower Bayano River, when data were last obtained (Powell 1971, Garrick in litt. to King 1975, Campbell pers. comm., Rand in litt. to Moler 1980). No systematic population surveys in coastal areas have been conducted, but three nights in the Perlas Islands in 1968 failed to yield a single specimen (Campbell, pers. obs.). Populations may still exist along the San Blas coast where Indian religious beliefs confer some protection (Myers 1970, Powell 1971). While not in immediate danger of extinction, nowhere is C. acutus abundant. In Panama crocodiles are severely depleted or threatened.

PERU.-- The American crocodile occurs in the lower reaches of the larger rivers in the Pacific drainage and apparently reaches the southernmost point in its distribution at the Rio Chira. Hofmann (1970) and Medem (1973a, b) confirmed the continued existence of C. acutus in the Rio Tumbes. The populations are not large, for there is little cover afforded the species in this arid region. Mangroves are all but nonexistent. In 1970 a total of only 22 juveniles and subadults were counted in the Tumbes (Hofmann 1970).

Crocodiles are protected by law (Resolucion Suprema No. 343, 16 October 1950), but are killed by ranchers and sportsmen at every opportunity (Medem 1971). Populations are small and isolated, and total protection is required if this endangered species is to survive in Peru. In addition, sanctuaries should be established for it on the Rio Tumbes.

PUERTO RICO.-- The species has not been recorded in Puerto Rico in historical times (Schmidt 1928, Schwartz and Thomas 1975).

TRINIDAD.-- Although Trinidad has resident populations of spectacled caiman, *Caiman crocodilus*, it has no permanent populations of crocodiles. At least five crocodiles landed on Trinidad shores after apparently being carried to sea when Venezuelan rivers were flooded (Urich 1893, Rousseau 1895, Medem 1973b). However, none of these specimens was preserved in a musuem, so it is impossible to ascertain whether they represent *C. acutus* or *C. intermedius*. In any event, all were killed shortly after coming ashore.

U.S.A., FLORIDA.-- Coordinated studies are currently being conducted by the U.S. National Park Service, Florida Game and Fresh Water Fish Commission, and Florida Power and Light Company to determine the status and management needs of *Crocodylus acutus* in Florida. The species is more or less restricted to the coastal fringe of extreme southern Florida. Much of this area is protected within Everglades National Park, but 9 (43%) of the 21 known nests in 1978 were outside of Everglades Park. The U.S. Fish and Wildlife Service has approved establishment of Crocodile Lake National Wildlife Refuge on Key Largo, an area which included 7 (33%) of the 21 known nests in 1978 (Moler pers. comm.). Habitats outside of Everglades National Park are being lost through habitat alteration associated with land development, and an occasional crocodile is struck and killed by automobiles while crossing highways. Based upon extrapolation from the number of known nests, the Florida population is estimated to include a total of 200-500 crocodiles. Until protection is afforded to the important crocodile habitats outside Everglades National Park, the U.S.A. population of *Crocodylus acutus* must be considered endangered.

VENEZUELA.-- Historically, *Crocodylus acutus* was found from the lowlands around Lake Maracaibo, along the Atlantic coast to the Manzanares River in the vicinity of Cumana (Humboldt 1859, Donoso-Barros 1965, Medem 1973b). Exact details of its geographic relationships to *Crocodylus intermedius* are poorly understood, but *C. intermedius* essentially occupies (occupied) the Orinoco drainage, with *C. acutus* occurring in suitable crocodile habitat outside that area.

Large-scale commercial hide hunting began about 1929. However, there are no detailed government records of the traffic in hides of *C. acutus* in Venezuela. We only know that hides had become scarce by 1940. In contrast, the detailed records of traffic in the Orinoco crocodile, *C.*

intermedius, hides show a peak of 730,401 kg in 1931, holding generally until 1934, and then declining rapidly to only 2400 kg in 1963 (Medem 1973b). Today the species is protected by law.

Crocodylus acutus is now extinct over much of its former range in Venezuela, with small isolated populations known from only a few areas. The Gulf of Coro supports a small remnant population, as does the region around the Parque Nacional Morrocoy. There are reports of small populations also in the Manzanares River and around the Gulf of Cariaco, but Medem (1973b) was unable to confirm these populations during his 1972 surveys in Venezuela. *C. acutus* must be considered an endangered species.

SUMMARY

There appears to be no area within the historic range of *Crocodylus acutus* where healthy populations exist without serious threat from exploitation and/or habitat degradation. The species exists today only in isolated, small populations scattered in the more isolated and impenetrable areas within the historical range and, wherever found, is still hunted commercially or for local consumption (both eggs and flesh) or killed as vermin. Wherever data exist, overexploitation for hides is clearly indicated as a major factor in the reduction of populations to the present lows, but today this threat is compounded by habitat degradation and/or increased human activities (e.g. commercial fisheries) in the remaining habitat. The species is recognized as endangered by the IUCN/SSC Crocodile Specialist Group.

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THE STATUS OF CROCODILIANS IN SOUTH FLORIDA

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Two species of crocodilians occur naturally in South Florida, the American Crocodile (Crocodylus acutus) and the American alligator (Alligator mississippiensis). The American crocodile is considered by the United States Government to be endangered, and the American alligator is presently considered to be threatened in Florida. Recent and ongoing studies have provided an increasingly precise understanding of the status of and threats to these species. In this report I discuss some of the preliminary findings.

AMERICAN CROCODILE

The American crocodile has an extensive neotropical range, which includes the west and north coasts of South America, both coasts of Mexico, the Greater Antilles, and South Florida. Only in Jamaica, Hispaniola, Cuba, and Florida do potentially viable populations persist, and each of these is in some jeopardy. Crocodiles in Florida are at the northern limit of their range, grasping tenuously to the barely tropical tip of the Florida peninsula. This fact is of considerable importance in understanding the species' status in South Florida, as it is probably near the limit of certain of its ecological or physiological tolerances. Under such circumstances, it would be unlikely to maintain a large population covering extensive areas.

The status of this population has long been a matter of concern, however. Moore (1953) documented its occurrence and distribution; Ogden (1978) monitored nesting success from 1968 to 1974 and drew some conclusions about its status. Preliminary results from that study supported the species' placement on the Federal list of endangered species. A recovery plan outlining steps for conservation has been approved (Klukas et al. 1979). Coordinated research efforts by several groups over the last few years have led to a substantial increase in our understanding of potential threats to this population. My colleagues and I began our work on the core of the extant population in Everglades National Park in 1977.

Ogden (1978) estimated that the population consisted of 100-400 non-juvenile animals. This estimate was based on the percentage of productive females in other crocodilian populations. Although it is probably a reasonable range, it is not rigorously derived. Our mark-recapture studies have proved ineffective in generating a population estimate. However, we expect to do so from population and survey data, at least in a gross way. Whatever the result of that effort, what we do understand well from our studies is the distribution of the population, the minimum number of nest sites, and, with increasing precision, the impact of some potentially limiting factors.

Crocodiles occur along both Florida coasts (Fig. 1). P. Moler (pers. comm.) has verified northern occurrences at Fort Lauderdale, where adults occupy power plant cooling canals, and at Naples. An animal recently took up residence on Sanibel Island. Farther south, we know of reliable records on the edge of southern Biscayne Bay and south of Everglades City. On the lower Florida Keys, recent searches have not been able to verify the natural, current occurrences of crocodiles there (Jacobsen in prep.).

Most remaining crocodiles occur along the mainland of extreme southern Florida. They occupy canals at a nuclear power plant at Turkey Point, and canals, pools, and mangroves on northern Key Largo. The bulk of the population occurs in northern Florida Bay and associated coastal swamps in Everglades National Park, the site of our studies.

The known range of nesting animals is even more restricted. Gaby (pers. comm.) has found a maximum of two nest sitea at Turkey Point. Moler (pers. comm.) has found a maximum of seven nest sites on North Key Largo. Most of the latter nests are located in the area that has been authorized to be purchased by the Federal government as the Crocodile Lake Wildlife Refuge. Currently, no purchase activity is underway. Over half of the known nest sites are in Everglades National Park, with at least 14 clutch sites known to be used by this subpopulation in some years. Two sites are used sporadically near Flamingo on the southwest coast. As many as 12 nest sites are known from a small area of northeast Florida Bay.

I have attempted to develop a system of monitoring the population on aerial surveys using fixed-wing aircraft and helicopters, each of which we flew monthly for a year, by boat surveys, and by capture-recapture studies. While substantial biological information has been obtained, it is probable that none of these methods will prove adequate as a population monitoring technique. Although probably not all nest sites are now known, many are and it is possible to search carefully the core nesting area each year. Monitoring these nest sites will probably be the best system available for tracking population status.

We can examine the number of active nests found in recent years from this perspective. Ogden (1978) found a maximum of eight clutches in 1971-74 in the primary area of crocodile occurrence near Little Madeira Bay and nearby Florida Bay. Since then, we have increased the number to 12. In certain sites two clutches of eggs occur together, probably from

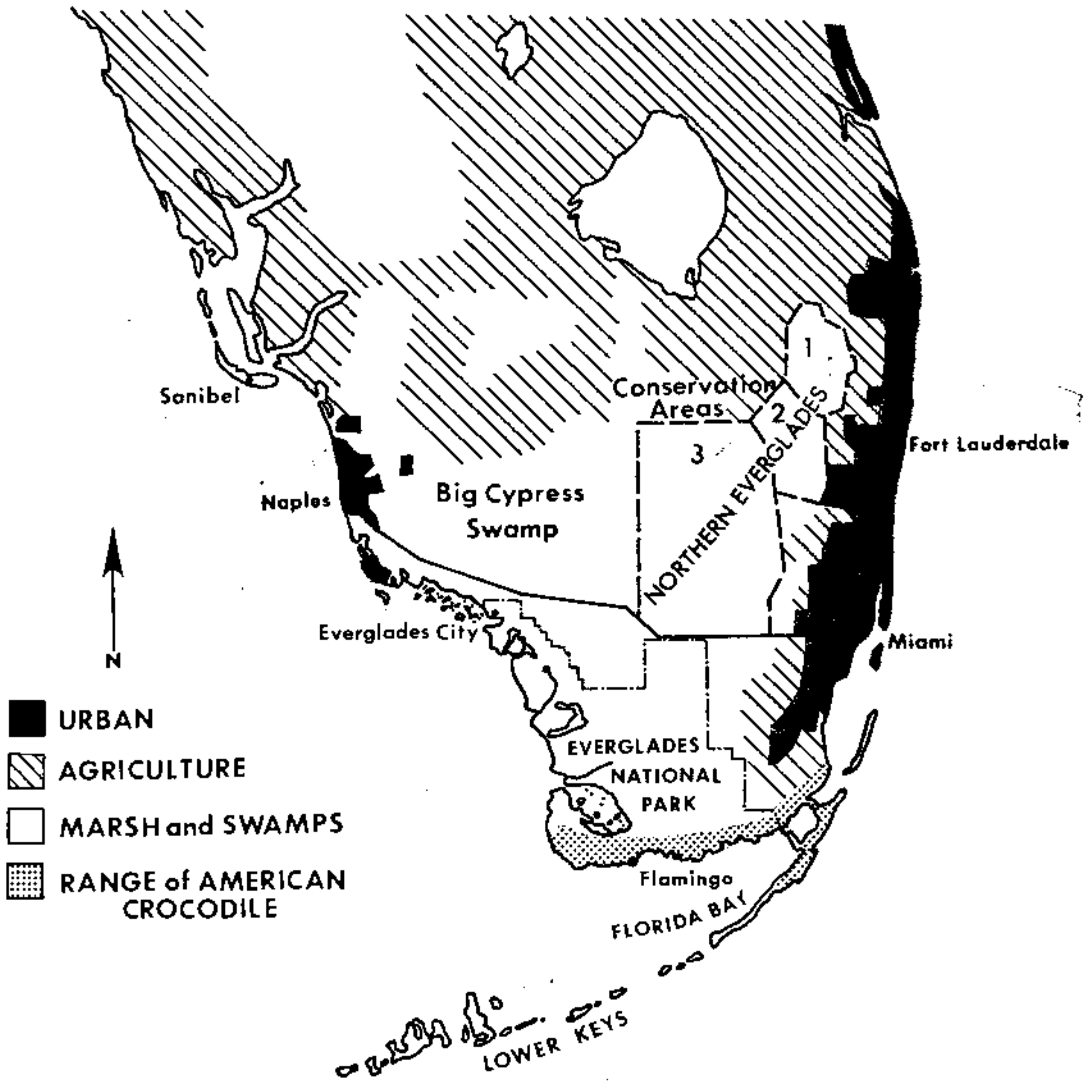

Figure 1. Natural and altered wetland habitat in South Florida and the distribution of the American Crocodile.

different animals. Some of the increase in the number of known clutches is due to our increasing skill at finding nests, but some nests are at entirely new sites. One nest contained few small eggs and was attended by a small animal. It seems such clutches may be from animals new to the breeding population.

We have been particularly concerned with nesting success (Patty, Kushlan, and Robertson in prep.). Ogden (1978) considered "embryonic mortality" to be an important limiting factor. Whether lack of hatching is due to infertility or early death has not been clear. We studied this phenomenon, especially thermal characteristics, diffusion, gas concentrations, and flooding of nest cavities. Preliminary results show that high CO_2 and low O_2 levels occur late in incubation, and in some years temperatures can approach expected lethal levels (38°C) (Lutz and Dunbar-Cooper in prep.). High nest temperatures may affect sex of the developing embryos. Short-term flooding takes place in some years (Mazzotti, Kushlan, and Dunbar-Cooper in prep.). Nonviable eggs have occurred in up to 25% of the nests in some years. However, we have found a mean egg loss of 14% (Patty, Kushlan, and Robertson in prep.), which is not overwhelming, and lack of hatching does not appear to be a major limiting recruitment. Predation on nests also has been considered to be an important cause of nest failure. However, we have found predation to average about 20% over 12 years, a figure that is not excessive for crocodilian populations. Thus, we believe that hatching success is fairly high, with 64% of all nests producing young (Patty, Kushlan, and Robertson in prep). In some years a conservative minimum of over 200 eggs are hatched.

Limited survival of hatchlings is another possible limiting factor. We have studied the survival of these hatchlings through radio telemetry and by tagging over 200 hatchlings in two years (Mazzotti and Kushlan in prep.). Although hatching occurs during the season of maximum freshwater runoff, salinities near nests are typically 50-100% sea water. Evans and Ellis (1977) showed that in the laboratory hatchlings submerged in salinities as low as 25% of sea water lose weight rapidly. As a result, a major concern has been adverse effect of ambient salinity on survival. We found, through telemetry, that hatchlings lose weight initially but begin to gain weight at two weeks of age (Mazzotti and Kushlan in prep.). Grigg and Taplin (in press) demonstrated the existence of salt secreting glands in *Crocodylus porosus*, and Grigg, Taplin, Dunson, and Ellis (pers. comm.) have extended this finding to *C. acutus*. Dunson (1970, in press) studied wild animals in Florida Bay, and found that their survival may be due to drinking fresh water and eating water-bearing prey. The functioning of glands in wild animals, the effect of high salinity on gland function, and the energy costs of osmoregulation remain to be determined; it appears that some osmoregulatory compensation exists, either physiological, behavioral, or both (Dunson in press). Data suggest that survival of hatchlings is possible in some locations, and that growth of young can be relatively rapid.

I have also examined whether adult interaction or lack of interaction could be limiting to the population. Through aerial surveys and radio telemetry, we have found seasonal shifts of adult females from inland swamps into Florida Bay during the summer (Kushlan and Mazzotti in prep.). We have also determined that adults have rather large activity areas. Many potential nest sites exist and, as noted previously, more than one female uses a single nest site. It does not appear that adult habitat requirements adversely affect the population.

Pesticide accumulation is often a matter of concern for an endangered carnivore. However, Hall et al. (1979) have shown that levels of pesticide residues in crocodile eggs are unlikely to affect reproductive success in the South Florida population. Heavy metal residue analyses are in progress.

An answer to the basic question of "does recruitment occur?" seems to be yes. The size distribution data shows the occurrence of juveniles (< 1 m in length), subadults (1-3 m), and adults (> 3 m) in the population. Considering the rapid growth rates, and perhaps the secretive nature of the subadults, it is encouraging that the existence of this potential breeding pool has been documented. We now need to know more about the distribution and growth rates of subadults.

Thus our preliminary analyses show crocodiles have a restricted distribution and a relatively small breeding population, but one which may be stable or perhaps increasing. Our ecological work and that of our colleagues suggest cause for optimism. There is also cause for optimism on the political front. Most nest sites are in Everglades National Park where environmental conditions remain relatively natural. The National Park Service has recently established a crocodile sanctuary in the center of the known distribution, prohibiting access by the public. This ecosystem approach to management of crocodiles in the park is supplemented by the planned, although currently inactive, purchase of the Crocodile Lake Wildlife Refuge on Key Largo. There most of the additional nest sites will be protected and, if necessary, the habitat can be enhanced for the benefit of crocodiles. This combined approach of ecosystem protection and restoration in one area and single-species management in another, bodes well for the future survival of the American crocodile in South Florida.

AMERICAN ALLIGATOR

Under historic conditions nearly all of South Florida was wetland, although Schortemeyer (1972) estimated that about 30% of this historic alligator habitat has been lost to development. Much of the inland area of southern Florida remains freshwater wetlands, including the Everglades, the Big Cypress Swamp, and coastal mangrove swamps, most of which is managed or protected by agencies of the State or Federal governments.

Alligator numbers were reduced throughout South Florida during the 1950's and 1960's, but the population responded to legislative protection and popular support. The recent population recovery of alligators in Florida is fairly well documented (Hines 1980). A statewide management program removes nuisance alligators from contact with Florida residents and sells hides and meat under state control (Hines and Woodward 1978).

Hunting and killing alligators is illegal throughout the undeveloped Everglades and Big Cypress Swamp, but illegal killing of alligators appears to have increased in recent years. Such killings do not yet seem to be numerous enough to impact population levels, but they are cause for concern, especially along the boundaries of reserves such as Everglades National Park.

The status of the American alligator differs somewhat in the various remaining natural areas in southern Florida, the Big Cypress Swamp, the northern Everglades included in Water Conservation Areas 1, 2, and 3, and the southern Everglades of Everglades National Park (Fig. 1).

The Big Cypress Swamp is a complex mosaic of cypress (Taxodium distichum) swamp, marsh prairies, and ponds. Much of the swamp is now owned by the Federal government as part of the Big Cypress National Preserve. Although some data exist on the ecological role of alligators, particularly the ecological effects of previous population losses (Kushlan 1974), little information is available on the current status of alligators in the swamp. The population appears to have increased in recent years, especially among juvenile age classes, but old alligator ponds remain overgrown in many areas, suggesting full recovery in numbers of large animals has not occurred.

The Everglades is an extensive sedge marsh, characteristically vegetated by sawgrass (Cladium jamaicense). The northern Everglades is now encompassed by the levees of three Water Conservation Areas, the northernmost (Area 1) being the Loxahatchee National Wildlife Refuge (Fig. 1). This area continues to support high alligator populations. Animals along perimeter canals especially appear to be of large size classes. Nesting sites on high islands are in good supply and overall the population appears healthy. In contrast, in Conservation Area 2, water levels have been held unnaturally high for several years. There J. Schortemeyer (pers. comm.) has been able to locate very few nests, most of which flood before hatching.

The status of the alligator population is better understood in Conservation Area 3, where alligators have been studied over a number of years by personnel of the Florida Game and Fresh Water Fish Commission under the direction of M. Fogarty and J. Schortemeyer. Since the conservation area generally slopes from north to south, water drains from the north and impounds behind southern levees. As a result, the northern part is drier than it would be under natural conditions and the southern part is wetter. Alligators in the north endure a long dry season, often accompanied by fires. In the southern end, high water floods nests. We have conducted surveys by helicopter and observed no nests in the southern, deep water end of Conservation Area 3-A. This confirms the findings of J. Schortemeyer (pers. comm.), who has been unable to find nests farther south than midway down the area. We have also conducted 3 years of nighttime line surveys along canals in this area and have found fewer animals (avg 5/mi, max 6.5/mi) than just to the south in Everglades National Park. Thus, alligators occur throughout Conservation Area 3 but are stressed in the north and south by drying and flooding, respectively.

These observations on alligator status in the Conservation Areas suggest a primary factor limiting alligator populations in South Florida is the effect of water management, provided harassment, illegal killing, and habitat destruction are minimized. The primary objective of my studies in Everglades National Park was to examine the relation of water level fluctuations to alligator population ecology. The management goal of the park is to recreate, as closely as possible, natural ecological conditions, and the alligator is an essential component of this ecosystem.

Because of the levees surrounding the Water Conservation Areas, natural surface water sheet flow into Everglades National Park has been blocked. Water enters the park from the north by four gated structures, through which flow is controlled by several government agencies. A certain amount of water is guaranteed to the park each month by Federal legislation. Should water levels become higher than desired in the Conservation Area, excess water is vented into the park, the amount and timing depending on hydrologic and engineering considerations upstream. The status of alligators in Everglades National Park is affected by such water management actions. So far we have been able to dissect some of these effects and are approaching an understanding of the Everglades alligator population.

As noted above, alligator populations in the southern Everglades are higher than those of the southern parts of the Conservation Areas. Line surveys were run monthly for two years along a transect of the Everglades from the northern boundary of the park into the coastal mangrove swamps, nearly to the Gulf of Mexico. Our longest span of data is from L-67 canal on the eastern boundary of the park. There alligator numbers vary inversely with water level and can achieve densities of over 50 animals per linear mile of survey.

Much of our research was conducted primarily in five 10 km^2 study areas along the northeast-southwest axis of the southern Everglades. Dry season counts of alligators in ponds in each of these areas were conducted for three years. The number of alligators at any time appears to depend on water level at the time of the survey. However, within a single year, alligator densities per pond varied from area to area, for example from 0.7 to over 2 animals per pond. Thus, even within a relatively homogeneous habitat such as the Everglades, alligator densities can vary substantially.

The intensity of alligator nesting has varied from 3 to 18 nests in the 10 km^2 main study area. Our preliminary analysis suggests that the number of nests may be directly related to water levels occurring in spring

(Kushlan and Kushlan 1981). Thus, nesting effort is highest in years of high water conditions.

Very few nests are lost to predation, and as a result, water level plays the most critical role in egg mortality in the Everglades. Once eggs are deposited, their position with respect to ground level is set for the 2-month incubation period. Attending alligators may later add vegetation to the top of their nest but it does not affect egg placement. Thus, eggs are subject to inundation should water levels rise too high. It appears that the height of the lowest egg above ground level is correlated with the water level on the date of laying. The higher the water level, the higher the eggs are located.

Some eggs are lost to flooding in most years. The loss of eggs in the main study area varied from none in 1976, to 35% in 1978, and probably 100% in 1981. The latter was due to a tropical storm. The 1978 loss was very useful in analyzing the effect of water management on alligators (Kushlan and Kushlan 1981). In 1978 water levels in Conservation Area 3 exceeded regulation level in July. In order to bring water atages down to regulation level, a relatively large amount of water was discharged into the park beginning in mid-July. This water reached the study area on 30 July. Alligator eggs began flooding at the beginning of August, and flooding increased through 12 August. Overall, 35% of the eggs flooded during a 2-week period. Since flooding can result from either on-site rainfall or from discharge into the park from higher marshes to the north, we aubtracted the effect of rainfall and determined that a 32% egg loss was due to discharge of water into the park.

Although a 30% loss of potential productivity in one year probably would not adversely affect an otherwise healthy alligator population, it does indicate the potentially severe impact of water management actions. Combined with the low alligator nesting success in deep water parts of the Conservation Areas, data from Everglades National Park suggest that water management can in itself be a primary determinant of alligator populations in South Florida. Thus, even with protection, the alligator populations continue to be subject to man-made threats in the remaining wetlands of South Florida.

ACKNOWLEDGEMENTS

I would like to thank my co-workers who participated in the studies preliminarily reported here. Frank Mazzotti, William B. Robertson, Jr., Paige Patty, William Dunson, Peter Lutz, Ann Dunbar-Cooper, John Behler, and Robert Menzies participated in crocodile studies. M. Spalding and M. Terri Jacobsen assisted in alligator work. I thank James Schortemeyer, Paul Moler, and Ronald Gaby for generously supplying information from their studies.

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BIOLOGICAL ASPECTS OF THE CONSERVATION OF AMAZONIAN CROCODILIANS IN BRASIL

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INTRODUCTION

The Amazon Basin covers approximately 7,000,000 km^2, the greater part of which falls within Brasil. Because the Basin is intersected by thousands of rivers and streams, it is almost all good crocodilian habitat, and supports four species of crocodilians: Melanosuchus niger, Caiman crocodilus, Paleosuchus palpebrosus, and P. trigonatus. The four species appear to have different habitat preferences (Medem 1958, 1960, 1967, 1971), but on a gross scale are sympatric throughout the Basin.

Morphologically, the three genera are very distinct, presumably reflecting differences in habits and habitats. One difference that has become critical since the advent of intensive commercial hunting is the degree of ossification of the ventral skin. Melanosuchus skin contains comparatively few osteoderms and commands a high price in the skin trade. Caiman crocodilus skin is heavily ossified but amenable to more complicated tanning techniques which remove most of the bone and, since the decline in the more valuable species throughout the world, has taken a major place in the illicit trade. In contrast, the skin of Paleosuchus is so heavily ossified that to date it has virtually no value to the leather industry.

All species of crocodilians are rigidly protected in Brasil, and there is no direct trade in skins through major Brasilian ports. However, because of the immense size of the Amazon Basin within Brasil, the small human population and widely-dispersed transport systems along the rivers, effective policing of the laws in this part of the country is almost impossible. Each year many hundreds of thousands of skins are transported across remote parts of the Colombian border and shipped from that country legally or illegally (Karlheinz Fuchs, pers. comm.).

In order to assess the effects of illegal hunting it is necessary to have data on the numbers and distributions of crocodilians before hunting began. These are almost totally lacking in Brazil. Apart from museum records (Carvalho 1951) the distribution and numbers of both species of Paleosuchus is unrecorded. The situation with Caiman crocodilus is similar, and it is frequently difficult to identify the species in reports dealing with smaller animals. It is a little easier to assess the magnitude of the original populations of Melanosuchus.

Because of its large size and the fact that it is the only Amazonian crocodilian known to attack man, it is often readily identifiable in the literature. Probably the best and most reliable accounts are those of Bates (1864), who spent eleven years making detailed observations and collections in Amazonia between 1848 and 1859. He encountered large numbers of large crocodilians in all areas that he travelled and gave a dramatic account of a man being taken by a crocodilian in front of the present township of Tefe. There can be little doubt that at the time Melanosuchus was the most conspicuous, if not the most common, crocodilian throughout the Amazon system. An objective assessment of the numbers of Melanosuchus can also be obtained from the photograph in Hagmann (1909) of dozens of Melanosuchus sunning together on a beach on Mexiana Island at the mouth of the Amazon.

Information on which to assess the present status of crocodilians in Amazonian Brasil is almost as deficient as for the original populations. I am aware of only two recent studies where biologists have taken a first hand look at numbers of crocodilians in this region. Vanzolini and Gomes (1979) investigated several aspects of the biology of Caiman crocodilus and Paleosuchus trigonatus on the Rio Japura in the central part of the basin. They found both species to be relatively common and suggested that neither was showing adverse effects from overhunting. I have looked at populations of C. crocodilus, P. trigonatus, P. palpebrosus, and M. niger at Lago Amana (an effluent of the Rio Japura), the area around Manaus (junction of the Rio Solimoes and Rio Negro), and the Parque Nacional da Amazonia (Rio Tapajos; see Magnusson 1980). Numbers of C. crocodilus, P. trigonatus, and P. palpebrosus were high in most areas, and populations appeared to be limited by habitat preferences rather than disturbance by man. In contrast M. niger constituted only a small proportion of the total population (10%), and three-quarters of the animals I saw were in one very small lake in the Parque Nacional da Amazonia (Tapajos).

How do these observations tie in with information from the skin trade? Both Paleosuchus species have little commercial value, are not used by the leather industry, and, as might be expected, are common in their natural habitat, even in the immediate vicinity of towns. Melanosuchus was once the mainstay of the hide industry in Brasil, which is in accordance with the reports that it was once one of the most common crocodilians. Now Melanosuchus probably contributes less than 1000 skins a year to the hide industry (Karlhienz Fuchs pers. comm.) and this, unfortunately, concurs with observations that it is rare or absent over much of its former range. The situation with C. crocodilus is more difficult to reconcile. Almost all the hundreds of thousands of skins being shipped to Colombia each year are from this species, yet it remains common throughout the same range from which Melanosuchus was extirpated by similar hunting pressure.

Data collected during the aforementioned surveys, I believe, give important indications as to the biological reasons behind the different responses of *Melanosuchus* and *C. crocodilus* to hunting pressure, and the rest of this paper will be directed toward a discussion of these factors.

METHODS

Intensive spotlight surveys were carried out in two areas: Lago Amana and its associated tributaries, and the aquatic systems of the Parque Nacional da Amazonia (Tapajos). Lago Amana is a mixed black water (low sediment loads, water discolored by organic acids) and white water (high sediment loads, low levels of organic acids) lake connected to the Rio Japura and Rio Solimoes by a complex series of paranas (natural canals). Hunting for crocodilians is carried on intensively in the area by two families who live on the lake. Trading vessels, mainly working out of Coari, transport the skins. One such vessel I boarded contained approximately 10 *Melanosuchus* and 40 *C. crocodilus* skins. All were from animals about 2 m in total length that had been taken in the local area.

The Parque Nacional da Amazonia (Tapajos) contains a number of aquatic habitats which can conveniently be divided into five categories (Magnusson 1980). Briefly they are:

1) The many small forest streams between 1 and 10 m wide draining into the Rio Tapajos.

2) Small lakes formed by the damming of small streams by the Transamazon Highway. These are connected to the main rivers by small forest streams.

3) The Rio Tapajos, a clear water (low sediment loads, low levels of organic acids) river, in the lower sections of the park where it contains many rapids and water falls.

4) The Rio Tapajos in the midsections of the park where there are few rapids and the banks are formed by sandy beaches in the dry season.

5) Small oxbow lakes and paranas (natural canals) around the Rio Tapajos in habitat 4.

For the purposes of discussion here categories 3 and 4 will be combined as the Rio Tapajos and for the purpose of illustration one of the oxbow lakes (Lago das Piranhas) will be presented separately, although the only obvious character that differentiates it from the other natural lakes is its complement of crocodilians.

Discussions with people living around the rivers in the park indicated that there had been little hunting of crocodilians in the four or five years before the survey, but that previously hunting had been intensive.

Rainfall and water levels are highly seasonal in both areas. Variations of up to 10 m are known, and at the period of high water the rivers flood the surrounding forest. Comparing a survey undertaken at high water level in which 15 crocodilians were sighted with a survey of the same area at lower water in which 49 crocodilians were sighted indicates the superiority of dry season surveys. Surveys were carried out in September (Lago Amana) and November (Tapajos) when water levels were close to minima.

An attempt was made to survey all habitats in each area. It was not feasible to use the same survey techniques in each habitat, so results are presented as relative numbers of each species in each habitat. Crocodilians were located at night by eyeshine, the reflection of the tapetum of the eye in a strong light. They were approached close enough to identify the species and make a size estimate. About 25% of individuals of each species sighted were captured to calibrate size estimates. Both the form and precision of the relationship between my estimates and actual sizes varied between species but not between areas. The geometric mean regressions describing the relationship for each species are given below:

Melanosuchus niger: $Y= -26.5 + 1.42x$, $r^2= 0.89$,* n=10.

Caiman crocodilus: $Y= -64.96 + 2.80\ x -0.01006\ x^2$, $R^2= 0.85$,* n=50.

Where Y = estimated length, x = actual length, * significant at 0.05.

The relationships between estimated and actual sizes are sufficiently precise to allow the production of meaningful size frequency distributions of those populations.

Details of distances surveyed in each habitat in the Parque Nacional da Amazonia (Tapajos) are given in Magnusson (1980). The Lago Amana surveys covered approximately 150 km of lake shoreline and paranas.

RESULTS

Size Distributions of Hunted Populations of *Melanosuchus* and *Caiman*--Lago Amana

The size distributions of *Melanosuchus* and *Caiman* sighted in the Lago Amana area are given in Figure 1. The size at which animals enter the hunted population is based on talks with local people and inspection of poached skins. The size at which *Caiman* breeds is based on Staton and Dixon (1977), and the size at which *Melanosuchus* breeds is an educated guess based on knowledge of *Alligator mississippiensis*. It can be seen that the potential recruitment of *Caiman* to the breeding and, potentially, the hunted population is great, but that *Melanosuchus* are being hunted at a size much smaller than that at which they are likely to breed. Therefore the recruitment to the hunted and breeding segments of the populations is low.

Responses of *Melanosuchus* and *Caiman* to Hunting--Approachability

Subjectively *Melanosuchus* are much easier than *Caiman* to approach, catch, and subsequently handle. It is difficult to quantify this aspect because the physical characteristics of the habitat often govern how close one can approach. Nonetheless, *Melanosuchus* and *Caiman* overlap sufficiently for comparison, provided those in difficult places (e.g. behind bushes) are excluded. The ratio of the number of *Melanosuchus* that allowed approach to touching distance (not necessarily capture) as opposed to diving before the boat reached them (17:13) is almost double that of *Caiman* (68:155), suggesting that *Melanosuchus* is approximately twice as approachable as *Caiman*.

Interactions between *Melanosuchus* and *Caiman*--Rio Tapajos

The distribution of *Melanosuchus* and *Caiman* in the various habitats of the Parque Nacional da Amazonia (Tapajos) is given in Table 1. These data are extracted from more detailed tables in Magnusson (1980).

Caiman crocodilus is the only crocodilian that has colonized the newly formed artificial lakes behind the Transamazon Highway. This is surprising, as *Caiman* would have to travel five or more kilometers through small forest streams to reach the lakes from the main river. This is habitat occupied almost exclusively by *Paleosuchus trigonatus* in this area. The one *Caiman* sighted in a small forest stream was within 50 m of the main river. *Melanosuchus* was not seen in the small forest streams or the artificial lakes and, according to local informants, never occurred there.

Table 1.

	Artificial lakes	Forest streams	Rio Tapajos	Natural Lakes and paranas	Lago das * Piranhas
Caiman crocodilus	11	1	93	53	5
Melanosuchus niger	0	0	1	5	29

* This lake apparently differs in no important respect from other natural lakes and paranas but is separated here to illustrate the differential distribution of animals.

Melanosuchus is extremely rare throughout the main river and all but one of the lakes and paranas. Local residents said that formerly the species was common in these areas, and that the present lack is directly attributable to hunting. In contrast, *Melanosuchus* was very common in the Lago das Piranhas. However, inspection of the size distribution in the lake indicates that the population consists mainly of animals 1- to 5-years old and that the whole population could be the result of a single pair of adults breeding successfully in the lake over successive years (Magnusson 1980). *Caiman* were common in the main river and in all of the lakes and paranas, with the exception of the Lago das Piranhas where there was the large population of *Melanosuchus*.

DISCUSSION

There are basic similarities in the behavior and ecology of all crocodilians. However, there are also differences in the life history parameters of each species that can cause major differences in the way each species responds to a given type of exploitation. These differences must be understood in order to manage the stocks rationally, whether for exploitation or conservation. This is especially true in multi-species systems where one form of management may benefit one species but be deleterious to another. Below I have tried to tie together what is known about the various Amazonian species. The data base is not large, but then it never can be when we set about trying to learn something of a species after it has been reduced to critical levels. The point is that if the hypothesis I present is true, even in part, we have to reevaluate our approach to the conservation of the group and make it a species by species effort.

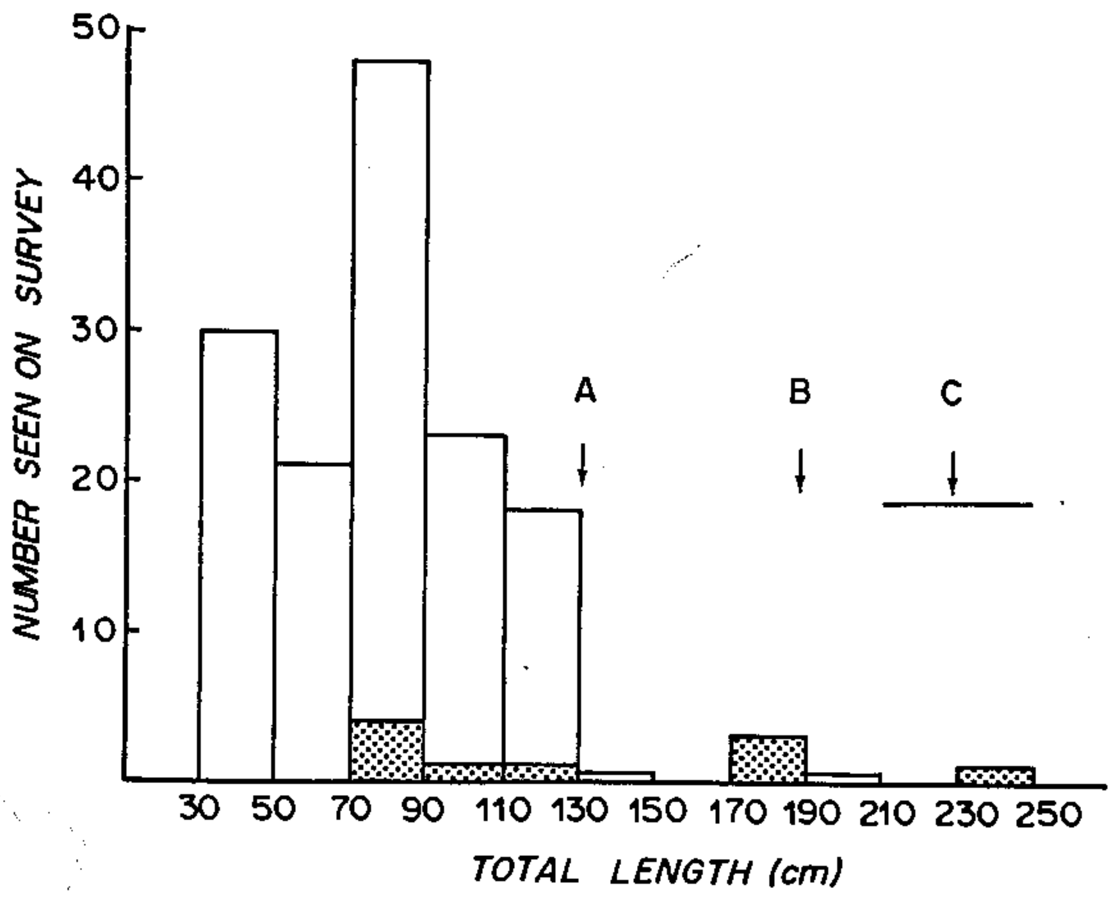

FIGURE 1. Size frequency distributions of Caiman crocodilus and Melanosuchus niger in Lago Amana and its surrounding tributaries. A) size at which C. crocodilus commence breeding. B) size at which both species are usually hunted. C) range of sizes at which female Melanosuchus probably commence breeding. White areas = Caiman; stippled areas = Melanosuchus.

First, it seems that at this point we need not invest much effort in the conservation of either species of Paleosuchus. Neither has been commercially valuable and both seem able to hold their own in close association with man, despite some hunting for food. Short of massive habitat destruction or a new market for their skins, they seem to be secure.

Second, Caiman crocodilus does not appear in danger of extinction at the present levels of hunting in Brasil—even though this hunting is extremely widespread and accounts for hundreds of thousands of animals per year. Two aspects of the biology of C. crocodylus that almost certainly play major roles in its resilience to hunting are its small size at sexual maturity (less than the size hunted most intensively) and, compared to Melanosuchus, its relative shyness. These lead to what is apparently a sustained yield (though not necessarily a maximum sustained yield) harvest under present conditions.

The distribution of Caiman relative to Mèlanosuchus in the Tapajos area indicates that the present high numbers of Caiman in most habitats is a result of this species dispersal into habitats altered by man and its colonization of habitats from which other species have been eliminated or depleted by man. The limited evidence from Lago das Piranhas seems to reinforce the suggestion that Caiman behaves as a colonizing species in that it fares poorly in association with closely related species under stable conditions. Caiman may in fact benefit from hunting which reduces the numbers of Melanosuchus more than it does Caiman.

The third aspect we need to consider is how to manage Melanosuchus, if it indeed does differ from the other species in its susceptibility to hunting. There are some areas where Melanosuchus may still be protected because of limited human access. There are certainly areas where Melanosuchus is more commom than those discussed here (P. E. Vanzolini, pers. comm.). These areas need to be surveyed now, and if viable populations are found they should be rigorously protected. The presence of other species in an area is not necessarily an indication that Melanosuchus is being adequately protected. In fact, the number of Caiman present may be inversely proportional to the amount of protection afforded Melanosuchus. While Melanosuchus may or may not once have been a major threat to Caiman, the reverse is certainly true now. The presence of large numbers of Caiman allows commercial hunting to continue long after populstions of Melanosuchus have dropped below the level of commercial extinction. The present trickle of Melanosuchus skins going out with the flood of Caiman skins could eventually lead to the former species' biological extinction.

In the event that enforcement of regulations over the entire Amazon system will not be feasible for some time, refuge areas may be critical to the eventual reestablishment of the species. The existing National Park System (only one park in Amazonia functioning with guards) is certainly not adequate to meet this task.

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STATUS OF *CROCODYLUS ACUTUS*, *CAIMAN CROCODILUS FUSCUS*, AND *CAIMAN CROCODILUS CROCODILUS* IN VENEZUELA

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This report summarizes information gathered while the author was engaged in other endeavors, primarily baseline investigations of the natural history of *Caiman crocodilus crocodilus* for the Venezuelan Government (1973-1977). It is based upon literature references, direct observations and conversations with knowledgeable persons familiar with the species in question. The continuing dubious status of many species of South American crocodilians has prompted me to present the following information at this time.

Crocodilians have traditionally been exploited by indigenous peoples in Venezuela for food, medicinal, and religious purposes. *Crocodylus acutus* is referred to "Caiman de la costa" and *Caiman c. crocodilus* and *Caiman c. fuscus* are referred to "Baba or Babilla" in Venezuela. Some animals were eliminated from the vicinity of fishing and washing localities. These uses probably had a negligible effect on local populations of crocodilians, and it was not until the advent of commercial hide hunting that systematic degradation began to seriously harm existing populations.

Through the foresightedness of the Venezuelan Government, a moratorium on all hunting of wildlife has been in effect since 1974 and continues to offer protection to crocodilians. Despite strong legislation, illegal poaching continues and I have seen *Crocodylus acutus* and *Caiman* hides that were confiscated by the Guardia Nacional as recently as the mid 1970's. There also was a report of an illegal shipment of crocodilian hides sent to Europe from Venezuela that was labelled "salted fish."

To a lesser extent, the pet trade and the manufacture of crocodilian curios have contributed to the downfall of *Caiman* in Venezuela. Specimens of *Caiman c. crocodilus* and *Caiman c. fuscus* illegally captured in and smuggled out of Venezuela to Colombia for curing and processing are then legally imported back into Venezuela to be sold as curios.

The rest of this report deals with the current status of *Crocodylus acutus*, *Caiman crocodilus fuscus*, and *Caiman c. crocodilus* in Venezuela.

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[1] Deceased.

Following the individual status reports are recommendations for future surveys. A range map depicting the historical and current distribution of *Crocodylus acutus* and target survey areas is presented (Fig. 1).

STATUS

Crocodylus acutus

The American Crocodile has been greatly reduced and in some cases eliminated from most of its former range. Historically it is recorded from the states of Zulia, Falcon, Miranda, Anzoategui, and the Island of Margarita. Current observations document its occurrence in the states of Falcon, Carabobo, Aragua, and Miranda (see Fig. 1).

Perhaps one of the few potentially breeding populations of this species is located at the Refugio de Fauna, Cuari, in the state of Falcon, where Robert Godshalk and I counted 23 individuals, all under 8 feet (2.4 m) total length, in 1975. There have been several unconfirmed reports of recent nesting from this same area.

Caiman crocodilus fuscus

Several localities for this species exist in the literature from western Zulia (Medem 1973). It has been reported to enter brackish water. A dried skin from Chichiriviche, Falcon, belonging to *fuscus*, has been brought to my attention by Dr. Federico Medem (*in litt*. 31 January 1975). Until detailed status surveys are carried out, no further comment can be attempted concerning the status of *Caiman crocodilus fuscus* in Venezuela.

Caiman crocodilus crocodilus

This species is the most common crocodilian to be found in Venezuela. It has been recorded from practically every state (King 1973, Medem 1973). Although it is in no danger at this time, its position is by no means guaranteed. Very high concentrations during the dry season, makes *Caiman c. crocodilus* an easy target for hunters and eventual Appendix I status if strict control is not maintained.

RECOMMENDATIONS

- Determine the southern and altitudinal limits for all three species.

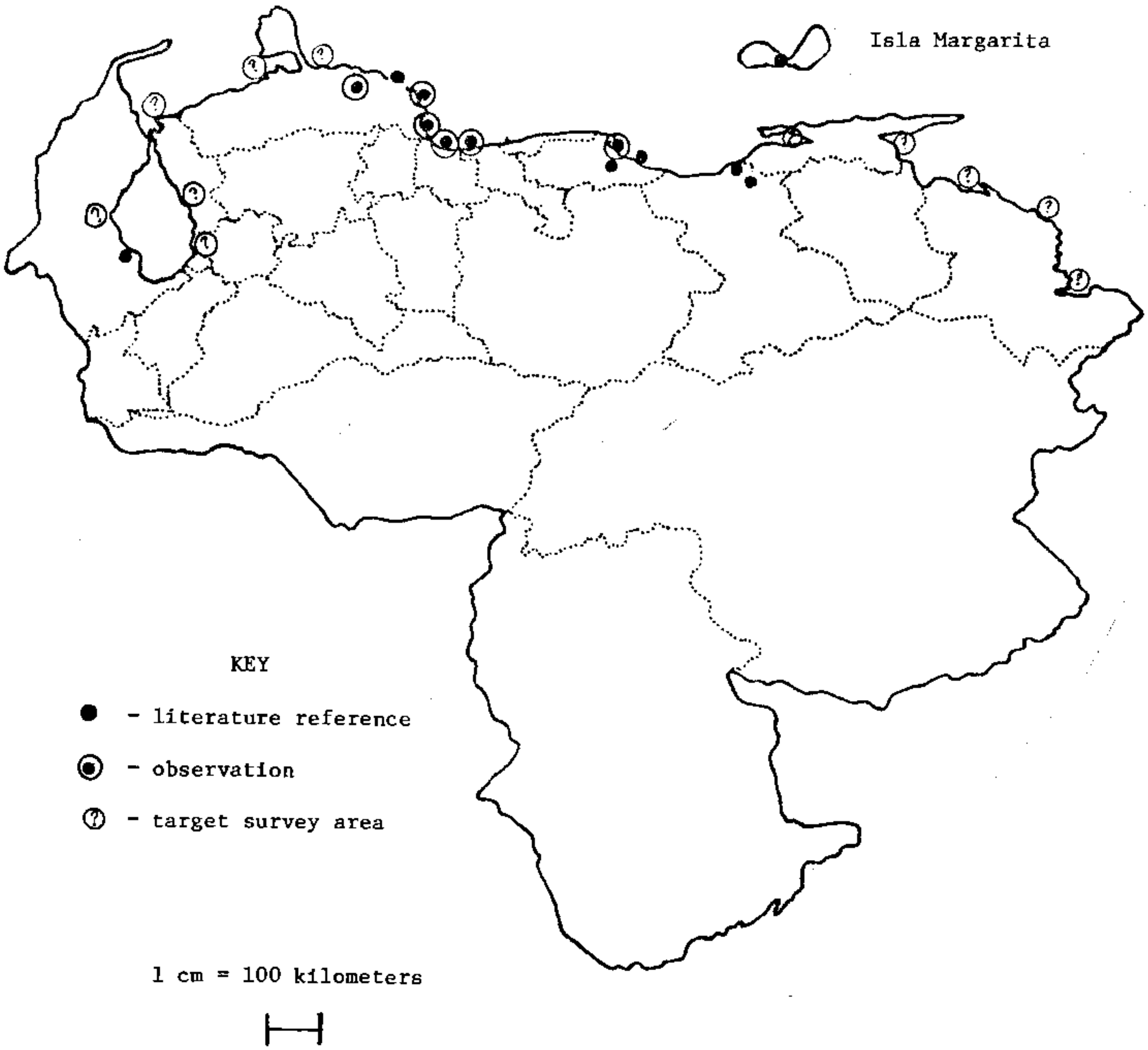

Figure 1. Historical and Current Distribution of Crocodylus acutus in Venezuela.

Crocodylus acutus

Recommended localities for status surveys:

- All historical localities
- Western Zulia (La Concepcion to San Carlos de Zulia)
- Eastern Zulia (Palmarejo to Cabimas)
- Trujillo (Sabana de Mendoza to Buena Vista)
- Falcon (San Felix to Coro) (La Vela de Coro to Boca de Aroa)
- Sucre (Peninsula de Araya and Golfo de Cariaco) (Parque Nacional Mochima) (Peninsula de Paria and Golfo de Paris) (fide; Dr. Medem)
- Territorio Delta Amacuro (Pedernales to San Jose de Amacuro)
  NOTE: This is a vast area. Dr. Medem informs me it is not known which species, if any, still inhabit this region. Both *Crocodylus acutus* and *Crocodylus intermedius* may overlap here.

Caiman crocodilus fuscus

- Survey northern coast of Zulia and Falcon
- Determine current range and status

Caiman crocodilus crocodilus

- Continue to protect

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SANCTIONED EXPORTATION OF CAIMAN HIDES FROM COLOMBIA

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This report may be considered in the following perspective: the original paper was prepared for the Species Survival Commission meeting in San Jose, Costa Rica, in March 1979. For various reasons, the paper was not presented, but the data prior to 1979 was subsequently offered to ORYX for publication; it was accepted and will appear in the next issue. Excerpts from this publication recently appeared as a single bibliographic entry in TRAFFIC (1980, Vol. II(5-6): 55). The original data will be referred to and compared with the 1979-1980 data, which are not contained in the ORYX article.

The data presented herein were compiled in 1977 and 1978 by Alberto Donadia and me. Those shown in Table 1 formed part of a report on Colombia for the New York Zoological Society in 1977, while the other figures were published by a group of ecologists at the University of Tolima, Ibague, Colombia (Palomino and Donadio 1978). In Table 1, only the total number of complete caiman hides exported under official sanction in 1976 is given. In order to avoid confusion, there is no separation into categories, such as "hides less than 1.20 m, flanks, etc.," but the information is given in Table 2. A large discrepancy of 164,828 is readily apparent in the totals of hides represented in Table 1 and Table 2 for 1976. This may be accounted for by the different methods used in reporting. All the data from 1976 to present were copied from the official registers of exportation issued by the Instituto Colombiano de Comercia Exterior (INCOMEX).

From 1951 to 1976 over 10 million hides of Caiman crocodilus were exported from Colombia (Table 1). This figure, as well as those for later years represent complete caiman hides of various lengths. In 1976 the total number was 484,673 (Table 1). In 1977 some 392,240 complete hides were exported from Colombia with official government sanction (Table 3). The data for 1978 are incomplete and comprise only the period from January to June. There were 183,156 entire hides exported from Bogota and Barranquilla during that period (Table 4).

If we total only the number of complete hides, without considering specified parts (e.g. flanks, tails, breast plates, or clippings), it is found that in the two and one-half years from January 1976 to June 1978 a total of 1,180,153 caiman hides were exported from Colombia under official government sanction, i.e. the exportation was technically illegal according to the national conservation laws. According to Resolution 530, hunting of the black, smooth-fronted, and dwarf caimans has been prohibited since

1970. Further, according to Resolution 847, hunting or capturing of live specimens of the spectacled caiman less than 1.50 m has been prohibited since 1973. Thus, one can hardly state, correctly, that the hides were exported legally, but rather that they were exported with official knowledge and sanction. Furthermore, these figures represent the absolute minimum, without consideration of illegal, unsanctioned trade nor of the various discrepancies in the official files. It is safe to assume that an additional one to two hides exist for every one officially counted. We are, therefore, discussing a total which could be two million within s two and one-half year period.

We recently received a copy of a letter from Peter Sand, General Secretary of CITES to the main office of the Colombian agency responsible for national conservation laws (INDERENA), in which he requested clarification of some 71 exportation permits signed by INDERENA officials authorizing the export of 330,000 hides and pieces of hides to West Germany during 1978 and 1979. These hides are not included in the data in Table 5. It is believed that they may have comprised the bulk of the thus far unexplained 400,000 hides smuggled from Manaus to Leticia in 1978, ultimately destined for West Germany.

Table 5 represents the data taken from the INCOMEX registers for the period between February 1979 and February 1980; some months in this period are not shown as the data could not be obtained. However, for the eight months that are shown, some 66,826 entire hides are listed without counting parts. Careful study of the INCOMEX registers reveals discrepancies almost too numerous to mention, but among the more frequent ones are the following: registers for different days will often show not only an exactly equal number of hides, but will also manifest that the total weight corresponded exactly with the number of hides on a previous day; the unitary designations change with such great frequency that one may not interpret whether they signify pieces or entire hides; the weight given within a particular category often does not agree with the total weight given for that category.

In contrast with former years, the latest figures for 1979 show a significant decrease, which one must assume indicates that fewer animals were available to the hide hunters. It is well known that even hatchlings are killed for the hide trade, as well as juveniles and adults, but this does not satisfactorily explain the ever present enigma of where these vast numbers of animals come from. Undoubtedly, other bordering countries are involved to extents which are difficult to determine exactly.

The future of crocodilians in Latin America can only be viewed as bleak. Moreover, our monitoring system is lacking in interested and qualified personnel actually in the field, making it extremely difficult to obtain relevant data. If this large scale slaughter is to be halted in time, immediate positive efforts must be made by the appropriate government agencies. A definite step in the right direction would be ratification of the CITES convention by Colombia.

TABLE 1. Export of hides of *Caiman crocodilus* ssp. and *Caiman crocodilus fuscus*.

Year	Number of Hides	From	Source
1951-1952	650,000	Magdalena; Sinu	Ricardo A. Tinoco, Director, Barranquilla Zoo; *in litt.* 19 July 1977
1953-1954	800,000	*Ibidem.*	*Ibidem.*
1955-1956	470,000	*Ibidem.*	*Ibidem.*
1958-1961	365,000*	*Ibidem.*	*Ibidem.*
1966-1970	1,842,000	Arauca	Medem 1977:3
1967-1968	30,000	Lower Caqueta; Miriti-Parana	Medem 1977:2 (unpublished)
1969	70,000	Cravo Norte	Medem 1977:2
1969-1970	1,461,870	Total for Colombia	Medem 1971:66
1970	998,930	*Ibidem.*	*Ibidem.*
1970-1973	1,047,718	Jan-Mar 1973 only	INDERENA statistics, March 1973:12
1972	388,098	Bogota, Jan 1-Aug 23 Cali, Jan 1-Jul 17	Figures taken from INCOMEX files; Oct 1972
1972	57,379	Leticia	Scheuerman and Foote *in litt.* 1972
1973	524,402	Barranquilla	INDERENA statistics 1973
1974	556,422	Total for Colombia	Donadio 1975
1974	61,899	Leticia, Jun only	Foote and Scheuerman *in litt.* 1974
1974	114,150	Barranquilla, Jan-Jul	Figures taken from INCOMEX files
1975	26,323	Leticia, Jan-Aug	Scheuerman *in litt.* 1975
1975	666,908	Total for Colombia	Figures taken from INCOMEX files
1976	484,673	*Ibidem.*	*Ibidem.*
1976	39,936	Leticia, Mar 24-Apr 10	Scheuerman *in litt.* 1976
Total number of hides	10,650,708		

* All these hides were exported from Barranquilla.

TABLE 2. Numbers of complete and specified parts of <u>Caiman</u> hides exported with official sanction in 1976.

Part/caiman size	Number	Total
Hides < 1.2 m	138,065	
Hides 1.2-1.5 m long	72,972	
Hides > 1.5 m	108,808	
TOTAL NUMBER OF HIDES		319,845
Breasts and tails	17,703	
Tails > 1.5 m	15,181	
Flanks > 1.5 m	9,272	
Flanks 1.2-1-5 m	27,561	
Flanks < 1.2 m	9,883	
Watchbands	3,000	
Shoe vamps (in pairs)	1,054	
TOTAL NUMBER SPECIFIED PARTS		83,654
GRAND TOTAL		403,499

TABLE 3. Numbers of complete hides and specified parts of <u>Caiman</u> exported from Barranquilla and Bogota with official sanction in 1977.

Part/caiman size	Number	Total
Hides (size not specified)	232,646	
Hides < 1.2 m	117,530	
Hides 1.2-1.5 m	42,064	
TOTAL NUMBER HIDES		392,240
Breasts and tails	63,310	
Heads	5,024	
Watchbands	4,150	
Belts	6,382	
Remnants (clippings, etc.)	380	
TOTAL NUMBER SPECIFIED PARTS		72,246
GRAND TOTAL		471,486

TABLE 4. Hides and specified parts exported from Bogota and Barranquilla between January and June 1978; data for the remaining half of 1978 are still unavailable.

Part/caiman size	Number	Total
Hides < 1.2 m	101,375	
Hides 1.2-1.5 m	35,875	
Hides > 1.5 m	45,906	
TOTAL NUMBER HIDES		183,156
Breasts and tails	39,059	
Flanks	4,825	
Remnants (clippings)	5,419	
TOTAL NUMBER SPECIFIED PARTS		49,303
GRAND TOTAL		232,459

TABLE 5. Number of tanned *Caiman crocodilus* hides exported with official sanction between February 1979 and February 1980.

Month	Tanned hides of specimens < 150 cm	Tanned hides of specimens > 150 cm	Tanned Hides of unknown length	Tanned tail pieces	Tanned breast-plate	U.S. Value (in dollars)
Feb	3,680	14,320		18,024	18,030	383,487.00
Mar	2,415	9,585	3,499			111,417.40
Jul	1,610	6,390		12,016	12,020	222,428.00
Aug	805	3,195	4,077	8,004	8,480	292,926.55
Sept				1.638		41,701.60
Oct	2,415	9,585				133,869.90
Dec			1,250	21,300*		121,535.40
Feb	805	3,195		7,300*		63,345.00
TOTALS	11,730	46,270	8,826	68,282	38,530	1,370,710.85

* Represents a combined total of tails and breast plates for these INCOMEX registers

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THE STATUS AND DYNAMICS OF CROCODYLUS POROSUS POPULATIONS IN THE TIDAL WATERWAYS OF NORTHERN AUSTRALIA*

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ABSTRACT: During a 9-year exploration-survey-research study of tidal waterways in northern Australia some 100 tidal systems were surveyed systematically. In the Northern Territory 3998 km of tidal waterways were surveyed, in Western Australia 527 km, and in Queensland 643 km. Basic nautical and habitat data were obtained for each of the waterways and a system of classifying the tidal systems, based upon their salinity profiles, was derived.

The populations of *Crocodylus porosus* were inventoried and their size structure determined. A picture of the dynamics of *C. porosus* populations was derived, and our results were shown to be interpretable in a consistent fashion in terms of this picture. Summaries of results, pertaining to the general nighttime crocodile surveys and resurveys are presented. Using these results we arrive at an estimate for the number of non-hatchling *C. porosus* in northern Australia: Northern Territory 10,000, The Kimberley 2,500, Northern Queensland 3,000 (total 15,500). These are very low numbers indeed, and it is estimated that the present population of non-hatchling crocodiles is probably no greater than 1% or 2% of its former extent.

The prognosis for recovery of *C. porosus* in northern Australia appears to be as follows:

Northern Territory - populations slowly recovering in tidal waterways of northern Arnhem Land and the Alligator Rivers Region; populations from the Adelaide River westward to the Western Australian border are steady or still falling; populations in the Gulf of Carpentaria are at extinction levels with the exception of the Roper and Towns rivers.

Western Australia - populations are probably recovering very slowly in major sections of the Kimberley tidal waterways.

Queensland - with the exception of the tidal waterways draining into Port Musgrave, populations are probably still falling and are at dangerously low levels.

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* This paper is based upon Chapter 9 of Monograph 1 (see reference list for details).

Attention is drawn to the danger that recovery may be halted on a number of the major breeding systems because of the destruction of riverine and swamp habitat by feral water buffaloes. The toleration of both legal and illegal net fishing for barramundi well upstream of tidal river mouths and often right up into the breeding areas is probably responsible for the drowning of several hundred large *C. porosus* annually. As barramundi are fished out, the fishing pressure increases and the number of *C. porosus* drowned in nets increases. If this folly is allowed to continue unabated then the remaining crocodile resource along with the fish resource will be rapidly depleted.

INTRODUCTION

A major study of tidal river systems in northern Australia was completed in December 1979. The work, which required a concentrated effort of nine years' duration, provides for many northern Australian tidal systems the first systematic exploration and basic survey data since settlement of the continent. The aims of the study were:

A. Tidal waterway studies.-- To explore, survey, and obtain basic nautical data and to classify the tidal waterways and their associated habitats in order to provide a foundation for future development and studies. The work was to include: the preparation of detailed river work maps, showing distances and navigational hazards and thus providing a common basis of reference for all who may use the waterways; the discovery of channels leading into the waterways; the preparation of sailing instructions; the preparation of seasonal temperature and river salinity profiles; the determination of tidal patterns; the determination of the distribution and cover abundance of mangrove species in fringing riverside vegetation.

B. Population studies of *C. porosus* in northern Australia.-- To determine the present magnitude of the populations of *Crocodylus porosus* in northern Australia and to monitor the recovery in different known habitats. To examine the population structure and to quantify such aspects as reproduction and survivorship. Studies were planned on feeding habits, growth, and movement, the last requiring the development and use of radio telemetry techniques.

C. Habitat suitability.-- To classify the tidal waterways in relation to habitat type and to relate these to abundance and/or nesting success of *C. porosus*, in order to predict habitat suitability.

D. Management procedures.-- To develop procedures for management and future utilization in a manner which would ensure survival of the species.

Some 100 tidal systems were surveyed systematically and many of these were surveyed more than once. The overall program necessitated some 50,000 km of waterway travel. The detailed results of the study and the analyses of these results have appeared or are appearing in a series of 17 Monographs, published by Pergamon Press (see Monograph Series Section) and in a series of reports and specialist papers.

In this paper we summarize the results pertaining to the general nighttime crocodile surveys, for all tidal waterways surveyed. Utilizing the assemblage of these results enables us to make an assessment of the overall status of C. porosus in the tidal systems of northern Australia. We have drawn freely from the material we presented in the 17 Monographs and especially from Monograph 1, in which Chapter 9 contains much of the material presented herein. Survey techniques and methods developed for analyses of the survey results are discussed at length in Monograph 1 and are not repeated here. The counts were found to be well described by the binomial distribution, and confidence limits were obtained by approximating the binomial distribution by a normal distribution of appropriate mean and variance.

CLASSIFICATION OF TIDAL WATERWAYS

Analysis of the number, distribution and size structures of crocodiles sighted during the general surveys of northern Australian tidal systems indicates that one of the most important parameters characterizing a tidal waterway is its salinity profile. The profile and habitat type image one another and appear to largely determine the suitability or otherwise of the tidal waterway for breeding, nesting and rearing. It was in Monograph 5, on the Goomadeer and King River Systems, that we first classified the tidal rivers and creeks on the northern Arnhem Land coastline roughly into three different types of waterways. The classification plays a critical role in the unravelling of the dynamics of populations of C. porosus (see Monographs 5, 9, 10 and 11) and is given by:

TYPE 1.-- Tidal river systems meandering through coastal floodplains and having a heavy freshwater input during the wet season. The freshwater inflow decreases but remains sufficient, as the dry season progresses, to prevent the salinity upstream (though progressing upstream gradually) from rising above the sea water values measured at the mouth of the system. Such systems usually have good to excellent nesting habitat and could be expected to have good recruitment potential. The Goomadeer River System was classified as such a system. The Blyth-Cadell Rivers System is one of the best examples of a TYPE 1 system on the northern Australian coastline.

TYPE 2.-- Tidal systems that fall somewhere between TYPE 1 and TYPE 3 and which tend to show hypersaline characteristics as the dry season progresses. Such systems usually have good to poor nesting habitat and equivalent recruitment potential, depending upon how close they are to TYPE 1 or 3. The King River (Monograph 5) and Dongau Creek on Melville Island (Monograph 6) are examples of such systems.

TYPE 3.-- Tidal waterways that also have a heavy freshwater input during the height of the wet season, but in which the freshwater input drops rapidly with the onset of the dry season. These waterways, which usually have short surveyable length and often direct openings to the sea, are typified by salinities which during the dry season are above those measured at their mouths and which increase with increasing distance upstream--they are hypersaline and become increasingly so as the dry season progresses. Nesting habitat in such systems is minimal or nonexistent. Recruitment potential is also usually low or nonexistent. All Night Creek (Monograph 5) is an example of such a system; most of the coastal creeks surveyed on the southern coast of the Gulf of Carpentaria also fall into this category (Monograph 13).

It will be seen that each of these three system types has its own characteristic type of salinity variation, with respect to both time of year and to distance upstream, and that the salinity characteristics largely determine the nature of the system. Figure 10 shows typical dry season salinity profiles for the three system types. The salinity profile of a system may be said to be its own unique signature. A large river system may have multiple signatures, one for its mainstream and different signatures for its creeks and subcreeks.

DYNAMICS OF C. POROSUS POPULATIONS

In Monographs 1, 9, 10, and 11 we were able to derive a picture of the dynamics of C. porosus populations on the northern Australian coastline, which accounted in a consistent fashion for the results we obtained during the surveys and resurveys of the tidal waterways.

It is the TYPE 1 systems which account for the major recruitment of C. porosus; all other systems contribute to a lesser degree and they must depend largely upon TYPE 1 systems for the provision of their crocodiles. It appears that the populating of the non-TYPE 1 systems is by the exclusion of a large fraction of the subadult crocodiles from TYPE 1 systems. Adult crocodiles appear to tolerate hatchlings, 2'-3' (0.6-0.9 m) and sometimes 3'-4' (0.9-1.2 m) crocodiles, but not larger crocodiles. Thus once a crocodile reaches the 3'-4' (0.9-1.2 m) and 4'-5' (1.2-1.5 m) size classes, it is likely to be challenged increasingly, not only by crocodiles near or in its own size class but by crocodiles in the larger size classes, and be excluded from the area it was able to occupy when it was smaller. A substantial fraction (80%) of the 3'-6' (0.9-1.8 m) size crocodiles may thus be excluded from the river or be preyed upon by larger crocodiles. Of those that leave, 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 go out to sea and possibly perish (perhaps because of lack of food, as they are largely shallow water on edge feeders, or they may be taken by sharks). Those finding non-TYPE 1 systems frequent these areas for varying periods, which act as rearing stockyards, until reaching sexual maturity, at which time they endeavor to return to a TYPE 1 breeding system. Both subadults and recently 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 and even though a fraction of crocodiles finally return to and remain in a TYPE 1 system, the overall numbers missing and presumed dead remain high (60-70%). Since a large fraction of crocodiles sighted in non-TYPE 1 systems are derived from TYPE 1 systems, they are predominantly subadults or recently mature adults. The loss factor which appears to occur during the movement 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 ramifications of the above picture for structuring a management strategy and eventual utilization of the valuable C. porosus resource are of the greatest importance. An adult C. porosus is a very valuable asset, whereas subadults are probably of less value as a component of the population--but probably have a more valuable skin. The release of hatchlings into river systems should be questioned and it would appear that if subadults are to be released for the restocking of rivers, then the non-TYPE 1 systems, especially permanent freshwater swamps and billabongs with an adequate food supply, should be chosen. Whether such animals would then be able to locate a TYPE 1 system at sexual maturity is an open question. Those in swamps and billabongs near TYPE 1 systems would probably have a much better chance of doing so than animals released into non-TYPE 1 coastal systems.

This picture of the dynamics of C. porosus populations indicates that, when discussing population fluctuations, it is essential to consider not only results for individual waterways, but also those for broad groups of tidal waterways. We were able to show in Monographs 1 and 9 to 11 that a decrease in crocodiles counted in a TYPE 1 waterway need not necessarily imply that the population of C. porosus is decreasing. The decrease may only imply that a fraction of the subadult C. porosus has been excluded from the system by adults; furthermore, the surviving fraction of the excluded subadults could produce an increase in numbers in adjacent TYPE 2 and TYPE 3 waterways. Such crocodiles could in due course return to the TYPE 1 systems as adults. Because C. porosus is known to travel long distances (Webb and Messel 1978), it is first necessary to consider small geographic subgroups and then larger groupings of tidal waterways, if one is to appreciate the overall changes occurring in C. porosus populations. The tidal waterways considered in each Monograph normally form a natural geographic subgroup and these often contain a mixture of TYPE 1, TYPE 2, and TYPE 3 systems. For instance those in Arnhem, Buckingham, and Castlereagh bays form such subgroups, whereas the overall assemblage of the waterways on the northern coast of Arnhem Land is an example of a group covering a large geographic area. The southern coast of the Gulf of Carpentaria is another such system; in Western Australia the tidal systems of the northwest Kimberley form s large group, as do those between Darwin and Cobourg Peninsula (see Figs. 1 to 9, placed at end of this paper).

SUMMARIES OF RESULTS BY SIZE CLASS AND BY WATERWAY CLASSIFICATION

In Table 1 (at end of this paper) we present for the tidal waterways of the Northern Territory, Western Australia, and Queensland the following results for each survey: the number of C. porosus sighted within each size class, the midstream distance surveyed, the density of non-hatchlings sighted, and the 95% confidence levels for the estimate of the actual number of non-hatchlings present. Also shown is the classification of waterway type as determined by the salinity signature of the main waterway; it usually does not include the often differing waterway's sidecreeks. All crocodiles whose size class could not be determined positively (the EO, EO < 6' [1.8 m] and EO > 6' [1.8 m] size classes) have been lumped together and shown in the EO size classes. When it is necessary to allocate these crocodilians to various size classes, probably the best one can do is to use the scheme outlined in Table 6.2.30 and Section 6.3.4 of Monograph 1.

Our results for the tidal waterways of the Northern Territory are presented in the same sequence as the Monographs. We then group and sum the results for the latest survey of each waterwsy, according to TYPE 1 (any waterway whose TYPE has a "1" in it), TYPE 2-3 (any waterway whose TYPE has a "2" but not a "1" in it) and TYPE 3; the summing of these three then yields the overall results for the Northern Territory. The percentage that each size class constitutes of the total number of C. porosus sighted is shown also. Next, we present the results for subgroups of waterways, grouped according to geographic proximity. Wherever possible, we show results for the 1975 and 1979 surveys so that changes in population size for the areas concerned may be examined. Finally the latest surveys of the tidal waterways of the Northern Territory are gathered and summed for the four large geographic areas:

1. Gulf of Carpentaria, which covers tidal waterways from the Queensland border to Gove (Figs. 5 to 7).
2. North Arnhem Land, which covers the tidal systems from the Burungbirinung River in the east to the King River in the west (Fig. 5).
3. Darwin eastward to Cobourg Peninsula including Melville Island waterways (Fig. 4).
4. Darwin westward, from Port Darwin to the Victoria River near the Western Australian Border (Figs. 2 and 3).

DISCUSSION

Number of Crocodiles and Their Size Class Structure

Northern Territory

The total number of *C. porosus* sighted on the 3997.6 midstream km of tidal waterways surveyed in the Northern Territory was 5472, of which 1293 were hatchlings. Since only some 50% of hatchlings survive from June of their first year to June of the next (Table 8.4.1, Monograph 1) they should not be included in any estimate of the viable population. We therefore usually give densities and estimates for the actual number of non-hatchling crocodiles only. On this basis the overall density of the 4179 non-hatchling crocodiles sighted is 1.0/km and the 95% confidence levels for the estimate of the number present is 6724-6984. This figure and corrections made to it for waterways which were not surveyed is discussed later.

The density figure of 1.0/km is of very limited value, for the density of non-hatchlings sighted in TYPE 1 and non-TYPE 1 systems is quite different. On the 2175.5 km of TYPE 1 tidal waterways surveyed, the density of the (4491-1197) = 3294 non-hatchlings sighted was 1.5/km whereas on the TYPE 2-3 and TYPE 3 systems it was 0.5 and 0.4 per km respectively.

The size-class structure of the crocodiles sighted in the TYPE 1, 2, and 3 systems varies also (Table 1). It should be cautioned that there can be considerable overlap between the system TYPES. For instance, large TYPE 1 waterways, such as the Adelaide and Liverpool River Systems, contain TYPE 2 and TYPE 3 systems as well. If these were subtracted from the systems, the differences would be further exaggerated. Table 1 also shows the percentage which each size class constitutes of the total number of crocodiles sighted. Thus in TYPE 1 systems some 27% of the crocodiles sighted are hatchlings, whereas in TYPE 2-3 systems this figure falls to 14% and in TYPE 3 systems to 4%, showing a much decreased hatchling production in non-TYPE 1 systems. In TYPE 3 systems 11% of crocodiles fall in the hatchling 2'-3' (0.6-0.9 m), and 3'-4' (0.9-1.2 m) size classes combined whereas in TYPE 1 systems at least 52% are in this group. On the other hand the percentage of crocodiles in the ≥4'-5' (1.2-1.5 m) size classes is 39% in TYPE 1 systems and 73% in TYPE 3 systems. These percentages do not take into account the EO class which amounts to 10%, 16%, and 16% for TYPE 1, TYPE 2-3, and TYPE 3 systems respectively. Since large crocodiles are usually more wary than small ones (Webb and Messel 1979), any correction for this class would tend to exaggerate further the differences between the TYPE 1 and non-TYPE 1 systems. It is likely that the differences in the EO size class between TYPE 1 and non-TYPE 1 systems reflects the higher fraction of large crocodiles in non-TYPE 1 systems.

On the 3997.6 midstream km of tidal waterways surveyed in the Northern Territory, 54% (2175.5 km) were TYPE 1, 23% (938.4 km) were TYPE 2-3, and 22% (883.7 km) were TYPE 3 systems. In making corrections for tidal waterways not surveyed one should use the density appropriate to the waterway TYPE.

Our estimate of the surveyable distance of tidal waterways in the Northern Territory not surveyed systematically is: Mellville and Bathurst Islands 330 km, Western Australian border to Gove 280 km, Gulf of Carpentaria 50 km (total 660). Since practically all of these waterways are non-TYPE 1 systems and many are difficult to enter and, furthermore, since we had a very large sample of non-TYPE 1 waterways, it was thought not worthwhile endeavoring to survey them. During 1972 one of the authors (HM) had surveyed most of the waterways on Melville and Bathurst Islands; it was found then that the waterways later omitted contained even fewer C. porosus than those tidal waterways on Melville Island chosen for more intensive study (Monograph 6).

The shores of the coastline (amounting to some 3200 km) have not been surveyed for a number of reasons. First, there is the risk to life involved in trying to do so; secondly, on each occasion that we have surveyed long sections of bays and inlets we have sighted either none or only sporadic C. porosus. Though the density of C. porosus along the shores of the coastline may have been greater in bygone days, it is almost negligible at present and must be considerably less than 0.1/km (see Monograph 9). The reasons for this are probably many; the more important being that there are so few C. porosus, even in favorable habitats, that C. porosus appear to dislike waves intensely (see Appendix A.1.2 of Monograph 1; wave action on the northern Australian coastline is high during much of the dry season), and also that there is little vegetation to provide cover along the long stretches of sandy and rocky foreshores.

In each tidal waterway surveyed, the survey boats proceeded as far upstream as water depth would permit. In the case of non-TYPE 1 systems this constituted a much higher fraction of the overall waterway than in the case of TYPE 1 systems which have more extensive drainage courses. In most non-TYPE 1 systems, the extreme upstream sections have no water in them at low tide, and thus their omission yields almost negligible error in the estimate for the actual number of C. porosus present on the system (see Monograph 10 on Buckingham Bay). The case of TYPE 1 waterways is more complex, for here the waterway courses may have non-navigable (by survey boat) freshwater sections greater in length than the sections surveyed. These are usually beyond the tidal limit and often consist of intermittent waterholes with sections in between which are dry during the dry season. C. porosus are known to inhabit the freshwater sections, but their density is low. On these sections of the waterways C. johnsoni appear to be the main species (Monographs 2, 3, 12, 13 and 16). The mighty Roper River is an example of such a river system, as are the McArthur, Adelaide, Alligators, Prince Regent, Mitchell, Ord, Victoria, and Blyth River Systems. As pointed out in Chapter 6 of Monograph 1, in our discussion of the distributional pattern of C. porosus, the number of C. porosus sighted on the freshwater section of the Blyth River falls quickly and drastically as one proceeds further upstream. The same phenomenon was discussed again at some length in Monograph 12 on the Roper River and in Monograph 10 on Buckingham Bay where it was cautioned that care must be taken when comparing non-hatchling C. porosus densities of one waterway with another. By including long freshwater sections one can bring down the density figure to very low values. For instance on the Roper River we found a non-hatchling density of 1.14/km for the 324 non-hatchlings sighted on the 283.9 km of waterway surveyed. If we exclude the long upstream freshwater sections above km 85, then the density of the 304 non-hatchlings sighted rises to 1.41/km. The density of the 20 non-hatchlings sighted on the 68.5 km of freshwater sections above km 85 was only 0.3/km. During the calibration surveys on the Blyth River, the average density of non-hatchlings sighted on the first purely freshwater (km 40-45) section was only 1.1/km compared to at least 2.7/km for the whole river system. The density could be expected to fall rapidly as one proceeded upstream of km 45. On the basis of the above discussion one could perhaps add some 1000 km of TYPE 1 river distance to the 2175.5 km surveyed, but the density of C. porosus on these unknown sections is unlikely to be more than 0.2/km. During 1972 we systematically surveyed waterhole after waterhole on the sections of the Goyder River upstream of the Goyder crossing and only sighted two C. porosus. The Goyder River runs into the Arafura Swamp which is known to be one of the few large remaining freshwater swamp areas in northern Australia.

The relatively few freshwater swamps, both large and small, in the Northern Territory are known to contain populations of C. porosus, but these have not been inventoried systematically and the present extent of the populations in them remains unknown. However, from the many casual observations already made, we believe it is likely to prove to be considerably less than 20% of the population sighted in TYPE 1 tidal river systems.

On the basis of the above (with due reservation being made), our estimate for the number of sightings of non-hatchling C. porosus in the Northern Territory which were omitted from our tidal river survey is:

Unsurveyed tidal waterways (660 km x 0.5/km)	330
Unsurveyed freshwater sections of TYPE 1 systems (1000 km x 0.2/km)	200
Unsurveyed foreshores of coastline (3200 km x 0.05/km)	160
Freshwater swamps, taking 20% of the number sighted in TYPE 1 tidal systems	836
TOTAL	1526

If one applies the same confidence limits for these 1526 non-hatchlings as we have for our surveys (this procedure for the assumed 836 non-hatchlings in freshwater swamps is dubious, but is as valid an assumption as any other at present!), then there could be between 2424 and 2582 non-hatchlings added to the 6724-6984 derived from our surveys. Thus using (4179 + 1526) = 5705 non-hatchlings, there could be between 9204 and 9508 non-hatchling C. porosus in the Northern Territory as of October 1979, and we feel it would require unrealistic assumptions to carry this figure much above 10,000. We even retain some doubts about the maximum figure of 10,000; it may be a substantial overestimate. On the other hand, we do feel that our estimate of 6724 to 6984 is a reliable lower one for the actual number of non-hatchling C. porosus, for this figure is based upon careful and systematic observations made over a period of almost 5 years and some 50,000 km of waterway travel.

Western Australia

Tidal river systems in the Kimberley (Figs. 1 and 2) were chosen for survey by the Department of Fisheries and Wildlife, Western Australia. It is believed that the majority of the large Kimberley tidal waterways were surveyed; the only significant areas not surveyed are the Walcott Inlet-Secure Bay area and the West Arm of the Cambridge Gulf, with their associated rivers and creeks. It is also believed that small populations occur in such areas as the mouth of the Drysdale River. Commonly, small coastal rivers and creeks in the Kimberley have short surveyable tidal sections which are terminated by rocky ledges and often by waterfalls.

We believe that we examined more than half of the better C. porosus habitat in the Kimberley. In the 527.3 km surveyed, 898 crocodiles were sighted, of which 227 were hatchlings. The 671 non-hatchlings yield a density of 1.3/km and the estimate for the actual number of non-hatchlings present, at the 95% confidence level, is 1048-1152. Assuming that the number of non-hatchlings that would be sighted in the areas not surveyed is also 671, we obtain lower limits of 2127-2275 for the number of non-hatchlings remaining in the Kimberley as of July 1978. (One can extend this estimate [of say 2500] almost without limit if one cares to make what we feel would be unreasonable assumptions.)

Queensland

A sample of four major tidal waterways on the west coast of southern Cape York Peninsula (Fig. 8), which were known to have contained some of the best populations of C. porosus during the 1950's and 1960's was chosen by the Queensland National Parks and Wildlife Service for survey. In addition the Port Musgrave area, containing what is believed to be the best remaining tidal waterway habitat for C. porosus in Queensland, and the Escape River on northeastern Cape York Peninsula were also chosen (Fig. 9). As seen in Table 1, the results for the Port Musgrave area and the other areas were quite different. Whereas the non-hatchling density was 1.8/km for the 241.0 midstream km surveyed on the Port Musgrave waterways, the non-hatchling density for the groups of waterways on southwestern Cape York Peninsula (359.7 km) was 0.4/km only and for the Escape River (42.0 km) it was 0.7/km. The overall density for the 606 non-hatchlings sighted on Queensland tidal waterways (642.7 km surveyed) is 0.9/km and the estimate at the 95% confidence level for the actual number of non-hatchlings present is 945-1043.

What estimate can one make for the total number of non-hatchling C. porosus in northern Queensland? The lengths of the remaining waterways on the maps look large, but most of the rivers have relatively short navigable sections. Without carrying out further surveys one can only make a broad estimate; it would be surprising if non-hatchling C. porosus densities on them were as high as the 0.4/km we found for the southern waterways surveyed, since these waterways were known to have contained some of the best populations. Erring on the generous side, we estimate that there are probably a further 2400 km of waterways not surveyed. Using a non-hatchling density of 0.4/km this would yield a further 960 crocodiles which would be sighted. On this basis, the estimate at the 95% confidence level for the actual number of non-hatchling crocodiles present, using the (606 + 960) = 1566 value, is 2488 to 2648 or say 3000. However, without further surveys one is unable to substantiate this number.

Northern Australia

We now have estimates for the populations of non-hatchling C. porosus in the Northern Territory, the Kimberley of Western Australia and northern Queensland. Only the figures for the tidal waterways surveyed may be deemed reliable; the remainder are probably upper limits and may be overestimated considerably. Only surveys of the waterways can yield accurate figures. In lieu of this, how high the estimate is depends upon individual predilection. With this warning in mind our upper estimates for the non-hatchling C. porosus populations are: Northern Territory 10,000, The Kimberley 2,500, Northern Queensland 3,000 (Total 15,500).

How large were the original numbers of crocodiles? We can never know for certain, for as usual, this Australian resource was neither inventoried nor studied until it was virtually exhausted. Those who permitted or even encouraged the depletion argue vehemently about its former extent. (An excellent example of the process is now seen with barramundi [Lates calcarifer] which is being netted and poached out at an alarming rate before the extent or biology of the resource has been assayed.) However, reports from hunters, figures on the skin trade, and above all the innumerable statements and journal entries by the early explorers, attest to the fact that the original numbers must have been huge. Explorers such as King, Stokes, Cadell, Searcy, and others refer time after time to the very numerous crocodiles on northern Australian rivers, and to the problems they had with them (see

Monograph 4 and 12). It is likely that the C. porosus population in northern Australia was well in excess of one million in the tidal rivers, in associated freshwater swamps, and along the coast, but as stated above, one will never be able to prove it. On the basis of this figure, which in our opinion is probably an underestimate, the present population of non-hatchling crocodiles is probably no greater than 1% or 2% of its former extent. Thus, what may have taken millions of years to achieve was wiped out by voracious hide hunters in less than 2 decades.

The figure of 15,500 is very low and one which would in almost any other developed country of the world evoke national concern and ensure remedial action. Instead in many (but fortunately not all) quarters of Australia there is a hue and cry to allow the harvesting of C. porosus again. One can only hope that this reflects more the still sanguinary aspect of our pioneer Australian society rather than its ability to think logically and make rational judgment based upon scientific data. In the U.S.A., the American alligator was accorded full protection from harvesting when numbers dropped to an estimated 450,000 (T. Joanen pers. comm.). Very strictly supervised and limited culling is only now being permitted when the estimated number of alligators is some 750,000.

PROSPECTS FOR RECOVERY OF C. POROSUS

The matter which must be raised first is, recovery where? As we stated earlier, because of the dynamics of C. porosus populations, it is essential to consider not only results for individual waterways but also for broad groups of tidal waterways; not doing so can easily yield a false picture of population decreases/increases.

The analyses of the results from our surveys of individual tidal waterways and of those in adjacent areas are given in the relevant Monographs and we refer the reader to these for details. One may determine roughly whether there has been a significant increase in non-hatchling numbers from one survey to another by examining the 95% levels column in Table 1 and seeing whether or not the levels overlap. If they do not, then the increase is said to be significant.

For closely adjacent groups of tidal waterways which were surveyed first in 1975 and again in 1979 (those in Castlereagh, Buckingham, Ulundurwi and Arnhem bays, Fig. 5) we were able to demonstrate a statistically significant increase at the 95% level of confidence (and some at the 99% level) in non-hatchling numbers during the intervening period, even though in some cases the increase on a number of the individual waterways constituting the group was not significant. An excellent example of this may be seen in the case of the Habgood River, a TYPE 1 system in Arnhem Bay (Monograph 11). Examination of Table 1 shows that the number of non-hatchling C. porosus sighted on this waterway during the 1975 and 1979 surveys was essentially constant.

However there was a significant increase on the adjacent non-TYPE 1 Darwarunga, Baralminar, and Gobalpa rivers (Fig. 5) whose non-hatchling C. porosus are likely to have been derived from the Habgood River. On the other hand, on Melville Island (Monograph 6), the increase in non-hatchling numbers on TYPE 1 Andranangoo Creek between 1975 and 1979 was sufficiently great that even though the numbers remained essentially constant on non-TYPE 1 Dongau and Tinganoo creeks (Fig. 4), the combination of the three still shows a significant increase. An even better example is to be found in the case of the rivers and creeks between the Blyth and King rivers (Fig. 5). The Blyth-Cadell, Liverpool-Tomkinson, and Goomadeer rivers are excellent TYPE 1 systems, yet the Blyth-Cadell and Goomadeer rivers do not show a significant increase in non-hatchling numbers between 1975 and 1979, nor do the Liverpool-Tomkinson rivers between 1976 and 1979. (Because of the unusually high recruitment of some 260 hatchlings on the Tomkinson River during 1979, a large increase in non-hatchling numbers is to be expected in 1980.) However, the non-TYPE 1 rivers and creeks such as the King, Majarie, Wurugoij, and All Night do show increases, as does Nungbulgarri Creek between 1976 and 1979 (1975 was a special case, see Monograph 7). Each of these non-TYPE 1 systems are likely to have derived a high fraction of their non-hatchlings from the adjacent TYPE 1 systems, and when the combined rivers from the Blyth to the King are considered, the increase between 1975 (however, using 1976 Liverpool results) and 1979 is significant.

When one then considers the combined rivers and creeks on the northern Arnhem Land coastline, from the Burungbirinung River in the east to the King River in the west (Fig. 5), the increase in non-hatchling numbers between 1975 and 1979 is highly significant. Thus there can be little doubt that we are witnessing a slow but important recovery in the C. porosus populations on this section of the northern Australian coastline. This section of the Northern Territory coast was chosen for early study because of its situation in Arnhem Land and the possibility that it had suffered less hunting pressure than other sections.

On the other hand, though there was a considerable increase in the number of crocodiles sighted in size classes 5', the loss of subadults (missing, presumed dead) along the northern Arnhem Land coast appears to be large. During 1975, 1069 (2'-5') (0.6-1.5 m) and 339 (5') crocodiles were sighted, whereas in 1979 the numbers sighted in size classes 5' was 696. Thus the 1069 subadults of 1975 appear to have given rise in 1979 to only (696-339) = 357 crocodiles in size classes 5'. This represents a loss (missing, presumed dead) of some 67% (also see Monographs 9, 10 and 11) during the intervening period. (Growth of C. porosus is discussed in Chapter 8, Monograph 1 and Webb et al. 1978.)

The largest complex of TYPE 1 tidal waterways in northern Australia, the Alligator Region River System is also recovering, and a significant increase in non-hatchling numbers was found between the 1977 and 1979 surveys. However, there is need for concern, for the excellent habitat provided on the system is being rapidly destroyed by feral buffaloes. Unless this is halted, recruitment on these river systems will come almost to a halt, as it already has on the South Alligator River (Monographs 4 and 14). In addition, the continuation of net fishing on important sections of these waterways leads inevitably to the continued loss of large numbers of large crocodiles. These matters are discussed again later.

The Adelaide River, which was surveyed in 1977, 1978, and 1979, shows no sign of an increase in non-hatchling *C. porosus* and in fact the decrease in numbers sighted during the 1977 and 1979 surveys is significant. However, caution must be used when interpreting this result for it is possible that substantial numbers of subadults may have been excluded from the river and entered other waterways which have been surveyed only once (for example, Cobourg Complex, Darwin, and Bynoe Harbours).

Examination of results for tidal waterways surveyed only once cannot by itself tell one whether the populations of *C. porosus* in them are increasing or decreasing, and one must utilize additional information in order to obtain some indication. For instance, in the case of the tidal waterways surveyed west of Darwin (Figs. 2 and 3), only 33 hatchlings were seen out of the 463 crocodiles sighted on the 793.7 km midstream surveyed. With the exception of Port Darwin, Port Patterson, and Bynoe Harbour, these waterways are TYPE 1 systems for which this is a very low rate of production. The density of non-hatchling crocodiles sighted is only 0.5/km which is to be compared with densities of at least twice that value on other predominantly TYPE 1 systems. Since harvesting *C. porosus* has been prohibited in the Northern Territory since 1972, any increase must be slow; however, it is likely that the number of *C. porosus* is at best steady or still decreasing. If there is to be a substantial recovery, then the recovery period may have to be measured in decades.

Matters are as bad or even worse in the Northern Territory sections of the Gulf of Carpentaria. Examination of the results for the tidal waterways surveyed in this area shows that, with the exception of the Roper and Towns rivers in the southwest corner of the Gulf, there is almost no recruitment taking place and the number of non-hatchling *C. porosus* sighted is at dangerously low levels. For instance, only 2 *C. porosus* were sighted on the Calvert River (38.4 km); 4 *C. porosus*, of which 2 were hatchlings, were sighted on the Wearyan River (34.4 km); none were sighted on the Robinson River (35.9 km), and 28 on the large McArthur River System (232.6 km), none of which were hatchlings. From the Calvert River near the Queensland border to the Limmen Bight River next to the Towns (Figs. 6 and 7) only 61 *C. porosus* were sighted (of which 3 were hatchlings) on a surveyed midstream distance of 543.5 km, yielding a non-hatchling density of 0.1/km. On the western side of the Gulf of Carpentaria 34 *C. porosus* were sighted of which 1 was a hatchling; this includes the Walker and Koolatong Rivers which both contain excellent *C. porosus* habitat.

Thus with the exception of the Roper and Towns rivers, C. porosus numbers in the remaining sections of the Gulf tidal waterways in the Northern Territory are at extinction levels. Their main hope for recovery would appear to be movement of subadult C. porosus from the Roper and Towns River Systems. However, even in the case of these two rivers we have no guarantee that non-hatchling numbers are increasing. The exceedingly heavy netting for barramundi well upstream in the breeding sections of the Roper River is undoubtedly taking a heavy toll on large crocodiles. During the six days we surveyed on the Roper River, two 10' (3.0 m) C. porosus were drowned in fishermen's nets and we were able to rescue a 5'-6' (1.5-1.8 m) specimen which we found caught in a net.

The probability of the C. porosus populations in the Kimberley of Western Australia recovering over a period of several decades is fair, especially in the George Water, St. George Basin, Roe-Hunter, and Ord River waterways where barramundi net fishing in the rivers is minimal and there is no destruction of nesting habitat by feral water buffaloes.

The same cannot be said for most of the tidal waterways in northern Queensland, where the density of C. porosus is probably already at dangerously low levels and recruitment is minimal. Barramundi net fishing, which is allowed in the rivers, is not only quickly exhausting the barramundi resource but also is drowning a substantial fraction of the few remaining large C. porosus. It is likely that, with the exception of the Port Musgrave area, the population of C. porosus in northern Queensland is still falling and is well on the road to exhaustion.

We may thus summarize our results and prognosis for recovery of the populations of C. porosus in northern Australia as follows:

Northern Territory - populations slowly recovering in tidal waterways of northern Arnhem Land and the Alligator Rivers Region; populations from the Adelaide River westward to the Western Australian border steady or still falling; populations in the Gulf of Carpentaria at extinction levels, with the exception of the Roper and Towns rivers.

Western Australia - populations probably recovering very slowly in major sections of the Kimberley tidal waterways.

Queensland - with the exception of the tidal waterways draining into Port Musgrave, populations probably still falling and at dangerously low levels.

It is necessary to draw attention again to two very important factors already alluded to. The first is the destruction of C. porosus nesting habitat on Northern Territory waterways by feral water buffaloes. The destruction of riverine and swamp habitat by these animals has to be witnessed to be believed, and on rivers such as the South Alligator, West Alligator, and Wildman the habitat is now also being rapidly destroyed (the same applies to the Adelaide and Daly rivers). Unless this destruction is halted, it can be safely predicted that any recovery of the C. porosus populations on these excellent TYPE 1 breeding systems will be halted.

The second matter, which requires further comment, is net fishing for barramundi well upstream of tidal river mouths, often in the breeding areas. This is done legally and illegally. Throughout the series of Monographs we have reiterated (see Monographs 4, 12, 13, 14, and 16, for example) that this is the height of economic and ecological folly; not only is it leading to the rapid exhaustion of barramundi but of C. porosus as well. The legal netting is being carried out with the encouragement of the Fisheries Division of the Northern Territory, and illegal netting appears to continue with impunity.

That numerous C. porosus are drowned in barramundi nets set legally is apparently denied by the Northern Territory Director of Fisheries, though we have much direct evidence that large numbers are drowned in nets set both legally and illegally. We found approximately 30 dead crocodiles ranging from 10' (3.0 m) to 15' (4.5 m) in less than 3 weeks (for details see Monographs 14 and 16). On the basis of the above it is likely that at least several hundred large C. porosus are drowned in barramundi nets each year. As the barramundi are fished out, the fishing pressure increases and the number of C. porosus drowned in nets increases. It has been proven elsewhere in the world, that the crocodile resource, as well as the fish resource, may be rapidly wiped out through net fishing alone.

We are aware that there are no easy answers to the questions we have raised, and that similar problems are being faced in many other areas of the world. A partial answer, which is becoming accepted more and more, is the establishment of national or specialist parks. In Australia both the national and state governments are wisely setting aside an increasing number of these. Both the barramundi and C. porosus resources of northern Australia could have their survival and partial recovery ensured by the establishment of a number of Specialist Parks or closed areas in Western Australia, the Northern Territory, and Queensland, wherein all marine species were accorded protection. Our work suggests that protected areas should be established in the George Water and Glenelg River region (or St. George Basin area, or the Roe and Hunter rivers area) in Western Australia; the complete Alligator Region area (already proposed for inclusion in Kakadu National Park), the Arnhem Bay and the Roper River areas in the Northern Territory; and the Port Musgrave area in northern Queensland. Net fishing in such areas should be totally prohibited, and steps taken to see that the riverine habitat is protected; in some cases this would necessitate the culling of feral buffaloes.

MONOGRAPH SERIES

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

A series of monographs covering the navigable portions of the tidal rivers and creeks of the Northern Territory. Published by Pergamon Press 1979, 1980, 1981.

1. The Blyth-Cadell Rivers System Study and the Status of *Crocodylus porosus* in Tidal Waterways of Northern Australia. Methods for analysis, and dynamics of a population of *C. porosus*. Messel, H.; Vorlicek, G. C.; Wells, A. G. and Green, W. J.

2. The Victoria and Fitzmaurice River Systems. Messel, H.; Gans, C.; Wells, A. G.; Green, W. J.; Vorlicek, G. C. and Brennan, K. G.

3. The Adelaide, Daly and Moyle Rivers. Messel, H.; Gans, C.; Wells, A. G. and Green, W. J.

4. The Alligator Region River Systems. Murgenella and Coopers Creeks; East, South and West Alligator Rivers and Wildman River. Messel, H.; Wells, A. G. and Green, W. J.

5. The Goomadeer and King River Systems and Majarie, Wurugoij and All Night Creeks. Messel, H.; Wells, A. G. and Green, W. J.

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7. The Liverpool-Tomkinson Rivers Systems and Nungbulgarri Creek. Messel, H.; Wells, A. G. and Green, W. J.

8. Some Rivers and Creeks on the East Coast of Arnhem Land, in the Gulf of Carpentaria. Rose River, Muntak Creek, Hart River, Walker River and Koolatong River. Messel, H.; Elliott, M., Wells, A. G., Green, W. J. and Brennan, K. G.

9. Tidal Waterways of Castlereagh Bay and Hutchinson and Cadell Straits. Bennett, Darbitla, Djigagila, Djabura, Ngandadauda Creeks and the Glyde and Woolen Rivers.

10. Tidal Waterways of Buckingham and Ulundurwi Bays. Buckingham, Kalarwoi, Warawuruwoi and Kurala Rivers and Slippery Creek. Messel, H.; Vorlicek, G. C.; Wells, A. G. and Green, W. J.

11. Tidal Waterways of Arnhem Bay. Darwarunga, Habgood, Baralminar, Gobalpa, Goromuru, Cato, Peter John and Burungbirinung Rivers. Messel, H.; Vorlicek, G. C.; Wells, A. G. and Green, W. J.

12. Tidal Waterways on the South-Western Coast of the Gulf of Carpentaria. Limmen Bight, Towns, Roper, Phelp and Wilton Rivers; Nayarnpi, Wungguliyanga, Painnyilatya, Mangkurdurrungku and Yiwapa Creeks. Messel, H.; Vorlicek, G. C.; Wells, A. G., Green, W. J. and Johnson, A.

13. Tidal Systems on the Southern Coast of the Gulf of Carpentaria. Calvert, Robinson, Wearyan, McArthur Rivers and some intervening Creeks. Messel, H.; Vorlicek, G. C.; Wells, A. G.; Green, W. J. and Johnson, A.

14. Tidal Waterways of Van Diemen Gulf. Ilamaryi, Iwalg, Saltwater and Minimini Creeks and Coastal Arms on Cobourg Peninsula. Resurveys of the Alligator Region Rivers. Messel, H.; Vorlicek, G. C.; Wells, A. G. and Green, W. J.

15. Work maps of Tidal Waterways in Northern Australia. Messel, H.; Green, W. J.; Wells, A. G. and Vorlicek, G. G.

16. Surveys of Tidal Waterways on Cape York Peninsula, Queensland, Australia, and their Crocodile Populations. Messel, H.; Vorlicek, G. C.; Wells, A. G.; Green, W. J.; Curtis, H. S.; Roff, C. R. R.; Weaver, C. M. and Johnson, A.

17. Darwin and Bynoe Harbours and their Tidal Waterways. Messel, H.; Vorlicek, G. C.; Elliott, M.; Wells, A. G. and Green, W. J.

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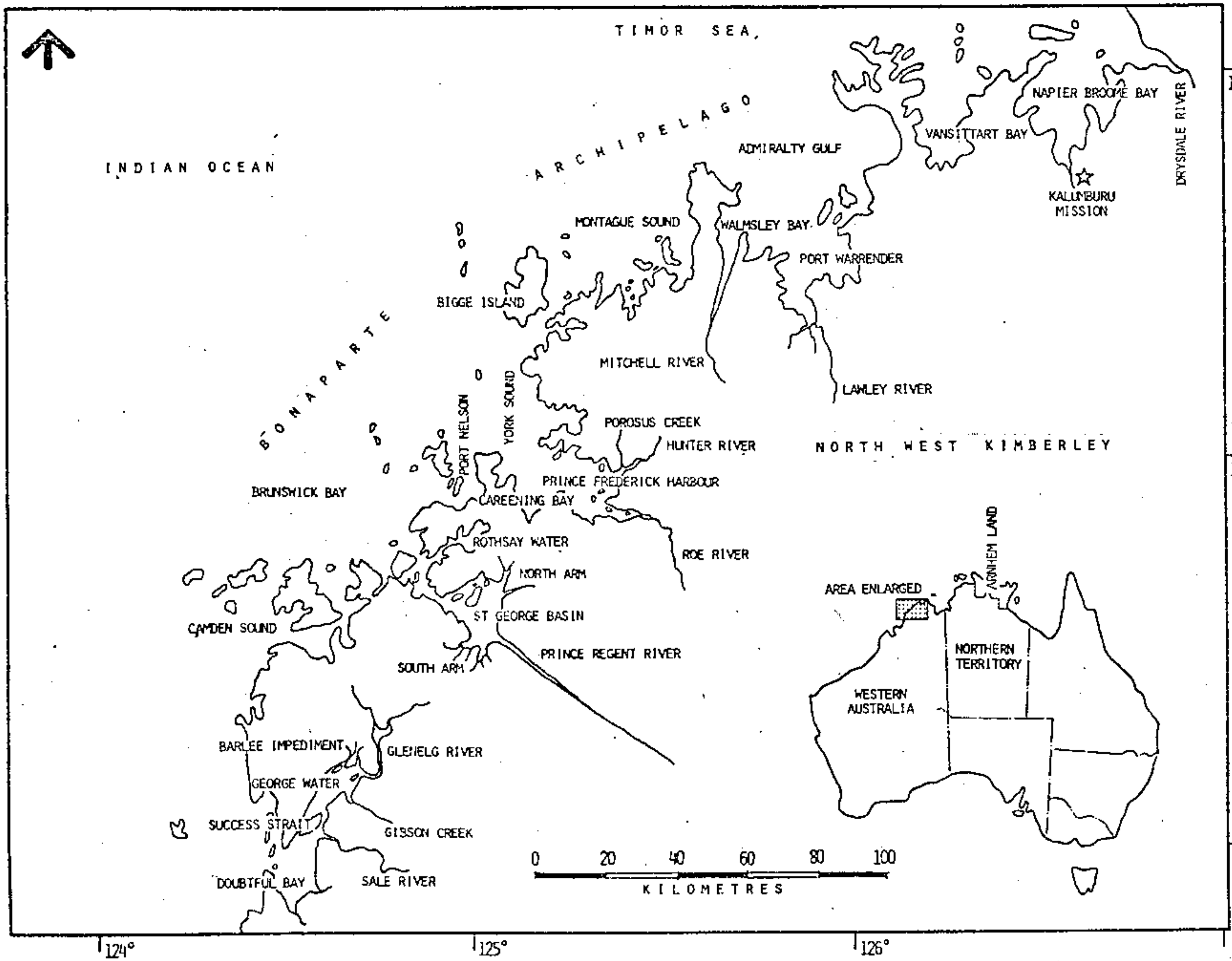

Figure 1. Area map, Northwest Kimberly, Western Austrailia

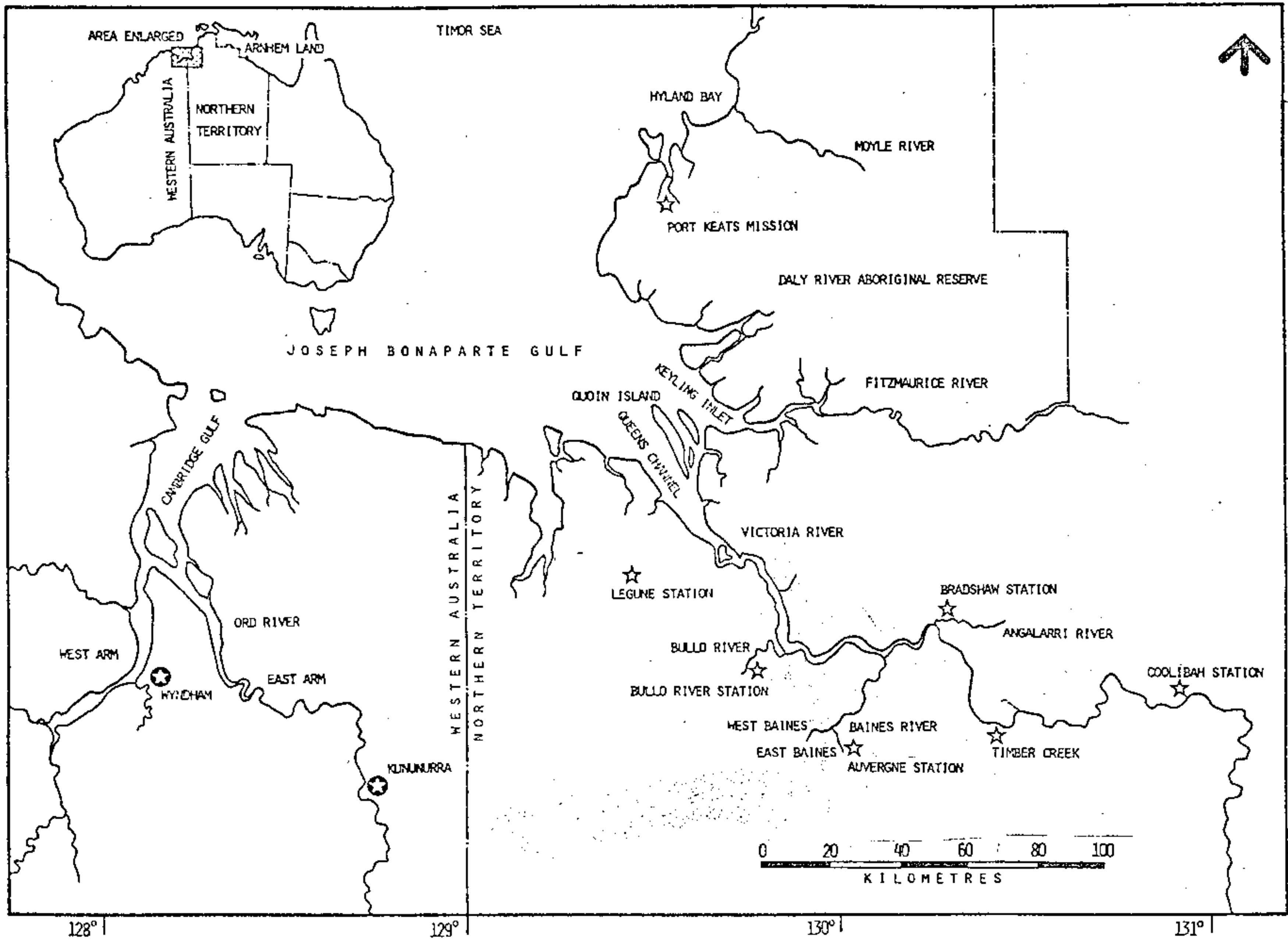

Figure 2. Area map, Western Austrailia-Northern Territory border.

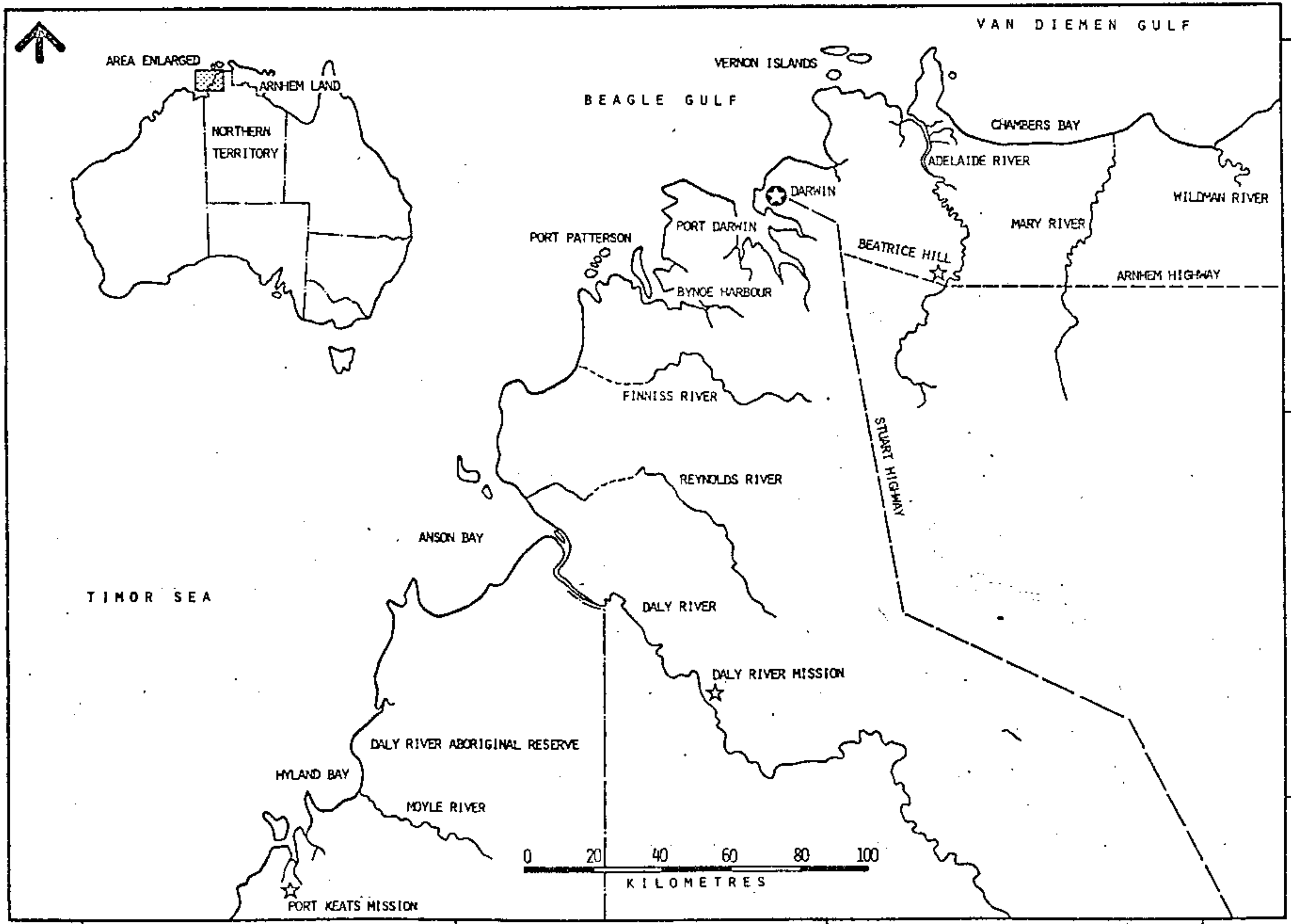

Figure 3. Area map, west of Darwin

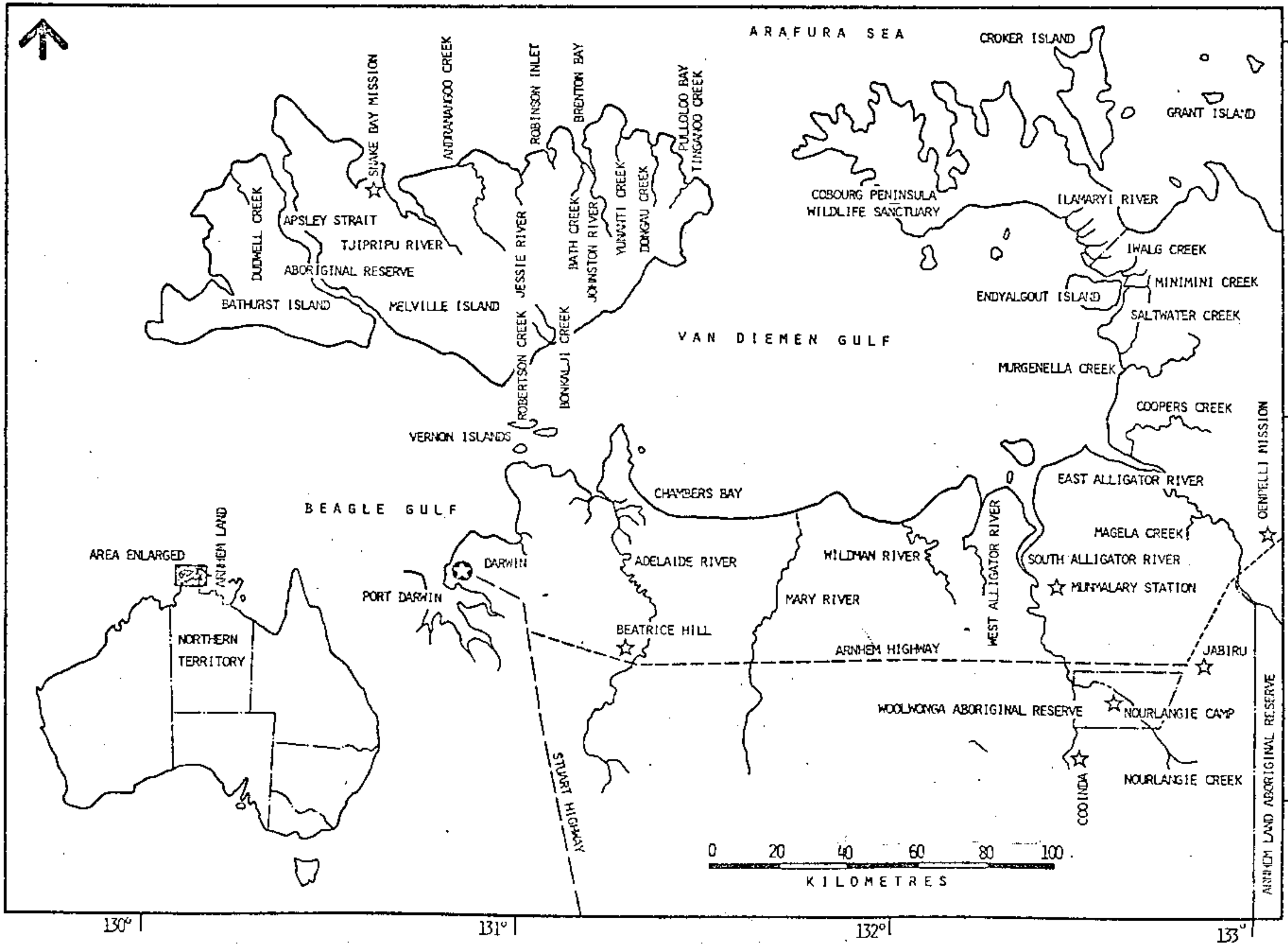

Figure 4. Area map, Darwin eastward to Cobourg Peninsula, also Melville Island.

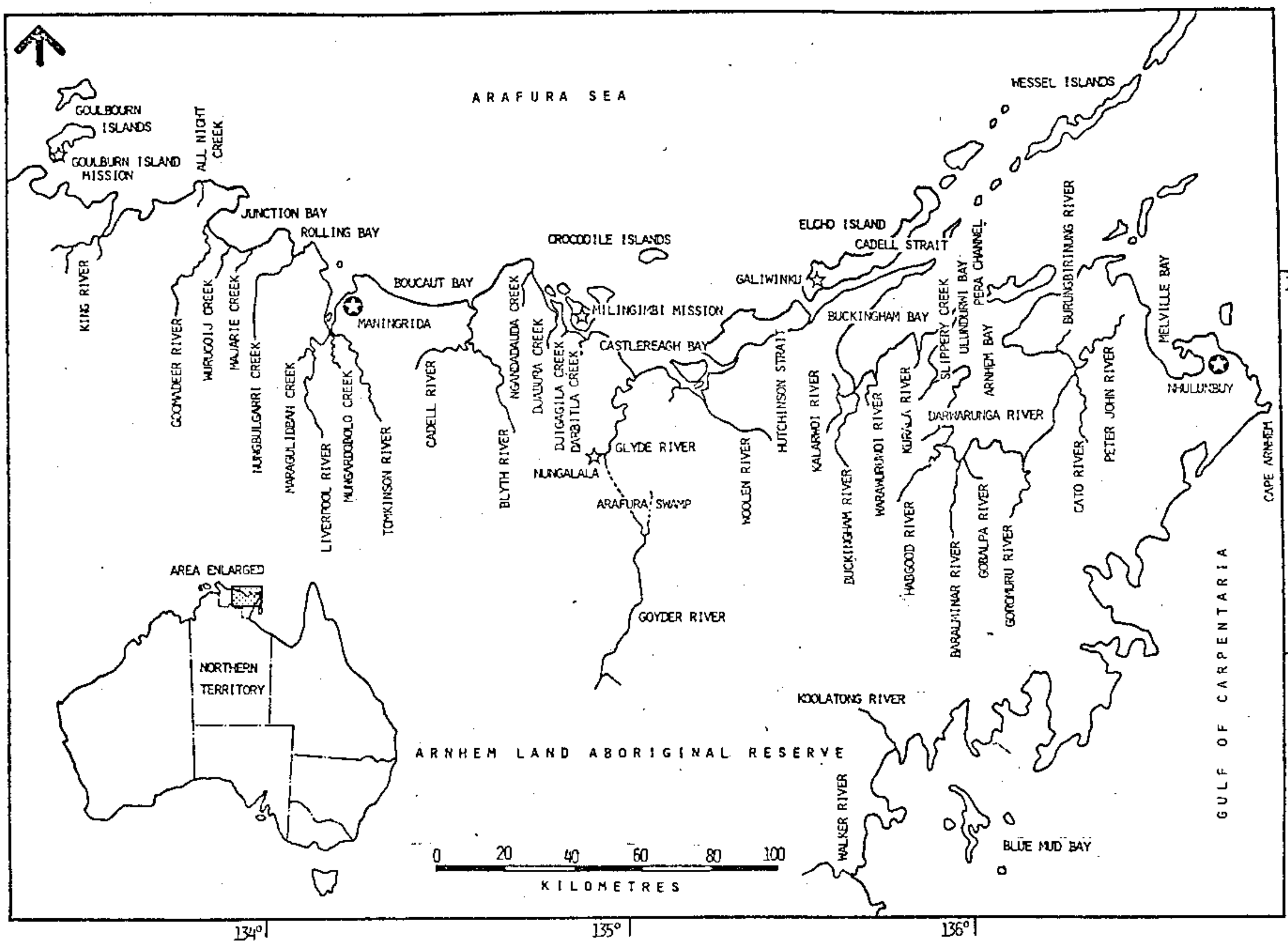

Figure 5. Area map of northern Arnhem Land coastline from Nhulunbuy (Gove) in the east to the King River in the west.

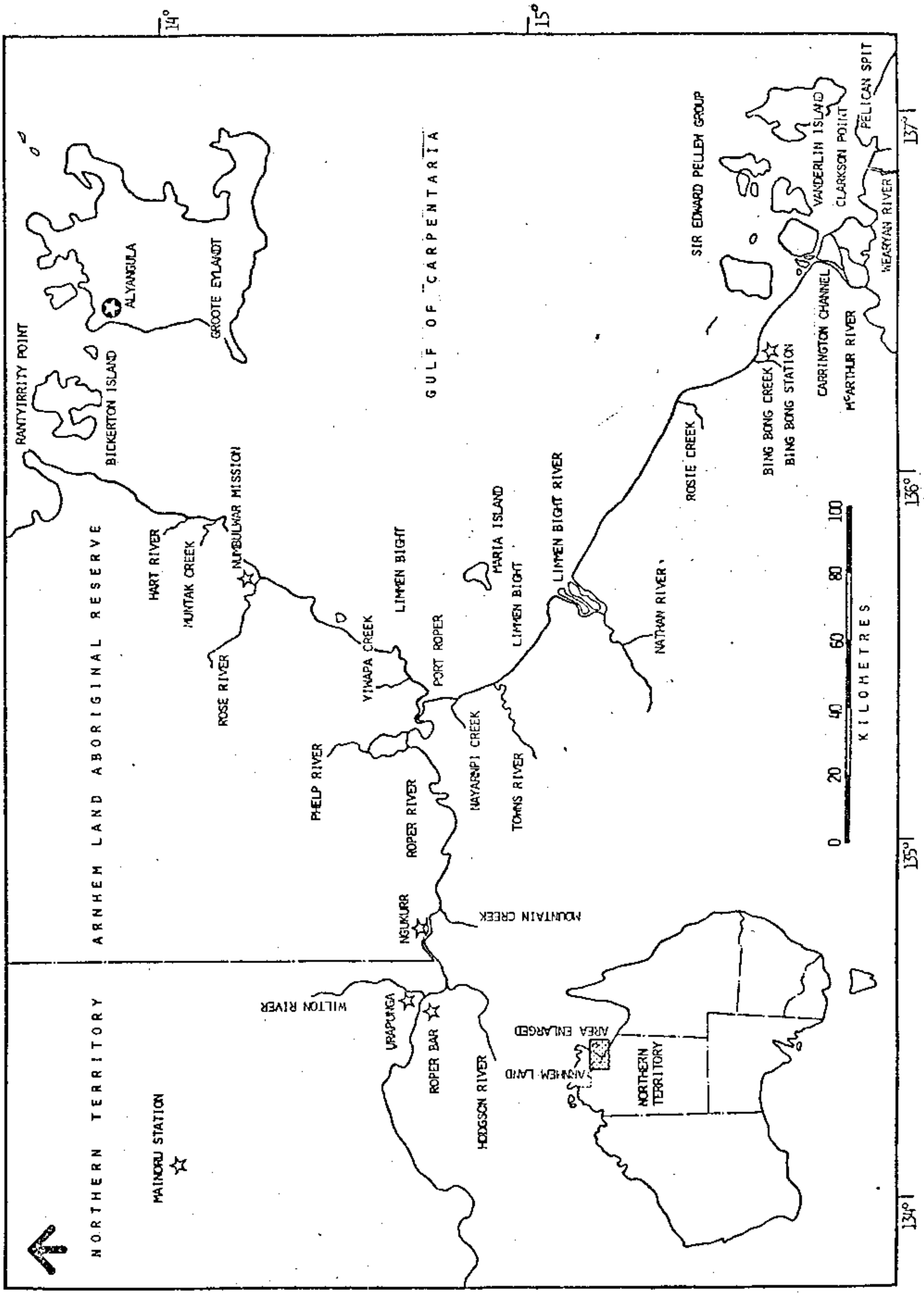

Figure 6. Area map, western and southwestern Gulf of Carpentaria.

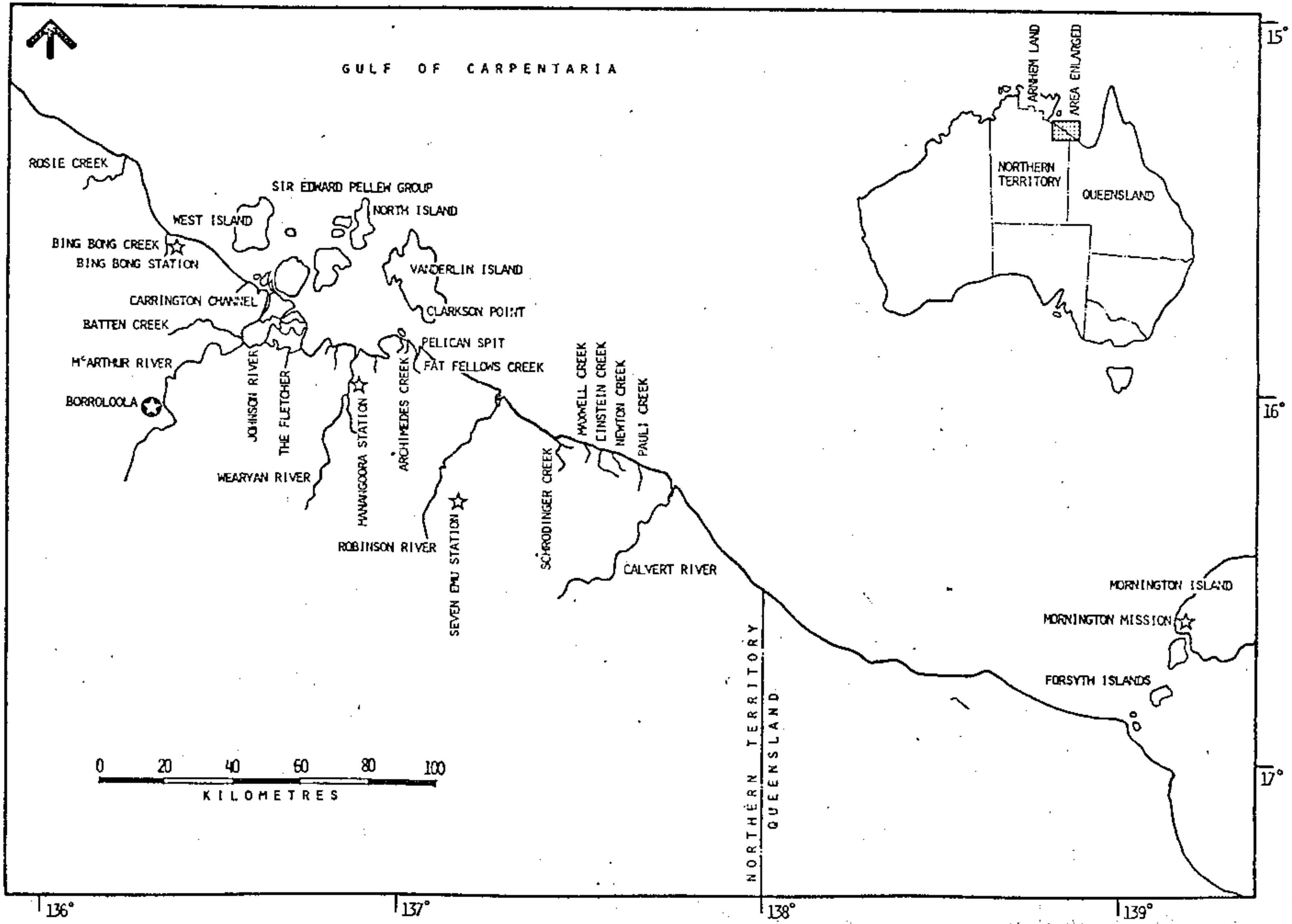

Figure 7. Area map, southern Gulf of Carpentaria, Northern Territory section.

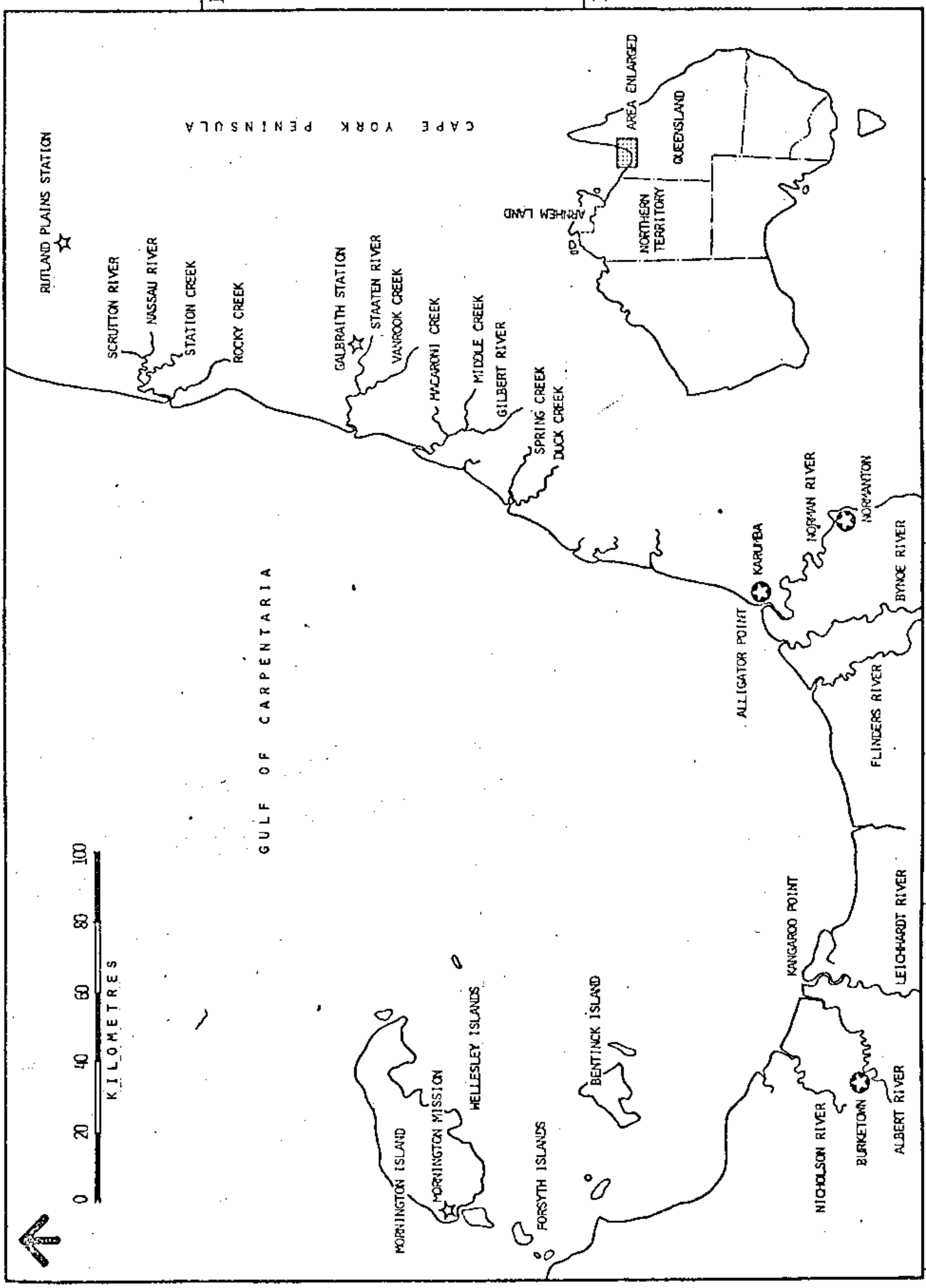

Figure 8. Area map, southeastern Gulf of Carpentaria, Cape York Peninsula, Queensland.

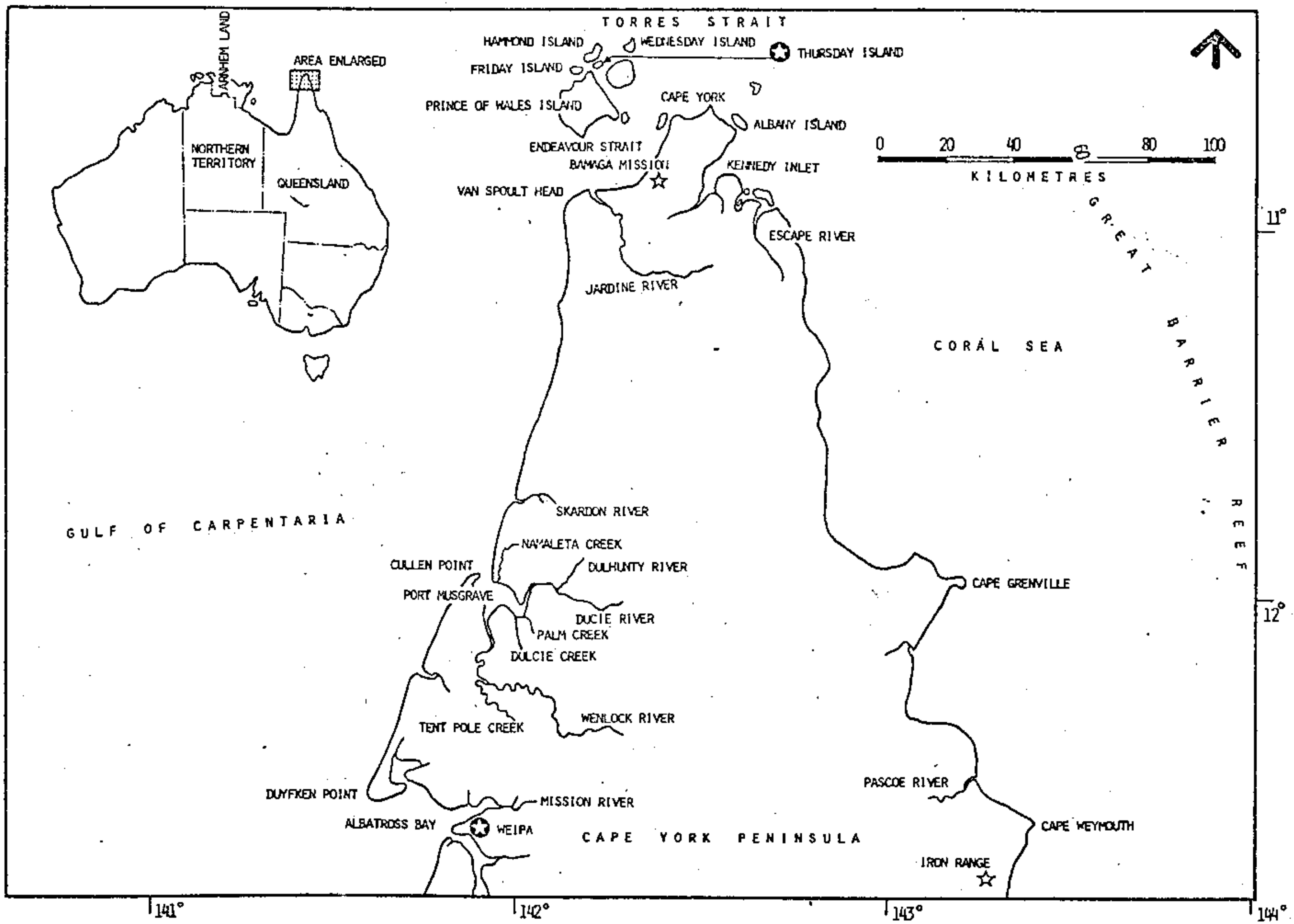

Figure 9. Area map, northern Cape York Peninsula.

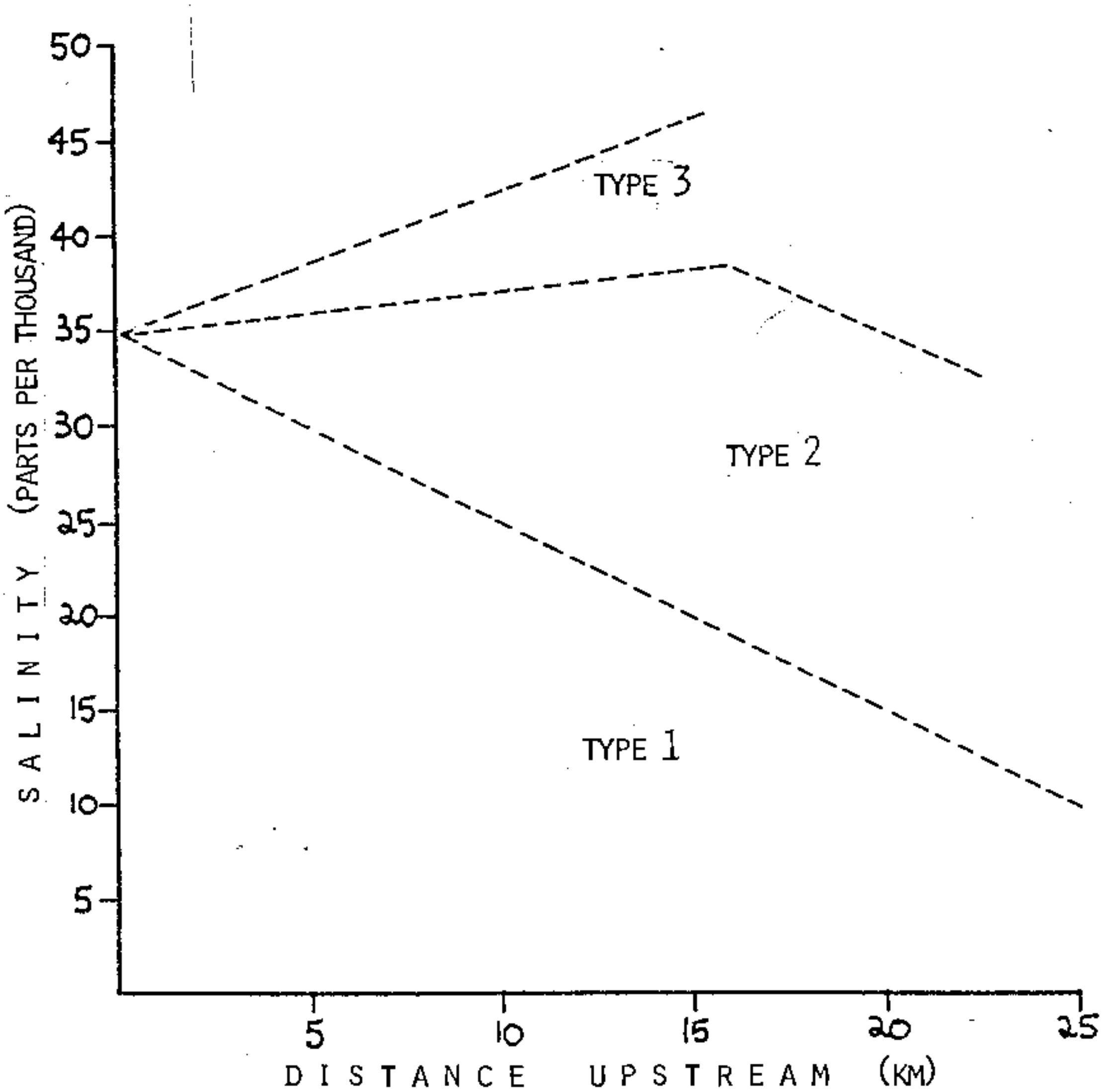

FIGURE 10. Typical dry season salinity profiles for the three types of tidal systems occurring in the classification scheme developed in the Monographs.

TABLE 1. Number of *C. porosus* sighted within each size class on tidal waterways of the Northern Territory, Western Australia, and Queensland during night-time spotting surveys. The midstream distance surveyed and density of nonhatchling 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 (see text).

Systems / Size Class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	7	EO	km surveyed	Density (crocs/km)	95% level	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	
June 79	465	123	91	93	59	31	16	26	26	94.5	3.6	524-598	
MONOGRAPH 2													
Victoria													
Aug. 78	139	13	8	21	22	26	8	13	28	229.1	0.6	184-230	1
Fitzmaurice													
Aug. 78	79	9	5	13	25	6	4	11	6	146.6	0.5	98-132	1
MONOGRAPH 3													
Adelaide													
July 77	417	48	24	88	116	47	35	33	26	226.3	1.6	566-644	1
Sept. 78	381	62	24	71	90	43	33	32	26	221.0	1.4	487-559	
Sept. 79	374	53	8	46	75	58	47	64	23	231.6	1.4	490-562	
Daly													
Aug. 78	115	5	7	16	25	21	11	18	12	90.0	1.2	159-201	

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	> 7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPH 3 (Continued)													
Moyle													
Aug. 78	16			1	4	2	1	2	6	10.0	1.6	18-34	1
MONOGRAPH 4 (14)													
Murgenella													
Oct. 77	95	1	1	8	33	13	6	18	15	45.9	2.0	135-173	1
June 78	173	48	16	4	17	24	23	30	11	44.9	2.8	183-227	
Aug. 79	198	47	24	12	22	24	27	26	16	45.6	3.3	223-273	
East Alligator													
Oct. 77	318	53	18	37	57	41	40	34	38	114.9	2.3	402-468	1
June 78	329	39	14	63	51	42	31	51	38	118 9	2.4	442-510	
Aug. 79	393	53	30	44	58	28	58	64	58	119 2	2.9	521-595	
South Alligator													
Oct. 77	142			12	24	24	25	31	26	113.8	1.2	209-257	1
July 78	157	6	3	4	14	43	24	38	25	113.2	1.3	223-273	
Aug. 79	164	4	1	4	12	24	31	51	37	114.0	1.4	237-287	
West Alligator													
Oct. 77	83	9	2	14	14	15	10	10	9	42.2	1.8	104-138	1
July 78	85	23	5	12	9	13	10	6	7	40.4	1.5	86-118	
Aug. 79	96	12	9	13	14	7	12	14	15	42.2	2.0	120-156	
Wildman													
Sept. 78	118	53	16	6	8	10	9	7	9	33.5	1.9	91-123	1
Aug. 79	155	21	34	15	14	7	17	31	16	33.5	4.0	197-243	
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	

Table 1 (Continued)

Systems	Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPH 5 (Continued)														
King														
Aug. 75		17	3	3	3	2			4	2	52.0	0.3	15- 31	2
Aug. 76		37	12	8	7	1	1	1	4	3	52.0	0.5	31- 51	
June 77		38	18	4	5	5	1		1	4	48.7	0.4	24- 42	
July 79		48	3		11	10	9	2	5	8	48.5	0.9	61- 87	
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	
Wurugoij														
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	
All Night														
Aug. 75		3					2	1			9.1	0.3	3	3
Aug. 76		0									9.1	0	0	
July 79		6		1				1		4	9.1	0.6	6	
MONOGRAPH 6														
Andranangoo														
June 75		40	14	2	5	6			2	11	47.8	0.5	33- 53	1
Nov. 75		17		1	4		1	2	2	7	47.8	0.4	20- 36	
Aug. 76		41	7	1	8	10	3	3	1	8	47.8	0.7	44- 68	
June 77		43	7	1	5	9	4		3	14	47.8	0.8	47- 71	
Oct. 79		56	4	1	3	9	7	6	10	16	48.4	1.1	71- 99	
Dongau														
Oct. 72		15	2	2		3			8		22.4	0.6	14- 28	2-3
July 75		10	4			1	4		1		22.4	0.3	6	
Nov. 75		2				2					22.4	0.1	2	
Aug. 76		17	3	2	3		1	1	5	2	22.4	0.6	15- 31	

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPH 6 (Continued)													
Dongau (Continued)													
June 77	17	5	1	3	3	1	1	3		22.4	0.5	13- 27	
Oct. 79	15				3	3	2	5	2	22.4	0.7	17- 33	
Johnston mainstream													
Oct. 72	4								4	30.0	0.1	4	2-3
June 77	17					3	3	7	4	30.0	0.6	20- 36	
Oct. 79	14				1	4	4	1	4	36.3	0.4	15- 31	
Overall Johnston													
Oct. 79	20			2	1	5	5	2	5	89.8	0.2	24- 42	
Bath													
Oct. 72	0									15.0	0	0	2-3
July 75	0									12.0	0	0	
Oct. 79	5		1		1	1		1	1	14.5	0.3	5	
Tinganoo													
Oct. 72	0(however, 2 large slides seen)									14.5	0	0	2-3
July 75	1					1				14.5	0.1	1	
Nov. 75	0									14.5	0.0	0	
Aug. 76	1							1		14.5	0.1	1	
Oct. 79	6				1	2	1	1	1	14.5	0.4	6	
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	

Table 1 (Continued)

Systems Size class numbers	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	2
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	
MONOGRAPH 8													
Rose													
Oct. 78	7				2		3		2	23.5	0.3	7	1
Muntak													
Oct. 78	3				1				2	6.7	0.4	3	2
Hart													
Oct. 78	4				1				3	7.5	0.5	4	2
Walker													
Oct. 78	15	1		4	2	1	2	1	4	24.4	0.6	15- 31	1
Koolatong													
Oct. 78	5					1	2	1	1	11.0	0.5	5	1
MONOGRAPH 9													
Bennett													
Sept. 75	3			1	1		1			17.6	0.2	3	3
June 79	10			1	1	3	2	3		53.0	0.2	10- 22	
Darbitla													
Aug. 75	13		1		5	3	2	1	1	34.8	0.4	14- 28	2-3
June 79	19		2		2		3	3	9	35.7	0.5	22- 40	
Djigagila													
Sept. 75	8		1	1	5	1				23.0	0.4	8	3
June 79	23	1			2	6	5	4	5	25.0	0.9	27- 45	

Table 1 (Continued)

Systems	Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPH 9 (Continued)														
Ojabura														
	Sept. 75	3			1	2				1	21.6	0.1	3	3
	June 79	14	1		1	7	3	1		1	25.7	0.5	14- 28	
Ngandadauda														
	Sept. 75	19	3	2	5	1	1	2	1	4	22.6	0.7	18- 34	3
	June 79	21			2	3	3	4	4	5	23.9	0.9	25- 43	
Woolen														
	Sept. 75	31	5	2	5	3	1	3	6	6	80.4	0.3	33- 53	2
	July 79	57	14	3	6	10	4	2	12	6	102.5	0.4	58- 84	
Glyde														
	Sept. 75	28			3	6	2	1	4	12	45.9	0.6	35- 57	1
	July 79	100	36	9	10	9	10	6	6	14	45.9	1.4	89-121	
Cadell Creeks							(not used)							
	Sept. 75	4		1		1	1			1	7.0	0.6	4	3
Hutchinson														
	Sept. 75	25	6	5	3	4	1	3	2	1	58.3	0.3	22- 40	3 and
	July 79	56	10	3	5	9	13	6	1	9	78.5	0.6	61- 89	mini 1
MONOGRAPH 10														
Kalarwoi														
	Sept. 75	82	38	15	17	3	4		4	1	38.9	1.1	59- 85	1 and
	June 79	132	45	7	16	19	11	16	7	11	40.1	2.2	124-162	2-3
Buckingham														
	Sept. 75	100	10	42	8	14	8	1	3	14	31.1	2.9	129-167	2
	June 79	101	16	7	24	17	9	8	4	16	35.3	2.4	120-158	
Warawuruwoi														
	Oct. 75	18		1	3	5	4	1	2	2	28.8	0.6	21- 39	3
	June 79	34			1	4	3	7	9	10	37.0	0.9	44- 68	

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPH 10 (Continued)													
Kurala													
Oct. 75	16			3	5	2	1	2	3	27.8	0.6	18- 34	3
June 79	26				6	7	3	6	4	36.4	0.7	33- 53	
Slippery													
Oct. 75	9			2	1	2	1		3	11.0	0.8	9	3
June 79	20		2	5	7	2	4			10.7	1.9	24- 42	
MONOGRAPH 11													
Burungbirinung													
Oct. 75	13	9	2			2				13.0	0.3	4	2
May 79	37	3	8	7	8	3	3		5	11.7	2.9	44- 68	
Peter John													
Oct. 75	142	27	59	17	23	7	3	4	2	41.5	2.8	167-211	1
May 79	300	136	60	48	21	11	5	3	16	42.1	3.9	243-295	
Cato													
Oct. 75	108	59	6	19	10	9	1	3	1	23.5	2.1	66- 94	1
May 79	89	34	19	19	5	3		4	5	23.0	2.4	75-105	
Darwarunga													
Oct. 75	15		1	4	7	1	1	1		47.8	0.3	17- 33	2-3
May 79	34	1	1	6	10	5	2	2	7	45.0	0.7	42- 66	
Habgood R.													
Oct. 75	101	13	24	14	25	10	2	4	9	22.0	4.0	125-163	1
May 79	111	23	15	23	23	15	3	2	7	22.1	4.0	125-163	
Habgood Ck.													
Oct. 75	6			1	2	1			2	4.4	1.4	6	3
May 79	4				3				1	3.4	1.2	4	

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPH 11 (Continued)													
Baralminar													
Oct. 75	15			1	6	4	1	3		25.2	0.6	17- 33	2-3
June 79	30			5	13	4	3		5	26.4	1.1	39- 60	
Gobalpa													
Oct. 75	15	2		3	6	2	1		1	19.3	0.7	14- 28	2-3
June 79	17			3	5	3	2	4		21.3	0.8	20- 36	
Goromuru													
Oct. 75	299	128	95	37	14	7	6	6	6	44.3	3.9	254-306	1
June 79	410	134	58	139	31	10	5	7	26	48.0	5.8	420-486	
MONOGRAPH 12													
Limmen Bight													
May 79	19	1	1		3	8	3	2	1	127.3	0.1	21- 39	2
Towns													
May 79	55	28	1	6	7	7	2	3	1	57.2	0.5	34- 54	2
Roper													
May 79	439	126	67	41	86	39	34	26	20	262.8	1.2	447-549	1
Yiwapa													
May 79	9				4	2	3			14.6	0.6	9	3
Mangkurdurrungku													
May 79	2					2				6.5	0.3	2	3
MONOGRAPH 13													
Calvert													
Apr. 79	2					1	1			38.4	0.1	2	2

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPH 13 (Continued)													
Einstein Apr. 79	1								1	6.6	0.2	1	3
Maxwell Apr. 79	0									2.0	0	0	3
Schrodinger/Fermi Apr. 79	1							1		2.0	0.5	1	3
Robinson Apr. 79	0									35.9	0.0	0	2
Fat Fellows May 79	1				1					11.0	0.1	1	3
Galileo May 79	0									8.0	0	0	3
Archimedes May 79	3					1	1		1	6.4	0.5	3	3
Planck May 79	1				1					15.1	0.1	1	3
Wearyan May 79	4	2				1	1			34.4	0.1	4	2
Faraday/Davy May 79	1				1					10.5	0.1	1	3

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPH 13 (Continued)													
Coulomb May 79	0									13.3	0	0	3
McArthur May 79	28			2	3	6	4	5	8	232.6	0.1	35- 57	1
MONOGRAPH 14													
Saltwater Aug. 79	29		1	1	6	4	6	9	2	14.1	2.1	37- 59	3
Minimini Aug. 79	11			1	4	3	1	2		43.8	0.3	11- 25	3
Middle Arm Aug. 79	6				3	2	1			28.5	0.2	6	3
Iwalg Aug. 79	10				3	1	2	2	2	53.5	0.2	10- 22	3
Arm A Aug. 79	5				3		1		1	26.7	0.2	5	3
Arm B Aug. 79	3				1		1	1		15.0	0.2	3	3
Arm C Aug. 79	7				3	1	1		2	29.3	0.2	7	3
Arm D Aug. 79	9				1		3	2	3	19.8	0.5	9	3

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPH 14 (Continued)													
Ilamaryi Aug. 79	16				3	4	3	3	3	44.4	0.4	18- 34	3
MONOGRAPH 17 Port Darwin Sept. 79	80	4	8	6	8	8	9	16	21	148.6	0.5	107-143	2-3
Port Patterson Sept. 79	10			1	1	2	2	1	3	59.9	0.2	10- 22	3
Bynoe Harbour Sept. 79	24	2	1	1	4	4		9	3	109.5	0.2	27- 45	3
LATEST SURVEY ONLY													
Total TYPE 1	4491	1197	478	629	597	392	353	413	432	2175.5	1.5	5287-5517	1
% of total		27	11	14	13	9	8	9	10	54			
Total TYPE 2-3	591	82	32	80	105	79	54	62	97	938.4	0.5	790-880	2-3
% of total		14	5	14	18	13	9	10	16	23			
Total TYPE 3	390	14	8	20	88	72	61	64	63	883.7	0.4	578-656	2-3
% of total		4	2	5	23	18	16	16	16	22			
Overall Total	5472	1293	518	729	790	543	468	539	592	2997.6	1.0	6724-6984	1 to 3
% of total		24	8	13	14	10	9	10	11				

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPHS 4 and 14 Alligator Region excluding Wildman													
77	638	63	21	71	128	93	81	93	88	316.8	1.8	895-991	1
78	744	116	38	83	91	122	88	125	81	317.4	2.0	980-1080	
79	851	116	64	73	106	83	128	155	126	321.0	2.3	1151-1259	
Alligator Region													
78	862	169	54	89	99	132	97	132	90	350.9	2.0	1084-1190	
79	1006	137	98	88	120	90	145	186	142	354.5	2.4	1386-1484	
MONOGRAPH 14 Cobourg Complex & Saltwater													
79	96		1	2	27	15	19	19	13	275.1	0.3	137- 177	3
Alligator Region Cobourg Complex & Saltwater													
79	1102	137	99	90	147	105	164	205	155	629.6	1.5	1521-1645	1 & 3
MONOGRAPH 6 Andranangoo, Dongau and Tinganoo													
75	51	18	2	5	7	5	3	11		84.7	0.4	42- 66	1 to 3
79	77	4	1	3	13	12	9	16	19	85.3	0.9	103- 137	
Melville I.													
79	102	4	2	5	15	18	14	19	25	189.6	0.5	141- 181	

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPHS 5 & 7 Nungbulgarri to King													
75	111	4	35	23	15	8	3	6	17	162.2	0.7	154-196	1 to 3
79	206	42	15	23	35	31	17	15	28	158.2	1.0	243-295	
MONOGRAPHS 1, 5, and 7 Blyth to King but using Liverpool 76 for 75													
75	712	73	180	162	116	46	13	11	111	416.0	1.5	997-1099	1 to 3
79	1186	454	117	155	137	96	62	61	104	402.7	1.8	1146-1254	
MONOGRAPH 9 Castlereagh Bay & Hutchinson Str.													
75	130	14	11	19	27	9	12	14	24	304.2	0.4	168-212	1 to 3
79	300	62	17	25	43	42	29	33	49	390.2	0.6	359-421	
MONOGRAPH 10 Buckingham and Ulundurwi Bays													
75	225	48	58	33	28	20	4	11	23	137.6	1.3	263-317	1 to 3
79	313	61	16	46	53	32	38	26	41	159.5	1.6	381-445	
MONOGRAPH 11 Arnhem Bay													
75	714	238	187	96	93	43	15	21	21	241.0	2.0	737-825	1 to 3
79	1032	331	161	250	119	54	23	22	72	243.0	2.9	1097-1203	

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
MONOGRAPHS 1, 5 7 to 11 North Arnhem Land to King 75	1781	373	436	310	264	118	44	57	179	1098.8	1.3	2234-2384	1 to 3
79	2831	908	311	476	352	224	152	142	266	1195.4	1.6	3066-3242	
MONOGRAPHS 12 and 13 Gulf south coast 79	116	31	2	3	16	24	12	11	12	600.7	0.1	120-158	1 to 3
Gulf south coast excluding Towns 79	61	3	1	2	9	17	10	8	11	543.5	0.1	80-110	1 to 3
Roper System & coastal creeks 79	450	126	67	41	90	43	37	26	20	283.9	1.1	495-567	1 to 3
MONOGRAPH 8 Gulf west coast 78	34	1		4	6	2	7	2	12	73.1	0.5	42- 56	1 to 2
TOTALS Gulf of Carpentaria 78, 79	600	158	69	53	112	69	56	39	44	957.7	0.5	683-767	1 to 3
North Arnhem Land 79	2831	908	311	476	352	224	152	142	266	1195.4	1.6	3066-3242	1 to 3

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
TOTALS (Continued)													
Darwin eastward to Cobourg incl. Melville 79	1578	194	109	141	237	181	225	288	203	1050.8	1.3	2195-2345	1 to 3
Darwin westward 78, 79	463	33	29	59	89	69	35	70	79	793.7	0.5	663-747	1 to 3
Northern Territory 78, 79	5472	1293	518	729	790	543	468	539	592	3997.6	1.0	6724-6984	1 to 3
WESTERN AUSTRALIA Reports 24 & 34													
Lawley July 77	44	13	1	4	6	8	5	3	4	37.0	0.8	40- 62	2
Mitchell July 77	50	8	1	9	12	8	3	6	3	47.7	0.9	56- 82	1
Roe July 77	176	52	40	27	22	14	8	6	7	68.6	1.8	181-225	1
Hunter July 77	47	11	7	5	10	6	4	2	2	39.3	0.9	47- 71	2
St. George Basin Arms July 77	72	10	1	2	18	10	15	13	3	estimated 36.0?	1.7	86-118	2 to 3
Prince Regent July 77	74	15	4	25	12	8	5	1	4	58.6	1.0	82-112	1

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
WESTERN AUSTRALIA Reports 24 & 34 (Continued)													
George Water and Glenelg July 78	213	73	33	26	33	18	12	12	6	96.3	1.4	206-254	1 to 3
St. George Basin Arms July 78	97	25	3	1	13	12	14	25	4	estimated 72.0?	1.0	101-135	2 to 3
Prince Regent July 78	92	31	11	17	11	8	6	6	2	68.0	0.9	84-116	1
Ord July 78	179	14	17	39	50	19	11	8	21	98.4	1.7	245-297	1
Total latest survey	898	227	113	128	157	93	63	68	49	527.3	1.3	1048-1152	1 to 3
% of total		25	13	14	17	10	7	8	5				
QUEENSLAND MONOGRAPH 16 Nassau Apr. 79	103	4	27	30	23	7	5	3	4	146.3	0.7	142-182	1
Gilbert Apr. 79	8				1	3	1		3	65.2	0.1	8	1 - 3

Table 1 (Continued)

Systems	Size class numbers Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
QUEENSLAND MONOGRAPH 16 (Continued)													
Staaten Apr. 79	20		6	3	2	2	3	3	1	74.5	0.3	24- 42	1
Ouck Apr. 79	27		2	5	5	3	6	4	2	73.7	0.4	34-54	1 - 3
Total	158	4		38	31	15	15	10	10	359.7	0.4	228-278	1 to 3
Wenlock Nov. 79	311	83	67	65	44	8	8	4	32	103.7	2.2	344-404	1
Duci Nov. 79	201	28	52	48	40	16	3	2	12	109.9	1.6	258-310	1
Dulcie Nov. 79	1					1				3.5	0.3	1	1
Palm Nov. 79	9	1		2	1	1			4	6.0	1.3	8	1
Namaleta Nov. 79	14		1		7			1	5	17.9	0.8	15- 31	3
Port Musgrave Nov. 79	536	112	120	115	92	26	11	7	53	241.0	1.8	654-736	1 & 3

Table 1 (Continued)

Systems / Size class numbers	Total	H	2-3	3-4	4-5	5-6	6-7	>7	EO	km surveyed	Density (crocs/km)	95% Levels	TYPE
QUEENSLAND MONOGRAPH 16 (Continued)													
Escape Nov. 79	31	3			5	6	2	7	8	42.0	0.7	35- 57	1
Total Queensland 79	725	119	155	153	128	47	28	24	71	642.7	0.9	945-1043	1 & 3
% of total		16	21	21	18	6	4	3	10				

THE STATUS OF AFRICAN CROCODILES IN 1980

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INTRODUCTION

This report is an updated version of "The Status of Crocodiles in Africa" by H.B. Cott and A.C. Pooley that was contributed to the First Working Meeting of Crocodile Specialists, March 1971 (published in "Crocodiles," IUCN Publications, New Series, Supplementary Paper no. 33, January 1972).

Since the formation of the IUCN Survival Service Commission's Crocodile Specialist Group in 1969, there has been a worldwide explosion of interest in the crocodilians, and a number of projects to study and breed endangered species are currently in operation.

In Africa, over the past decade there has been an increase in commercial crocodile farming enterprises and in pilot projects. Some countries have initiated population surveys or are currently involved in monitoring programs and/or cropping schemes with a view to harvesting the Nile crocodile, *Crocodylus niloticus*, on a sustained-yield basis. More intense research has in some fields led to a better understanding of the biology of the Nile crocodile. Interpretation and tourist information centers involving display of live crocodiles have been developed in some countries but, regrettably, there has been little progress in documenting the life histories of the West African species. The biology and ecology of the slender-snouted crocodile *Crocodylus cataphractus*, the West African dwarf crocodile *Osteolaemus tetraspis tetraspis*, and the much more rare Congo dwarf crocodile *Osteolaemus tetraspis osborni* is still poorly known.

Judging from the data gathered over the past few years there has been a general decline in the overall status of the African species. Most reports are in agreement, whether specifically stated or implied, that populations can only be restored by stringent conservation measures.

In many countries our knowledge of the current status of crocodilian populations is fragmentary, and it is hoped that this report will stimulate further local investigation.

We urgently require data on legal status--the degree of legal protection accorded in each country, and whether the species are adequately protected in reserves or sanctuaries. Information is needed on condition of habitat, on past and present distribution, habits, ecology, and future prospects. Data on decline in populations because of exploitation for hides or other human pressures should be collected, including statistics on numbers of hides exported annually from each country.

Crocodiles are important predators of the waterways, and the removal of large numbers from some areas has resulted in an imbalance in the fish fauna. Crocodiles are a major tourist attraction in many wildlife preserves and the Nile crocodile with its valuable hide could, in some countries, be managed on a sustained-yield basis to earn revenue and foreign exchange for these under-developed nations. The spectacular recovery in the USA of the American alligator, *Alligator mississippiensis*, an endangered species some ten years ago, is an example of how an animal can be managed successfully. Today it is once more possible to allow controlled harvesting of populations in some states.

African conservation departments are thus urged to pay more attention to their crocodilian stocks. The introduction of protective legislation and effective control of exploitation could lead to wise utilization of a natural resource, benefitting both crocodile and man.

The setting aside of sanctuaries for the rare and inoffensive long-snouted and dwarf crocodiles, now on the brink of extinction, will earn the respect and admiration of conservationists world-wide.

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STATUS OF THE NILE CROCODILE *C. niloticus*

ANGOLA

Legal Status.-- Protected throughout Angola by Decree No. 14539 since 1969. Hunting in all forms is prohibited and so is export of skins (Cott and Pooley 1972).

Distribution.-- Occurred in the following major rivers: Congo, Mbridge, Loge, Bengo, Cuanza, Longa, Cugal, Kunene, Cubango, Cuando, Zambezi, Cuango, as well as in their smaller tributaries (Vet. Dept, Angola *in litt*. 1971; van der Riet 1965). Good numbers occurred on the lower Kunene, Cuanze, and the rivers to the east (e.g. Kasai) (Huntley *in litt*. 1980).

Conservation Status.-- Considered to be rare to vulnerable (Huntley *in litt*. 1980).

Reasons for Decline.-- Professional hunters operated along all the major rivers and to a large extent reduced populations, as hunting was allowed for many years (Cott and Pooley 1972).

Further decline probably escalated during 1975/1976 due to increased availability of arms and general lawlessness, but probably stable now due to strict control of arms available to all but the military (Huntley *in litt*. 1980).

Angola shares many of its rivers with neighboring countries, and borders South West Africa/Botswana/Zambia/Congo. Illegal hunting is known to occur on the borders. Small numbers of crocodiles are also no doubt killed by fishermen.

BENIN (DAHOMEY)

Legal Status.-- Unknown.

Distribution.-- Unknown.

Conservation Status.-- *C. niloticus* occurs in Pendjari National Park and nearby Bali water hole. Burrowing behavior was recorded (Larsen 1976).

Reasons for Decline.-- No data available.

BOTSWANA, REPUBLIC OF

Legal Status.-- Crocodiles are scheduled under the Fauna Conservation Proclamation of 1961, Part B. Schedule 3. This covers Game Reserves, Sanctuaries, Private Game Reserves and controlled Hunting Areas. Protection and the issuing of permits controls capture, killing, export and import of animals, trophies, and meat, and the sale and manufacture of articles from trophies. In controlled hunting areas crocodiles may be shot on a supplementary license issued by the controlling Wildlife Department. Export on permit may be allowed and a fee is levied in respect of each skin exported (Cott and Pooley 1972)

Considered to be "out of danger" (1980). No change in legal status (Williamson *in litt.* 1980). Considered by Graham (1976) as indeterminate.

Distribution.-- Principally the Okavango Delta and Chobe River swamps of Botswana northward to the Caprivi.

Conservation Status.-- Existing protected areas probably contain viable crocodile populations, and there is no reason to believe that they cannot survive indefinitely (Williamson *in litt.* 1980).

The Okavango Delta (6000 sq mi or 15,540 km^2) is the main habitat. Much of it is dense papyrus habitat difficult to penetrate by boat; this habitat is the crocodiles' greatest protection and appears to be stable at present.

Graham (1976) proposed a management plan involving cropping for skins on the assumption that if the Okavango crocodiles are not exploited they will be treated as pests regardless of any legal status they may enjoy, and as pests they must be exterminated sooner or later. This policy has not yet been implemented. Graham (1976) also recommended that the Okavango River and its floodplain should be declared a Wildlife Management Area.

In certain areas the crocodile is the totem of various tribes and is not molested by them.

Reasons for Decline.-- According to A.C. Campbell (in litt. 1973), over the period 1958-1969 a professional hunter (Mr. B. Wilmot) operated a commercial hunting scheme in the Okavango Delta and took an estimated 40,000 crocodiles over a 12-year period. In 1967 the number of large crocodiles seen in the Delta had dwindled enormously and the contractor was given an annual quota for 2000 crocodles, reduced annually by 500, to nothing. This operator ceased hunting before his quota reached zero as it was no longer profitable for him (Taylor 1973).

A total of 55 crocodiles were shot by non-resident hunters under license over the period 1969-1972. During 1974, 17 crocodiles were sold and 9 shot (Flemming 1976).

A commercial pilot culling project was initiated in 1973 and terminated in early 1975. During the 2-year period a total of 940 crocodiles were shot (W. von Richter in litt. 1976; Blomberg 1976). Habitat disturbance has been described as a cause contributing to decline of crocodiles (von Richter in litt. 1976). Along the upper reaches of the Okavango Delta crocodile nesting sites suffer from trampling by cattle and tribal peoples collect eggs.

Expansion of the fishing industry and introduction of gill nets as opposed to traditional fish traps has accounted for a reduction of the crocodile population in some regions according to A.C. Campbell (in litt. 1973). Graham et al. (1976) reports that reedbeds, which form an important part of the crocodile habitat, are regularly burnt and this is an undesirable practice. Population expansion and agricultural development, particularly along the Limpopo river, and the drying up of Lake Mbabe have also contributed to a reduction in numbers. Crocodile traps on the Chobe and Linyanti rivers have helped to cause a decline in numbers (Henley in litt. 1975), and poaching has been recorded from the Caprivi area (Attwell in litt. 1973).

BURUNDI

Legal Status.-- Unknown.

Distribution.-- Still common in mouth of Rusizi River near Capital Bujumbura (J. Verschuren in litt. 1977). Lake Tanganyika crocodiles have not been exterminated (Verschuren 1978).

Conservation Status.-- Unknown.

Reasons for Decline.-- No data available.

CAMEROON

Legal Status.-- Protected in National Parks and Game Reserves.

Distribution.-- Occurs in the Kalamaloue National Park in the north, in the Chari River, and in Benone, Uayo Rey, and Boubaudjidja Faor Game Reserves in the northern territory.

Conservation Status.-- It appears that control of the reserves is not very effective. Crocodiles are openly sold in Yaounde and Douala to skin merchants although it is illegal (Dragesco *in litt*. 1971; Geerling *in litt*. 1980). According to Abercrombie (1978) there is apparently no current trade, because populations large enough to support regular commercial exploitation have not existd for at least a decade.

All crocodiles are regarded as endangered according to the Fauna Department (*in litt*. 1980). This species is considered to be scarce and has almost disappeared from inhabitated areas.

Reasons for Decline.-- Illegal hunting for skins.

CENTRAL AFRICAN REPUBLIC.

Legal Status.-- Unknown.

Distribution.-- Unknown.

Conservation Status.-- Unknown in 1980. This country shares borders with Zaire, Sudan, Chad, Cameroon, and Congo.

According to Spinage (*in litt*. 1980) crocodiles have been drastically reduced everywhere, but some still exist just about everywhere and are still fairly common in the rivers in the East. They have been exterminated in the Saint Floris National Park since the 1950's but still occur in rivers to the south.

Reasons for Decline.-- Over exploitation for belly hides. Spinage (*in litt*. 1980) relates that about a year ago, the Ivory and Diamond exporting monopoly, "La Couronne," obtained permission to collect and export crocodile skins; also, a team recently recovered about 20 skins of 1-2 m from a poachers' camp in the Banjei area.

CHAD, REPUBLIC OF

Legal Status.-- Prior to 1970, protected by Ordinance 32 of 1965 which was replaced by the following conditions:

i) Except for the controlled provisions described in Articles 5, 6, 7, 8, the capture of reptiles for the sale of skins is free to all Chad nationals.

ii) Collectors of skins and agents must be licensed. Licenses are issued by Department of Forestry and Water Affair.

iii) A killing tax is levied on all skins exported. Export of skins is allowed only through Fort Lamy or Fort Archambault aerodrome. Export of skins is only allowed on production of the necessary permit.

iv) Hunting of reptiles is forbidden in National Parks and Nature Reserves.

v) Hunting remains forbidden north of 16°N, which is in the district of B.E.T. and vicinity. It was not allowed for a period of two years from 1 January 1968 in the waters of the districts of Bongor and Moundou.

vi) Capture or export of crocodile skins less than the following sizes is prohibited: 25 cm ventral size measured between the horny scales of the two sides.

vii) The collection of eggs is forbidden throughout the country.

viii) The tax for killing a crocodile (in 1968) was f 100.

Newby (in litt. 1979) reports that by 1979 hunting pressure continued to be high and very difficult to control. Since the civil war the entire National Parks system has been abandoned. He regards the crocodile to range from rare to locally vulnerable.

Distribution.-- Occurs in the two main rivers, Chari and Lagone, with all their tributaries that flow into Lake Chad; as well as other lakes such as Iro, Fittri, Lere, Tickem, and Fiango (M. Anna in litt. 1971).

Newby reports the major population centers to be Lake Chad and The Bahr Salamat water basins. In the lower and middle reaches of the Chari and Logone rivers, they were fairly rare. However, the Bahr Salamat River system was quite rich in crocodiles, and theoretically many of them were protected by the Zakouma and Manda National Parks and the Bahr Salamat and Siniaka - Minia Game Reserves. The river systems bordering on the Central African Republic (Bahr Ko, and Bahr Aouk) were quite rich in crocodiles.

Conservation Status.-- According to M. Anna (in litt. 1971), total protection for five years was sought several times by the conservation body without success. The commercial operators were against such a proposal. One of the problems also is the illegal trade with neighboring countries such as Central African Empire, Cameroon, Nigeria, and Niger.

Attempts to farm crocodiles commercially were commenced in 1972, but the project was abandoned because of climatic, dietary, and other problems (King in litt. 1974).

Newby reports that in 1979 hunting pressure continued to be high and very difficult to control. Development around Lake Chad also had serious consequences by reducing the marsh habitat. Even before the civil war, there was quite a flourishing trade in crocodile skins and skin products.

Reasons for Decline.-- Hunting to satisfy the demand for skins. In 1940 or thereabouts the crocodile population of Chad would be estimated at more than several hundred thousand and perhaps as many as one million individuals. It is considered that 90% of the population has gone (M. Anna in litt. 1971).

There are three licensed dealers who hold the monopoly on the export trade. During the years 1966-1970, one dealer exported 21,159 skins. It is considered that the other two dealers handle about the same numbers annually. These three dealers handled a minimum of 100,000 skins during the period 1951-1954.

One of the reasons why crocodile extermination on such a large scale has been allowed is the revenue earned from license and export fees. From 21,159 skins an amount of F 2,115 was paid in hunting licenses, and F 5,057,480 in custom charges.

Judging by the observations of Newby (in litt. 1979), illegal hunting continues uncontrolled in this country.

CONGO: REPUBLIQUE POPULAIRE

Legal Status.-- Protected in National parks. (1980). Considered to be an endangered species (M. Nsosso in litt. 1980).

Distribution.-- Unknown. C.A. Spinage (in litt. 1980) reports that small specimens were present in the Conkouati Lakes and are plentiful enough in the northern tropical forests up near the CAR border, much of which is uninhabited.

Conservation Status.-- Considered to be poor, poaching is rife and uncontrolled due to a scarcity of conservation officials. The existing reserves and National Parks do not appear to provide adequate protection (Nsosso 1980).

Spinage (in litt. 1980), however, reports that crocodiles are plentiful enough and secure in the northern forested areas.

Reasons for Decline.-- There has been a steady trade in crocodile skins over a number of years. Over the period 1974-1979 a total of 85,967 skins were exported under license. In 1979, 13,863 skins were exported. (E. M'Beri-M'Babou, in litt. 1980).

A decline in poaching and hunting is currently thought to be a result of depletion of stocks in the rivers.

Spinage (in litt. 1980) reports that small crocodiles are caught from time to time in the Conkouati Lakes. In Pointe Noire, small stuffed specimens were openly sold for tourists. From about 2°S to the coast I would guess that they have largely been exterminated.

ETHIOPIA

Legal Status.-- In 1971 protected only in reserves e.g. a small area of the upper Awash River, the Omo Game Park. Status in 1980 unknown.

Distribution.-- Awash River and lakes lying west of the river; two lakes adjacent to the river along its middle reaches; Lake Margherita (Abaya), Lake Chamo and the connecting river; Lake Stephanie and five other rift valley lakes may contain crocodiles seasonally; the Webi Shebeli, Dawa Parma, and Ganale Doria rivers; the Omo River and Lake Turkana (Rudolph); Lake Dipa: the Baro, Gilo and Akobo rivers which flow west to the White Nile; the Blue Nile; Lakes Hertale and Cadebassa on the Awash River; and Lake Murle on the Omo River. (See Cott and Pooley 1972).

Occurs in the Illubabor and Gambella Provinces in S.E. Ethiopia (Duckworth 1974), in the proposed Mago National Park (Stephenson 1978), in the Danakil (northern province), and in sections of the Alurero River.

Conservation Status.-- It appears that most of the hunting took place over the period 1955-1970. Concessions were granted by the Ethiopian Government to various people and in 1963 Dofan Ethiopia Share Company obtained concessions on several rivers. Under supplementary agreemnt of 15 March 1966, Dofan was given sole hunting rights on most rivers providing that they built a tannery in Ethiopia. This tannery was completed in 1968. According to Brigadier General Mabratu Feseha (Head, Wild Life Conservation Department in litt. 31/3/1971), the species was considered to be seriously depleted. (See Cott and Pooley 1972, for results of surveys conducted by Colin Chapman, May 1967-May 1968.) According to Stephenson (1978) the species occurs commonly in the proposed Mago National Park, covering the eastern Rift Valley depression. No recent data available.

Reasons for Decline.-- Hunting for skins. A total of 26,045 skins were legally exported from 1965 to 1971 (Feseha *in litt.* 1971). Several thousand skins were taken from the Rift Valley lakes between 1960 and 1966 (M. Bolton *in litt.* 1968). Crocodiles in the rivers flowing west to the Nile are subject to poaching from the Sudan. Hunting and poaching have greatly reduced the numbers of crocodiles in all but a few areas of Ethiopia (1971). According to Brown (*in litt.* 1973) crocodiles are heavily hunted in the Illubabor and Gambella provinces in S.W. Ethiopia and skins exported through the Sudan. The Dofan Co. has now taken about 49,000 skins since it began operating in 1966. Dr. John Hukku who visited the Awash River (Danakil region of Gewani, Buri, Ba Lake, Urfage, Kodo'i fe ayt Debel Gufferamo, and Weinharra regions of Ethiopia) reported heavy exploitation of crocodiles by Danakil tribesmen and white hunters.

Duckworth (1974) observed over a hundred Nuer tribesmen hunting crocodiles on the Akobo River. They sold the skins at Jakoa and from there skins would be shipped to Khartoum. Hunters with skins were also seen at Ciam. Nuer hunters have cleaned out crocodiles from large sections of the Alurero River (IUCN/CSG Newsletter, No. 11, 1975). As in other African countries the borders with neighbouring countries are impossible to patrol. Ethiopia is bordered by Kenya in the south, Somalia in the east, Sudan in the west and Eritrea in the north.

GABON, REPUBLIC OF

Legal Status.-- Protected by Decree No. 0032/PR/MEF/SF 5234 dated 11/1/1966. Crocodiles are protected not only in National Parks and Reserves but also throughout the entire breeding season. However, permits are issued each year for commercial operators. The export quota for skins during the last few years reached 20,000 skins, but it was higher than this five years ago (E. Ossinga *in litt.* 1971). According to Powell (1976) there is no *de facto* legal protection of crocodiles in Gabon, whatever laws may exist on paper, outside of National Parks and similar protected areas, and protection in National Parks is nebulous.

Distribution.-- Widely distributed throughout the country. Particularly in the Iguela, Sette Cama, Ouanga, Moyen Ogooue, Nyanga watersheds (Ossinga, *in litt.* 1971). Abundant in the low coastal strip between Port Gentil and Mayumbe (Cousins, 1978). This species is reported from Lambarene (Powell, 1976).

Conservation Status.-- In 1980 unknown, but Abercrombie (1978) states that "I am convinced that in West Africa the number of Nile Crocodiles has been reduced to the point at which regular commercial exploitation is no longer widely profitable."

Reasons for Decline.-- Commercial hunting and overexploitation as well as "illegal" poaching.

GAMBIA

Legal Status.-- None in 1970. A 5-year ban on hunting was suggested in 1970 but legal protection was only introduced in February 1977 (Brewer *in litt.* 1980). Described as vulnerable in status.

Distribution.-- Formerly widespread but according to Brewer now rarely seen except in the Abuko National Park.

Conservation Status.-- In 1970, Brewer stated; "It is felt that the crocodile population in the Gambia is in urgent need of complete protection, having seriously declined to a very low level over the past three or four decades, due mainly to incessant hunting of skins, and sometimes for flesh. It is now possible to travel by boat from Bathurst to Basse and not see a single specimen." (Brewer *in litt.* 1970). Habitat destruction has undoubtedly had an adverse effect, but by far the greatest damage to the crocodile populations has been sustained hunting over many years. There are, however, indications that this species is beginning to increase in numbers again (Brewer *in litt.* 1980).

Reasons for Decline.-- As above.

GHANA

Legal Status.-- Formerly, under the current Ghana Wildlife Act crocodiles received no protection at all. They were classed as vermin and could be killed without license at any time (Merz *in litt.* 1970).

The laws of Ghana (The Wild Animals Preservation Act 1961) placed crocodiles among "genera as to which measures may be taken to reduce the numbers." There has thus been no legal protection for crocodiles (E.A.O. Asibey *in litt.* 1970). Asibey also reported "It is signigicant to note that in Ghana all wildlife is to a greater or lesser degree endangered but this Department is not large enough for effective work outside reserved areas. There are even some reserves which have not been manned."

In 1971 the Wildlife Conservation Regulations, L.I. 685, were promulgated and in the First Schedule, Series B. all three species of crocodiles were given the status of Animals Completely Protected.

Distribution.-- Formerly in considerable numbers in lagoons and lower parts of the Volta, Winnba, and Ankobra rivers. Recorded from Tamale reservoir, near Bolgatanga and in the sacred pool at Pago and the Volta dam and the Densu River near Accra.

Conservation Status.-- Unknown (1980). See remarks in Cott and Pooley (1972). The flooding of the Volta River as a result of the building of the dam at Akosombo has resulted in the creation of a lake of approximately four and a half thousand square miles, of which much of the shoreline is totally uninhabited. The creation of the lake could well create ideal conditions for crocodiles (Merz *in litt*. 1970).

Reasons for Decline.-- Asibey (*in litt*. 1971) reported that there are no trade figures for skins obtainable, but I am aware of a lucrative trade in crocodile skins.

Mrs. V. Sackey (*in litt*. 1970) reported that there appears to be a considerable but unrecorded trade in skins across the border to neighboring countries, particularly Togo and Upper Volta, and that locally crocodile skins were made up into handbags, purses, etc., and sold inside Ghana.

Merz (*in litt*. 1970) remarked that "It seems they have been decimated both for their meat and by the Hausa traders for their skins. In Kumasi market, however, the bush-meat traders say they still get four a month from the Bolgatanga area."

IVORY COAST

Legal Status.-- Total protection was introduced in 1970. Described as out of danger (Roth *in litt*. 1980).

Distribution.-- Unknown, but occurs in Parc National de la Comoe, Reserve d'Assagny and Parc National de Tai.

Conservation Status.-- It is probable that crocodile populations have generally declined in recent years due to loss of habitat as a result of expansion of agricultural activities and due to increasing illegal hunting pressure. Theoretically the existing National Parks and Reserves would suffice for the survival of crocodiles; however, in practice law enforcement is not effective enough to ensure this. Also, specially protected areas along the coastal lagoons do not exist as yet.

An experimental crocodile farming project has been established in this country (D. Blake pers. comm. 1980).

Reasons for Decline.-- Considerable illegal trade in crocodile skins, which originate from neighboring countries (Liberia, Guinea, Republic of Mali, Upper Volta, and Ghana) and from the Ivory Coast. Poaching pressure increases due to agricultural development and thus increased accessibility to remote areas.

KENYA

Legal Status.-- Commercial hunting was stopped by law in 1955. Protected in National Parks, Game Reserves, local sanctuaries. Crocodile hunting is limited by annual license to two animals (Modha *in litt.* 1970). Condidered to be out of danger in 1980. Protected in five National Parks and three Nature Reserves. Total ban on hunting introduced 12 March 1978 (all game animals affected) (Parker *in litt.* 1980, Duff-MacKay *in litt.* 1980).

Distribution.-- Unknown. Occurs in large numbers in Lake Turkana, also in the northern Uaso Nyiro, Tana, Sabaki (Galana, Athi) rivers; Samburu, Tsavo East, Tsavo West and Mara Parks (see Cott and Pooley 1972 for observations by M. Modha on the Lake Turkana [Rudolph] population). Occurs in concentrations in the Omo River which drains into the lake from the north (Ethiopia).

Conservation Status.-- Between 1946 and 1955 crocodiles were heavily exploited in all Kenya waters except Lake Turkana, which was too remote, and where there is a very high incidence of "buttons" in the belly skins. In 1955 commercial hunting was stopped by law, and more effectively by scarcity of crocodiles. Since then they have made a substantial comeback in the Northern Uaso Nyiro, Tana, and Sabaki (Galana, Athi) rivers--to the point where humans and stock are being taken once more with some regularity. However, in Lake Turkana the trends have been the opposite. Here the launching and growth of a widespread gill-net fishing industry has brought about considerable conflicts of interest. As netting is done with very large mesh nets for *Lates niloticus*, crocodiles are easily caught and drowned. It is unlikely that this has not been commercially exploited, though large scale sales are not documented (Parker *in litt.* 1980). Local declines almost certainly continue outside specifically protected areas due to human population encroachment (Duff-MacKay *in litt.* 1980).

One of the problems in controlling crocodile skin trsde in Kenya is that this country shares borders with Somalia, Ethiopia, Sudan, Uganda, and Tanzania.

Reasons for Decline.-- Heavy commercial exploitation particularly between 1946 and 1955, animals trapped and drowned in gill nets on Lake Turkana, and to a lesser extent insidious illegal poaching.

According to Inskipp and Wells (1979), Kenya exported 3000 crocodile skins in 1976. During the period 1977-1979 export of crocodile skins to France, Japan, and Austria amounted to 1520 kg. (IUCN Traffic Bull. 11 [7]).

LIBERIA, REPUBLIC OF

Legal Status.-- Considered to be endangered. No legal protection exists and no reserves have been established to date (Steiner *in litt.* 1980).

Distribution.-- Said to occur commonly in mangroves on the outskirts of the capital city, Monrovia (Verschuren *in litt.* 1980).

Conservation Status.-- Unknown. Habitat destruction and heavy poaching for skins have depleted populations (Steiner *in litt.* 1980). Small trade in live crocodiles is apparently carried out from this country according to Jeffrey (1977). Live exports of crocodiles were 138 crocodiles from 1973 to 1974.

Reasons for Decline.-- Unknown.

MALI, REPUBLIC OF

Legal Status.-- Protected in the National Park and in Nature Reserves and partially protected in classified Forestry Areas by the Hunting Code, contained in Ordinance No. 60/CMLN of 11 November 1969. Established hunters may trap crocodiles throughout the country (except in classified areas). A permit enables each hunter to trap three crocodiles per year and, on payment of a fee, is issued by the Department of Forestry and Water Affairs (M. Sangare *in litt.* 1971).

In response to a a suggestion by Dr. H.R. Bustard (*pers. comm.* 1973) of the CSG that there was concern over killing of crocodiles in this country, the following reply was received: "We feel that the number of animals killed legally is not excessive in view of the present status of the species. The majority of animals killed are taken illegally, and it is unlikely that changing the license procedure would affect this poaching. Also, since most of the money for wildlife conservation in Mali comes from the sale of licenses we need to keep these licenses as attractive as possible. We have improved our performance in the anti-poaching field enormously in the past few years and should be able to continue to do so" (J-D. Keita *in litt*. 1973).

Status in 1980 unknown.

Distribution.-- No data available.

Conservation Status.-- Suitable crocodiles habitats have deteriorated due to cutting down of indigenous forest, mainly along the river banks and margins of swamp areas for the purpose of establishing fields (mainly rice). Erosion too has been severe.

Position in 1980 unknown.

Reasons for Decline.-- Killed for belly skins, particularly by peoples of the Bozos and Somonos tribes, and because prior to introduction of a permit system in 1969 crocodiles were not protected in any way. Also there was a great market demand for hides which encouraged hunting. It is considered that the number of crocodiles has decreased even in reserves, and without the partial protection now in force the species would soon be exterminated (M. Sangare *in litt*. 1971).

Habitat deterioration as described above may have affected breeding grounds.

MALAWI

Legal Status.-- Protected under the Crocodiles act (Laws of Malawi) Chapter 66: 06 pages 1-8 of 1968 (which replaced the Ordinance of 1951). Crocodiles were regarded as a common resource, the ownership of which is vested in the State. Under Section 3 of the Ordinance, no person may hunt, rear, or be in possession of any crocodile or crocodile product, unless he is the holder of a license. Such licenses were issued by the Deptartment of Fisheries and were valid for specified areas (Ministry of Agriculture 1971). There has been no change in status (G.M. Nongwa *in litt*. 1980). Considered to be in no immediate danger of extinction, though its range may have been, and still is in the process of being considerably reduced (R.H.V. Bell *in litt*. 1980). Legally crocodiles may be killed on licenses. Regulations exist concerning size ranges that may be killed. If killed in defense of life or property, the trophy becomes Government property (R.H.V. Bell *in litt*. 1980).

Distribution.-- Lake Nyasa, Lake Chiuta, Lake Malonbe, and the Shire River as far as Chiromo; Nkhotakota Game Reserve (Bua River) and in the Dwangwa River; Majete Game Reserve. Appear to be fairly common in most parts of Lake Malawi, in marshy areas and the estuaries of major rivers; common in the middle Shire, i.e. Liwonde to Mpatamanga, and the densest concentration appears to be between the lower Shire and Elephant Marsh. Records exist for the following rivers: Ruo, Diampwe, Linthipe, Lilongwe, Bua, Dwangwa, South Rudura, Luweya, Limphasa, North Rukuru, and in the Lingadzi, a tributary of the Lilongwe.

Conservation Status.-- There are four National Parks and four Game Reserves in Malawi, while a new National Park is about to be proclaimed at Cape Maclear on Lake Malawi. Most of the crocodile populations are outside conservation areas and a more or less continuous conflict exists between human and crocodile populations. The general attitude toward crocodiles is negative, because they are seen as a danger to life, as a source of damage to property such as fish nets, and as a depressive influence on fish stocks.

Reasons for Decline.-- The crocodile skin industry started in 1951 and to some extent owed its origin to the publicity surrounding the Government Crocodiles Destruction Scheme, financed by the Native Development Fund, which was conducted in an effort to improve the gill-net fishery. The Government scheme started in 1949 and continued until the early part of 1951 when commercial interests were awakened. Under the Crocodile Ordinance of 1951, a licensing system was introduced in favor of commercial enterprise. The total number of crocodiles destroyed by the Government scheme of 1949-1951 was estimated at about 3000, of which 1000 were confirmed by dead bodies. The commercial effort accounted for about 10,000 up to the end of the third quarter of 1956, making a total of 13,000 since 1949. All observations by Game Department Staff and the licensees themselves suggested a marked decrease in the number of crocodiles (H.J.H. Borley 1956).

There do not appear to be records for licenses or skins exported between 1956 and 1967, but between 1968 and 1978, 6976 skins were legally exported (R.H.V. Bell *in litt.* 1980).

Generally it is felt that the number of crocodiles has declined in some areas of Malawi in recent years. In certain areas the decline has been quite significant (G.M. Nongwa *in litt.* 1980). Other reasons for a decline in recent years have arisen because there are a number of hotels with bathing beaches, and crocodiles appearing in these areas are shot.

MALAGASY REPUBLIC

Legal Status.-- None 1971. Unknown 1980.

Distribution.-- In the past, Sibree (1880) recorded crocodiles in every river and lake and even in small pools. During a journey down the Betsikoka River we saw as many as a hundred in a day. Cott and Pooley (1972) and Osborn (1925) also confirmed the very large numbers in the Betsikoka, the former regarding them as perhaps the commonest vertebrates in the island. The species is still widespread, even in the waters of the high Ventral Plateau and remained abundant up till about 15 years ago (ca. 1955).

No recent information available (1980).

Conservation Status.-- In 1970 it was not yet considered to be seriously threatened, but because of its economic importance (skins, taxidermy, tourist attraction, etc.) it will be absolutely essential that the stock be restored (Ch.P. Blanc in litt. 1970).

In 1970, the Council for Nature Protection suggested the following measures for improved protection (Ch.P. Blanc in litt. 1970):

a) Increase on the export tax for skins of less than 35 cm in length from the present 13% ad valorem FOB to 35% in order to direct exploitation towards the larger animals.

b) Prohibition on hunting of crocodiles under 80 cm in length.

c) Prohibition on destruction of nests and taking of eggs.

d) Fixing of an annual quota for the small sized specimens allowed to taxidermists.

No recent information available (1980).

Reasons for Decline.-- Chiefly hunting, but also destruction of nests by the Malagaches, who class the crocodile as a noxious animal, have led to a serious reduction in numbers.

During 1957-1969 no export figures were recorded but the weights of skins amounted to 374,527 kg.

MOZAMBIQUE

Legal Status.-- Completely protected within the Gorongoza National Park, the Maputo Elephant Reserve; also along a section of Lake Nyasa, and in southern Mozambique as defined in Official Bulletin No. 17., Series 1, of 1967 which came into operation in September 1967.

In the southern area of the country no crocodile below 1.5 m in length may be hunted or molested. During the period September to March inclusive, no crocodiles may be hunted in southern Mozambique (Cott and Pooley 1972).

Regarded as being vulnerable in Mozambique outside of conservation areas. Crocodiles may be hunted under license outside of National Parks and Game Reserves, according to the latest regulations: 117/78 of 16/5/78. A hunting license for residents costs Escudos 250 or about R 7, while non-residents would pay Escudos 8250 or about R 250.

For purposes of evaluating the fine for killing a crocodile without a license, an amount of Escudos 3000 or about R 80 is stipulated.

New conservation areas are being planned which will considerably extend the existing protection afforded to the population in the country (A.J. Rosinha _in litt_. 1980).

Distribution.-- Throughout the country in former times, but populations have been very severely depleted--particularly in the rivers Savie, Incomati, Umbeluzi, Maputo, and lakes Satine, Poolele, Bambene, Quissico, Inhampavale, Xuali, Mandjane, Chinguti, Piti, and Catuane in the south (da Costa _in litt_. 1967).

The Zambezi River was extensively hunted, and the building of the Cabora Bassa dam in the north brought in thousands of construction workers who hunted crocodiles. There was evidence of illegal hunting and trading in skins between Mozambique, Tanzania, Malawi, Rhodesia, and Swaziland (da Costa _in litt_. 1968).

Conservation Status.-- The increasingly widespread use of gill nets has resulted in the killing of crocodiles, and numbers are killed for medicinal properties by local tribes people. In addition, numbers of small crocodiles are killed for a flourishing taxidermy trade operating from Lourenco Marques (Pooley pers. obs. 1967-1969).

During 1968, the Department of Fauna and Veterinary Services issued 49 licenses, and during 1969 an additional 38 licenses. The department keeps no records of crocodiles shot or captured under permit. The entire country is patrolled by only a few conservation officials and policing is hopelessly inadequate. Technical aid as given to the Department to start a rearing station but lack of finance, staff, and official support has not encouraged development (Cott and Pooley 1972).

In response to a request from the IUCN/CSG the Government agreed to suspend the killing of crocodiles under license for the years 1972/1973 (Paisana _in litt_. 1971).

Tinley _et al_. (1976) described the animal in Gorongoza Parque da National as being very common, and occurring in fair numbers in Reserva Especial do Maputo.

No reliable data on crocodile status are available for areas other than Maputo Game Reserve and Gorongoza National Park, where the populations are secure. However, as all legal exploitation of this reptile was terminated after independence in 1966, crocodiles in the less densely populated areas are probably abundant. On the other hand increasing agricultural activity will place greater pressure on nesting habitats (Rosinha in litt. 1980).

NIGER

Legal Status.-- Unknown 1980. Presumably protected in Niger's "W" National Park, adjoining Upper Volta and Dahomey. Considered to be certainly an endangered species (Newby in litt. 1980). A.A. Green (pers. comm. 1980) records that crocodiles are still widespread, but uncommon in the reserves. Probably the Arli, Pendjari, Singou, Mekrou, and Alibori rivers have crocodiles. Animals up to 4 m in length have been seen in the Pendjari and Mekrou rivers.

Distribution.-- Known to occur in the Niger River on the east, and in seasonal tributaries, the Tapoa in the north and the Mekrou in the south in the "W" National Park. Between Niamey and the Mali frontier small numbers are seen (Newby in litt. 1980).

According to A.A. Green (pers. comm. 1980) there are also crocodiles in some permanent waterholes on the Pendjari floodplain.

Conservation Status.-- Unknown 1980. Jones (1973) reported that crocodiles can easily be seen in all the rivers within the National Park.

Reasons for Decline.-- Gill-net fishermen kill crocodiles in their nets in the rivers. Heavy losses are reported from the Niger River. It would seem that the small crocodile skin trade that exists relies on imported skins from Benin, Nigeria, and Cameroon (Newby in litt. 1980).

According to Poche (1973) there is no control over poaching in the "W" National Park. Luggage make of crocodile skins is common and many skins are suspected to come from there.

NIGERIA

Legal Status.-- None of the crocodile species are protected in the Wild Animal laws of Nigeria, and no protection is contemplated. In reserved areas, (e.g. Yankari, Borgu, and Upper Ogun Reserves) all species are protected (Cott and Pooley 1972).

According to Geerling (1980), Yankari is the only reserve in Nigeria where crocodiles are effectively protected.

The area of Lake Chad south of Baga has been reserved as a Game Sanctuary (Honegger in litt. 1974).

Considered to be still widespread but generally rare (Happold in litt. 1974).

Distribution.-- Gaji River in Yankari Game Reserve, Borgu, and Upper Ogun Reserves, from the region of Oyu southward, extending towards Abeokuta. Also from the midwest, in the Kyarima Park in Maiduguri in the northeast, in southern Adamawa Province, Lake Chad.

According to Happold (in litt. 1974), formerly distributed in most large rivers throughout the country, except in the extreme north.

Conservation Status.-- In various parts of Nigeria, crocodiles are kept in enclosures in villages and towns. This is probably because of interest and curiosity, but also because of the supposed magical properties of the crocodile (Cott and Pooley 1972).

A small pilot breeding scheme with the aim of restocking has been started in the Kyarimi Park in Maiduguri (Morgan-Davies in litt. 1979).

Status of the habitat is generally being destroyed or disturbed except in the few proclaimed game reserves (Happold in litt. 1974).

Reasons for Decline.-- There is a considerable trade in crocodile skins and leather work (bags, cases, etc.). Most are sold by Hausa traders from North Nigeria. Probably some of the skins originate in Nigeria, but undoubtedly others are imported from Niger, Upper Volta, and Cameroon (Happold in litt. 1971).

Geerling (1980) mentions skins and handbags as being on sale locally.

The skin trade is carried on mainly through Kano International Airport. At one place near the Oshun River west of Ibadan one can buy small live crocodiles (Happold in litt. 1974).

RWANDA

Legal Status.-- Unknown.

Distribution.-- Unknown.

Conservation Status.-- According to Fuchs *et al.* (1974), *C. niloticus* occurs in this country.

Reasons for Decline.-- Unknown.

SENEGAL, REPUBLIC OF

Legal Status.-- Protected in National Parks, Nature and Forest reserves only. Permits are issued for commercial hunting by the Service des Eaux et Forets, under Article D.6. of the Hunting and Fauna Protection Law. Killing of crocodiles measuring less than 19 cm in breadth at the widest point between the horny flank scales is forbidden (Cott and Pooley 1972).

Distribution.-- Formerly occurred along the Senegal, Faleme, Gambia, Casamance, and various smaller rivers and tributaries. (1971). Very scarce in Delta du Saloum National Park, but common in Parc National du Niokolo Koba (Verschuren *in litt*. 1980).

Still reasonably common in the Gambia river and its tributaries in 1977 (Verschuren *in litt*.).

Conservation Status.-- Considered to be endangered (Dupuy *in litt*. 1980).

Reasons for Decline.-- Commercial overexploitation and illegal poaching. From 1961 to 1969, 153,667 skins were legally exported, with a significant drop in numbers exported annually, from 34,259 in 1964 to 4,218 in 1969. This was thought to arise because of the closing of the frontiers by the customs authorities to the former traffic in skins imported from Guinea, Mali, and the Gambi (Dioum *in litt*. 1970).

According to Verschuren (*in litt*. 1977), all attempts to arrest the decrease in their numbers due to poachers have failed. The demand for skins and the prices offered are so high that it is hard to deter men from defying the regulations.

Dupuy (*in litt*. 1980) reports that the collapse of the crocodile populations is spectacular and undesirable since 1970. Illegal poaching is the cause. No export figures are available for recent years.

SIERRA LEONE

Legal Status.-- In 1967, before the N.R.C. Military government assumed power, a bill entitled The Wild Life Conservation Act 1967 appeared as a supplement to the Sierra Leone Gazette (vol. 98 No. 31 of 30 March 1967). It listed crocodiles as a Game Animal and Dangerous Animal (Owen *in litt.* 1970). This bill was apparently only accepted in 1972 and specifies crocodiles as game animals to be hunted under license with a bag limit of 10 per person (Palmer *in litt.* 1980).

Distribution.-- Unknown. Said to occur both in the peninsular and up country (Owen *in litt.* 1970).

Conservation Status.-- Unknown 1980. Crocodiles are rarely seen according to Lowes (1970). There is definitely a decline in the populations due to commercial hunting, and loss of habitat (Palmer *in litt.* 1980).

T.S. Jones (1955) recorded that in the Bonthe district eggs were in demand for food, as well as the meat.

SOMALIA

Legal Status.-- Unknown. According to Fuchs *et al.* (1974) this species occurs in this country.

Distribution.-- Unknown 1980.

Conservation Status.-- Unknown 1980.

SOUTH AFRICA, REPUBLIC OF
NATAL, PROVINCE OF

Legal Status.-- Formerly protected under the Reptiles Protection Ordinance, No. 32 of 1968 (commenced 24 April 1969). This prohibited the killing, capturing, or export of crocodiles dead or alive, including the skins and hides thereof, without a permit. Provision allowed for a landowner to kill a crocodile in defense of life or property.

In 1980, crocodiles were protected under the Nature Conservation Ordinance No. 15 of 1974 : Chapter VII, Amphibians, Invertebrates and Reptiles. This was substituted by Section 13 of Ordinance 25/1979 dd. 2/4/1980 w.e.f. 1/6/1980. In the new ordinance there are controls for the killing or capture, the keeping in captivity, and export and import of protected species. Also, there are regulations and controls of enclosures and cages, their dimensions and appointments, and the number of animals which may be housed in enclosures and cages.

Provision is made for the killing of a crocodile in defense of human life or property, provided that any officer or temporary officer may require that any protected indigenous reptile so killed or captured be surrendered to Natal Parks, Game and Fish Preservation Board.

Distribution.-- Formerly occurred in every river along the coast of Zululand and Natal as far as the Umtamvuna River, the Natal/Cape Province border and farther southwards into the Eastern Cape (Pooley 1976).

By 1970, the occasional specimen was found south of the Tugela River, the Zululand/Natal Border.

In 1980, fair populations existed in Ndumu, Hluhluwe, Umfolozi, and Lake St. Lucia Game Reserves in the province. In addition small isolated populations occur in the Kozi Lakes, Lake Zilonde, Lake Sibaya, and Mbibi pans, Ngobazeleni pan, Mbazewana floodplain, the Pongola River and floodplain lakes, the Makhatini pans, Lakes Bangazi north and south of the Mkuze River floodplain, Msinduzi, Mzinene, Hluhluwe, Nyalazi, Umsundazi rivers and floodplains, lakes Etza, Richards Bay, Lake Mzingazi and the Enseleni, Inyoni, Mhlatuzi, Amatikulu, Hlabane and Tugela rivers (Pooley 1976).

Conservation Status.-- Considered to be good (1980). The Natal Parks Board operated an experimental rearing and restocking atation in the Ndumu Game Reserve during 1967-1974, and from here 858 live young were distributed to chosen habitats in the Province and to other areas (Pooley 1980).

A new crocodile center was established at Lake St. Lucia Estuary in June 1974, and captive breeding of crocodiles for restocking has continued. The center comprises a research section plus a large interpretation center concentrating on educational exhibits pertaining to crocodile biology and habitats, and live display of animals.

Extensive research has been undertaken on captive study groups, and field studies have included mapping of nest sites, basking grounds and techniques for the capture of problem animals. Interpretation effort has included making documentary TV films on the life history of the Nile crocodile, and guided lecture tours for school groups at the Crocodile Center.

In 1980 an area of the Mkuzi swamps at the northern end of Lake St. Lucia was set aside as a crocodile sanctuary. This area will provide protection for an important breeding population.

Reasons for Decline.-- Prior to introduction of the Reptiles Protection Ordinance of 1968, crocodiles were regarded as vermin in the Province. Numbers were destroyed by farmers because of the threat to livestock;

certain tribal peoples snared crocodiles for their supposed medicinal properties. Agricultural development was intensive throughout the range of the crocodiles. Rivers were dammed, in some cases leading to obstruction of seasonal movements along the waterways. Swamps and feeding grounds were reclaimed and nesting sites destroyed by chopping down riverside forests. Irrigation schemes on rivers flowing into Lake St. Lucia have caused concern during recent drought years. The salinity levels reached such high levels in 1970 that some 40 adult crocodiles died, and it became necessary to capture and translocate a further 40 adults to a freshwater stream to save them.

Commercial hunters operating in the Mkuzi and Pongola river floodplains and on the Usutu River in the north, and along the Umfolozi, Umsinduze, Nyalazi and Hluhluwe rivers in central Zululand took a heavy toll of the populations. In recent years the steadily increasing human pressures in the form of shore and boat angling, launch tours, dredging operations, and habitat disturbance has affected the range of the crocodile (Pooley 1969, 1976).

Bruton (1979) records disturbance of nest areas by herdsmen and cattle at Lake Sibaya.

SOUTH AFRICA, REPUBLIC OF
TRANSVAAL PROVINCE

Legal Status.-- Protected to a degree under Schedule 111 of Ordinances 17 of 1967, No. 22 of 1968, and No. 7 of 1969.

Landowners may hunt crocodiles without a permit on their property. Non-owners may hunt on the same basis, providing they have written permission from the landowner. No person may possess, sell, buy, donate, receive consequent upon a donation, convey, keep in captivity, or be in charge of any live crocodile without having a permit (Cott and Pooley 1972).

Status in Transvaal (1980) unchanged; however the Nature Conservation Division is a signatory of the IUCN Convention on Endangered Species, and thus crocodile skins are not allowed out of the province until the Division receives an import permit from the country of which the hunter is a resident. Only then is an export permit issued, subject to the additional provision that the skin is not used for commercial purposes. All trade in crocodile products is therefore presently at a minimum (Jacobsen *in litt.* 1980).

Distribution.-- In all the perennial rivers of Kruger National Park-- Crocodile, Sabie, Sand, Olifants, Letaba, and Levubu. They are also widespread in other permanent or semi-permanent waterways. See Pienaar, (1966: 123) for distribution within the K.N.P. Outside of the K.N.P.

occurs in rivers such as Komati, Olifants, Blyde, Sabie, Letaba, Crocodile, Limpopo, and smaller watercourses; on private sanctuaries and reserves.

Conservation Status.-- There are only a few rivers remaining in the Transvaal outside protected sanctuaries that are still suitable for crocodiles. Extensive irrigation schemes, dams, and water use for industrial needs have largely affected the present day habitat and distribution of this animal, and numbers have certainly been reduced.

Its current status in the Transvaal outside of the K.N.P. is considered vulnerable (Jacobsen in litt. 1980).

Endangered in the Olifants and Levuba rivers, as well as streama of the Letaba and Sabie (van der Waal in litt. 1980).

In the K.N.P. the major crocodile populations are confined to and dependent on perennial rivers. Provided these rivers are unaffected by industrial and other forms of use in their catchment areas, there is no reason to expect any drastic change in the crocodile populations (Joubert in litt. 1980).

A crocodile farm is operated by Mr. J.G. Kuhlmann near Pretoria. According to the owner, he has released several thousand live young into various rivers in the Transvaal. The Division of Nature Conservation has no knowledge of this (Jacobsen in litt. 1980).

There are also plans at present for another crocodile farm to begin shortly on the Sabie River near the Kruger Gate entrance to the Kruger National Park. A smaller undertaking is also in this vicinity on the upper Sabie River.

Reasons for Decline.-- Within the Kruger National Park and during the early years of its existence crocodiles were culled in the belief that this would promote a healthy predator-prey relationship; crocodiles were shot at every opportunity, particularly from 1933 to 1960 (Stevenson-Hamilton 1947, Pienaar 1969).

In former years hunters operated extensively on the major rivers. The position was complicated, in that several larger rivers rising in the Transvaal flow through protected areas and then into Mozambique, where no protective measure existed. The Limpopo river is an example, as it is shared by Botswana/Zimbabwe/Transvaal/Mozambique. Four different sets of regulations thus apply to crocodiles occurring in this river.

SOUTH WEST AFRICA

Legal Status.-- Formerly, the Game Ordinance 31 of 1967, Chapter 7, stated that a permit was necessary to keep a crocodile in captivity and listed specific dimensions for pens. Provision was also made in the Nature Conservation Ordinance of 1975 to control any trade, transport, or captivity of wild animals.

In 1980 there are at least three Nature Conservation laws for the S.W.A. area. Kavango has legislation of 1975, and although crocodiles are not specifically protected, it is stated in this Ordinance that no animal may be caught, kept, exported, etc., without a special permit.

In Kaokoland Proclamation R188 of 1976 (Nature Conservation) in certain Native areas in S.W.A. is presently in force where the crocodile is specially protected game.

Caprivi adopted the S.W.A. Nature Conservation Ordinance in 1979. Furthermore, in 1978 Proclamation R6 Nature Conservation in Black areas was passed, referring to S.A. Trust Areas in all Provinces. Here the crocodile is regarded as Protected Game.

Distribution.-- The Kunene and Okavango rivers in the south to the Botswana border. Occurs in the Zambezi, Chobe, Linyanti floodplains in the Caprivi area.

Conservation Status.-- Considered to be out of danger in Kunene Rever. Endangered in the Kavango area, out of danger in Caprivi (van der Waal 1980). Overall thought to be vulnerable (Director, Department of Nature Conservation and Tourism *in litt.* 1980).

Reasons for Decline.-- Occasionally specimens are shot as problem animals because of attacks on humans, or have caused damage to fishing gear. In Caprivi some trade in skins took place before 1977. The department sold about 50 skins to Botswana (animals shot at Lake Liambezi).

SUDAN

Legal Status.-- Prior to 1970, there was no legal protection for crocodiles in this country. Hunters operated actively. In September 1970 the crocodile was listed under Schedule III of Protected Wild Animals in the Ordinance, where its killing is subjected to permissioon from the Department of Game and Fisheries (Hassan *in litt.* 1970). Status in 1980 unknown.

Distribution.-- The Nile and the Lake Chad drainage systems, the Bahr el'Arab, the Wadi'Azum, Bahr el Ada headwaters, Lake Tisi/Nzili Pools and in the Darfur province; the province of Bahr el Ghazal; and in the Dinder National Park.

Conservation Status.-- Populations have been seriously depleted and this seems to have begun at least 20 years ago. Thus, "On a 75 mile stretch of the Nile north of Malakal and south of Khartoum in 1948, 50 crocodiles might be seen in a day's passage. In 1952, along the same stretch of water, none. Crocodiles are being hunted for skins, having been killed with spears, clubs or foul-hooked on lines. The small skins were more in request than large skins, the size preferred for export being about one meter in length" (R.E. Taylor pers. comm. 1952).

According to Cloudsley-Thompson (1973), in the Dinder National Park crocodiles were killed by an earlier chief warden some years ago but are now beginning to reappear.

Wilson (1978) relates that this species was until very recently of considerable to very great abundance in Darfur, the westernmost province of the Sudan. Of late, probably within the last 40 years, numbers have been reduced to such an extent that it can now be described as very rare. The reasons for this are probably attributable to a rapid increase in the numbers of people and domestic stock in the same period, resulting in larger numbers of crocodiles being killed by humans, not only as a livestock protection measure, but also for the value (and easily saleable nature) of the skins, and to a lesser extent the use of crocodile eggs and young crocodiles for food.

Wilson (1978) further relates that Darfur is a center for the collection and export of skins. Legally, 5343 skins were exported between 1967 and 1977. These figures do not include the very large numbers of skins that are used within the province for the manufacture of such items as shoes and bags, or of skins brought in by nomadic Baggara Arabs, who exchange them for milk and other livestock products while on their annual migrations outside Darfur, and also by Fulani and Hausa immigrants from West Africa. Wilson also is of the opinion that many skins are illegally imported into Darfur from the province of Bahr el Ghazal to the south and from Central African Empire and Chad to the West.

Parker and Watson (1970) reported that many skins exported through Uganda, originated from the southern Sudan.

Reasons for Decline.-- Illegal hunting and trading as described above.

SWAZILAND

Legal Status.-- The crocodile is not mentioned in the existing Game Regulations (Chapters 195 and 198 of the Laws, 1960) and may be freely hunted. There is in fact no Game Conservation Department in Swaziland. One National Park and a Game Reserve have been proclaimed. Considered to be endangered in Swaziland (Reilly in litt. 1980).

Distribution.-- Small numbers occur in the Usutu, Umbeluzi, Mkomati, and Mgwavuma rivers.

Conservation Status.-- Considered to be very poor. In addition to the fact that the animal is not protected, except in two small sanctuaries where only about 30 animals remain, any measure to introduce protection would be unpopular. Attempts by the Natal Parks Board and the IUCN in 1971 to persuade Swaziland to introduce legislation similar to that existing in South Afirca were ignored by Swaziland officials.

Thirty young crocodiles were donated to the Mlilwane Game Sanctuary in November 1974 by the Natal Parks Board. The existing Nature Parks do not afford adequate protection for this species (Reilly in litt. 1980).

Reasons for Decline.-- In the past, before stocks were depleted, extensive hunting took place freely, in addition to the capture of live young for sale by commercial hunters. One hunter interviewed had shot 88 crocodiles in the year 1971 on the Usutu River despite the denials of local officials that hunting was taking place.

Crocodiles are also killed by trapping or snaring methods by indigenous people because of the danger to livestock and humans, and for medicinal reasons.

TANZANIA

Legal Status.-- Formerly protected under the following (see Cott and Pooley 1972 for the text of these proclamations):

1) The Fauna Conservation (Hunting of Crocodiles) Prohibition Order. Govt. Notice No. 183 of 1959.

2) The Fauna Conservation (Hunting of Crocodiles) Permits Order of 1959. Govt. Notice No. 184 of 1959.

3) The Fauna Conservation (Hunting of Crocodiles) Prohibition Order of 1960. Govt. Notice No. 21 of 1960.

Basically the ordinances proclaimed areas where crocodile hunting was prohibited, or where hunting waa allowed under permit, and details of license fees and conditions relating to hunting were set out.

Until 1970 crocodiles were protected under the former Fauna Conservation Ordinance hunting regulations which prohibited hunting of crocodiles less than 6 ft (1.8 m) in length. Under Section 16 of the present law, the Wildlife Conservation Act of 1974, crocodiles are listed under National Game. This states that "No person shall, except by, and in accordance with the written permission of the Director of Wildlife previously sought and obtained, hunt, kill, capture or wound crocodiles less than two meters in length" (Njau in litt. 1980).

Distribution.-- Mbeya Region: Ulanga, Kiwira, Mbaka, Lufirio, Songwe, Momba river systems, and in Lakes Rukwa and Nyasa; Iringa Region: Ruaha, Little Ruaha and Lukosi river systems; Dodoma Region: Ruaha river; Tabora Region: Lakes Chada and Ikuu; Kigomo Region: Malagarasi and Rugufu rivers and in Lake Tanganyika; West Lake Region: Kagera, Ruvuvu rivers and in Lakes Rushwa and Victoria; Mwanza Region: Lake Victoria; Musoma Region: Mara, Grumeti, Orangi, Barageti, and Rubana river systems; Arusha Region: Ruvu River; Kilimanjaro Region: Lake Jipe and Ruvu River; Tango Region: Ruvu River; Morogoro Region: Ruaha, and Rufiji Rivers; Coastal Region: Wami and Rufiji Rivers; Mtwara Region: Matandu and Mvemkuru rivers; Ruvuma Region: Ruvuma River system; Ulanga Region: Kilombero River; Karagwe Region: Kagara River; Kilwa Region: Lake Maliwe.

Conservation Status.-- Despite the legislation, the actual protection afforded to crocodiles is seriously affected by lack of sufficient staff and equipment. Complete protection is given in the National Parks, Game Reserves and controlled areas (Cott and Pooley 1972).

Increased poaching of key trophy animals in Tanzania led to the hunting ban of all species of game, including crocodiles in 1973. According to Njau (in litt. 1980) there has been no commercial exploitation since 1974, and although the species is adequately protected in Game Reserves, such as Selous Reserve, he regards the Nile crocodile to be rare in Tanzania.

Reasons for Decline.-- A decline in crocodile stocks was noted in 1954 when skins exported from Tanzania, Uganda, and Kenya for that year totalled about 60,000.

In Lake Rukwa one hunter killed several thousand a year, but by 1959 his license was for 750 only, and local inhabitants were allowed a further 750 because the status of the animal was then described as very serious. Mr. Miles Turner estimated that a total of 35,000 crocodiles had been taken out of Lake Rukwa (1970) and stated that hunting was no longer economical. Considerable illegal hunting on the Great Ruaha resulted in 300 skins going out through Mbeya alone. One trader was reported as buying 400 skins per month in the Ifakara area, and this is estimated as about half the total off-take from this river.

Heavy exploitation almost led to the extermination of crocodiles in the Pangani, Ugalla, and Kagera rivers.

In Lake Victoria crocodiles were still numerous in places: Emin Pasha Gulf, near Nyamirembe on SW shore of the lake in 1949. Most had disappeared by 1952 when hunting was beginning to be abandoned, and by 1955 it came to a standstill, there were no crocodiles left (see Cott and Pooley 1972).

TOGO, REPUBLIC OF

Legal Status.-- No laws or regulations provide protection for crocodiles. In Ordinance 4, of 16 January 1968 which governs protection of fauna and hunting in Togo, the crocodile is classed as a predator. The killing of crocodiles is allowed in inhabited and agricultural areas, by holders of hunting licenses, or in defense of life or property (Gnrofoun *in litt*. 1970).

Status in 1980 unknown.

Distribution.-- No data available.

Conservation Status.-- Apparently most rivers in the north of the country dry up for 5-7 months a year, but many lakes, lagoons and rivers still support crocodiles, though only about 1000 animals were thought to survive in 1970 (Gnrofoun *in litt*. 1970).

The status in 1980 is unknown.

Reasons for Decline.-- Although not yet considered to be on the way to extinction, crocodiles have certainly suffered a marked decrease in the last 12 years and particularly in the last 5 years.

The immigration of a large number of Yoruba and Hausa settlers has recently altered the situation. Some of these people eat crocodile meat, and others have organized a trade in the skins which were previously of no commercial interest to the indigenous peoples (Gnrofoun *in litt*. 1970).

In recent years, an animal dealer operating from Lome has been selling live animals to zoos and other institutions.

UGANDA

Legal Status.-- Formerly protected only on National Parks such as Murchison Falls National Park and Kidepo Valley National Parks and Game Reserves. Legal status was granted in 1970, and in 1979 the Government banned hunting in the country (Edroma *in litt*. 1980).

In Uganda regarded as Highly Endangered by Dr. E. Edroma (in litt. 1980) and as an endangered species by Prof. J. Okedi (in litt. 1980).

Distribution.-- Lakes Victoria, Albert, Kyoga and Kwania. In the major rivers, the Semliki, Victoria Nile, Albert Nile, and lesser rivers and their tributaries. These are the Ome, Achwa and Tangi flowing into the Albert Nile; the Zoila flowing into Victoria Nile, the Waiga and its major tributary the Joliya; and the Muzizi and Wasa that flow into Lake Albert. Grumeti River that flows into Lake Victoria.

Conservation Status.-- See Cott and Pooley (1972) and Parker and Watson (1970) for observations on status for the period 1900-1971. Earlier observations are contained in references in the bibliography. Parker and Watson (1970) made a number of recommendations for the management of crocodiles in Uganda. However the recent civil war in this country and the increased poaching of crocodiles as described by Edroma (in litt. 1980) and Okedi (in litt. 1980) suggest that the status of this animal in Uganda is very poor. It appears that remnant populations are still existing in Kabalega Falls (ex Murchison) and Kidepo Valley National Parks, but illegal poaching is still rife even in these areas.

Reasons for Decline.-- Commercial exploitation for hides, illegal poaching, and from some areas this species was exterminatd by officials of the Wild Life department. See Johnston (1902) and Charles Pitman in Cott (1961): Uganda's Game Department implemented a policy of extermination, particularly of breeding stock, on Lake Victoria in the 1930's.

As Parker and Watson (1970) remark: "Quite apart from the damage crocodiles inflict on a gill net fishery, crocodiles are an unacceptable feature of man's environment as they prey both on him and his stock".

See Cott and Pooley (1972) for observations on early hunting pressure. Parker and Watson (1969) record the following: "Confidential information from one of the major crocodile skin buyers in East Africa indicates that from 1950 until 1965 the number of crocodile skins coming out of Uganda was at least 7,200 annually and that this was probably an underestimate."

In the 1950-1965 period at least 108,000 crocodiles were exported from or through Uganda. Probably at least half of these originated from Uganda. Since 1965, the trade has dwindled to a mere trickle--Uganda's stocks have gone. At the outset of the boom in crocodile skins most were from mature animals. By 1965 the animals averaged 3 ft 6 in. (107 cm) in length, and last year's average was 2 ft 5 in. (74 cm) (Parker and Watson 1970).

According to Edroma (in litt. 1980) there has been a gross increase in poaching as well as habitat destruction. In his opinion, by December 1978 there were not more than 1000 adult crocodiles left in Uganda.

Okedi (*in litt.* 1980) states that there was a steady increase in the poaching of crocodiles which most likely reached a peak in 1978 and early 1979, during the war years. Also that a large number of crocodiles are killed each year in areas where commercial gill netting takes place.

S.N. Semakula (*in litt.* 1971) estimated that over the last decade the number of hides exported was 76,520, but that many of them came in from neighboring countries.

UPPER VOLTA

Legal Status.-- Protected in National Parks and in certain tribal sanctuaries. Not specified in the hunting or fishing regulations (Roman *in litt.* 1970). Status in 1980 is unknown. Data are urgently required.

Distribution.-- Found in large numbers in all the lakes and rivers in the 1950's, but by the 1970's it was seldom seen. A.A. Green (*in litt.* 1980) believes that there are still crocodiles to be found in the Black Volta, Red Volta, and White Volta rivers in this country.

Conservation Status.-- No conservation measures outside of National Parks, but in some areas tribal peoples protect the crocodile because of superstition and for religious reasons. Also protected in a few lakes as a tourist attraction. Considered to be rare (Roman *in litt.* 1970). Green (*in litt.* 1980) reports that the classified forests are thoroughly overrun by poachers, fishermen, and herdsmen. Also that skins poached are transported by bicycle southwest into Togo to be sold there.

Reasons for Decline.-- Hunted in most areas by local people, as well as those of neighboring tribes, because of its valuable skin. The flesh is well liked and the eggs are also collected and eaten.

ZAIRE

Legal Status.-- Protected by Ordinance 68 - 074 of 8 March 1968, Chapter 1, Section 1 (amending the decree of 21 April 1937) in Katanga Province. These regulations stated:

1) Without the permission of the administration no person may hunt, capture, sell, offer for sale, buy, give, receive by any means, transport or hawk crocodiles or their skins or any part of these creatures.

2) Article 1 allows persons holding licenses to hunt for their or their families benefit. Hunting licenses were issued by the Department of Agriculture.

3, 4, and 5) All skins, or crocodiles are required to be registered at a fee of 10K each. Permits are then issued which have to be tendered to the customs officer at the point of departure when skins are exported.

The species was considered to be rare in Katanga Province in 1971 (Heymans in litt. 1971).

Distribution.-- Formerly in major river systems and lakes, unknown in 1980.

Conservation Status.-- According to Verschuren (1975) opinions differ widely on the current status of crocodiles in Zaire. We consider that in many parts of the country crocodiles are declining rapidly but other observers are less pessimistic. Accidents involving humans have been commonly reported in recent years, near the Dungu ferry, in the Garamba Park, on the banks of Lake Tanganyika, between Bujumbura and Uivra, and even in the immediate vicinity of Kinshasa on the Zaire river (Verschuren 1975).

Verschuren (in litt. 1980) remarks that the species is very rare in estuaries but in some areas locally common and well protected.

Reasons for Decline.-- Illegal poaching chiefly, slaughter by local peoples who considered crocodiles harmful. Bounties were apparently paid for heads and eggs collected in former times (Heymans in litt. 1970).

Poaching has been intense and it is still extremely difficult to protect the few dozen animals in the extreme north of the Virunga National Park (Verschuren 1975).

In Virunga National Park (ex Albert) no crocodiles are now seen above the Semliki Falls. These concentrations were important till the 1950's, greatly diminished between 1950-1975 (Verschuren in litt. 1980).

Attwell (in litt. 1973), an agent for the French Tannery (Gordon-Choisey) based at Victoria Falls in Rhodesia, stated that his Paris-based firm were handling 100,000 skins a year from Africa, 60,000 of which came out of Zaire. Zaire shares borders with Angola, Zambia, Tanzania, Burundi, Rwanda, Sudan, Central African Empire, and Congo Republic.

It would appear that skins from these neighboring countries are channelled through Zaire for export.

ZAMBIA, REPUBLIC OF

Legal Status.-- Crocodiles were regarded as game animals under the Fauna Conservation Ordinance and protected in National Parks and Game Reserves. Prior to 1966 unlimited numbers were allowed to be hunted on license from the Wildlife, Fisheries and National Parks Department. Crocodiles may be hunted on an ordinary or National Game license with a limit of one crocodile only per license annually, but trapping or snaring is prohibited (Ansell *in litt.* 1970).

There has been no change in legal status (Sichone *in litt.* 1980).

Distribution.-- Widespread throughout the country but particularly in Lake Mweru wa Ntipa, Lake Kariba on the Zambezi, and in the Zambezi River and its tributaries. The Kalungwishi River, from Kundabwida to the confluence of the Mutomfu and Kalungwishi and from Kaunga on the Mukubwe River to the point where it enters Mweru Marsh Game Reserve. In the Kafue above Heshi-Teshi towards the Dafue flats, and in the Lufupa River in the northern sector of Kafue National Park. Also in the Lusiwashi River and Lake Lusiwashi. The Bangweleu Swamps.

Said to be still numerous in the Kafue and its tributary and the Nampogwe in 1978 (Rees, 1978).

Conservation Status.-- In Lake Kariba it was considered that damming of the Zambezi river adversely affected crocodile breeding, ancestral nest sites were flooded. The range of the crocodile and its status however has not been materially affected (Ansell *in litt.* 1970). Populations in National Parks are considered to be reasonable to good (1970).

Considered to be out of danger (Sichone *in litt.* 1980). There has been no noticeable decline in numbers.

However, Bell-Cross (1974) reported that on the upper Zambezi crocodile populations were extremely low, also that illegal hunting was prevalent everywhere outside reserves and National Parks.

The Government is currently cropping a sample of crocodiles from Lake Mweru with a view to estimating the population and allowing private enterprise to harvest a percentage of the animals. Conant (*in litt.* 1980) relates that these areas have large populations and no tourist industry, and the best way to protect these remote populations may well be to contract a certain number of animals to private firms who would then find it in their interest to protect them. To date 108 animals have been cropped and in September a further 2000 will be collected. It is from these data that recommendations for further cropping will be based (Conant *in litt.* 1980).

Reasons for Decline.-- Extensive hunting prior to 1966, notably on the Zambezi, particularly along the stretch that is now Lake Kariba, the Lusiwashi River and Lake Lusiwashi, as well as in other smaller rivers (Ansell, in litt. 1970). Damming of the Zambezi may have adversely affected nesting, and the increasing use of gill nets may have been responsible for the loss of stocks.

Illegal hunting still continues, according to Bell-Cross (1974).

ZIMBABWE

Legal Status.-- The crocodile was scheduled under the Wild Life Conservation Act : Chapter 199 of 1961, which covered Game Reserves, Private Game Reserves, Non-hunting Reserves and Controlled Hunting Areas. Hunting was allowed under permit in certain areas. Export and import of animals, trophies, and meat without permit was prohibited. The capture of live animals for rearing or display purposes required a permit, and the harvesting or collection of eggs was prohibited without a permit (Cott and Pooley 1972).

In terms of Government Notice 969 of 1975 Act 14/1975, crocodiles are now placed under the protection of the Director of National Parks and Wildlife Management, along the whole of the Zambezi river (including Lake Kariba) on the Zimbabwe side. This means that no person without a permit shall:

a) Injure, willfully disturb or remove eggs of any crocodile, or
b) Hunt or remove any crocodile.

This was done as a Conservation measure in order to protect the main source of the eggs for the Rearing Scheme. A clear-cut policy on crocodiles (Section 5) has been laid down by the Wildlife Department in respect to conservation and management of crocodiles. This policy covers the controls for harvesting of wild laid eggs, hunting in recreational areas, capture or destruction of problem animals in conflict with human interests, and controls the commercial exploitation of the crocodile through all facets of the operation.

The status of the crocodile in 1980, is considered to be Out of Danger (Blake in litt. 1980).

Distribution.-- Lake Kariba and principally the Zambezi River and its feeder streams, rivers and tributaries: the Deka, Msuna, Gwai, Mlibizi, Sebungwe, Senkwi, Ruziruhuru, Mwenda, Sengwa, Sibilobilo, Bumi, Samyati, Gache Gache, Tsororo, Charara, Myakasanga, Rukomeshe, Sapi, and Chewore.

Numerous water courses and interleading waterways shared by this country and South Africa, Botswana, and Mocamibque. In numerous streams, rivers, pans and lakes, both within protected Reserves, Tribal Trust Lands, National Parks and Recreational Areas in Zimbabwe-Rhodesia.

Conservation Status.-- Adequately Protected in National Parks and Game Reserves and good concentrations exist in remote areas in Lake Kariba. There are, in 1980, four Rearing Stations with permits to collect 8500 eggs per annum. Crocodiles cropped for skins on all rearing stations for the past two and a half years are as follows:-

1978	-	696
1979	-	612
1980	-	945
Total	-	2,253

Less than a dozen animals were allowed to be hunted on Permit over the 1979/1980 period.

The following Rearing Statiions are in operation:

A) Kariba Crocodile Farm (Pvt.) Ltd., at Kariba; established in 1965.
B) Binga Crocodile Rearing Station at Binga (on Lake Kariba); established in 1967.
C) Spencers Creek Crocodile Ranch (Pvt.) Ltd., at Victoria Falls; established in 1971.
D) Sengwa River Mouth Rearing Station at Sengwa Mouth, Lake Kariba; established in 1977.

In 1979 captive- and farm-reared animals produced 565 eggs from about 25 females at Kariba and 1341 eggs from about 62 females at Victoria Falls. The Binga Station has also recently set aside 30 females from reared stock for future breeding.

Five per cent of the eggs taken by Rearing Stations are available for restocking purposes. Due to the war situation no restocking has taken place in the last three years. It is proposed to stock an additional 100 in the Upper Zambezi in 1980.

The Wildlife Department has established a crocodile interpretation center (the Roelf Attwell Interpretative Centre) at Lake Kyle where, in addition to educational display material, live animals in breeding pens are on view.

In collaboration with the owners of the rearing stations, officials of the Veterinary and Wildlife Department are undertaking, and in recent years have carried out a number of research projects aimed at improving crocodile rearing, animal husbandry, and general management techniques (Blake and Loveridge 1972, 1975; Blake, 1974).

A successful workshop meeting of biologists, conservationists, and commercial operators was held at Victoria Falls in September 1978.

In addition to these projects the Wildlife Department has initiated a number of field studies to monitor wild populations, breeding success, survival, growth in the wild, etc.

Reasons for Decline.-- Prior to 1961 and introduction of the Wildlife Conservation Act, the crocodile was not protected and hunting took place freely on private lands and farms. There was no restriction on the sale of the skins and many professional hunters operated, particularly along the Zambezi River. No records are available to indicate numbers shot or trapped.

The damming of the Zambezi River to form Lake Kariba had an effect on breeding because of unseasonal flooding, and as the water level rose, ancestral nesting sites were inundated (Attwell 1970). However in recent years the water levels have remained stable, and it is considered that the population of crocodiles has probably increased in Lake Kariba (Blake *in litt*. 1980). Of importance is the fact that Zimbabwe-Rhodesia shares rivers and borders with South Africa, Zambia, and Mozambique. Illegal poaching is thus almost impossible to control. Also that during the recent war years there has been a certain amount of indiscriminate shooting of wildlife.

STATUS OF THE LONG-SNOUTED CROCODILE *CROCODYLUS CATAPHRACTUS*

ANGOLA

Legal Status.-- Protected throughout Angola by Decree no. 14539. which prohibited hunting in all forms and export of skins (1970). Decline probably escalated during 1975-1976 due to increased availability of arms and general lawlessness, but probably stable now due to strict control of arms available to all but the military (1980).

Conservation Status.-- Considered to be endangered. Only occurs in the northern-northeastern rivers bordering the enclave of Cabinda.

Reasons for Decline.-- Illegal hunting and poaching, habitat degradation (Huntley pers. comm. 1980).

BENIN (DAHOMEY)

Legal Status.-- Unknown.

Conservation Status.-- It was still very common in 1959 along the lower Oueme River and its tributaries, but did not appear to be present in the upper reaches of the river. The best area found for the species was about 45 km north of Djidja.

Reasons for Decline.-- Unknown.

CAMEROON

Legal Status.-- Unknown.

Conservation Status.-- According to Abercrombie (1978), the species may be quite common in the more remote tributaries of the Cross River. The flesh of this species is highly esteemed, but the hides were not considered to be valuable. According to Powell (in litt. 1976), crocodiles have no protection outside of National Parks.

Considered to be Endangered (Fauna Cons. Dept. in litt. 1980).

Reasons for Decline.-- Hunting for skins.

CENTRAL AFRICAN REPUBLIC

Legal Status.-- Unknown.

Conservation Status.-- This species occurs but no further data is available.

Reasons for Decline.-- Overexploitation for belly hides.

CHAD, REPUBLIC OF

Legal Status.-- Control of hunting and export of skins, no hunting in National Parks (1971). Endangered (1980) due to civil war and collapse in most reserves of sdequate law enforcement, and abandonment of reserves (February 1979).

Conservation Status.-- Unknown. Thought to occur on the border of Chad and Central African Empire, and in the tributaries of the River Chari, namely the Aouk, Aoukale, and Bangoran.

Reasons for Decline.-- Unknown.

CONGO: REPUBLIQUE POPULAIRE

Legal Status.-- Protected in National Parks. Considered to be out of danger by E. M'Beri-M'Babou (*in litt.* 1980).

Conservation Status.-- Spinage (*in litt.* 1980) considers that the species is secure in the northern tropical forests up near the CAR border much of which is as yet unvisited by white man. There are extensive areas of inundated forest.

See also for *C. niloticus*.

Reasons for Decline.-- Hunting for skins. See under *C. niloticus*.

GABON, REPUBLIC OF

Legal Status.-- Protected by Decree No. 0032/PR/MEF/SF dated 11/1/1966. Crocodiles are protected in National Parks and Reserves, and throughout the entire country during the breeding season. However permits are issued each year for commercial operators (1971).

Conservation Status.-- Unknown. According to D. Cousins (1978), crocodiles are abundant in the low coastal strip between Port Gentil and Mayumba. Abercrombie (1978) reported the species to be common on sections of the Ogooue River and in the vicinity of Lambarene. In 1970 suitable habitat was found throughout the country.

Reasons for Decline.-- James Powell (*in litt.* 1979) observed that this animal is hunted for food by people of the Onkouni tribe. Abercrombie (1978) observed freshly killed carcasses at villages on the Ogooue River, and that skins are also sold locally.

Commercial exploitation for hides was severe. Over the past few years (1970) a quota of 20,000 crocodile skins was exported annually, and in 1965 this figure was higher. It is not known how many hides of this species were exported (E. Ossinga pers. comm. 1971). According to Powell (*in litt.* 1976), in the remoter parts of Gabon this species seems for the moment to be holding its own, due to sparse human population and inefficient hunting methods.

GAMBIA

Legal Status.-- All crocodiles protected by law from February 1977.

Conservation Status.-- Regarded as rare or endangered. Brewer (*in litt*. 1980) remarks: "I personally have only seen three specimens--all dead--in 20 years or so, in the hands of fishermen who stated that they were going to eat them. However the fishermen seem to know of the species and say they are not plentiful. Thus I suppose one can assume that is has a wide but very thin distribution."

Reasons for Decline.-- Before the law became effective in February 1977 crocodiles were subjected to heavy exploitation over many years. Populations had been severely depleted. There is still illegal hunting being practiced.

Habitat destruction has undoubtedly had an adverse effect. Greatly depleted in Abuko Game Reserve (Thomson 1970).

GHANA, REPUBLIC OF

Legal Status.-- Unknown in 1980. All three species of crocodiles included in the Wildlife Conservation Regulations introduced in April 1971 (Anon. 1971). Protected by the Wildlife Conservation Regulations, 1971, L.1. 685.

Conservation Status.-- This species is sometimes found in coastal lagoons and the larger rivers of the forest zone such as the Densu and Pra. It has probably never been very common (Mrs. Anna Merz, *in litt*. 1970).

Reported from the larger rivers in the forest zone. Also reported from Volta Lake and in the Mole River and its tributaries (E.D.A. Asibey *in litt*. 1970).

Found in the Obosum River and its tributaries, the Dwija River and tributaries, and the Sene River and tributaries which flow into Volta Lake on the western shore (Gilbert Child *in litt*. 1978).

Recorded on the Kainji Lake near the dam (Happold *in litt*. 1971) and in the Densu River near Accra (Cansdale 1955).

Reasons for Decline.-- Hunting, fishing.

IVORY COAST

Legal Status.-- Crocodiles have been regarded as totally protected since 1970. This species is considered to be presently out of danger.

Conservation Status.-- It is probable that crocodile populations have generally declined in recent years because the expansion of agricultural activities has resulted in habitat loss and because of an increase in illegal hunting. There is considerable illegal trade in crocodile skins locally and from northern countries. Theoretically the National Parks and Reserves should be adequate for survival of crocodiles. However, in practice law enforcement is not effective enough to ensure this. Also, specially protected areas along the coastal lagoons do not exist as yet (Dr. H.H. Roth *in litt.* 1980).

Reasons for Decline.-- As for *C. niloticus*.

LIBERIA, REPUBLIC OF

Legal Status.-- Not protected. No reserves exist for the protection of wildlife (Sawyerr *in litt.* 1980).

Conservation Status.-- Still in great abundance in the St. Paul River, Monrovia, Montserrado County; the St. John River, Buchanan, Bassa County, and the Maa-fa River, Robertsport, Capemount County (Page *in litt.* 1968).

Poaching or hunting for crocodiles is very rare (T. Hector Milton Gorgla *in litt.* 1970).

According to Jeffrey (1977), the 138 live crocodiles exported during 1973-1974 may have included this species.

Common in mangroves on the outskirts of the capital city, Monrovia, and apparently little hunted (J. Verschuren, *in litt.* 1980). Considered to be endangered (Sawyerr *in litt.* 1980).

Reasons for Decline.-- Habitat destruction and heavy poaching for skins.

MALI, REPUBLIC OF

Legal Status.-- Protected in National Parks and Nature Reserves and partially protected in classified Forestry areas by the Hunting Code in Ordinance 60/CMLN of 11 November 1969.

Conservation Status.-- Unknown (1980). Threatened by hunting pressures and habitat destruction (Sangare *in litt*. 1971).

Reasons for Decline.-- In 1971 established hunters under permit were allowed to kill three animals each per year on payment of a fee to the Department of Forestry and Water Affairs. Prior to 1969 there was a great market demand for hides which encouraged hunting, particularly by people of the Bozos and Somonos tribes, as prior to 1969 the species was not protected. It is considered that crocodile habitats have deteriorated due to cutting down of indigenous forest in order to establish rice fields.

NIGERIA

Legal Status.-- Unknown 1980. Crocodiles were not protected in 1974. Skins were being exported through Kano International airport (Ministry Nat. Resources).

Conservation Status.-- Probably rare. No specimens had been brought into the Ibadan zoo since 1964. It occurs in the Gaji River, Yankari River, S.E. of Bauchi (Happold *in litt*. 1971).

Recorded in the Barkono River Gorge, Yankari Game Reserve where it is not common (C. Geerling, 1980). Considered to be endangered (A.R.K. Saba *in litt*. 1971). Recorded from Benue River (Neill 1971). Recorded from the creek country of Nigeria by Cansdale (1955).

Reasons for Decline.- No data available.

SENEGAL, REPUBLIC OF

Legal Status.-- In the greater part of the country unprotected. Though hunting is controlled under license issued by the Service des Eaux et Forets, under Article D.6 of the Hunting and Fauna Protection Law. The killing of crocodiles measuring less than 19 cm in breadth, or at the widest point between the horny flank scales, is forbidden. A register is maintained of the permits issued each year.

Conservation Status.-- Protected in National Parks, nature reserves, and forest reserves (1971). Occurs in the Delta du Saloun National Park and in Parc National du Noikolo Koba (Verschuren *in litt.* 1980). Occurs also in the Gambia river and its tributaries (Dupuy and Verschuren 1977). Still occurred in Senegal, Faleme, Gambia, and Casamance rivers and various smaller rivers and tributaries (1971). Total protection for crocodiles introduced 23/2/1973.

Reasons for Decline.-- During 1961-1969, a total of 153,667 crocodile hides were legally exported from Senegal. It is not known how many were of this species (Mr. B. Dioum *in litt.* 1940).

All attempts to arrest the decrease in numbers due to poachers have failed. Demand for skins and prices offered are so high that it is hard to deter men from defying the regulations (J. Verschuren and A.R. Dupuy, 1977). The collapse of the crocodile populations is spectacular and undesirable since 1970. Illegal poaching is the cause (Verschuren *in litt.* 1980).

SIERRA LEONE

Legal Status.-- Unknown.

Conservation Status.-- According to Dr. Jennifer Owen (pers. comm.), no records of this species have been traced. However Lowes (1970) states that three species of crocodile, now rarely seen, occur in this country.

Cansdale (1955) states that in Sierra Leone this species is much less common than the Nile crocodile and is found in some salt mangrove areas.

Reasons for Decline.-- No available data (1980).

TANZANIA

Legal Status.-- Up to 1970 crocodiles were protected under the Former Fauna Conservation Ordinance. This prohibited hunting of animals less than 6 ft (1.8 m) in length. Under section 16 of the Wildlife Conservation Act of 1974 crocodiles are listed as National Game. No person shall, except by and in accordance with a written permission of the Director of Wildlife, hunt, kill, capture, or wound crocodiles less than 2 m in length (F.S. Njau *in litt.* 1980).

Conservation Status.-- First recorded at mouth of the Luichi River south of Ujiji in about 1902 and still well known in that area in 1930 (Loveridge 1940). Not uncommon off the shores of Kigomo (Thomas 1961), and occurs between Karago and Iragala on the Malagarasi River (east Lake Tanganyika) a few miles south of the Tabora to Kogoma railroad (Thomas _in litt_. 1971). Considered to be a vulnerable or threatened species occurring only in Lake Tanganyika (F.S. Njau _in litt_. 1980).

Reasons for Decline.-- Increased poaching of key trophy animals led to the hunting ban of all species of animals in 1973 (F.S. Njau _in litt_. 1980).

TOGO, REPUBLIC OF

Legal Status.-- Unknown 1980.

Conservation Status.-- Unknown. Reports from northern regions of Togo describe a 'Savannah Crocodile' thought to be this species. Crocodile flesh is eaten by people of the Yoroubas and Haoussas tribes. During the past five years there has been a marked decline in populations (1971). _C. cataphractus_ was being sold by an animal dealer in Lome (S.J. Maness _in litt_. 1975).

Reasons for Decline.-- No data available.

UPPER VOLTA

Legal Status.-- Unknown. Protected in National Parks and in certain tribal sanctuaries. Not specifically mentioned in the hunting or fishing regulations (Roman _in litt_. 1971).

Conservation Status.-- In the 1950's it occurred commonly in all the lakes and rivers, but in recent years has disappeared from most localities. In some areas tribal people protect the crocodile because of superstition and for religious reasons. They are also protected in a few lakes as a tourist attraction.

Reasons for Decline.-- Tribal people search for crocodile eggs which they eat. Hunted for its valuable skin.

ZAIRE, REPUBLIC OF

Legal Status.-- Protected in National Parks.

Conservation Status.-- Recorded from Avakubi, Dungu River at Faradje, Malela, Nepoko River near Medje, Niangara (close to Ugandan and Sudan borders) (Schmidt 1918). Also from Uele River.

Reasons for Decline.-- No data available.

ZAMBIA, REPUBLIC OF

Legal Status.-- See under *C. niloticus*.

Conservation Status.-- Apparently confined to Lake Mweru and the Luapula River, also successfully hunted on Kalungwishi River, which flows from the east into Lake Mweru (H.B. Cott pers. obs. 1956). Possibly in Lake Tanganyika as well as in Lake Mweru Wantipa (Sichone *in litt.* 1980).

Reasons for Decline.-- Commercial hunting, prior to 1966, notably in Lake Mweru.

STATUS OF THE WEST AFRICAN DWARF CROCODILE *Osteolaemus tetraspis*

ANGOLA

Legal Status.-- As for *C. niloticus*.

Conservation Status.-- Unknown. Considered to be very rare and seems to occur only in the enclave of Cabinda (Veterinary Department, Instituto de Investigafao Cientifica *in litt.* 1971). Rare or indeterminate (Huntley *in litt.* 1980).

Reasons for Decline.-- No data available.

BENIN (Dahomey)

Legal Status.-- Unknown.

Conservation Status.-- In 1959 this species was very common in the higher regions. Considered to be harmless and very stupid, it was regularly eaten by the local people (Roth *in litt.* 1971).

Reasons for Decline.-- As above.

CAMEROON

Legal Status.-- Unknown in 1980.

Conservation Status.-- Occurs in the vicinity of Douala on the coast and around the inland town of Mamfe (Abercrombie 1978). Crocodile leather products are for sale in Douala. Crocodiles have no legal protection outside of National Parks and similar areas (Powell *in litt.* 1976).

Eisentraut (1963) obtained specimens from slow-flowing, muddy water courses, not more than 3 or 4 m broad on Cameroon Mountain.

Reasons for Decline.-- Hunted for the skin and curio trade.

CENTRAL AFRICAN REPUBLIC

Legal Status.-- Unknown in 1980. As for *C. niloticus*.

Distribution.-- According to Dr. C.A. Spinage (*in litt.* 1980), this species is still apparently plentiful in the Birao region, a most arid part of the country.

Conservation Status.-- Unknown in 1980. As for *C. niloticus*.

Reasons for Decline.-- As for *C. niloticus*.

CONGO: REPUBLIQUE POPULAIRE

Legal Status.-- Protected in National Parks; considered to be out of danger (E.M'Beri-M'Babou *in litt.* 1980).

Conservation Status.-- (See also for *C. niloticus*) Spinage (*in litt.* 1980) considers that this species is secure in the northern tropical forests up near the CAR border, much of which is as yet unvisited by white men.

Reasons for Decline.-- Hunting for skins. See under *C. niloticus*.

GABON, REPUBLIC OF

Legal Status.-- Unknown in 1980. See under *C. niloticus*. According to Powell (*in litt.* 1976), outside of National Parks and similarly protected areas, there is no *de facto* legal protection for crocodiles in Gabon. Even protection in National Parks is nebulous. Crocodile skin handbags were on sale at almost every market stall in Libreville.

Conservation Status.-- Considered to be plentiful in the swampy and flooded areas known as Woleu N'tem and Ogooue Ivindo (Ossinga *in litt.* 1971). According to Abercrombie (1978), the species is rare but present in mangrove swamps near Libreville. Crocodile skin handbags on sale in this city were mostly of *Osteolaemus* skin.

Reasons for Decline.-- Exploitation for skins; possibly for food.

GAMBIA

Legal Status.-- Protected by law since February 1977.

Conservation Status.-- Endangered. Does not apparently occur out of the western division and is nowhere abundant (Brewer *in litt.* 1980).

Reasons for Decline.-- Before the law of 1977 came into force crocodiles had been subjected to extensive and heavy exploitation over many years, and populations have been severely depleted. Habitat destruction has undoubtedly had adverse effects on crocodiles (Brewer *in litt.* 1980).

GHANA, REPUBLIC OF

Legal Status.-- Unknown in 1980. All three crocodile species were granted complete protection in the new Wildlife Conservation Regulations L.1. 685, First Schedule, Series B, introduced in April 1971 (Anon. 1971).

Conservation Status.-- It may still be reasonably plentiful and in small streams rather than rivers of the high forest areas. Mrs. Sonia Jeffreys (pers. comm.) has seen them in snares and offered for sale as meat in the Bia River tributaries area. Two small specimens were caught in the Offin River near Kumasi (1969) (Mrs. Anna Merz *in litt.* 1970).

This crocodile is not very common and found mostly in smaller streams and rivers, although it has been observed on the shores of Lake Volta (E.O.A. Asibey *in litt.* 1970).

Osteolaemus evidently occurs in Volta Lake, as six very recently hatched specimens were found on Obeng Island (Gilbert Child *in litt.* 1970). According to Martin (1979), hunting or capturing this species is absolutely forbidden. He records that it is sporadically found in badly polluted gutters on the outskirts of towns. It is, however, hunted illegally for meat and may succumb to hunting pressure in densely populated areas.

Reasons for Decline.-- Cultivation is now done right into streams and rivers. This very adversely affects the preferred habitat of this animal. Also used as food (Asibey *in litt.* 1970). Exploitation for skins.

GUINEA

Legal Status.-- Unknown 1980.

Conservation Status.-- According to Schmidt (1919), found in the upper rivers of Guinea. Confirmed by Neill (1971).

Reasons for Decline.-- No data available.

IVORY COAST

Legal Status.-- Protected since 1970.

Conservation Status.-- Considered to be rare (Dr. H. Roth *in litt.* 1980).

Reasons for Decline.-- As for *C. niloticus*.

LIBERIA, REPUBLIC OF

Legal Status.-- Not protected 1980.

Conservation Status.-- Unknown. Said to be common in mangroves on the outskirts of Monrovia (Verschuren *in litt.* 1980). There are as yet no National Parks or reserves to protect wildlife (Sawyerr *in litt.* 1980). The species is considered to be endangered.

The forest people of Liberia told Buettikofer (1890), that this species inhabited holes dug into the banks of forest streams.

Reasons for Decline.-- Habitat destruction and heavy poaching for skins. No figures available on animals hunted (Sawyerr *in litt.* 1980).

NIGERIA

Legal Status.-- Unknown in 1980.

Conservation Status.-- Apparently rare in the Western State, and commoner in the midwest and rivers areas (Happold and Golding *in litt.* 1971). At Abua in Ahoada Division was apparently common in 1948. Also found in rivers and streams of the forested areas in East Central State (A.R.K. Saba *in litt.* 1971).

Reasons for Decline.-- No data available.

SENEGAL

Legal Status.-- Unknown in 1980.

Conservation Status.-- Common in Parc National du Niokolo Koba, very scarce in Delta du Saloum National Park. Still occurs in the Gambia River and its tributaries.

Reasons for Decline.-- Exploitation for skins has been spectacular since 1970.

SIERRA LEONE

Legal Status.-- Unknown in 1980.

Conservation Status.-- According to Lowes (1970), rarely seen. Apparently occurs in a 12 sq-mile wildlife reserve that is being set up around Mamunta in the northern Province.

First described from this country by Lilljeborg (1867).

Reasons for Decline.-- No data.

TOGO, REPUBLIC OF

Legal Status.-- No data available.

Conservation Status.-- Occurs in Togo according to Neill (1971).

Reasons for Decline.-- No data available.

UPPER VOLTA

Legal Status.-- Unknown in 1980. Protected in National Parks and in certain tribal sanctuaries. Not specifically mentioned in the hunting or fishing regulations (Roman *in litt.* 1971).

Conservation Status.-- Unknown in 1980. Said to be protected because of superstition and for religious reasons in some areas.

Reasons for Decline.-- Exploitation for hides.

ZAIRE

Legal Status.-- Unknown in 1980. Export prohibited (Honegger 1975).

Conservation Status.-- Unknown. A subspecies, *O. tetraspis osborni*, is found in northeastern Zaire; *O. tetraspis tetraspis* is absent for the lower Congo but occurs in Sudanese subprovince of Zaire (Schmidt 1919).

Reasons for Decline.-- No data.

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PRESENT STATUS AND DISTRIBUTION OF THE CROCODILES AND GHARIAL OF BANGLADESH

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ABSTRACT: *Crocodylus porosus*, *C. palustris*, and *Gavialis gangeticus* were common in all suitable habitats of Bangladesh about two decades ago. Now, no more than 20 *G. gangeticus* and about 200 *C. porosus* are present in restricted habitats, whereas *C. palustris* is feared extinct.

INTRODUCTION

Bangladesh, lying between 20°34' to 26°38'N and 88°01' to 92°40'E, has an area of about 142,776 km^2, including 8300 km^2 of rivers, estuaries and streams of various dimensions (Fig. 1). The mightiest rivers are the Padma (Ganges), Jamuna (Brahmaputra), and Meghna. The tributaries of these rivers are the Tista, Surma, Kushiyara, Karnaphully, Passur, Balleshwar, Bhadra, Sibsa, Sela, Bhola, etc. The largest rivers have all originated in the high mountains of the Himalayas, and most run in a north-south direction and meet the Bay of Bengal in the south. Most rivers south of 22°30'N are rather saline, and those south of 23°N are subjected to daily tides. The water of the rivers of the Sunderbans Mangrove Forests become more saline during winter, allowing purely marine elasmobranch fish (*Pristis* sp.) to inhabit them (Haque 1978).

All the rivers mentioned above had either the marsh crocodile (*Crocodylus palustris*) and/or gharial/gavial (*Gavialis gangeticus*) during at least the monsoon period (June-September). The southerly rivers traversing the Sunderbans Mangrove Forests supported good populations of the estuarine crocodile (*C. porosus*) up to 1960. The marsh crocodile now appears to be extinct from most of its range in Bangladesh. The gharial habitat has been restricted to two smaller pockets of Padma and Jamuna. The estuarine crocodile is now limited to the southerly rivers of the Sunderbans.

I have some records of the occurrence of the crocodilians in Bangladesh from 1972, mainly based on the information received from officials of the Forest department, fishermen, boatmen, and the captains of the steamers and motor launches plying through the major rivers of the country. Some information is available from the Working Plans of different Forest Divisions and in the unpublished reports of these divisions, as well as from O'Malley (1908, 1912, 1914), Garrett (1910),

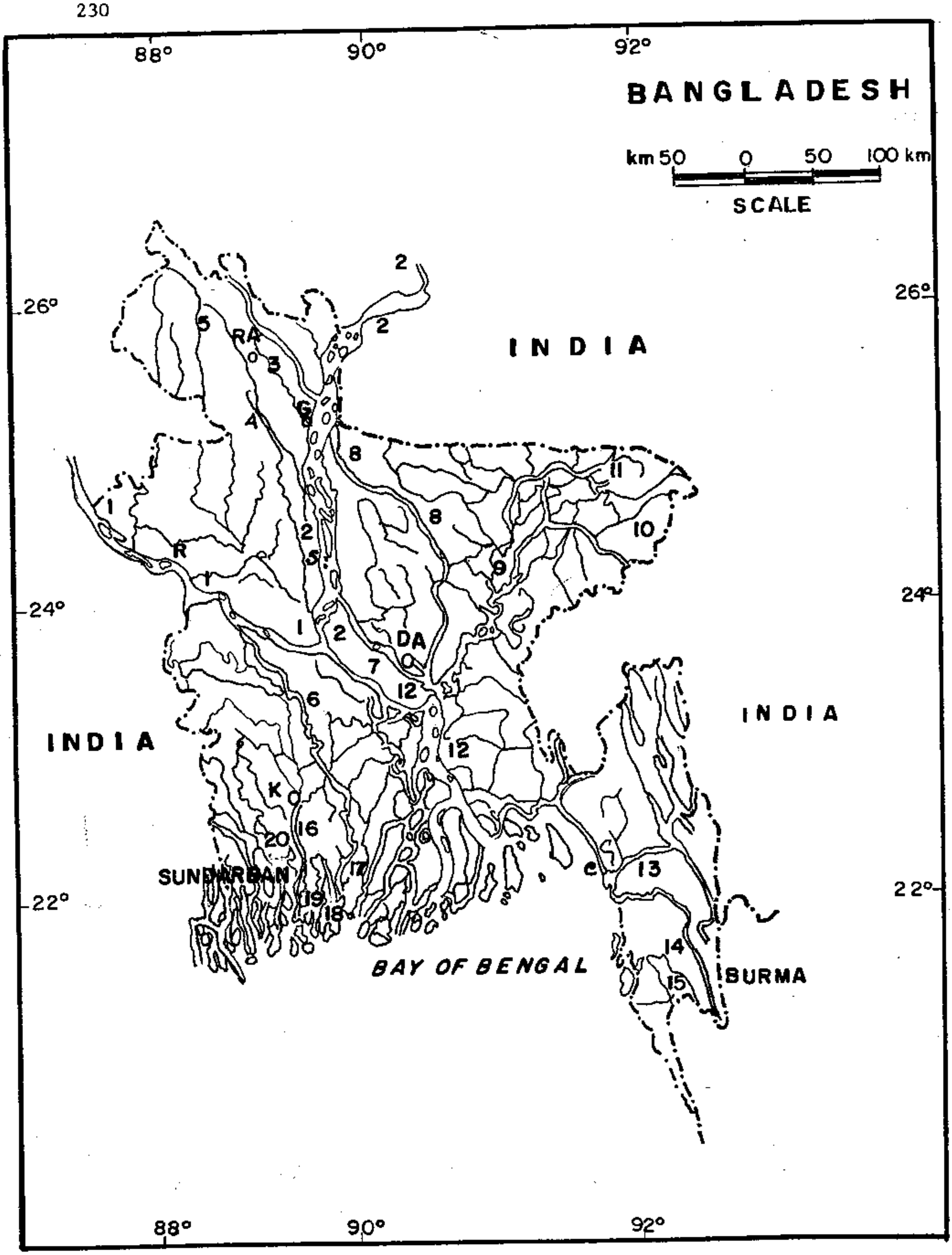

FIGURE 1.-- Major rivers of Bangladesh. Towns: C = Chittagong; DA = Dacca; G = Gaibandha; K = Khulna; R = Rajshahi town; RA = Rangpur. Rivers: 1 = Padma; 2 = Jamuna; 3 = Tista; 4 = Karotoya; 5 = Atrai; 6 = Madhumati; 7 = Dhalleshwari; 8 = Old Brahmaputra; 9 = Kalni; 10 = Kushiyara; 11 = Surma; 12 = Meghna; 13 = Karnaphully; 14 = Sangu; 15 = Matamuhuri; 16 = Passur; 17 = Balleshwar; 18 = Bhola; 19 = Sela; 20 = Bhadra.

Vas (1911), and Strong (1912). In addition, I have personally visited most of the existing crocodile habitats.

This paper provides updated information regarding all species of crocodilians present in Bangladesh and enumerates their chief causes for decline.

STATUS AND DISTRIBUTION

The status and distribution of the crocodiles of Bangladesh may be described under three periods: the distribution prior to 1950, 1951 to 1960, and from 1961 to the present.

Marsh Crocodile

Crocodylus palustris was not uncommon over entire Bangladesh during the first period (Fig. 2). The rivers Padma, Jamuna, Meghna, and most of their tributaries from the northernmost limit of the country to 22°30'N in the south supported this species. Possibly it was also present in the mountainous rivers Karnaphully, Matamuhuri, and Sangu (Fig. 1), as Mitra (1957) reported that the people of Chittagong District used to eat crocodile eggs. He also reported official records of the killing of some 1000 crocodiles between 1936 and 1946 from the forested areas of what was then Bengal (Bangladesh and West Bengal of India). The lion's share of this, I understand, was from Bangladesh. Official estimates for the district of Faridpur alone reported crocodiles killing 10 humans during 1943-44, which means that marsh crocodiles were common in the rivers Madhumati, Padma, and Meghna. They used to become more widely distributed during the monsoon months, entering into smaller rivers, streams, and sometimes in the larger bodies of marshy areas, locally called *haors*. This habit is similar to the one exhibited by the Ganges Susu *Platanista gangetica*.

Local residents interviewed have agreed that almost every day of a journey through the major rivers this crocodile could be seen during the first period. They occasionally attacked bathing villagers and cattle. By the end of 1960 the species had been virtually wiped out from the tributaries of Padma, Jamuna, and Meghna, and from Karnaphully, Matamuhuri, and Sangu rivers (Fig. 3, cf 2). Sight records after this time are wanting. From 1961 there is only one doubtful sight record from the Meghna estuary. A few possibly survive in the northern, less saline waters of the Sunderbans Mangrove Forests (Fig. 4). Hendrichs (1975) has reported it from the Sunderbans, but I could not trace it there in 1980, 1981, nor 1982. There are two semi-captive populations of three crocodiles each in the only zoo of the country and in a large tank close to the Sunderbans.

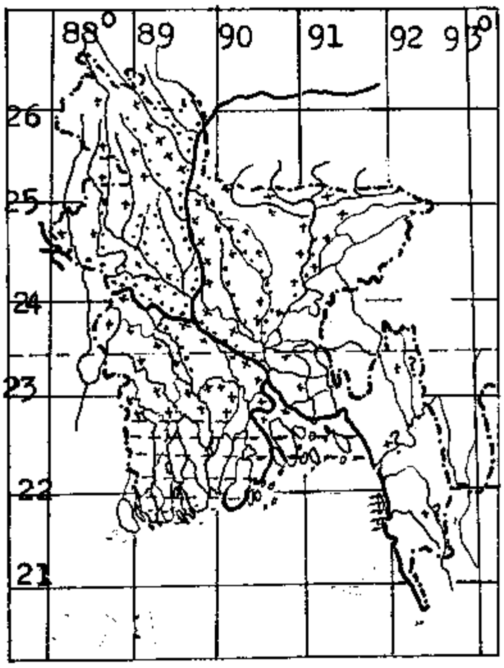

FIGURE 2. Distribution of *Crocodilus palustris* (++), *C. porosus* (--), and *Gavialis gangeticus* (..) in Bangladesh prior to 1950.

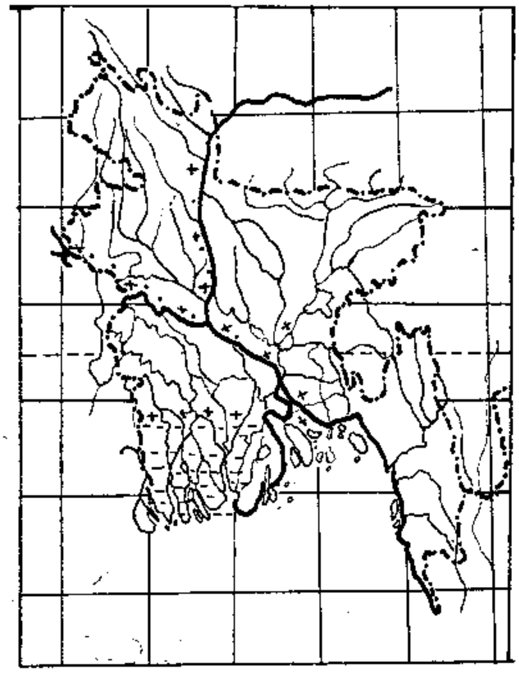

FIGURE 3. Distribution of *C. palustris* (++), *C. porosus* (--), and *G. gangeticus* (..) in Bangladesh from 1951 to 1960.

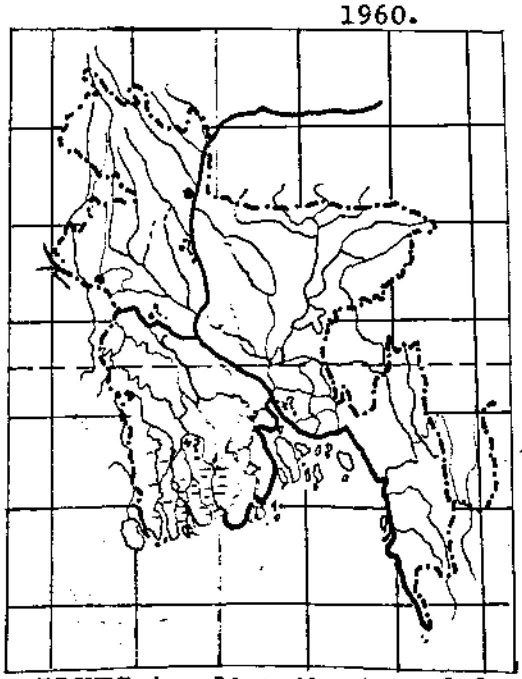

FIGURE 4. Distribution of *C. palustris* (++), *C. porosus* (--), and *G. gangeticus* (..) in Bangladesh from 1961 to 1980.

Estuarine Crocodile

Crocodylus porosus occurred in most of the rivers south of 23°15'N traversing the Sunderbans and possibly in the estuaries falling within 21° and 22° N in the district of Chittagong (Fig. 2) until the close of the first period. By the beginning of the second period, all populations from Chittagong district, Meghna and Balleshwar estuaries, and from the northerly rivers of the Sunderbans were exterminated. During 1967-68 three crocodiles were caught from Bhadra River; they died in captivity. The corpses were transported to a proposed sanctuary at Katka (S-E Sunderbans) and were left on chars (sandbars) in basking postures to enthrill the then president of Pakistan, who was visiting the sanctuary. During his three-month study in the Sunderbans in 1971, Hendrichs (1975) sighted only one crocodile. At the time of my visits to the Sunderbans during 1980-82 I did not see any but was able to locate several basking sites.

Survey results showed that this crocodile prefers rivers which have good basking grounds during winter and less current during tides. The most preferred areas appeared to be the Balleshwar, Bhola, Sela, Katka, Ambaria Ghat, and other tributaries of Passur, Bhadra, and the northern belt of Sibsa between 22° and 22°40'N. The rivers around this belt end in innumerable streams traversing the mangrove forest, rejoining again south of 22°N, and give rise to the larger rivers before joining the Bay of Bengal.

My assumption is that the population size of estuarine crocodile in Bangladesh may not exceed 200 in number in the whole of the Sunderbans Mangrove Forests, an area of about 780 km^2 water (Fig. 4) within about 6000 km^2 of the Sunderbans, including water courses (Choudhury 1968).

Gharial

Gavialis gangeticus was quite common in the Padma and Jamuna river systems till the end of the first period (Fig. 2). It was wiped out from Tista, Atrai, Karotoya, and other tributaries of the Jamuna (Fig. 3), and the number started declining during the second period in the Padma as well as in the Jamuna. One of the Padma specimens, a juvenile ca 1.5 m, was caught accidentally on a baited fishing hook, near Rajshahi town (Fig. 1). The other one was a large gharial (3.1 m) caught in a fishing drag net which was left on a flat char for drying, also near Rajshahi town. As the gharial got up on the bank for basking it was entangled in the drag net. A third gharial was caught by the fishermen with a drag net in Jamuna near Gaibandha (Fig. 1).

Between March 1980 and December 1981 about 20 baby gharials were caught by the villagers of Rajshahi and Sirajganj. About 16 of these specimens died in captivity when the rest were procured by the zoo and

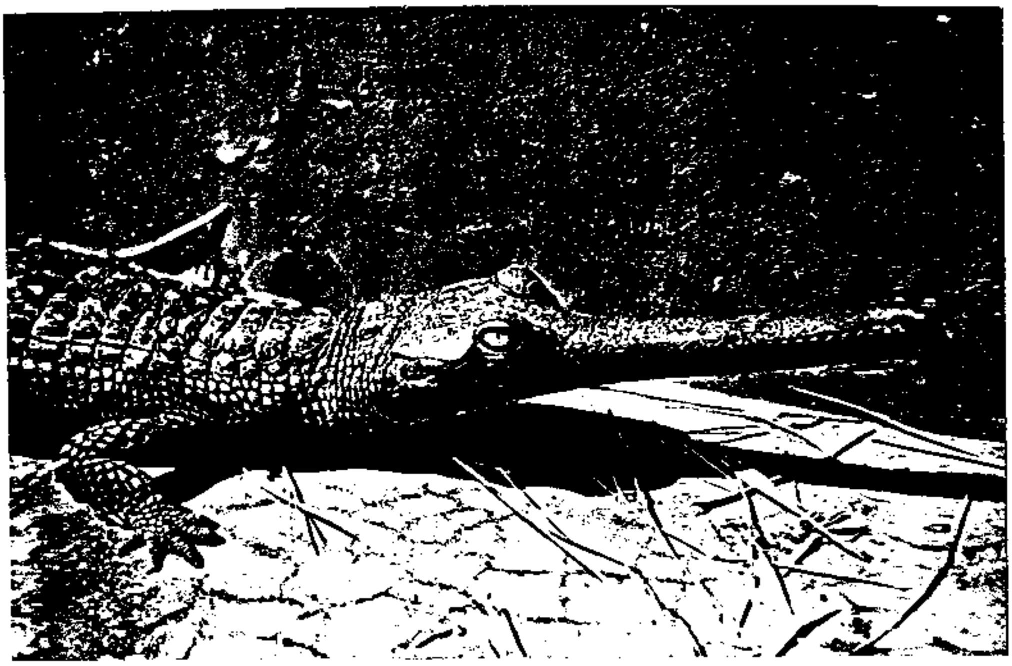

FIGURE 5. Photograph of a gharial from the Padma River, near Rajshahi town.

park authorities. So far I have found four breeding sites of gharial. Two of these are in Padma, near Rajshahi town, between 24°15' to 24°22'N and 88°35' to 88°45'E. Of the remaining two, one is around Sirajganj between 24°22' to 24°30'N and 89°40' to 89°50'E, and other near is Gaibandha between 25°15' to 25°30'N and 89°35' to 89°50'E.

The survey suggested that the gharial population in the Padma and Jamuna may be a dozen or so; my estimate is around 20. This very small population is divided into two smaller sub-populations, with the most gharials in the Padma. These two sub-populations are isolated from one another for the most part of a year. Only during the monsoon period, when both the Padma and Jamuna become confluent, are the chances good for the meeting of the Padma and Jamuna gharials.

Vas (1911) and Strong (1912) reported this species from the tributaries of the Jamuna, whereas Husain (1974) has suggested its occurrence only from the Padma and its tributaries. My report confirms the presence of gharial in both the river systems.

REASONS FOR DECLINE

1) All three species of crocodilians of Bangladesh have declined since 1940 when their persecution became rampant. They were killed mostly with 12-bore guns, rifles, baited hooks and traps, harpooning, and fishing gear. The crocodiles were sought mostly for their skins; tanned skins were used as drawing room decorations in addition to export.

2) Local officials and dignitaries both before and after the 1947-partition of the country used to visit crocodile basking spots and hunt them. This unrecorded killing has taken a heavy toll.

3) Fishermen, other than Muslims, used to eat crocodile eggs and have destroyed the egg-beds. Some tribes ate their flesh also.

4) Most of the tributaries, as well as the major rivers, have become silted up and lost their current during the lean period. The main stream of each river has been interrupted at various points by the recent formation of chars, which have already been converted into human habitations.

5) After the commissioning of the Farakkah Barrage in West Bengal (India), the salinity has increased in many rivers and the process of siltation has been enhanced (Haque 1978). This has ultimately disturbed the aquatic ecosystem.

6) After 1947, human activities in all the rivers have increased manifold, upsetting the daily activities of the crocodiles and the gharials and destroying egg-laying beds or making them unavailable to breeding animals. Urchins and the cowboys remove clutches or otherwise trample the nests containing eggs with the help of the cattle, usually taken to the river for bathing.

7) Modern nylon nets, especially the drag and gill nets, are a real menace for the gharials.

8) Despite a Government ban on shooting (Bangladesh Wildlife [Preservation] Order 1973) there appears to be little control over killing of crocodile and gharial.

CONCLUSIONS

As no systematic survey of the status of crocodilians has been done in Bangladesh, this should be a priority venture of the Government Forest Department and University of Dacca. Objectives should be to trace the remnant populations of marsh crocodiles and gharials and to isolate the crocodile-rich areas of the Sunderbans Mangrove Forests in order to suggest conservation measures. Before any survey is done, crocodile farming within the Sunderbans must be discouraged, as there is every chance that these farmers would exploit the dwindling natural population of the estuarine crocodiles instead of rearing them in their farms.

ACKNOWLEDGEMENTS

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STATUS OF ASIAN CROCODILIANS

Romulus Whitaker

Madras Snake Park Trust
Raj Bhavan P.O., Madras 600 022, India

INTRODUCTION

The problem of presenting data on the status of crocodilians in an area covering millions of square kilometers and numerous political boundaries has resulted in resorting to the following data sheet presentation. Numerous individuals and organizations have been instrumental in supplying the information contained herein and most are gratefully acknowledged by means of the References Cited list. It should be pointed out that the lack of comment on various aspects indicates the paucity of data from some countries. In few cases do we have any indication of present populations in the wild, which emphasizes the critical need for basic survey efforts.

This report is an effort to standardize data presentation on crocodilian status, and it is hoped that it will act as a guide and impetus for action for the species and areas which are in need of the most attention. The contact addresses provide initial links with people involved in the conservation/management of crocodilians in the areas discussed. As information is received by the author these sheets are revised to provide a continually updated service by the IUCN/SSC Crocodile Specialist Group. Correspondence is encouraged.

DATA SHEET - ASIA

SPECIES: *Crocodylus palustris* COUNTRY: Iran

LEGAL STATUS: Total protection by Iran Game and Fish Department

CITES APPENDIX: I, signed

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS: Baluchistan

PROTECTED AREAS: Sarbaz River

TOTAL WILD POPULATION: 60-100 (estimated)

TOTAL CAPTIVE POPULATION: Unknown

MANAGEMENT/CONSERVATION EFFORT: Medium. Protected area established but no follow up.

MAIN THREATS: Habitat loss

REFERENCES: Honnegger 1971, 1975; Webb 1978

SPECIES: Gavialis gangeticus COUNTRY: Pakistan

LEGAL STATUS: Hunting and export banned

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS: Nara Canal, Indus River

PROTECTED AREAS: Indus River Dolphin Sanctuary

TOTAL WILD POPULATION: 30 (estimate)

TOTAL CAPTIVE POPULATION: Few

MANAGEMENT/CONSERVATION EFFORT: Medium. Request for assistance on breeding and restocking

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

Conservator of Wildlife
National Council for Conservation of Wildlife
Ministry of Agriculture
Street no. 51
Sector F6/4
Islamabad

SPECIES: Crocodylus palustris COUNTRY: Pakistan

LEGAL STATUS: Hunting and export banned

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS: Unknown

PROTECTED AREAS: Lal Suhanra National Park

TOTAL WILD POPULATION: Unknown, extremely low

TOTAL CAPTIVE POPULATION: Few

MANAGEMENT/CONSERVATON EFFORT: Medium. Wildlife Department has requested advice on crocodile breeding and restocking

MAIN THREATS: Formerly for skin and alleged competition with human fishing interests; now habitat loss

CONTACT ADDRESSES:

Conservator of Wildlife
National Council for Conservation of Wildlife
Ministry of Agriculture
Street no. 51
Sector F6/4
Islamabad

REFERENCES: H.W. Campbell in litt.

SPECIES: *Crocodylus palustris* COUNTRY: India

LEGAL STATUS: Total protection in all states

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS:

	SIZE:	STATUS:
Hiran Lake, Gir National Park, Gujarat	50+ adults	stable
Amaravathi Reservoir, Tamil Nadu	25 adults	stable
Sathanur Reservoir	15 adults	stable

TOTAL WILD POPULATION: Fewer than 1000 adults

TOTAL CAPTIVE POPULATION: Over 1500 (most juveniles)

MANAGEMENT/CONSERVATION EFFORT: Excellent. Several states have rehabilitation programs with Central Government financial assistance and UNDP/FAO expertise

MAIN THREATS: Habitat loss and alleged competition with human fishing interests

CONTACT ADDRESSES:

Director, Wildlife Dept. of Agriculture Krishi Bhavan New Delhi	B.C. Choudhury C/O Crocodile Breeding & Management Training Lake Dale Rajendranagar Road Hyderabad, A.P.	R. & Z. Whitaker Madras Snake Park Guindy Deer Park Madras 600 022

REFERENCES: Whitaker and Whitaker 1976, Webb 1978

SPECIES: Gavialis gangeticus COUNTRY: India

LEGAL STATUS: Total Protection

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS:	SIZE:	STATUS:
Chambal River Sanctuary, Rajasthan	300+ - all sizes	increasing
Katerniaghat Sanct., U.P.	50 - all sizes	increasing
Satkoshia Gorge Sanct. Orissa	100 - all sizes	increasing

TOTAL WILD POPULATION: Fewer than 50 adults

TOTAL CAPTIVE POPULATION: More than 2000 juveniles, 20 adults

MANAGEMENT/CONSERVATION EFFORT: Excellent. Successful rehabilitation programs, sanctuaries and enforced protection in practice under FAO/UNDP advice

MAIN THREATS: Habitat loss and alleged fishing competition with human fishing interests

CONTACT ADDRESSES:

L.A.K. Singh Crocodile Breeding & Management Training Inst. Rajendranagar Road Hyderabad, A.P.	Chief Wildlife Warden Rana Pratap Marg Lucknow, U.P.

REFERENCES: Whitaker 1976, Singh pers. comm., Basu pers. comm., Bustard 1974

SPECIES: Crocodylus porosus COUNTRY: India

LEGAL STATUS: Total protection

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS:	SIZE:	STATUS:
Bhitar Kanika, Orissa	20+ adults	stable
Sunderbans, West Bengal	Unknown	unknown
Andaman & Nicobar Islands	Unknown	decreasing

PROTECTED AREAS: Bhitar Kanika Sanctuary, Orissa; Sunderbans Tiger Reserve, W. Bengal; North Reef Island, Andamans

TOTAL WILD POPULATION: Unknown

TOTAL CAPTIVE POPULATION: 200-300

MANAGEMENT/CONSERVATION EFFORT: Medium. Excellent protection and restocking programs in West Bengal and Orissa but little protection management in the Andamans and Nicobars

MAIN THREATS: Habitat loss; alleged competition with fisheries interests and threat to humans/livestock; collection of eggs for human consumption

CONTACT ADDRESSES:

Director, Wildlife
Department of Agriculture
Krishi Bhavan
New Delhi

Mr. Sudhakar Kar
C/O Crocodile Breeding and
Management Training Inst.
Lake Dale
Rajendranagar Road
Hyderabad, A.P.

REFERENCES: Whitaker and Daniel 1978, Webb 1978, Choudhury and Bustard 1979

SPECIES: Gavialis gangeticus COUNTRY: Nepal

LEGAL STATUS: Total protection

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS:

	SIZE:	STATUS:
Rapti/Narayani Rivers	15 adults	stable
Karnali River	7 adults	stable

PROTECTED AREAS: Royal Chitwan National Park; Royal Karnali National Park

TOTAL WILD POPULATION: 30-40 adults

TOTAL CAPTIVE POPULATION: 200+ juveniles

MANAGEMENT/CONSERVATION EFFORT: Good. National parks populations secure; rearing/release program started in Chitwan (Frankfurt Zoological Society funding)

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

Hemanta Mishra
C/O Director, National Parks
Chief Conservator of Forests
Kathmandu

Tirtha Maskey
Dept. National Parks and Wildlife
P.O. Box 107
Kathmandu

Charles McDougal
Tigertops
Royal Chitwan National Park

REFERENCES: Whitaker and Basu 1974

SPECIES: Crocodylus palustris   COUNTRY: Nepal

LEGAL STATUS: Total protection

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS:

	SIZE:	STATUS:
Scattered few in major rivers and forest jheels (ponds) in the Terai	Unknown	Stable in Parks

PROTECTED AREAS: Royal Chitwan National Park; Shukla-Phanta Reserve; Royal Karnali National Parks

TOTAL WILD POPULATION: Remnant few

TOTAL CAPTIVE POPULATION: Unknown

MANAGEMENT/CONSERVATON EFFORT: Medium. A few survive in protected areas but no attempts to rehabilitate the species

MAIN THREATS: Habitat loss; alleged competition with fisheries interests

CONTACT ADDRESSES:

Mr. Hemanta Mishra
C/O Director, National Parks
Chief Conservator of Forests
Kathmandu, Nepal

REFERENCES: Whitaker 1976; Webb 1978

SPECIES: Gavialis gangeticus COUNTRY: Bangladesh

LEGAL STATUS: Unknown

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS: Khan, this volume. One breeding pair known (Reza Khan, pers. comm.)

CONTACT ADDRESSES:

Dr. M. A. Reza Khan
Department of Zoology
Dacca University
Dacca

SPECIES: Crocodylus porosus COUNTRY: Bangladesh

LEGAL STATUS: Total protection

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS:	SIZE:	STATUS:
Sunderbans (Ganges delta)	Unknown	Unknown

PROTECTED AREAS: Same

TOTAL WILD POPULATION: Reportedly "not uncommon"

TOTAL CAPTIVE POPULATION: Nil

MANAGEMENT/CONSERVATION EFFORT: Medium. Though protected, no management follow-up. Government interested in farming

MAIN THREATS: Habitat loss; alleged competition with fisheries interests and threat to humans and livestock

CONTACT ADDRESSES:

Dr. M. A. Reza Khan
Department of Zoology
Dacca University
Dacca, Bangladesh

REFERENCES: Whitaker 1976; Whitaker and Daniel 1978

SPECIES: Crocodylus palustris COUNTRY: Bangladesh

LEGAL STATUS: Total protection

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

STATUS: Probably extinct

CONTACT ADDRESSES:

Dr. M. A. Reza Khan
Department of Zoology
Dacca University
Dacca, Bangladesh

SPECIES: Crocodylus porosus COUNTRY: Sri Lanka

LEGAL STATUS: Hunting and export banned

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS:	SIZE:	STATUS:
S. W. Coast	unknown	decreasing

PROTECTED AREAS: Yala National Park (few sighted, little habitat)

TOTAL WILD POPULATION: Fewer than 250 adults

TOTAL CAPTIVE POPULATION: Few

MANAGEMENT/CONSERVATION EFFORT: Medium. Though protected from hunting and export no protection of habitat or management undertaken

MAIN THREATS: Habitat loss; killed for meat and as alleged threat to humans

CONTACT ADDRESSES:

Lynn de Alwis
Director
National Parks and Wildlife

President
Wildlife and Nature Protection Society
Marine Drive, Fort
Colombo

REFERENCES: Whitaker and Whitaker 1979

SPECIES: Crocodylus palustris COUNTRY: Sri Lanka

LEGAL STATUS: Limited hunting under license (one per year per license); export banned

CITES APPENDIX: I

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS:	STATUS:
Numerous tanks and rivers, notably in the southeast and northwest (see Whitaker and Whitaker 1979)	stable in national parks, decreasing elsewhere

PROTECTED AREAS: Wilpattu and Yala National Parks

TOTAL WILD POPULATION: 2,000-3,000 adults (healthiest population in existence)

TOTAL CAPTIVE POPULATION: Few

MANAGEMENT/CONSERVATION EFFORT: Medium. National park populations well maintained; crocodiles outside these protected areas are subject to uncontrolled, mainly seasonal exploitation

MAIN THREATS: Habitat loss and killing by itinerant fishermen for meat, marketed along with dried fish (rarely for skin)

CONTACT ADDRESSES:

Mr. Lynn de Alwis
Director
National Parks and Wildife

President
Wildlife & Nature
Protection Society
Marine Drive, Fort
Colombo

REFERENCES: Honegger 1971, 1975; Whitaker and Whitaker 1979

SPECIES: Gavialis gangeticus COUNTRY: Bhutan

LEGAL STATUS: Unknown

CITES APPENDIX: I

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS: If Gavialis is present in this country it is an occasional specimen in the Manas River, Manas National Park, which is contiguous with the National Park in Assam. An FAO consultant (H.R. Bustard) has visited the country and reported on the prospects for reintroduction, management, and conservation (FAO, Rome, 1978)

CONTACT ADDRESSES:

Dasho C. Dorji
Director of Forests
Royal Government of Bhutan
Thimphu

Species: Crocodylus porosus Country: Burma

LEGAL STATUS: Recently protected

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS:	SIZE:	STATUS:
Irrawaddy delta	4000?	decreasing

PROTECTED AREAS: Decreasing

TOTAL WILD POPULATION: Seriously depleted but still exploited

TOTAL CAPTIVE POPULATION: 600

MANAGEMENT/CONSERVATION EFFORT: Medium. Recent protection and management action taken. Recent interest in village level farming with delegation visit to Papua New Guinea

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

Minister for Agriculture and Fisheries	Dr. Nyan Taw Research Officer Peoples Pearl & Fishing Co-op Mykhwanye Street Thaketa, Rangoon	F.A.O. Representative P.O. Box 650 Rangoon

REFERENCES: Whitaker and Daniel 1978; Caughley 1980; Taw and Moe 1980

SPECIES: Crocodylus palustris COUNTRY: Burma

CITES APPENDIX: I

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS:	STATUS:
Thayetmo (reported locality)	Extinct or possibly originally misrecorded

CONTACT ADDRESSES:

Minister for Agriculture and Fisheries	Dr. Nyan Taw Research Officer Peoples Pearl & Fishing Co-op Mykhwanye Street Thaketa, Rangoon	F.A.O. Representative P.O. Box 650 Rangoon

REFERENCES: Smith 1931

SPECIES: Crocodylus porosus COUNTRY: Thailand

LEGAL STATUS: No protection

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS:	SIZE:	STATUS:
Pran Buri Dist., Prachuab Khirikhan Province	unknown	decreasing

PROTECTED AREAS: Nil

TOTAL WILD POPULATION: Remnant few

TOTAL CAPTIVE POPULATION: 3000-5000 at Samut Prakan Crocodile Farm

MANAGEMENT/CONSERVATION EFFORT: Poor. No protection or management action taken. Private captive stock (Samut Prakan) has potential for helping restock selected areas

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

FAO
Regional Office for Asia
Maluwan Mansion
Phra Astit Road
Bangkok

Mr. Pong-Leng-EE, Director
Wildlife Conservation Division
Royal Forest Department
Paholyothin Road
Bangkhen, Bangkok

Fisheries Department
Min. of Agriculture and Conperat
Bangkok

U. Yangprapakorn
Samut Prakan Crocodile Farm
Bangkok

SPECIES: Tomistoma schlegli COUNTRY: Thailand

LEGAL STATUS: Unprotected

CITES APPENDIX: I

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS: Reportedly extinct

TOTAL CAPTIVE POPULATION: Over 170 specimens of all sizes at Samut Prakan

CONTACT ADDRESSES:

FAO
Regional Office for Asia
Maluwan Mansion
Phra Astit Road
Bangkok

Mr. Pong Leng-EE, Director
Wildlife Conservation Division
Royal Forest Department
Paholyothin Road
Bangkhen, Bangkok

Fisheries Department
Min. of Agriculture and Conperat
Bangkok

U. Yangprapakorn
Samut Prakan Crocodile Farm
Bangkok

SPECIES: *Crocodylus siamensis* COUNTRY: Thailand

LEGAL STATUS: No protection

CITES APPENDIX: I

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS:	SIZE:	STATUS:
Bung Boraphet Reservoir, Nakhon Sawan Province	100-200	decreasing

PROTECTED AREAS: Ditto (under Fisheries Department)

TOTAL WILD POPULATION: 100-200 (estimated)

TOTAL CAPTIVE POPULATION: 20,000 (estimated at Samut Prakan Farm)

MANAGEMENT/CONSERVATION EFFORT Poor. No protection or action taken. The private captive stock at Samut Prakan has potential for restocking selected areas

MAIN THREATS: Hunting for skins; habitat loss; hybridization of captive stock with *C. porosus*

CONTACT ADDRESSES:

FAO
Regional Office for Asia
Maluwan Mansion
Phra Astit Road
Bangkok

Mr. Pong Leng-EE, Director
Wildlife Conservation Division
Royal Forest Department
Paholyothin Road
Bangkhen, Bangkok

Fisheries Department
Min. of Agriculture and
Conperat
Bangkok

U. Yangprapakorn
Samut Prakan Crocodile Farm
Bangkok

REFERENCES: Honegger 1971; Webb 1978

SPECIES: Crocodylus porosus COUNTRY: Malaysia

LEGAL STATUS: Protection in some states

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: Unknown, reportedly in larger rivers like Lupan, Baram Rijan delta, Lokan

PROTECTED AREAS: Klias National Park (Klias peninsula, Sabah)
Crocker Range National Park (Tenam)

TOTAL WILD POPULATION: Remnant few

TOTAL CAPTIVE POPULATION: Several hundred on rearing farms

MANAGEMENT/CONSERVATION EFFORT: Medium. Some states are interested in conservation/management and initial surveys are being drafted. 800 on Sandakan farm belonging to Chai Yau Look

MAIN THREATS: Hunting for skins; collection of eggs and young for rearing; habitat loss

CONTACT ADDRESSES:

Patrick Andau
Game Warden
P.O. Box 311
Forestry Department
Sandakan, Sabah
East Malaysia

K.R.S. Proud
National Parks &
Wildlife Officer
Forestry Department
Jalan Gartak
Kuching, Sarawak

A.H.K. bin Morishidi
O.I.C. National Parks
and Wildlife Section
Forestry Department
Sarawak

Louis Rathnam Director General National Parks P.O. Box 611 Kuala Lumpur	David Labang National Parks Jalang Gartak Kuching, Sarawak	Chai Yau Look P.O. Box 633 Sandakan, Sabah E. Malaysia

REFERENCES: Webb 1978; Mitchell in litt.

SPECIES: Tomistoma schlegeli COUNTRY: Malaysia

LEGAL STATUS: Protection in some states

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS: Loagan Bunut Lake, Tinjar River, Baram, Sarawak; Sadong River; Tasek Bera Lake; Pahang River (peninsular Malaysia)

PROTECTED AREAS: Tasek Bera National Park

TOTAL WILD POPULATION: Unknown but depleted

TOTAL CAPTIVE POPULATION: Unknown

MANAGEMENT/CONSERVATION EFFORT: Medium. Little enforcement

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

Patrick Andau Game Warden P.O. Box 311 Forestry Department Sandakan, Sabah East Malaysia	K.R.S. Proud National Parks & Wildlife Officer Forestry Department Jalan Gartak Kuching, Sarawak	A.H.K. bin Morishidi O.I.C. National Parks and Wildlife Section Forestry Department Sarawak
Louis Ratnam Director General Dept. Wildlife and National Parks P.O. Box 611 Kuala Lumpur	David Labang National Parks & Wildlife Jalang Gartak Kuching, Sarawak	Chai Yau Look P.O. Box 633 Sandakan, Sabah East Malaysia

SPECIES: C. siamensis COUNTRY: Malaysia

LEGAL STATUS: Reportedly extinct (Wycherly in Webb 1978). Ditto for Brunei, Vietnam, Laos. In Indonesia, unconfirmed reports from Sumatra, Kalimantan, and Java.

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

SPECIES: Alligator sinensis COUNTRY: People's Republic of China

LEGAL STATUS: Reportedly protected since 1958

CITES APPENDIX: I

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS: Kien, Chure, Xuancheng Wan Provinces (Yanzie River)

PROTECTED AREAS: Unknown

TOTAL WILD POPULATION: Remnant few; 300-500 in Xuancheng Province

TOTAL CAPTIVE POPULATION: 150-200

MANAGEMENT/CONSERVATION EFFORT: Medium. Need for protection and study publicized

MAIN THREATS: Habitat loss

CONTACT ADDRESSES:

Dr. Huang Chu-Chien
Department of Zoology
Peking Institute of Science
Peking

Dr. Myrna Watanabe
141 Columbia Heights
Brooklyn, NY 11201
U.S.A.

REFERENCES: H.W. Campbell pers. comm. 1979

SPECIES: Crocodylus porosus COUNTRY: People's Republic of China

LEGAL STATUS: Unknown

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: Canton (?)

TOTAL WILD POPULATION: Unknown, possibly a remnant few exist in Kwangtun Province

CONTACT ADDRESSES:

Dr. Huang Chu-Chien
Department of Zoology
Peking Institute of Science

Dr. Myrna Watanabe
141 Columbia Hts.
Brooklyn, N.Y. 11201
U.S.A.

SPECIES: C. porosus COUNTRY: Taiwan

LEGAL STATUS: Unknown

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: Though there are no reported wild populations, several small farms or rearing stations have started rearing crocodiles

TOTAL CAPTIVE POPULATION: Several hundred on small farms

CONTACT ADDRESSES:

Karlheinz Fuchs
Schillerstrasse
6257 Hinfelden 2
West Germany

REFERENCES: Karlheinz Fuchs pers. comm.

SPECIES: Crocodylus porosus COUNTRY: Laos

LEGAL STATUS: Unknown

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

TOTAL WILD POPULATION: Nothing known

MAIN THREATS: Unknown

SPECIES: *Crocodylus siamensis* COUNTRY: Kampuchea

LEGAL STATUS: Unknown

CITES APPENDIX: I

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS: Unknown. In 1978 several specimens were gifted to the Burmese Government

REFERENCES: Taw and Moe 1980

SPECIES: *Crocodylus porosus* COUNTRY: Kampuchea

LEGAL STATUS: Unknown

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

TOTAL WILD POPULATION: Not known; Webb (1978) says probably overexploited

REFERENCES: Webb 1978

SPECIES: *Crocodylus porosus* COUNTRY: Vietnam

LEGAL STATUS: Unknown

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

TOTAL WILD POPULATION: Nothing known; Webb (1978) suggests species extinct

SPECIES: *Crocodylus porosus* COUNTRY: Brunei

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: Not known

TOTAL WILD POPULATION: Nothing known; Webb (1978) says probably overexploited

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

Curator
Brunei Museum
Bandan Seri Begawan
Brunei

NOTE: Confirmed sightings in 1977 by helicopter pilots (MacKinnon *in litt*. 1978)

SPECIES: *Tomistoma schlegelii* COUNTRY: Indonesia

LEGAL STATUS: Protected, exploitation on permit

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Endangered

MAIN POPULATIONS: Beran River, Tanjung Redeb (N.E. Kalimantan)
Banumuda River (N.E. Kalimantan)

TOTAL WILD POPULATION: Unknown but depleted

TOTAL CAPTIVE POPULATION: Unknown but being reared in Tanjung Redeb

MAIN THREATS: Hunting for skins; collection of young for rearing; habitat loss

CONTACT ADDRESSES:

Director
Direcktorat Perlindungan den
Pengawetan Alam
jl. Ir. H. Juanda No. 9
Bogor
Indonesia

John MacKinnon
Project Manager
C/O UNDP
P.O. Box 2338
Jakarta
Indonesia

SPECIES: *Crocodylus porosus* COUNTRY: Indonesia (Sumatra)

LEGAL STATUS: Protected, exploitation on permit

CITES APPENDIX: I--Party

MAIN POPULATIONS: Rian Province, S. Kuba
Northern half of island contains suitable habitat

TOTAL WILD POPULATION: Unknown but depleted

TOTAL CAPTIVE POPULATION: Farm at Sikakap village on Pagai, W. Sumatra

MANAGEMENT/CONSERVATION EFFORT: Unknown. 550 skins exported in 1978

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

Director
Direcktorat Perlindungan den
  Pengawetan Alam
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Bogor
Indonesia

John MacKinnon
Project Manager
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P.O. Box 2338
Jakarta
Indonesia

SPECIES: Crocodylus porosus COUNTRY: Indonesia (Java)

LEGAL STATUS: Protected, exploitation on permit

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: Ujong Kulon, W. Java

TOTAL WILD POPULATION: Unknown but seriously depleted

MANAGEMENT/CONSERVATION EFFORT: Unknown. 1400 skins exported in 1978

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

Director
Direcktorat Perlindungan den
  Pengawetan Alam
jl. Ir. H. Juanda No. 9
Bogor
Indonesia

John MacKinnon
Project Manager
C/O UNDP
P.O. Box 2338
Jakarta
Indonesia

REFERENCES: Inskipp 1979

SPECIES: Crocodylus porosus COUNTRY: Indonesia (Sulawesi)

LEGAL STATUS: Protected, exploitation on permit

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: Marisa River

TOTAL WILD POPULATION: Unknown but depleted (C. siamensis may also be found on Sulawesi [C.A. Ross pers. comm.])

MAIN THREATS: Hunting for akins; habitat loss

CONTACT ADDRESSES:

Director
Direcktorat Perlindungan den
Pengawetan Alam
jl. Ir. H. Juanda No. 9
Bogor
Indonesia

John MacKinnon
Project Manager
C/O UNDP
P.O. Box 2338
Jakarta

SPECIES: Crocodylus porosus COUNTRY: Indonesia (Timor, Bali)

LEGAL STATUS: Protected, exploitation on permit

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: Jaco Is. (S.E. Coast Timor)
Fatu Berliniu (S. Central Coast, Timor)

PROTECTED AREAS: Lore Reserve (S.E. Coast, Timor)

TOTAL WILD POPULATION: Unknown but depleted

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

Director
Direcktorat Perlindungan den
Pengawetan Alam
jl. Ir. H. Juanda No. 9
Bogor
Indonesia

John MacKinnon
Project Manager
C/O UNDP
P.O. Box 2338
Jakarta
Indonesia

SPECIES: Crocodylus porosus COUNTRY: Indonesia (Kalimantan [Borneo])

LEGAL STATUS: Protected, exploitation on permit

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: Banumuda River

PROTECTED AREAS: Kutai Nature Reserve

TOTAL WILD POPULATION: Unknown but depleted

MANAGEMENT/CONSERVATION EFFORT: Unknown. 1100 skins exported in 1978

MAIN THREATS: Hunting for skins

CONTACT ADDRESSES:

Director
Direcktorat Perlindungan den
Pengawetan Alam
jl. Ir. H. Juanda No. 9
Bogor
Indonesia

John MacKinnon
Project Manager
C/O UNDP
P.O. Box 2338
Jakarta
Indonesia

REFERENCES: Inskipp 1979

NOTE: Considerable good habitat

SPECIES: Crocodylus porosus COUNTRY: Indonesia (Moluccas)

LEGAL STATUS: Protected, exploitation on permit

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Vulnerable

TOTAL WILD POPULATION: Unknown but depleted

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

Director
Direcktorat Perlindungan den
Pangawetan Alam
jl. Ir. H. Juanda No. 9
Bogor
Indonesia

John MacKinnon
Project Manager
C/O UNDP
P.O. Box 2338
Jakarta
Indonesia

SPECIES: Crocodylus porosus COUNTRY: Indonesia (Irian Jaya)

LEGAL STATUS: Protected, exploitation by permit

CITES APPENDIX: I--Party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: South coast in general and island of Pulau Dolok in particular
Mamboramo River delta (north)
Teluk Beran (MacCluer Gulf)

PROTECTED AREAS: Lorentz River Reserve, proposed Mamboramo R. Reserve, Pulau Dolok Island, Wasar Reserve (east of Merauke)

TOTAL WILD POPULATION: Unknown but significantly declined

TOTAL CAPTIVE POPULATION: 500-1000 on village and commercial rearing farms for skin exports

MANAGEMENT/CONSERVATION EFFORT: Medium. Protected list but no enforcement, size limitation 2500 skins exported in 1978

MAIN THREATS: Hunting for skins

CONTACT ADDRESSES:

Director
Direcktorat Perlindungan den
Pengawetan Alam
jl. Ir. H. Juanda No. 9
Bogor
Indonesia

John MacKinnon
Project Manager
C/O UNDP
P.O. Box 2338
Jakarta
Indonesia

REFERENCES: Blower pers. comm.; Lever pers. comm.; Inskipp 1979

SPECIES: Crocodylus n. novaeguineae COUNTRY: Indonesia (Irian Jaya)

LEGAL STATUS: Protected (Ministerial Decree No. 327/Kpts/Um/5/1978), exploitation on permit

CITES APPENDIX: II--party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS:	SIZE:	STATUS:
Meervlakte plains	unknown	decreasing
Mamberamo delta	unknown	decreasing

PROTECTED AREAS: Lorentz River Reserve (South-central)

TOTAL WILD POPULATION: Unknown

TOTAL CAPTIVE POPULATION: 4000 on village and commercial farms

MANAGEMENT/CONSERVATION EFFORT: Medium. Protective legislation enacted but little implementation. Recent survey by UNDP/FAO consultant. 22,000 skins exported in 1978

MAIN THREATS: Hunting for skins

CONTACT ADDRESSES:

Director
Direcktorat Perlindungan den
Pengawetan Alam
jl. Ir. H. Juanda No. 9
Bogor
Indonesia

John MacKinnon
Project Manager
C/O UNDP
P.O. Box 2338
Jakarta
Indonesia

REFERENCES: Blower pers. comm.; Level pers. comm.; Van der Zon and Mulyana 1978; Inskipp 1979; Lever 1980

SPECIES: C. novaeguineae mindorensis COUNTRY: Philippines

LEGAL STATUS: Unknown, apparently unprotected

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS:	SIZE:	STATUS:
Mindoro Oriental Quezon Province (Luzon) Mindanao Island	reportedly large	In general, critically endangered according to C. A. Ross pers. comm. 1980

PROTECTED AREAS: Unknown

TOTAL WILD POPULATION: Unknown; some populations extinct, others pressurized

TOTAL CAPTIVE POPULATION: 6-10 known

MANAGEMENT/CONSERVATION EFFORT: Poor. Philippine Fisheries Research Society planning to create a "crocodile nursery" at the Agusan Marsh on Mindanao

MAIN THREATS: Hunting for skins; habitat loss

CONTACT ADDRESSES:

C. A. Ross
c/o Div. Amphibs. & Reptiles
National Museum
Smithsonian Institution
Washington, D.C. 20560, U.S.A.

Bienvenido Y. Datingaling
Chief Fisheries Biologist
Bureau of Fisheries
Intramuros, Manila
Philippines

REFERENCES: Whitaker 1978; Webb 1978; Ross pers. comm. 1980

NOTE: The report of C. n. mindorensis in the Caroline Islands has yet to be confirmed. It is likely that C. porosus is found inland on this island as observed in inland crater lakes and streams on islands in Papua New Guinea

SPECIES: Crocodylus porosus COUNTRY: Philippines

LEGAL STATUS: Unknown, apparently unprotected

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: Palawan(?), Mindoro(?)

CONTACT ADDRESSES:

C. A. Ross
c/o Div. Amphibs. & Reptiles
National Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560, U.S.A.

Bienvenido Y. Datingaling
Chief Fisheries Biologist
Bureau of Fisheries
Intramuros, Manila
Philippines

SPECIES: *Crocodylus porosus* COUNTRY: Solomon Islands

LEGAL STATUS: Crocodile skins under 50 cm width cannot be sold except farm raised crocodiles (Statutory Instrument No. 21 of 4.11.77, Fisheries [Amendment] Regulation, 1977)

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

PROTECTED AREAS: Alitii Is. (Three Sister group) - private

TOTAL WILD POPULATION: Unknown

TOTAL CAPTIVE POPULATION: Unknown - some on rearing farms

MANAGEMENT/CONSERVATION EFFORT: Medium. Law exists but smuggling reports - law opposite to PNG's leaving big loophole. One dealer exports about 600 skins per year.

MAIN THREATS: Hunting for skins, unpopularity among islanders

CONTACT ADDRESSES:

Minister for Fisheries
Honiara

REFERENCES Webb 1978; R. Shaw 1979; Stone 1979; Cross 1980

SPECIES: *Crocodylus porosus* COUNTRY: Papua New Guinea

LEGAL STATUS: Export of skins over 510 mm in width (belly width measurement) banned

CITES APPENDIX: II--party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS: Sepik Province; Western Province; West New Britian Province; Bougainville Province; Milne Bay Province; Gulf Province

PROTECTED AREAS: Tonda Wildlife Management Area; Aird Hills

TOTAL WILD POPULATION: Unknown

TOTAL CAPTIVE POPULATION: 3 - 4,000

MANAGEMENT/CONSERVATION EFFORT: Monitoring program being formulated; public education, farming replacing hunting, captive breeding and restocking being pushed. 7,150 skins exported annually for past eight years

MAIN THREATS: Overhunting in some areas

CONTACT ADDRESSES:

Navu Kwapena Director Wildlife Division Ward's Strip Waigani	Melvin Bolton Project Manager FAO/UNDP Crocodile Project P.O. Box 3041 Port Moresby	Miro Laufa O.I.C. National Crocodile Project P.O. Box 2585 Konedobu

REFERENCES: Webb 1978; Whitaker 1980

SPECIES: *Crocodylus n. novaeguineae* COUNTRY: Papua New Guinea

LEGAL STATUS: Crocodile (Trade) Protection Act, 1969. Trade and Export of skins over 510 mm (20") commercial belly width prohibited

CITES APPENDIX: II--Party

IUCN RED DATA BOOK: Vulnerable

MAIN POPULATIONS:	SIZE:	STATUS:
East and West Sepik Provinces	large	appears stable
Madang Province	large	appears stable
Western Province	large	appears stable
Central Province	large	appears stable

PROTECTED AREAS: Tonda Wildlife Management Area

TOTAL WILD POPULATION: Unknown but could be several hundred thousand

TOTAL CAPTIVE POPULATION: 14,000

MANAGEMENT/CONSERVATION EFFORT: Excellent. Major management program with FAO/UNDP assistance, IUCN advice. 30,000 skins exported annually for past 8 years

MAIN THREATS: Killing adults; egg consumption

CONTACT ADDRESSES:

Navu Kwapena	Melvin Bolton	Miro Laufa
Director	Project Manager	O.I.C. National Crocodile Project
Wildlife Division	FAO/UNDP Crocodile Project	P.O. Box 2585
Ward's Strip	P.O. Box 3041	Konedobu
Waigani	Port Moresby	

REFERENCES: Webb 1978; Whitaker 1980

SPECIES: Crocodylus porosus   COUNTRY: New Hebrides

LEGAL STATUS: Unknown

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

TOTAL WILD POPULATION: Nothing known; Webb (1978) says likely severely reduced

SPECIES: Crocodylus porosus   COUNTRY: Western Caroline Islands (Palau)

LEGAL STATUS: No protection

CITES APPENDIX: I

IUCN RED DATA BOOK: Vulnerable

PROTECTED AREAS: Unknown

TOTAL WILD POPULATION: Unknown, reportedly "relatively common" in 1975

TOTAL CAPTIVE POPULATION: One adult, 10 juveniles at Entomology, Babelthaop

MANAGEMENT/CONSERVATION EFFORT: 1975 about 300 skins exported by one hunter. Now 10-15 caught/killed per month in Airai and Koror Municipalities by four hunters of the Island Crocodile Farm Center

MAIN THREATS: Hunting for skin and meat; little suitable habitat

CONTACT ADDRESSES:

Research Officer
Entomology Department
Babelthaop, Palau
Western Carolines

Hashida Kebekol
Island Crocodile Farm Center
Airai, Babelthaop
Palau, Western Carolines

REFERENCES: Webb 1978; Inskipp 1979; Kebekol pers. comm. 1980

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Taw, N., and U.P.K. Aung Moe. 1980. A brief account on the status of crocodiles and the crocodile farm in Burma. PPFC Report: 1-3.

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Webb, G.J.W. 1978. The status, conservation, and management of world crocodilians. Report prepared for Australian National Parks and Wildlife Service. Pp. 1-83.

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------, and D. Basu. 1974. Chitawan Sanctuary, Nepal. in J.C. Daniel (coord.): Gharial Survey Report. Madras Snake Park Trust, Madras. 16 p.

______, and J.C. Daniel. 1978. The status of Asian crocodilians. Tiger Paper (FAO Asia) 5(4): 12-17.

______, and Z. Whitaker. 1976. Endangered reptiles of India. 20 p.

______, and Z. Whitaker. 1979. Preliminary crocodile survey, Sri Lanka. J. Bombay Nat. Hist. Soc. 76(1): 66-85.

HUSBANDRY OF ORINOCO CROCODILES (Crocodylus intermedius) IN VENEZUELA

Tomas Blohm

Apartado 69, Caracas 1010-A, Venezuela

INTRODUCTION

The Orinoco crocodile has been declining towards extinction for about four decades. By 1946, when we spent 16 days in the area of the island of Pararuma, close to the confluence of the Parguaza and Orinoco rivers, tales about its past abundance were being told.[1] At the conference that wrote the Convention on International Trade in Endangered Species of Wild Fauna and Flora, held in Washington, D.C., during early 1973, Crocodylus intermedius was listed under Appendix I as a "Species Threatened with Extinction."

Although officially protected in Venezuela, and in spite of international mesures, little more than an occasional confiscation of hides and the prosecution of traders actually takes place. Hunters are almost never caught in the act of poaching, and the sale prices are so attractive that fines do not serve as a deterrent. Jail sentences are not allowed under Venezuela's wildlife-protection law.[2] Campaigns to promote awareness of wildlife have not really reached the hunters or poachers. The vastness of the Venezuelan and Colombian Orinoco Basin does not permit effective surveillance. It is a folly to believe that protective measures may allow the species to ever recuperate naturally; man will continue to shoot or trap C. intermedius on sight.

Survival of mature crocodiles in the wild depends on how well they can elude man, and on their presumed longevity. Heavily pursued adults cannot protect their nesting sites nor the hatchlings. The adults in the thinly spread remaining population may not always be able to find each other to breed. However, hope should not be given up. Urgent practical alternatives to preserve Crocodylus intermedius must be implemented. Reintroducing it into a natural habitat will make sense only if effective protection is previously established in such an area. It is no exaggeration to suggest that efforts should be made to at least "postpone extinction."

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1 Expedition of the Sociedad de Ciencias Naturales La Salle (Blohm 1948).

2 Ley de Proteccion a la Fauna Silvestre. 11 August 1970. Articles 100-124.

The main purpose of this paper is to present suggestions that may be of aid in the prevention of the extinction of these crocodiles. First, I would like to suggest that attempts to set up commercial farming should not be allowed for a species that has almost vanished, and whose genetic pool may already be insufficient for actual preservation.

Non-biological obstacles seem to be the biggest problems. For example, the procurement of funds for a sound project designed for a viable site, and the finding of a capable expert to do the job.

The biological problems can be solved, and they were at the "Parque Loefling," Puerto Ordaz, Venezuela (Gorzula et al. 1977) in spite of the psucity of specific information about the ecology of C. intermedius. Reproduction occurred there several times until both breeding males were lost (i.e. one escaped, one died).

NESTING SITES AND NESTING BEHAVIOR

My personal observations of Crocodylus intermedius nesting involve four sites in the wild and two in captivity. Near the village of Camatagua, State of Aragua, I own a private 996 ha wildlife refuge called Hacienda Refugio de Fauna El Paraiso on the shores of an artificial lake (Embalse de Camatagua) at 300 m above sea level. Here I built the compound in which I keep my breeding pair.

Nesting in the Wild

In 1946 we found a nest of C. intermedius on the collapsing edge of the sandbar "Playon del Medio" near the island of Pararuma in the Orinoco River. It was being actively eroded by the rising waters. The egg chamber was about 76 cm below the surface of coarse-grained sand. Footprints of an adult crocodile were present and partially washed out by the waves. The sand was very hot and there were several dead hatchlings on it. Croaking of hatchlings drew our attention, and we dug into the already naturally opened nest. As we lifted up a few eggs there was a "trigger effect," and the hatchlings literally jumped through the egg shells, leaving relatively small exit holes. We photographed a pair of twins as they emerged from a slightly elongated egg. The contents of the nest were not counted because the boat owner insisted on leaving. He believed the female would defend her nest and "eat her hatchlings"--a common popular belief--but she never appeared.

We tried to force the hatchlings into the water or back into the nest chamber so they would not die on the hot sand, but they continued to rush onto the sand. Their croaking was clearly audible. The shells of the unhatched eggs showed no cracks, but after eclosion the brittle calcified layer easily crumbled off the shell membrane. The eggs were as rough as sandpaper. This nest provided information useful for future reference:

(a) it was located at the edge of the water, (b) in deep sand, and (c) the hatchlings did not voluntarily enter the water. On 24 May 1980, the date of eclosion of my captive C. intermedius described below, one hatchling swam into the mouth of the female in an effort to climb on her head. The hatchling remained for about one minute between her jaws, turned around, spent another minute with its head protruding from her teeth, and then slipped into the water for another try. The female tolerated the hatchling. Hence there may be good reason to pay attention to such popular beliefs. Similar carrying of young has been reported in C. niloticus (Pooley 1978) and C. acutus in Florida (Ogden 1973).

On 29 July 1980, Luis Felipe Paris, Luis Mendoza, and I found three C. intermedius nests on an island in the Camatagua reservoir. Because crocodiles today are usually unable to elude man, it was good news to find more than one nest in an artificial lake where much boating, fishing, and poaching take place.

The soil of the nesting sites--schists of metamorphic rock mixed with clay--was certainly not the sand Orinoco crocodiles normally use. C. intermedius does not strictly depend on sandy beaches for nesting, as had always been assumed. In 1951, Hugo Mantilla found a nest on a hill on which the Ariporo River had swept logs, branches, and debris. This nest has been built in "caiman fashion," and there was no sandy beach near the nest, only gravel and clay (Medem 1976).

Characteristics of Nests Found in 1980

The females had used a road built during August 1979 along the edge of the water, on what had been a steep hill before the reservoir was filled in 1969. The slope of the hillside has an angle of about 40°, and the road caused severe erosion. Several trees had been bulldozed into the water, and aquatic vegetation floated into the bay. The nest chambers were very close to the formerly vertical cut made by the bulldozer, and erosion had caused minor landslides on all nests. In January 1980 I visited the place, and site of one nest was submerged. After collecting the fragments of the shell membranes, analysis revealed that eclosion had occurred in the three nests. The distance was 29 m between nests No. 1 and No. 2, 27 m between No. 2 and No. 3, thus nearly equidistant. There were depressions next to all three nests, but because the ground was most uneven, they may or may not have been false nests.

During June 1980, Colonel Leandro Potenza saw six hatchlings 3 km south of the site of the nests. In 1971 I saw three crocodiles 16 km eastwards, and in 1972 a poacher killed one about 9 km eastwards. The recent discovery of these three nests and Colonel Potenza's information certainly calls for official protection of the Camatagua reservoir.

Nests in Captivity

Site Testing for Feasibility of Captive Breeding in the Orinoco Crocodile

No artificial environment can fully replace a natural habitat, but we can often select a site where the species is still found or where it had existed. If such a place cannot be obtained, a site should be selected in which a number of factors found in natural habitats appear to be present. At Camatagua we had seen Orinoco crocodiles since 1971, but did not see evidence of reproduction until 1980. Other species of wildlife found in crocodile habitats were present and reproduced naturally. We found a nest of *C. crocodilus crocodilus* used during two consecutive years, hatchlings of a tortoise, *Geochelone carbonaria*, an abundant population of *Podocnemis vogli* turtles, and iguanas. In 1971 we collected a few eggs of *G. carbonaria*, placed them in a petroleum drum filled with sand, and left it outdoors where the sun reached it from noontime on. After five months the first hatchlings emerged, thus providing indirect information about what could have happened if we had incubated crocodile eggs instead.

In 1972 I noticed caiman hatchlings in one of the lagoons built for cattle; in 1974 Mark A. Staton (Texas A & M University) released caimans in another such lagoon, where they bred successfully in 1977. These released caimans had been incubated and raised artificially.

Dr. Pedro Trebbau suggested I build an artificial lagoon for Orinoco crocodiles, and in 1973 I did so. A meander of the Camataguita River was deepened with a bulldozer, and vegetation was allowed to grow back naturally. The heavy soil did not seem fit for nesting, and five cubic meters of sandy gravel were dumped on a sunny site close to the lagoon. Iguanas began to make use of the mound from then on, and their egg shells and hatchlings were observed several times. Thus, the artificial nesting site had been "tested," and we had additional reasons to expect success with Orinoco crocodiles.

Searching for a Breeding Pair

The search for a breeding pair of *C. intermedius* continued. Two mature crocodiles were offered by Dr. Carlos Anglade and Ricardo Zuloaga, but for unknown reasons both died before I received them.

In 1974 the site was fenced in with wire mesh. In 1977 Eugenio Mendoza offered FUDENA (Fundacion para la Defensa de la Naturaleza) three Orinoco crocodiles, none of which had been sexed, which had been raised together in his private children's zoo at a cement factory in Pertigalete. FUDENA transferred the offer to me, and the crocodiles were transported to my farm, Hacienda Refugio de Fauna El Paraiso. One specimen arrived during the last quarter of 1977, the second one died in the Zoological Garden of Las Delicias (Maracay) due to a tumor on its upper jaw, and the third one arrived on 23 January 1978. The latter was sexed and measured by R. Godshalk and turned out to be a male with a body length of 3.5 m. The first one was a female with an estimated body length of 3.0-3.2 m.

Their new captive environment consisted of a lagoon dug down to the water level, about 60 m long and 10-12 m wide. There is a gallery forest to its south and brush along its southern, western, and northern edges, some of which overhangs the water. The eastern side consists of a clearing covered by grasses, weeds, and some bushes. The mound of sand is located on this clearing at a distance of about 4 m from the lagoon. The perimeter fence encompasses about 0.5 ha. The site looks like a natural environment with hiding places both in the lagoon and on land. The height of the fence is 1.83 m, with its upper part bent inwards. A 5 cm guage wire was used.

During the rainy season the river occasionally flows over the site, thus replacing the water of the lagoon. In 1978 a flash flood tore down the fence, but the crocodiles remained in their newly accepted territory.

The Orinoco crocodile pair bred unsuccessfully during the first nesting season in 1979, but were successful during the second breeding season in 1980.

Nesting

The depth of the nest egg chambers of my captive breeding pair varied throughout the incubation periods; sand had been added to and subtracted from both the real and the false nests in 1979 and 1980. Three false nests in 1979 and two in 1980 were located at distances of no more than 1.83 m. Such adding and subtracting of sand occurred not only after we had done some excavating in an effort to locate the eggs, but also when there had been no human disturbance. Even after the female was already guarding her young, hatched on 24 May 1980, sand was added to the empty nest at some date between 13 and 24 June 1980, i.e. from 20 to 31 days after eclosion. In Caracas, I keep a breeding pair of *Caiman crocodilus crocodilus* that also added nesting material to the nest. I supplied nesting material at a distance of 2 m from the nest, and on two successive nights the volume of the nest had been considerable increased. Hatchlings were later obtained (Blohm 1973).

Knowing the depth of a nest may be less important than knowing that at least captive Orinoco crocodiles dedicate part of their time to reshaping nesting sites, and that such reshaping may not only affect the temperature in the egg chambers but also fulfill other biological functions that likely affect hatching success. Thus it probably is best not to disturb nests throughout the incubation period. Human intervention should be limited to building a fence around the entire compound, to exclude predators. Measurements and counts can always be taken after natural eclosion has taken place.

Some digging by the parent crocodile seems to amount to the exploration and selection of eventual nesting sites. Through observations of the female's behavior we were able to anticipate events that actually happened later on:

1) As early as 8, 9, and 12 September 1978, about 3 months before the laying season, the female became aggressive whenever we stood between the lagoon and the mound of sand or behind the site she later used for nesting.

2) During the first week of December 1979, about one month before the nesting season, we found two excavations on the nesting site.

3) In 1980 she used the same nesting site she had used in 1979, and the egg chamber was found exactly on the same spot it had been the year before, but one foot deeper.

4) On 3 and 15 March 1980 the female calmly approached my assistant as he was searching for eggs. On both occasions she climbed on the nesting site.

5) Throughout the nesting seasons of 1979 and 1980 both the male and the female were frequently seen on the nesting site.

Apparently a strong link exists between the C. intermedius female and the general nesting area, and not just during the actual incubation period. Observations of my captive female indicate that interest in the nesting area seems to last about 10 months--from early September to June. (The female launched out of the lagoon, crossed the nesting site, and cornered my assistants against the fence on 12 September 1979.) Since basking on the nesting site was observed at any time of the year, the nesting site in the compound seems to be about as important as the lagoon.

Since 1977, when the female was first introduced into the captive compound at Camatagua, and also after the male was released into it on 23 January 1978, we noticed changes in the width and height of the nest constructed from the artificially provided nesting materials. Hence a certain amount of shovelling, reshaping, and digging was evident in my compound. The actual action of adding and subtracting nesting materials was not observed.

On one occasion after we had examined all the nests, the false nests were repaired before the real nest. Repair of the false nests caused the collapse of two burrows, probably dug by tegu lizards (Tupinambus nigropunctatus), which had reached the egg chamber. Predation caused the loss of an egg found empty on 13 March, and also of twelve eggs found on

27 April 1979, the day the egg chamber was finally found. The collapse of these tunnels prevented further predation of the remaining 15 infertile eggs, which we collected on 12 March 1979.

The false nests had deceived us. In 1979 the true nest and egg chamber were found by following the predators' tunnel; in 1980 we were not able to find the real nest until the day of eclosion.

Behavior and Aggressive of the Breeding Pair

The crocodiles never tried to climb the fence. When the female was first introduced into the compound, she walked frequently along the fence and across the enclosed territory, crossing the forest, the clearing, and the artificial nesting site, and we never knew where she was. Several times we discovered her on land after hearing her hiss. Her trails were clearly visible. During the first week she cleared a well hidden basking site, not visible from any point of the fence, on a reduced sunny spot on the edge of the lagoon and the gallery forest. She had also visited and flattened the artificially supplied mound of sand. The trail between the lagoon and the mound of sandy gravel remained. The other trails were soon overgrown by vegetation. At first she approached us during feeding time, then she became reserved and hid under the overhanging vegetation at the western end of the lagoon, picking up the food only after we were out of sight.

For several weeks we could not even locate her and we began to wonder if she had escaped. On the afternoon that the male was introduced, she stationed herself in the center of the lagoon and watched the unloading procedure. After the male had been untied, he headed slowly for the water, and the female approached him. Their heads were facing each other at a distance of about 61 cm. Then she turned and both swam slowly toward the hiding place at the western end of the lagoon. There was no doubt that they had recognized each other.

Signs of active pacing along the fence and through the territory were again observed after the arrival of the male. On the next day, both crocodiles used the same basking site the female had been using. A second basking site was later built from a mound of sand intended by us to be their nesting site. Whenever we entered the enclosure, the pair would dive into the lagoon. After a while only their nasal turrets surfaced.

Later, in an attempt to feed the crocodiles, we releases ducks, rabbits, and three young goats into the enclosure. The goats used the crocodiles like logs, jumping on them and walking over their backs. The first to disappear were the two caimans originally present in the lagoon. The ducks grew wing feathers and flew off. After a couple of months two of the goats were found killed but not eaten.

I spent the following nine weekends trying to get the pair used to just one feeding site. I imitated hatchling distress calls to attract them, but there was no reaction. However, they did react to imitations of their coughs. The male was always the first to approach the edge of the lagoon. He caught meat thrown at him, but wasted much of it. Meat deposited on land right next to the water had to be moved with a long stick to draw his attention. Fish that were still flipping did attract him, but were too slippery. Both were capable of picking up even very small pieces of meat by using their teeth like pincers, showing surprising flexibility of their necks. During feeding time, the female tended to remain in the background, and the male chased her away whenever she managed to catch prey we had thrown to her.

Chicken turned out to be the most desirable food item; their wing-flapping after we had just killed them immediately attracted the crocodiles. Not only did the hens solve the food problem, but the crocodiles also began to abandon the lagoon to pick them up and they became readily visible. In addition, undetected food no longer polluted the lagoon.

Now they were conditioned to swim to the feeding site, where they waited for food. But simply "waiting" was not always the case; it more often tended to be an impetuous chase for food or a violent approach that turned the feeding site into a danger zone for strangers. However, since they were not fed anywhere else along the lagoon, we were able to walk around it and identify "safe" and "unsafe" areas within the compound.

Aggression seemed to depend on several factors, which were not constant throughout the year in either the male or the female. It seemed to vary according to the object of aggression, the site where it occurred, and the phases of their yearly breeding cycle.

A change in aggression was first observed on 8 December 1979 between the male and the female, with a temporary inversion of the "pecking order," mainly during feeding time. Until that date the male did not allow the female to approach the feeding site and, if she managed to grab some meat, he pursued her and forced her to speedily flee and take refuge on land. When panicking, the female abandoned the lagoon by way of the original basking site and took refuge in the forest. The male stopped short before the water's edge and quickly returned to the feeding site. After 8 December he became submissive, and the female began to take first turns at feeding time by hissing and a quick lateral movement of her head toward the male, thereby forcing him to wait. He then retreated backwards, but he did not flee. Throughout the nesting and incubating periods in 1979 and 1980 the female dominated. After hatching, she kept the male at bay whenever he came within approximately 5 m of the hatchlings. The female arched her tail and hissed softly, placing herself between the young and the male. He then patrolled around nervously, submerging and reappearing somewhere else. At first I thought that he was not wanted by the female and had nothing to do with caring for the young, but by 24 June, four weeks after eclosion, signs of the female's aggression toward the male ceased, and during feeding time she even retrieved a prey from his jaws as if there was absolute mutual understanding.

Before December 1979, the female approached the male from the rear and nibbled on the side of his tail and rib area. The male either hissed and twitched his head slightly sideways, or he did not react at all. If he hissed and twitched his head, the female retreated immediately. If he did not react, she continued to advance and to nibble the side of his neck and the lateral part of his jaws, her flank touching his. This seemed to be a submissive begging signal. From then on she could pick up food without running any risk and feeding continued on peaceful terms.

Aggressiveness toward people was also different. We regularly visited the crocodiles after they were placed in the compound, and most of the feeding was done by my assistant or me. Both crocodiles evidently recognized us, and we were able to approach them up to about 1.5 m without noticing aggressiveness. Even after eclosion, we only expected aggression if we approached the female closer than 1.5-2.0 m. However, the male and female were aggressive toward strangers--hissing, "head emergent tail arched posture" (as described by Garrick and Lang, 1977), splashing, roaring, and even chasing them on land took place if approached as close as 8-10 m. A stranger could approach them by staying close to us, but hissing soon became audible as the pair spotted him.

Aggression also varied according to the sites within the compound. It was nil in the forest and intense near the hiding places of the hatchlings; it was noticeable in the area of the the nesting site from September to May; it did not occur when the crocodiles were basking. On the feeding site, aggression was hard to define when we were present, but strangers did get attacked there. The crocodiles never attacked when on land. They only hissed and headed first for the lagoon.

On the edges of the lagoon aggression was unpredictable while the animals were in the water. It was not to be expected when the water was clear, but if the crocodiles stirred it up, thus turning it muddy, we could expect an attack.

Hence the compound of my captive crocodiles is not just a lagoon surrounded by land and vegetation, but an area subdivided into several subterritories, with no visible boundaries, but well-defined by the crocodiles. A keeper should be well aware of these subterritories, and strangers should not venture on their own into a compound.

Aggression on the part of the female excited the male. On 8 and 9 September 1978 we were attacked by the female while standing between the lagoon and the nesting site. On both occasions she jumped up, roaring and splashing, and landed next to our feet. Simultaneously the male was swimming and diving in circles at about 15 m offshore, producing great quantities of bubbles and finally surfacing on the edge of the lagoon next to us. Thus there was communication between the male and female during aggression.

Aggression also happened before certain events took place; even before eclosion the female hissed at the sites used later on to hide the hatchlings, and, as I mentioned, aggression on the nesting site happened long before oviposition.

The pair of crocodiles took their time before deciding on an attack. Both the male and the female remained motionless within attack distance. The launch up from below the water surface with a roar and a splash was preceded by slow-motion sinking and slow-motion surfacing at some other site, i.e. attack triggered off from below the surface of the lagoon. No previous bubbling was observed before such attacks. If copious bubbling was observed, attacks did not occur.

Hatchlings and Their Behavior in Captivity

On 24 May 1980 we went to feed the breeding pair and noticed that the 1979 nesting site had apparently been sacked by predators. We found empty egg shells and fragments of shells mixed with the sand and on the surface. The volume of excavated soil was 0.33-0.50 m^3. A dead hatchling[1] was found at the bottom of the empty egg chamber, covered by 2 inches of sand. The first few egg shells (all badly smashed) showed blood vessels and smelled like fresh chicken eggs. We began to search for additional hatchlings but, at first, could not find any. At the first basking site of the adults I found the female, and next to the drainage of the lagoon I heard a single distress call of a hatchling past the small peninsula (see Fig. 1). To the side of the first basking site we sighted a few young under the overhanging vegetation. The hatchlings were divided into two groups: 4 close to the drainage and 8 next to the guarding female.

On 30 May 1980 my son took photographs, and we found the group again split up into 5 and 8 hatchlings. Thus a total of 14 hatchlings (including the one dead specimen) from approximately 31 eggs was obtained.

We saw all 13 living hatchlings, again separated into two schools of 5 and 8, only on 5 July 1980. The school of eight had moved to the feeding site, and the school of five had moved to a territory 10 m away from the feeding site. This territory has a waterfront of about 5 m, reaches inland about 3 m, and is covered with shade, brush, and low grassy vegetation.

[1] Weight 81 g, body length 27.5 cm, snout/vent length 13.4 cm, tail/vent length 14.1 cm, head 4.2 cm, rear leg 6.4 cm, front leg 5 cm, weight of its sun-dried shell membrane without calcified layer 10 g. Umbilical cord still attached to shell membrane when found. Time of eclosion, just before our 10:30 a.m. arrival.

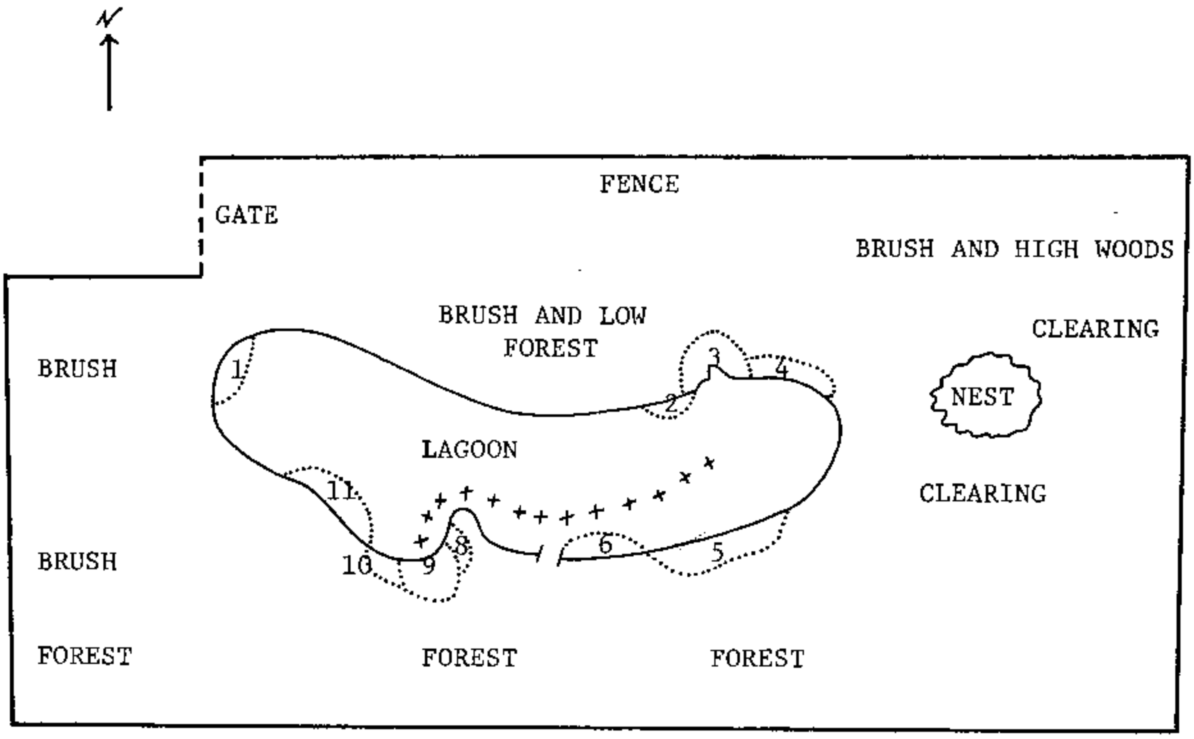

FIGURE 1. Compound of breeding pair of Orinoco crocodiles (Crocodylus intermedius) kept at "Hacienda Refugio de Fauna el Paraiso," Camatagua, State of Aragua, Venezuela. (1) Hiding site of hatchling; one seen on 28 July 1980. (2) Hiding site of one hatchling seen on 24 July 1980 next to snout of aggressive male (parent). (3) Feeding site of adults and also site they use for resting in shade. (4) Basking site of school of 8 hatchlings from 6 June 1980 until at least 28 July 1980. (5) Territory used by school of 5 hatchlings seen on 5 July 1980. (6) Hiding site of school of 5 hatchlings on eclosion day, 24 May 1980. (7) + + = course followed by adults when switching positions during parental care. (8) Basking site of 5 hatchlings photographed on 30 June 1980. (9) Original basking site used by female when first released into compound. Still used for basking by both adults. (10) Basking site on which the 8 hatchlings were seen on day of eclosion and photographed on 30 May 1980. (11) Hiding site used by both hatchling groups on 30 May 1980 and by the group of 8 on eclosion day.

NOTE 1: Sketch not drawn to scale.

NOTE 2: Observations of hatchlings took place between 24 May and 28 July 1980 (65 days) during 12 sporadic visits of 1-3 hours each by Tomas Blohm.

Why 5 and 8 and not 13 hatchlings together? There must be a reason for the hatchlings to have maintained themselves in two separate groups for exactly six weeks and probably more. First, eclosion of a single clutch does not necessarily occur simultaneously. With Geochelone carbonaria, Podocnemis vogli, and Caiman crocodilus crocodilus I have never obtained uniform hatching under artificial conditions. Neither did eclosion occur simultaneously in the Playon del Medio Crocodylus intermedius nest in 1946.

Differences of days seem to be common for turtles, and this variation, even if it only amounts to hours, may explain the separation of my captive C. intermedius hatchlings into two groups. Just as the female and the hatchlings recognize each other through some form of "imprinting," some similar mutual recognition may have occurred between the members of each of the two schools. Perhaps each group only establishes a direct relationship with the female and male. Such subdivision into two cohorts may be favorable to survival; the distress calls of one cohort attacked by a predator may allow the second to escape. The distance between the two varied from about 3 to 12 m when they were not hiding out. It would be ideal to mark the hatchlings to discover eventual intermingling of the cohorts, but the process would probably cause severe disturbance to the hatchlings and the adults. It seems preferable to look for individual characteristics of the hatchlings, such as differences in size, color, and individual behavior.

When looking for hiding places, the cohort of eight left first and the other lagged behind. Also, during repeated observations, two hatchlings within the group of eight lagged behind their members, and one within the group of five did the same.

Parental Care

During the first weeks maternal care of the hatchlings was clearly observed. The female's position always led to the location of the young after they had first been seen and subsequently gone into hiding. The role of the male was not so clear; he also approached the hiding places of the hatchlings, but the female hissed and interposed her body between the male and the hatchlings, as if she were to prevent eventual cannibalism on his part. She adopted the "head emergent tail arched posture" described by Garrick and Lang (1977). This rejection of the male when he was in the proximity of the hatchlings seemed to imply that he did not play a role in the guarding of the young. However, a month after eclosion there was no doubt that the male helped care for the hatchlings. Now the male, as the female had done before, positioned himself next to the hiding places of the hatchlings, hissed at intruders, adopted the inflated position, and also caused violent splashes.

On 30 May 1980, six days after eclosion, my son, Tomas Felipe, was taking some pictures. He had been standing at a distance of 5 m from the female and the hatchlings, close to the first basking site when the male attacked him from behind. The crocodile speedily approached him through the drainage and stopped 3 m inland, right next to the tripod. As the male attacked, the female moved up the ramp, roared, and then remained still, her front legs on land and her jaws opened, without emitting any further sound. She had approached Tomas Felipe from the front.

On 31 May, one week after eclosion, the male adopted the inflated posture when a stranger was 5 m inland. In all these cases of aggressiveness hatchlings were nearby. On 24 July the male was reluctant to climb to the feeding site. After a close look we discovered a hatchling floating next to his snout. Obviously he was guarding it.

Four weeks after eclosion, parental care was evenly shared by the adults. During 12 observations periods of 1-3 hours each between 24 May and 28 June we observed that the male and female never guarded the cohort of hatchlings together. Whenever the cohorts got together in hiding, either one or the other adult guarded them. The one who was not on guard remained at a relatively great distance. However, male and female would suddenly switch positions simultaneously, even if they had been at sites where one could not possibly have seen the other. The most frequent switching of positions occurred from the original basking site to the area of the feeding site and vice versa. The distance between these two sites is about 30 m. They would either dive or swim with their heads above the surface when performing the switching. These exchanges took place 2-4 times during all observation periods. It had not been observed before hatching.

On 15 March 1980 we first observed an odd behavior on the part of the female. She carried a dead chicken to the original basking site, began to hiss softly, sink, and surface, then to suddenly crunch and toss the prey and slam it on the water edge. After a while she repeated the process and finally swallowed the chicken. She returned for a second one, but during a repeat of the crunching, tossing, and hissing, the prey disintegrated. After hatching, this procedure became so standard for the female, that small bits of fatty tissue and tripe of the chicken floated on the water and appeared on land. She would also carry prey to the vicinity of the hatchlings and leave it floating nearby. On 19 June she tossed a hen inland and retrieved it after a few minutes.

On the day of eclosion the male, which had never delayed feeding before hatching occurred, commenced to retain the prey between its jaws to carry it back and forth and also to leave it floating. On 12 July he began the same crunching, tossing, and hissing procedure as the female was doing, also always in the vicinity of the hiding sites of the hatchlings. Several times this procedure was perfectly synchronized by the male and female.

During the observations the hatchlings never paid attention nor fed from the remnants of the disintegrated chickens. A total of 18 hens were fed to the female during nine observation periods, and all were subjected to the procedure described above. The male was fed the same number of hens, but only during the last four observations periods did he submit one of the hens to the same procedure.

Feeding by only one of the hatchlings was observed on 24 June, when it approached an insect on the shore and trapped and swallowed it.

The first basking site is surrounded by brush, low grasses, and low forest. The feeding site has low grass to one side and shade from trees on the other. The territory of the cohort of five hatchlings seen on 5 July consisted of low grassy vegetation, brush, and forest. In all these three sites we have found hatchlings scattered throughout the vegetation, walking slowly, lying down, and again advancing slowly as if they were stalking prey. We found flies, ants, and wasps in abundance, but could not observe any of the hatchlings feeding.

The significance of the crunching, tossing, and hissing procedure is not clear to me. An observer may think he is witnessing the apparent delivery of food by the parents to the young, but the young seemed to ignore such "service." Flies certainly posed on the pieces of floating prey and on those that remained on land, but indirect feeding was not observed either.

HOW THE HISTORY OF AN ABANDONED, OR SACKED, NEST MAY BE CONSTRUED

The scarcity of active Orinoco crocodile nests makes it most difficult to obtain ecological information about the species, but abandoned, preyed-upon nests yield many clues.

When an abandoned or sacked nest is found, absolute silence should be kept. Croaking of the young, hissing of adults, and splashes should be listened for. Hatchlings may remain in the vicinity of the nest for a period of several weeks, after which they turn watchful and elusive and will be very difficult to find. This happened with the captive hatchlings when they were about 2 weeks old. Unlike spectacled caiman hatchlings, Orinoco crocodile hatchlings are rather quiet and do not tend to answer imitations of distress calls. This makes it more difficult to locate them. One may hear an occasional single croak which calls for special precautions because the guarding female and/or male may be attracted.

There will be fragments of egg shells, an excavation, access trails or ramps heading for the shore, and perhaps tracks. The search for evidence should begin in the surroundings. Photographs should be taken. Tracks should be measured, as well as the size of the excavation, the distance to the water, and the height of the nesting site above the water level. The length of the track of a rear foot multiplied by 12 may be used as a "thumb rule" to estimate the size of an Orinoco crocodile. Egg shells, shell membranes, and fragments of both should be collected from the surface. The excavated sand or soil should be carefully removed and sieved. The water must also be searched for shells. Next, the egg chamber should be emptied of sand to look for dead hatchlings or unhatched eggs. Egg shells found in the egg chamber might be filled with sand and should be lifted out carefully. All shells and their fragments should be placed in containers and accurately labelled. These data allow estimation of how many eggs may have been in the clutch, how many hatched, and how large the female may be.

Normal hatching will leave only a relatively small exit hole on one end of the egg, if the calcified layer is not too brittle. In very brittle eggs the shell membrane will have a large slit, as if cut with a razor blade, from the tip of the egg down one side. The calcified layer will flake off the shell membrane easily, more so after the shell membrane dries up. The sun-dried shell membrane weighs about 10 g. There may be blood and sometimes a few capillary vessels inside such egg shells. The brittleness of eggs that have gone through normal incubation and produced hatchlings contrasts significantly with the hardness of fresh or sterile egg shells. Unless they are rotten, sterile eggs that have been in the egg chamber during the entire incubation period will be as white as fresh eggs. Rotten eggs have a grayish or even pinkish appearance. Sterile eggs, even after having remained many weeks in the ground, do not smell bad. An egg from which a hatchling has just emerged smells like a fresh chicken egg. Hence, if egg shells found on an old nesting site have a firmly adhered, hard, calcified layer, now matter how fragmented and crushed, were either sterile eggs that lasted through the entire incubation period, or eggs that were depredated during early incubation. Usually hatchlings have emerged from eggs with utterly brittle shells or shell membranes without the calcified layer. Eggs with firm shells and lateral holes rather than small exit holes on one end will most likely have been predated, more so if the border of the hole is bent inward. Eggs that contain very visible blood vessels and have yolk and blood smeared over their shells, whether brittle or not, will most likely have been the object of predators after embryos were already developing.

A rough estimate of how many eggs were in the egg chamber can be made from the shells and fragments found. Fragments can be classified on a tray; the least damaged shells will give an indication of how many fragments may represent one egg.

The size of the female can be derived from the tracks. Joanen (1969) found no correlation between the size of *Alligator mississippiensis* and numbers of eggs produced. Dr. Evan Dario Maldonado (INVEGA) keeps two male and one female *C. intermedius* for breeding purposes on his ranch, El Frio, near El Saman, State of Apure. One of the females (ca. 3.0-3.2 m) unsuccessfully laid 30 eggs in 1979 and 34 in 1980. My female, about the same size, laid 27 or 28 in 1979 and about 31 in 1980. Paris, Mendoza, and I found three abandoned *C. intermedius* nests on 29 July 1980 which may have contained 6, 11, and 13 eggs, according to reconstruction work. The rear foot tracks next to the nest of 13 eggs measured 14 cm, but may not have belonged to the corresponding female.

Nests indicate the presence of mature Orinoco crocodiles. My captive female used her first nest the following year also. Knowledge of such repeat behavior is useful when a nesting site in the wild has been discovered, because it may allow for the selection of a research site. Thus, the scientist will be able to take the necessary steps. Installation of blinds and infrared illumination ought to be set up long before the expected oviposition time to habituate the crocodiles to such alterations in their environment. It is recommended that a research project and a student be ready when it is time for field work, for chances to study the Orinoco crocodiles in the wild are dwindling at a faster rate than the species itself.

AN AILMENT CASE

In 1972 I obtained two Crocodylus intermedius males collected near Puerto Paez on the Meta River. Their weights and lengths were: No. 1 = 675 g, 58.5 cm; No. 2 = 837 g, 60.5 cm. Their body lengths corresponded to those of yearlings (Blohm 1973).

Crocodile No. 2 lost its appetite and regurgitated food four weeks before its death on 22 July 1980. On this day it measured 225.5 cm and weighed 43 kg. At first its front legs seemed to be paralyzed, and later on it did not use its rear legs either. Salmonellosis was first suspected, and it reacted favorably to antibiotics and a vitamin B complex, but only for a few days. A week before it died it ceased to move in its pool. Penicillin shots were changed to Cloromycetin, and Cortisone was injected two and one days before its death. Intestinal occlusion and brain or spinal damage were also suspected. X-rays taken by Angel Gracia Rodrigo showed it had swallowed a wire, clearly seen among many gastroliths. As we were getting the operating room ready, it died.

We decided to autopsy it anyway, but first wanted to experiment on extracting the wire through the esophagus. We wrapped heavy cloth around each jaw, thus covering the teeth. The introduction of Dr. Gracia's fist and arm presented no problem. Clamps used to keep dogs' jaws separated were used. The wire was retrieved in a matter of seconds. This experiment will hopefully prevent future waste of lives of crocodilians when searching for stomach contents, and also prevent abdominal operations when captive animals swallow strange objects. The loss of the crocodile was due to vandalism, as often happens in zoological gardens.

The autopsy, performed by Eglee Machado, revealed that the wire had not perforated the stomach but blocked the pylorus. Sharp-edged gastroliths may have worsened the severe gastritis caused by the wire.

It is recommended that the diagnosis of crocodilian illnesses begin with taking X-rays. It is also recommended that round pebbles be used in crocodilian compounds.

CONCLUSIONS

With what we presently know about the Orinoco crocodile (Crocodylus intermedius), a viable breeding project to save the species from extinction could be set up. The project urgently needs IUCN's international endorsement, influence, and support. It needs FUDENA's promotion and assistance in Venezuela. Private and official efforts must join to create a wildlife refuge for Orinoco crocodiles.

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Josefina Figueroa and my daughter Cecilia de Lucca helped me when drafting this paper. My daughter Lotti Carolina has often played a fine role as nurse to sick crocodiles and caimans. My wife, Cecilia, has allowed me to keep sick crocodiles in her bathtub, without too much protestation.

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APPENDIX

Data on the eggs of *Crocodylus intermedius* kept in captivity at the Hacienda Refugio de Fauna El Paraiso, State of Aragua, Venezuela

Clutch of 1979

The sand was found to be wet. A 35.2 mm rainfall on 21 March 1979, during the dry season, may have caused this humidity. The eggs were found on 12 May 1979. Of an estimated total of 27 or 28 eggs, the 15 remaining eggs were measured and weighed individually.

Egg No.	Grams	Length in cm	Width in cm	Observations
1	70.14	7.77	5.93	Indented, rotten
2	115.531	8.08	5.03	Translucid
3	118.631	8.36	4.95	Translucid
4	115.53	8.30	4.94	Translucid, indented
5	110.38	7.67	5.00	Translucid
6	95.93	7.66	4.99	Translucid
7	113.47	7.70	5.08	Translucid
8	112.44	7.98	4.96	Translucid
9	115.53	7.70	5.00	Translucid, indented
10	121.72	8.04	5.07	Translucid
11	115.53	7.87	5.00	Translucid
12	86.65	7.20	5.98	Translucid
13	117.60	7.70	5.08	Translucid
14	118.63	7.10	5.05	Translucid
15	72.21	7.20	5.00	Indented, 1/2 translucid, 1/2 dark
Mean =	106.66*	7.76**	5.14**	

* If the four eggs under 100 g are discarded, the average weight of the remaining 11 eggs is 115.89 g.

** The eggs varied as much as 1.16 cm in length and 1.04 cm in width. Such size variation in the *C. intermedius* of this clutch were specially noticeable in eggs No. 3 and No. 4. Their elongated shape resembled the egg from which twins eclosed in 1946.

BREEDING CROCODILES IN CAPTIVITY,*
A RETROSPECT 1960 - 1980.

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Analyzing the trend in the development of the breeding of crocodiles under captive conditions in the years between 1960 and 1980, it is apparent that the number of crocodilians bred and the number of institutions engaged in breeding have both increased (Tables 1 and 2). The reasons for such a development, which I did not dare to predict in my earlier paper (Honegger 1971), are manyfold:

A very positive reaction to the various recommendations by professional organizations (IUCN/SSC Crocodile Specialist Group 1971 and AAZPA resolutions on captive crocodilians from 1971) (for details see Honegger 1975).

I am sure that this is also a reaction to the increasing interest by the general public in crocodile biology, triggered by the various popular and technical papers and by some of the outstanding TV-films on prime-time. Stimulated by such media, zoo visitors more readily accept crocodilians as animals that are able to show highly specialized behaviors, e.g. maternal care.

Some zoos that have made commitments in their zeal towards education and conservation consider it an important task to breed crocodiles. The single-species exhibits, which are becoming more and more common, offer more space and more natural decorations.

The study of reptilian behavior has become a highly sophisticated and popular discipline of modern zoology (see Carpenter and Ferguson 1977), and the recent interest in modern herpetological research is well documented. "This is an exciting period in herpetology" (Gans 1977).

Another factor that probably has added to the increasing interest in crocodilian biology is the availability of reports from various regions of the globe through such publications as the International Zoo Yearbook or the International Zoo News and the increasing flow of data from a growing group of crocodile specialists.

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* United States data not included; see Tryon and Behler this volume.

The two surveys on crocodilians in captivity (King and Dobbs 1975, Honegger 1975) probably have stimulated an exchange of specimens with an aim to concentrate breeding efforts. Published records show that some instances of breeding are chance success that breeding one species over consecutive generations is still a novelty (Table 3).

However, I am sure that these data reflect somewhat the modern trend in the development of zoo attitudes toward the "last of the ruling reptiles," although much understanding from zoo directors, board members, and, last but not least, from the visitors is still required.

There is still much to do, especially with those species which are collectors' items because of their rarity in the wild. Many languish as isolated individuals because their owners regard them as status symbols and are unwilling to make exchanges to produce breeding pairs (see Table 4).

As pointed out recently (Honegger 1980), breeding reptiles under captive conditions provides data needed for a much better understanding of a species in the wild (see Hunt 1980, Tryon 1980). It also acts, and I consider this an important factor, as a stimulus to potential financial supporters of sound conservation programs involving wild populations. The majority of successful captive breeding of a given species took place in institutions within or near its natural geographical distribution.

Table 1.

Species	Year	Number of Institutions	Institutions, number of specimens hatched (figure in brackets = did not survive)	Reference
ALLIGATORIDAE				
Alligator mississippiensis				
	1968	1	Jerusalem	(IZYB 1970)
	1973	1	Gosford AUS 3(2)	(IZYB 1975)
Caiman crocodilus				
	1961	1	Chiapas MEX	(IZYB 1962)
	1966	1	Tuxtla MEX 28	(IZYB 1968)
	1968	1	Tuxtla MEX 28(3)	(IZYB 1970)
	1970	2	Tuxtla MEX 29(4); Caracas VEN 5	(IZYB 1972)
	1971	2	Tuxtla MEX 21 = fuscus; Amsterdam NL 9	(IZYB 1973)
	1972	1	Tuxtla Mex 21 = fuscus	(IZYB 1974)
	1976	2	Munich D 1 = fuscus; Shizuoka J 14 = yacare	(IZYB 1978)
	1977	1	Amsterdam NL 8	(IZYB 1979)
	1978	2	Amsterdam NL 8; Shizuoka J 2 = yacare	(IZYB 1980)
Caiman latirostris				
	1964	1	Erfurt DDR	(IZYB 1966)
	1966	1	Rio de Janeiro BR 27	(IZYB 1968)
	1976	2	Higashi J 7(2); Sao Leopoldo BR 6(3)	(IZYB 1978)
	1978	1	Rio de Janeiro BR 12(11)	(IZYB 1980)
CROCODYLIDAE				
Crocodylus johnsoni				
	1975	1	Melbourne AUS 4	(IZYB 1977)
	1978	1	Melbourne AUS 8(2)	(IZYB 1980)

TABLE 1 (Continued)

Species	Year	Number of Institutions	Institutions, number of specimens hatched (figure in brackets = did not survive)	Reference
Crocodylus acutus				
	1977	2	Berlin W D 1; Santo Domingo DOM 14(6)	(IZYB 1979)
	1979	1	Berlin W D 1	(Lange 1980)
Crocodylus moreletii				
	1972	1	Tuxtla MEX 15(2)	(IZYB 1974)
	1973	1	Tuxtla MEX 25	(IZYB 1975)
	1975	1	Tuxtla MEX 43	(IZYB 1977)
	1978	1	Tuxtla MEX 25	(IZYB 1980)
Crocodylus niloticus				
	1963	1	Tel Aviv Univ. IL	(IZYB 1965)
	2964	2	Tel Aviv Univ. IL; Elizabethville CGO	(IZYB 1966)
	1965	1	Tel Aviv Univ. IL	(IZYB 1967)
	1966	1	Tel Aviv Univ. IL	(IZYB 1968)
	1967	I	Tel Aviv Univ. IL 11(5)	(IZYB 1969)
	1969	2	Tel Aviv Univ. IL 8; Paris F (2)	(IZYB 1971)
	1970	1	Tel Aviv Univ. IL 7	(IZYB 1972)
	1971	1	Kumasi GH 1	(IZYB 1973)
	1972	1	Tel Aviv Univ. IL 5	(IZYB 1974)
	1974	2	Katowice PL 5(1); Tel Aviv Univ. IL 8	(IZYB 1976)
	1975	4	Cologne D 1; Katowice PL 3; Maiduguri NIG 4(2); Tel Aviv Univ. IL 1	(IZYB 1977)
	1976	4	Budapest H (1); Cologne D 3; Katowice PL 3; Maiduguri NIG 3	(IZYB 1978)
	1977	4	Dudley GB 1; Ibadan Univ. NIG 18(1); Katowice PL 2; Maiduguri NIG 39(3)	(IZYB 1979)

TABLE 1 (Continued)

Species	Year	Number of Institutions	Institutions, number of specimens hatched (figure in brackets = did not survive)	Reference
	1978	3	Berlin W D 3; Maiduguri NIG 112(4); Wassenaar NL 6	(IZYB 1980)
Crocodylus palustris				
	1960	2	Ahmedabad IND; Jaipur IND	(IZYB 1961)
	1961	1	Ahmedabad IND	(IZYB 1962)
	1962	2	Ahmedabad IND; Jaipur IND	(IZYB 1963)
	1963	1	Jaipur IND	(IZYB 1965)
	1964	1	Baroda INS 2/3	(IZYB 1966)
	1965	2	Bangkok T 30; Jaipur IND 23	(IZYB 1967)
	1966	1	Ahmedabad IND	(IZYB 1968)
	1967	1	Jaipur IND 29	(IZYB 1969)
	1968	1	Jaipur IND 12	(IZYB 1970)
	1969	1	Ahmedabad IND (23)	(IZYB 1971)
	1970	2	Ahmedabad IND; Jaipur IND 31	(IZYB 1972)
	1972	2	Ahmedabad IND; Jaipur IND 10/13	(IZYB 1974)
	1973	1	Ahmedabad IND 10	(IZYB 1975)
	1974	1	Ahmedabad IND 10	(IZYB 1976)
	1975	2	Ahmedabad IND 20(10); Jaipur IND 20/11	(IZYB 1977)
	1976	3	Ahmedabad IND 8; Delhi IND 12;	(IZYB 1978)
			Jaipur IND 14/20(3/4)	(IZYB 1978)
	1977	1	Ahmedabad IND 13(3)	(IZYB 1979)
	1978	3	Ahmedabad IND 12(4); Jaipur IND 17(13); Madras IND 96(6)	(IZYB 1980)
Crocodylus porosus				
	1971	1	Higashi J 13	(IZYB 1973)
	1975	1	Singapore 18(5)	(IZYB 1977)
	1976	1	Singapore 32(30)	(IZYB 1978)
	1977	1	Djakarta INDON (2)	(IZYB 1979)

TABLE 1 (Continued)

Species	Year	Number of Institutions	Institutions, number of specimens hatched (figure in brackets = did not survive)	Reference
Crocodylus rhombifer				
	1965	1	Havana C 26(3)	(IZYB 1967)
	1976	1	Higashi J 5(1)	(IZYB 1978)
Osteolaemus tetraspis				
	1969	1	Victória CAM (6)	(IZYB 1971)
	1970	1	Kumasi GH 5	(IZYB 1972)
	1972	1	Tokyo Ueno J 4	(IZYB 1974)
	1973	1	Tokyo Ueno J 6(2)	(IZYB 1975)
	1975	3	Kumasi GH (2/4); Tokyo Ueno J 3; Toronto CDN (1)	(IZYB 1977)
	1976	3	Kinshasa CGO 3; Kuala Lumpur MAL 5(1); Tokyo Ueno J 2	(IZYB 1978)
	1978	4	Kuala Lumpur MAL 6(2); Tel Aviv IL 10; Tokyo Ueno J 8	(IZYB 1980)
			Helfenberger (Privat) CH 2	(Helfenberger pers. comm.)
Tomistoma schlegelii				
	1976	1	Kinshasa CGO (1)	(IZYB 1978)
Crocodylus acutus X *Crocodylus niloticus*				
	1970	1	Hamburg D 1	(IZYB 1972)

Table 2.

Time Period	Number Species Bred	Number Zoo Breeding Crocodiles
1960-1965	5	7
1975-1980	11	24

Table 4. World-wide position and trend of four species of crocodilians 1969-1978
(Source: International Zoo Yearbook, London)

(Figures in brackets = number of specimens bred in captivity)

	Year	♂/♀/Sex Unknown	Total	Number Zoos	
Alligator sinensis	1969	12/11/50	73	38	
	1970	11/14/42	67	37	
	1971	22/08/35	65	39	
	1972	17/15/35	67	41	
	1973	10/15/35	60	38	
	1974	11/10/38	59	38	
	1975	11/13/44	68	40	
	1976	19/19/25	63	37	
	1977	12/13/31	56	32	no data Bandung; Warsaw
	1978	10/11/25	46	29	no data Higashi; Pilsen
	1979	11/13/23	47	29	
Crocodylus moreletii	1969	3/--/28	31	16	
	1970	6/02/36	44	19	
	1971	8/08/24	40	15	
	1972	19/16/22 (8)	57 (8)	19	
	1973	22/18/52 (38)	92 (38)	18	
	1974	20/17/75 (65)	112 (65)	15	
	1975	18/13/89 (82)	120 (82)	14	
	1976	20/12/105 (2/1/97)	137 (2/1/97)	15	no data Tuxtla
	1977	17/06/91 (83)	114 (83)	15	no data Atlanta; Havana; Higashi; Pilsen
	1978	9/10/08	27	15	no data Atlanta; Pilsen; Tuxtla
	1979	10/09/09	28	13	no data Atlanta
Crocodylus rhombifer	1969	2/02/14	18	15	
	1970	5/01/15	21	14	
	1971	2/02/15	19	12	no data Havana
	1972	10/05/21	36	18	no data Havana

Table 3. Additional biological information

Species	Institution	Date of oviposition	Number of eggs	Date of hatching	Incubation time in days/ No. hatched	Incubation temperature	Remarks/References
Caiman c. fuscus	Oga Aquarium J	12 May 1970	12	-	72-75d/7	32° C.	Eggs laid into water (Takeshi & Yoshikazu, 1973)
Crocodylus johnsoni	Melbourne	8 Aug 1975 9 Aug 1976	12 14	-	99d/4		(Anon, 1977 a) (Dunn, 1977)
Crocodylus niloticus	Cologne D	-	-	-	100d/1		Eggs laid into water (H. Jes, in litt.)
	Maiduguri Nig	-	-	-	70-77d/		
	Berlin W D	-	-	-	101d/		(Lange, 1980)
Crocodylus acutus	Sto Domingo, Dom	4 Mar 1976	34	-	107d/14	27-34° C.	(Anon, 1977 b)
	Berlin W D	-	?	-	85d/1	?	(Lange, 1980)
Crocodylus porosus	Jaipur IND	9 May 1967	41	3 Jul 1967	55d/29		After the 1974 eggs proved infertile, the male (over 30 years old) was successfully treated with PERANDREN (Ciba) for male androgen deficiency. Seven days 50 mg PERANDREN orally.
		18 May 1968	22	6 Jul 1968	49d/12		
		22 May 1969	28	5 Jul 1969	44d/28		
		25 Apr 1970	35	2 Jul 1970	68d/31		
		5 May 1971	33	26 Jun 1971	52d/27		
		25 Apr 1972	25	30 Jun 1972	66d/23		
		24 Apr 1973	27	24 Jun 1973	61d/24		
		2 May 1974	29	infertile			
		11 May 1975	34	29 Jun 1975	49d/31		
		13 Apr 1976	35	21 Jun 1976	69d/34		
		15 Apr 1977	31	All spoiled			
		19 Apr 1978	34	28 Jun 1978	70d/30		(Yadav, 1979)
Osteolaemus tetraspis	Kuala Lumpur MAL	23 Jun 1976	-	29 Aug 1976	68d/5+(1)	-	(Sims & Singh, 1978)
	Tokyo Ueno J	"Jun"	-		102-126d/ (mean 115, 4)	22, 5-32, 5° C.	(Hara & Kikuchi, 1978)
	Helfenberger CH Private Coll.	24 May 1978	14	-	72-84d/2	27-33° C.	(Helfenberger, pers. comm.)

Table 4. Continued

	Year	♂/♀/Sex Unknown	Total	Number Zoos	
	1973	12/11/18	41	21	no data Havana; Higashi
	1974	11/10/13	34	16	
	1975	16/17/19 (6)	52 (6)	22	no data Silver Springs
	1976	15/22/16 (2/2/2)	53 (2/2/2)	25	
	1977	15/19/25 (1/1/9)	59 (1/1/9)	28	no data Havana
	1978	14/17/09 (4)	40 (4)	22	
	1979	16/16/10	42	21	no data Havana
Gavialis gangeticus	1969	6/09/37	52	23	
	1970	7/15/24	46	24	
	1971	7/16/31	54	26	
	1972	8/07/38 (1)	53 (1)	25	
	1973	11/14/21	46	24	no data Boroda; Karachi; Colombo
	1974	6/12/21	39	21	
	1975	7/10/14	31	18	no data Calcutta; Gdansk; Silver Springs
	1976	7/07/21	35	20	
	1977	3/03/13	19	12	no data Mysore; Trivandrum
	1978	7/41/54	102*	12	no data Atlanta; Bojnice; Mysore
	1979	8/07/05	20	8	

* Hyderabad had 2/40/42 Of the 102.

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MANAGEMENT OF THE ALLIGATOR AS A RENEWABLE RESOURCE IN LOUISIANA

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INTRODUCTION

The first program established to manage the alligator (*Alligator mississippiensis*) on a sustained-yield harvest was initiated in Louisiana in 1972. The management program resulted from 15 years of research, dedicated enforcement, and enactment of effective state and federal laws governing the taking, possession, and transportation of alligators and their products. By 1970, such legislation was in effect in Louisiana (Joanen et al. 1981).

Public Law 91-135, known as the "Amended Lacy Act," was passed in December 1969. Lacy Act provisions made it a federal crime to sell or transport in interstate or foreign commerce any form of wildlife or products made from wildlife taken in violation of the laws of any state or foreign country. In 1970 the Louisiana Legislature enacted Act 550 giving the department of Wildlife and Fisheries full authority to regulate the alligator in the state. Louisiana law classifies the alligator as a non-game quadruped along with wild fur-bearing animals valuable for their skins or hides. The alligator is therefore considered a commercial wildlife species, and Act 550 formed the framework that permitted the implementation of a closely regulated commercial harvest (Palmisano et al. 1973).

Alligators occur throughout the state, and populations have demonstrated dramatic increases in recent years. The largest populations are found in the southern one-third of the state the coastal marsh and cypress tupelo swamps. Due to its value and vulnerability to hunting, the species requires special regulations, which must be designed to regulate the harvest of surplus animals yet distribute the kill over the area opened for harvest.

A complex system of applications, licenses, tags, and report forms were necessary to implement the management program.

METHODS AND MATERIALS

Inventory

Nest Surveys.-- Aerial nest censuses have been conducted annually in the coastal marsh zone since 1970. Alligator nests were counted from a helicopter flying permanently established transect lines. Each line extended from the marsh-swamp demarcation to a cutoff point in brackish marshes where nesting did not occur (McNease and Joanen 1978). The entire Louisiana coastal marsh, including salt marsh which is normally not used by alligators, comprises 1.7 million ha (Chabreck 1970) and is subdivided into three major subdivisions according to origin: the Chenier Plain, Sub-Delta, and Active Delta Zones. The Chenier Plain Zone makes up 0.5 million ha and is located in the southwest corner of the state. The Sub-Delta Marsh Zone contains 1.1 million ha (2/3 of total) and extends from the Vermilion Bay complex to the Mississippi-Louisiana border. The Active Delta comprises 0.1 million ha and consists of the present Mississippi River Delta. Each marsh zone is further divided according to salinity and vegetation. Generally, the brackish marsh is located nearer the Gulf of Mexico and experiences higher salinity levels than do the other two types. The intermediate marsh generally is a band separating fresh from brackish. Fresh marshes lie farther inland and are not usually affected by tidal action. Alligators do not normally utilize the saline marsh type; hence the 0.4 million ha of this type was omitted from the survey.

The fresh marsh made up 41% of the area (0.53 million ha), intermediate marsh comprised 22% (0.28 million ha), and the brackish marsh, minus marshes over 10 ppt salinity, comprised 37% (0.48 million ha). Data analysis was based primarily on Chabreck's (1966) figure of 5% for the percentage of nesting females in a population. The number of nests transected by marsh type and zone were converted to ha per nest. The ha/nest figure was then divided into total size of each individual sample area to arrive at total nesting females. A simple 20 times conversion converted to total population.

Establishing Harvest Regulations

The Louisiana Department of Wildlife and Fisheries authorized light seasons for the taking of alligators for the sale of skins between 1972 and 1981 (Palmisano et al. 1973, McNease and Joanen 1978). The first hunt, authorized in 1972, was confined to one parish in southwest Louisiana which according to the aerial nest survey housed the largest coastwide alligator population. The hunt area was gradually expanded until 1981 when the season was opened statewide (Table 1).

Information obtained from night counts on Rockefeller Refuge in 1966 and data gathered from managed hunts on Sabine National Wildlife Refuge

Table 1. Season dates and areas opened to alligator harvest in Louisiana 1972-1981.

Year	Season Dates	Number Hunting Days	Parishes
1972	5-17 Sept	13	Cameron
1973	10-28 Sept	19	Cameron, Vermilion
1975	20 Sept-19 Oct	30	Cameron, Vermilion, Calcasieu
1976	9 Sept- 8 Oct	30	Cameron, Vermilion, Calcasieu
1977	1-30 Sept	30	Cameron, Vermilion, Calcasieu
1979	7 Sept-7 Oct	31	Cameron, Calcasieu, Vermilion, Iberia, St. Mary, Terrebonne, Lafourche, St. Charles, Jefferson, Plaquemines, St. Bernard, St. Tammany
1980	4 Sept-4 Oct	31	Cameron, Calcasieu, Vermilion, Iberia, St. Mary, Terrebonne, Lafourche, St. Charles, Jefferson, Plaquemines, St. Bernard, St. Tammany
1981	31 Aug-30 Sept	31	Statewide

in 1947 and 1948 were used to determine the size composition of alligator populations (Chabreck 1966). These data indicated that alligators 1.2 m in length and larger constituted 39.4% of the population, and suggested maximum harvest of 20% of these alligators was determined to be a rate which would provide for the continued increase in the alligator population and at the same time permit an economically feasible harvest (Palmisano et al. 1973). The season was expanded in 1973 to include two parishes of southwest Louisiana. No season was allowed in 1974 as a result of the passage of the Federal Endangered Species Act. After an 18-month delay, caused by delisting requirements of the U. S. Fish and Wildlife Service, Louisiana again initiated its harvest program expanding to three parishes in 1975. The hunts were held annually in the three-parish area through 1977. Due to limited markets for skins within the United States and the ban on overseas shipment of skins as a result of the Convention on International Trade of Endangered species (CITES), no season was allowed in 1978. In March 1979, CITES under convention regulations, allowed the export of skins in international commerce. Along with this, the U. S. Fish and Wildlife Service delisted an additional nine coastal Louisiana parishes. As a result of the changes in the legal status and restrictons of shipments, the Louisiana Department of Wildlife and Fisheries authorized a regulated harvest in 12 coastal parishes in 1979 and 1980. In 1981 the alligator was reclassified statewide and a statewide harvest was authorized.

State law prohibited the taking of alligstors between the hours of sunset and sunrise and those animals less than 1.2 m in length. Other provisions regulating the taking and shipment of alligators were established by the Department.

Hunter Application and Tags

A potential hunter had to satisfactorily complete an application provided by the Department and show proof of ownership or a notarized statement from the landowner stating he had permission to take alligators from a specified piece of property. Information as to the location and acreage of the property was required. To qualify for a resident license the hunter must have resided in Louisiana for 1 year preceding the season. The fee for a resident license was $25.00, and the non-resident fee was $150.00. All licenses were non-transferable. Non-resident hunters coordinated their hunt through landowners and licensed resident hunters. In addition to a valid commercial alligator hunting license, the hunter had to obtain from the Department official alligator tags which must be firmly attached to each skin immediately upon taking. The serially numbered tags had to be attached in the last 15 cm of the tail. The number of tags issued were based on the quantity and quality of the habitat. Tags could only be used on the lands applied for and approved on the application. Unused tags had to be returned to the Department no later than 15 days after the close of the season. Lost or stolen tags were not replaced but had to be reported.

To avoid the possibility of skins taken illegally prior to the season from entering the legal traffic, hunters were issued special skinning instructions by Department personnel. Skins processed contrary to the specific requirements of the Department were considered illegal and confiscated.

Alligator Parts

Meat and other parts from lawfully taken alligators could only be sold according to Louisiana Health Department regulations, Louisiana Department of Wildlife and Fisheries regulations, and federal laws. The Louisiana Department of Wildlife and Fisheries regulations required that all alligator hunters and parts dealers maintain records of all transactions, purchases, and sales on forms provided by the Department. Transaction forms were submitted to the Department within 30 days following the close of the season and thereafter at 60-day intervals until all parts were sold. All alligator meat and parts had to be tagged with an official alligator parts tag furnished by the Department. Hunters and dealers had to furnish a bill of sale to all retailers and restaurants purchasing alligator parts. Transaction records had to be maintained for six months.

Alligators had to be skinned in state approved processing plants if the meat was sold for human food. Processing, packaging, storage, and labelling of meat is regulated by Chapter VI of the Louisiana State Sanitary Code as well as the Louisiana State Food, Drug, and Cosmetic Law.

The special rule on the American alligator (50 CFR Parts 13 and 17), promulgated under authority of the Endangered Species Act of 1973, was revised on 25 November, 1980, to allow the sale of meat and other psrts nationwide, provided such sale is in accordance with the laws and regulations of: (1) the state in which the taking occurs, and (2) the state in which the sale occurs. Special rules were adopted which standardized the tagging and labelling of any package or container used for ahipping alligator parts.

Alligator Harvest

Size class and sex information were obtained for 1972 through 1977 from freshly killed alligators by checking hunters at their place of skinning. Reproductive organs, especially females, were categorized as sexually active, barren, of quiescent for the season killed. Some tracts were preserved for laboratory study when questions arose about the reproductive condition.

The harvest was monitored by either checking skins at a central check-in point or at the commercial dealer's plant whenever a shipment was being prepared. Hide lengths by individually serially numbered tags were obtained after the close of each season.

As the hunt area and kill was expanded so did the amount of paperwork involved in monitoring the kill and commercial aspects of the harvest. Consequently, in 1979 a computer program was developed to follow hides (by individually serially numbered tags keyed to hunter or buyer/dealer license numbers) from the hunters level through commerce until tanned into leather. Taxidermy or trophy hides, which did not enter commercial channels, were monitored through a system of report forms, as were alligator meat and parts (other than hides).

Buyers and Dealers

A fur buyer license or fur dealer license was required for purchasing and handling raw alligator skins in Louisiana. An alligator parts dealer license was required of anyone purchasing alligator parts (other than hides) for resale, manufacturing, processing, and distribution, excluding retailers and restaurants. Persons or firms entering alligators in interstate/foreign commerce in the course of a commercial activity had to be licensed in accordance with state and federal regulations.

All buyers and dealers making purchases of alligator skins had to maintain a complete set of records of all purchases and sales on forms furnished by the Department. Such records included names and addresses of buyers and/or sellers, alligator hide tag numbers, date, and length. All raw skins shipped out-of-state had to bear official shipping tags provided by the Department. Forms provided had to be filled out completely and returned to the Department within 15 days after each shipment.

Nuisance Alligator Control Program

As the alligator population throughout the state increased, so did human/alligator conflicts, which presented many problems to Department personnel and affected citizens. Large numbers of alligators were found within the confines of many rural communities and within the metropolitan areas of Baton Rouge and New Orleans. During summer months, some Department personnel were spending as much as 50% of their time responding to alligator complaints and relocating nuisance alligstors. It was apparent that alligators were very abundant in Louisiana and did represent a potential threat to humans, livestock, and pets. Live removal of nuisance alligators by Department personnel proved futile, time consuming, and costly.

In 1979, the State of Louisiana initiated a nuisance alligator control program using private licensed hunters in 12 coastal parishes. During the 1979 and 1980 seasons, this program was incorporated into the alligator harvest program in an attempt to remove problem alligators occurring within the confines of communities which could not be hunted under the tag allotment system. The same basic regulations which governed commercial hunters were applied to hunters of nuisance alligators such as license requirements, skinning instructions, minimum size class, and methods of take. However, this program deviated from the commercial harvest program in that tags were allocated by Department personnel on a complaint basis rather than by habitat appraisal. Skins, meat, and parts taken in the nuisance alligator control program were allowed to be sold under the same regulations governing the skins, meat, and parts taken in the commercial harvest program.

The selection of nuisance hunters was in cooperation with local governing bodies, e.g. police juries, parish administrators, city administrators, lake commissions, etc. The final selection of hunters rested with Department personnel. The most economical and effective approach for resolving alligator complaints in Florida was the use of contracted hunters (Hines and Woodward 1980).

RESULTS AND DISCUSSION

Population Surveys

Population estimates in the coastal marsh varied from a low of 134,000 in the drought year of 1971 to a high of 520,000 in 1979 (Table 2). Overall, populations increased dramatically in the Chenier Plain and Sub-Delta Zones from 1970 to 1979. The Active Delta showed a decrease in alligator populations and was adversely affected by drastic changes occurring to marsh habitat: hurricane damage, marsh subsistence, and flooding. A comparison of alligator densities, expressed as acres (ha)/alligator, shows much higher population levels in the Chenier Plain Zones. The Chenier Plain averaged 1 alligator:6.2 acres (2.5 ha), the Sub-Delta 1:19.8 acres (8.0 ha), and the Active Delta 1:34.6 acres (14.0 ha). Population distribution by marsh types on a coastwide basis showed the intermediate marsh type contained highest alligator densities, 1 alligator to 7.9 acres (3.2 ha). The brackish and fresh marsh were about equal in area and population density; 1 alligator to 14.1 acres (5.7 ha) (McNease and Joanen 1978).

The coastwide average annual increase of nests for the period of 1970-1979 was 16.9%. The average annual increase in the Chenier Plain of southwest Louisiana was 18.2% for the same period. A further analysis of population dynamics in the Chenier Plain demonstrated average annual increases in nest production were considerably greater on 850,000 acres (344,250 ha) or privately owned property than for 285,000 acres (115,425

Table 2. Louisiana coastal marsh alligator population based on nest surveys, 1970-1979.

Year	Population Estimate	Percent Change in Comparison to 1970
1970	172,000	
1971	134,000	-22
1972	182,000	+ 6
1973	153,000	-11
1974	213,000	+24
1975	272,000	+58
1976	282,000	+64
1977	274,000	+59
1978	285,000	+66
1979	520,000	+202

ha) of refuge property. Privately owned property, 84% of which was hunted, showed an average annual increase in nest production of 23.4% over the 9-year period of 1970-1979. Refuges, where no hunting occurred, had an average annual increase of 13.3% in nesting for the same 9-year period.

Air temperature affects the timing of nesting and egg laying activity (Joanen and McNease 1979). Nesting occurred in early June for the years with the highest March-May temperatures and occurred as late as the first week in July when springtime temperatures were the lowest. This factor must be taken into account when establishing time tables for nest censusing and season dates. Extremes in water levels, droughts, and flood conditions adversely affect nesting (McNease and Joanen 1978). Surface water conditions probably affect nesting potential more than any other environmental factor, and thereby may cause considerable bias in annual population estimates based on nest transects.

Alligator Harvest

During the perid of 1972-1979, 37,892 alligator tags were issued to 1501 hunters. Average tag allotment per hunter was 25.2 (Table 3). Of the privately owned marshlands open for harvest, 84% was actually hunted. A total of 34,854 alligators were taken, representing a 92% hunter success. Not all skins were sold; 1768 skins were tanned at the expense of the hunter or landowner for trophy skins or manufactured into boots, saddles, gun cases, belts, etc. Prices varied from $16.55/linear foot (0.3 m) in 1976 to $7.88 in 1975. Prices varied according to the demand for skins, restrictions placed on the sale of products within certain states, and international prohibition on foreign commerce. International trade restrictions along with a restricted United States market reduced the demand for skins to such an extent that the Louisiana Department of Wildlife and Fisheries did not recommend a harvest program in 1978.

As a result of the CITES delisting of 1979, international commerce was allowed under a rigid permit system. The U. S. Fish and Wildlife Service delisted nine additional coastal Louisiana parishes. Louisiana resumed harvest in 12 parishes in 1979. However, 1979 hide prices were much below world market value because only one foreign buyer was permitted.

Sex and Size Composition of Harvest

Telemetry studies (Joanen and McNease 1970, 1972a) suggest a September hunt restricted to daytime hunting and open water areas would result in a kill composed largely of larger males and immature animals of both sexes. By restricting the pole hunting method in interior marshes, the take of breeding females was minimized. During the 1972 harvest season, 303 alligator carcasses were examined. Adult males over 6 feet (1.8 m) made up 83.1% of the mature alligators inspected, and adult females constituted 16.9%. During the 1973 harvest, 843 alligator carcasses were examined. Adult males made up 67.9% of the mature alligators harvested (total percentage of males in kill 66.3%), and adult females 32.1% (Table 4).

Alligator populations appear to have more males than females in the larger size classes (Chabreck 1966). Joanen and McNease (1972b, 1973) estimated 2500 and 2662 (5% of population) breeding females in the area open for harvest during 1972 and 1973. The projected adult female kill was 140 in 1972 and 550 in 1973. The high kill on females in 1973 as compared to the 1972 season was attributed to the flooded conditions as a result of Tropical Storm Della. Excessive amounts of rainfall coupled with high tides provided hunters easy access into marshes which were usually not accessible at that time of the year (Joanen et al. 1974).

In 1975, 85.5% of 684 mature alligators examined were males. Mature males also comprised the majority of the kill the following two years; 78.3% of 398 checked in 1976 and 70.3% of 212 sampled in 1977 (Table 4). The average size class of the animals taken during the 6 years of harvest remained fairly constant from year to year. The average skin size was 7'1-1/2" (2.14 m) with a range of 4'-14' (1.2-4.2 m). Of the skins taken, 77.2% were between 5 and 8 feet (1.5-2.4 m) (Fig. 1).

The largest female harvested was taken in the Mermentau Basin of southwest Louisiana. This female measured 9'1" (2.73 m) and weighed 208 pounds (94 kg). Internal examination of the ovaries indicated she was barren. The largest male was taken in the Pearl River complex of southeast Louisiana and measured 14'0" (4.2 m). No weight was obtained.

The size of harvested mature animals appeared to be at a percentage at which they existed in the hunt area for the 7' (2.1 m) size class and above. However, other factors such as hunter accessibility to animals during low rainfall years, easy accessibility during high rainfall years, and skin prices may affect the harvest to some degree. When high prices were paid for skins, hunter interest was stimulated the following year. The reverse was true when prices were lower.

Most of the large animals were taken by the fishing method. Those shot free-swimming were generally of the smaller size classes. No instances were reported of alligators less than 4' (1.2 m) being caught on lines. Smaller alligators usually remain in shallow interior marsh ponds and feed on crustaceans or small fish (Chabreck 1971, Valentine et al. 1972, McNease and Joanen 1977). McNease and Joanen (1974) found the immature females, 3'-5' (0.9-1.5 m) size class, showed a preference for the natural marsh during the autumn period, similar to that preferred by adult females during the same period. Only 40% of the immature female

TABLE 3. Results of the alligator harvest program in Louisiana 1972-1979.

Year	Parishes Hunted	Number Hunters	Tags Issued	Area Hunted Acres	Area Hunted Ha	No. Taken	No. Sold	Price Paid for Skins	Avg./Foot (0.3 m)	Avg./Skin	Avg. Length Feet	Avg. Length m	Hunter Success (%)
1972	1	59	1,961	278,168	111,267	1,350	1,337	$ 74,773	$ 8.10	$ 55.93	6'11"	2.11	69
1973	2	107	3,243	541,361	216,544	2,921	2,916	$ 268,542	$13.13	$ 92.09	7'0"	2.13	86
1975	3	191	4,645	822,867	329,147	4,420	4,302	$ 251,876	$ 7.88	$ 58.55	7'5"	2.26	93
1976	3	198	4,767	817,590	327,036	4,389	4,301	$ 501,977	$16.55	$116.71	7'1"	2.16	92
1977	3	236	5,760	989,162	395,665	5,474	5,275	$ 470,749	$12.23	$ 89.24	7'4"	2.24	95
1979	12	708	17,516	2,618,076	1,047,230	16,300	14,955	$1,711,500	$15.00	$105.00	7'0"	2.13	93
TOTAL		1,501	37,892	6,067,224	2,426,890	34,854	33,086	$3,279,417					92

TABLE 4. Size and sex composition of alligators taken during the Louisiana harvest program of 1972-1977.

Size Class		1972				1973				1975				1976				1977			
		Males		Females		Males		Females		Males		Females		Males		Females		Males		Females	
Feet	m	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
4-5	1.2-1.5	21	8.8	13	20.0	45	8.1	29	10.2	10	1.5	5	3.7	31	6.9	16	11.4	16	8.3	7	8.0
5-6	1.5-1.8	55	23.1	19	29.2	110	19.7	64	22.5	52	8.0	31	23.0	81	18.0	30	21.4	28	14.5	18	20.5
6-7	1.8-2.1	61	25.6	13	20.0	96	17.2	108	38.0	161	24.9	73	54.1	104	23.1	60	42.9	24	12.4	39	44.3
7-8	2.1-2.4	42	17.7	18	27.7	100	17.9	61	21.5	198	30.6	24	17.8	118	26.2	29	20.7	46	23.8	23	26.1
8-9	2.4-2.7	29	12.2	2	3.1	68	12.2	20	7.0	100	15.5	2	1.5	58	12.9	5	3.6	31	16.1	1	1.1
9-10	2.7-3.0	16	6.7	0	0.0	68	12.2	2	0.7	65	10.0	0	0.0	33	7.3	0	0.0	28	14.5	0	0.0
10-11	3.0-3.3	10	4.2	0	0.0	49	8.8	0	0.0	41	6.3	0	0.0	18	4.0	0	0.0	14	7.3	0	0.0
11-12	3.3-3.6	3	1.3	0	0.0	21	3.8	0	0.0	19	2.9	0	0.0	6	1.3	0	0.0	5	2.6	0	0.0
12-13	3.6-3.9	1	0.4	0	0.0	2	0.4	0	0.0	1	0.2	0	0.0	1	0.2	0	0.0	1	0.5	0	0.0
13+	3.9+	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0
TOTAL HARVESTED		238	78.5	65	21.5	559	66.3	284	33.7	647	82.7	135	17.3	451	76.3	140	23.7	193	68.7	88	31.3
PERCENT ADULTS IN HARVEST		162	83.1	33	16.9	404	67.9	191	32.1	585	85.8	99	14.5	339	78.3	94	21.7	149	70.3	63	29.7

segment of a population would be available if hunting were restricted to deep water bayous, lakes, and canals. Data collected during Louisiana's 1972 experimental alligator season (Palmisano et al. 1973) indicated immature females constituted 29.6% of the immature size classes of alligators harvested. In 1973, 1975, 1976, and 1977, immature females made up 37.5%, 36.7%, 29.1%, and 36.2% respectively of the immature alligators harvested (Table 4). Immature males showed a marked preference for deep water areas during summer and autumn. Usage by males of natural marsh area was substandard for all seasons when compared to availability (McNease and Joanen 1974).

Validation and Sale of Skins

At the close of the 1972-1977 seasons, all hunters were required to bring their skina to one centrally located place to be inspected by Department personnel. The alligator tag number and hide measurement was recorded for each skin and a monel validation tag was attached. Skins were also made available to the buyers for inspection and grading. After all skins were validated and graded, buyers submitted sealed bids for each individual hunter's lot. Hides were sold to the highest bidder. Hunter report forms were completed at time of validation and public auction. From these forms, the buyer of each skin was identified. Dealers shipping their skins out-of-state were required to complete official shipping tags furnished by the Department of Wildlife and Fisheries. The destination of the shipment and content information were recorded on the shipping tags.

With the expansion of the harvest to 12 parishes in 1979, skins were validated at the dealers' level just prior to shipment. Hunter report forms and unused tags were returned to Department personnel within 15 days after the close of the season. All buyers and dealers making purchases maintained a complete set of records on forms furnished by the Department. These records included names and addresses of buyers and/or sellers, alligator hide tag number, date of purchases, and length of skins. Dealers submitted these reports to the Department within 15 days after each shipment.

Of the 33,086 belly skins sold during the 6 hunts, 39.5% were purchased by a South Carolina-based tannery. A French tanning company purchased 35.7% of the skins. Two Louisiana dealers purchased 22.7% of the skins. These skins were contract-tanned in Italy, returned to Baton Rouge, and later sold to manufacturers within the United States. A New Orleans-based tannery/manufacturer purchased 2.0% of the skins. The 0.1% remaining, a small shipment of hornbacks, were purchased by a Japanese tanner.

Nuisance Alligator Control

During the 1979 nuisance harvest program, 122 tags were issued to 11 hunters who killed 51 alligators in six coastal parishes (Table 5). In 1980, 265 tags were issued to 34 hunters in the same six parishes. The 1980 take increased sharply to 225. The number of tags issued were based on the number of complaints received (Linscombe 1975). Some complaints were randomly investigated by Department personnel on the site. Alligators taken under this program were taken in accordance with state and local regulations/ordinances.

During 1979-1980, Department personnel relocated alligators in the delisted areas. The magnitude of these requests were only slightly lessened with the nuisance complaint program. Any future nuisance complaint program should be conducted on a year-round basis and in conjunction with the annual commercial harvest program. A statewide nuisance complaint program will be initiated in September 1981. Skinning instructions issued by the Department will be for one calendar year and any skin not prepared according to the instructions issued will be considered illegal. Disposition of skins, meat, and parts taken in the nuisance complaint program will be the responsibility of the local governing body and/or the hunter.

Alligator Meat and Parts

During the 1979 season, approximately 100,000 pounds (45,000 kg) of alligator meat were sold. Prices varied across the coast; however, the average price paid to hunters in southeast Louisiana was about $1.00 per pound (0.5 kg), whereas in southwest Louisiana it averaged $2.00 per pound (0.5 kg). Over half of the meat sold was purchased by individuals for home consumption. The remainder was sold to restaurants and fish markets.

Reports received from 15 licensed alligator parts dealers indicated teeth and skulls were sold to the jewelry trade and biological supply houses. Most jewelry items were sold within Louisiana, primarily in the New Orleans area.

SUMMARY AND CONCLUSION

The Louisiana Department of Wildlife and Fisheries established 8 alligator harvest seasons in south Louisiana between 1972-1981. The primary objective of this program was to manage the alligator on a sustained-yield harvest. This program was aimed at regulating the harvest of surplus animals and yet distribute the kill in proportion to

TABLE 5. Results of the Louisiana nuisance alligator removal program conducted in six (6) parishes 1979-1980.

Parish	Year	No. of Tags Issued	No. of Alligators Killed	No. of Hunters
Plaquemines	1979	67	23	2
Plaquemines	1980	150	134	25
St. Bernard	1979	10	10	1
St. Bernard	1980	30	30	1
St. Tammany	1979	5	-	4
St. Tammany	1980	30	16	5
Jefferson	1979	10	9	1
Jefferson	1980	25	25	1
St. Charles	1979	10	9	1
St. Charles	1980	20	20	1
Terrebonne	1979	20	-	2
Terrebonne	1980	10	-	1
TOTAL	1979	122	51	11
TOTAL	1980	265	225	34
GRAND TOTAL		387	276	45

the existing population over the area opened for harvest. In order to accomplish this objective, a system of applications, licenses, tags, and report forms were necessary.

A total of 1,501 licensed alligator hunters was issued 37,892 tags. During six harvest seasons, 34,854 skins averaging 7'1-1/2" (2.14 m) were taken. Skins sold to dealers in Louisiana totaled 33,086 and were valued at $3,279,418.

As predicted, males comprised the majority of the harvested animals; 74.6% for 1972-1977. Population surveys indicated a 16.9% average annual population increase of nesting females in the area open for harvest.

A nuisance complaint program was initiated using private licensed hunters during the 1979 harvest; however, the number of complaints the Department received the following year were only slightly lessened with the nuisance removal program. It was recommended that future nuisance complaint programs be conducted on a year-round basis not just in conjunction with the annual harvest program.

Alligator meat sold for human consumption was monitored by the Louisiana Department of Health as well as the Louisiana Department of Wildlife and Fisheries. The majority of alligator meat sold was for home consumption.

Alligator parts (teeth and skulls) were sold only by licensed hunters or dealers and a complete set of records concerning all transactions were reported to the Department. Periodic inspections were carried out by Department personnel.

Skins, meat, and parts were followed through commercial channels with no evidence of illegal skins or parts entering the legal traffic.

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THE NATIONAL CROCODILE PROJECT IN PAPUA NEW GUINEA
A SUMMARY OF POLICY AND PROGRESS

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'Assistance to the Crocodile Skin Industry'

It is now well over a year since the Second Conference of the Parties to CITES, and recently our thoughts have been turning toward the approaching third meeting and to the time, which cannot now be far off, when UNDP/FAO assistance is phased out, and the government of Papua New Guinea (PNG) assumes full responsibility for the long-term management of the crocodile resource.

Needless to say the project has been continually subjected to intensive and critical review by the project leaders, government departments, and by UNDP/FAO. But we are also aware of the keen interest with which the project is regarded by international conservation and wildlife organizations who, though not directly involved with the project, would understandably like to be better informed. Of course, although PNG fulfills her international obligations to CITES by providing the required trade reports, we believe that a brief, periodic appraisal of the project would not only be welcomed but would lead to a better understanding of the unique situation which prevails in Papua New Guinea with regard to the crocodile resource.

The purpose of this summary therefore is simply to offer an overview of the project, as it stands now, and to indicate what may be expected in the future.

BACKGROUND TO THE PROJECT

The national policy for management of the two species of crocodiles in PNG (Crocodylus porosus and C. novaeguineae) was formulated in the early 1970s, following the uncontrolled destruction which had taken place during the previous decade. Basically the policy seeks to:

1) Replace the indiscriminate and wasteful hunting of wild crocodiles for skins by the capture of very young crocodiles to be reared to commercial size in captivity.

2) Ensure that the village people, in whose territory the crocodiles live, are involved in and benefit, insofar as possible, from management and utilization of the resource.

3) Ensure that the resource is managed on a long-term, sustained yield basis in the natural environment.

In 1975 a law that prohibited trading in crocodile skins of more than 20 inches (51 cm) belly width was accepted by the people and became operative in every province. This was a first step in implementing the national policy in that it afforded some protection to crocodiles of breeding size. The next, and vastly more difficult step, was to establish a nationwide system of rearing pens (farms) so that a harvest of very young crocodiles (more easily sustained by the wild populations than is the loss of adult breeders) could replace the existing removal of bigger animals being hunted for skins. It was for assistance in this task especially that the government of Papua New Guinea approached the United Nations.

The UNDP/FAO project PNG/74/029 "Assistance to the Crocodile Skin Industry" was set up and commenced operations in January 1977.

PROGRESS WITH THE FARMING NETWORK

The Village Level

Perhaps the most fundamental fact that must be addressed in any policy for crocodile management in PNG is that the crocodiles belong to the people in whose territory they exist. This means that virtually all wild crocodiles are the property of rural communities, for in PNG about 98% of the land remains under traditional tenure. Any policy for management of this natural resource must therefore have the support of the people involved. It must also be accepted that many of the swampland communities have few or even no other natural resource which can be used to earn cash, and for decades crocodiles have been an important part of the economy in such localities.

In recognition of these facts it was accepted that any attempt to diminish the trade in skins would need the cooperation of large numbers of village people--many of them in very remote settlements. Consequently it was also accepted that a village capacity for rearing crocodiles would need to be established before a corresponding reduction in hunting large crocodiles for skins could be expected.

It was stated at the outset ("An Explanation of the National Policy on Crocodile Farming," Wildlife Division 1974) that the farming network would have to include technically sophisticated farms as well as simple village rearing pens. It was foreseen that village holdings would be extremely vulnerable to adverse factors such as drought, flooding, and seasonal food shortages. Nevertheless, until 1979 the main thrust of the field work was directed toward the establishment of a system of rural rearing pens ranging from tiny seasonal holdings to larger group enterprises with several hundred crocodiles each.

By the end of 1979 an enormous amount of rural training and demonstration had been conducted by government extension workers, and more than 200 village crocodile-rearing establishments had been set up. Scores of water pumps and kilometers of pipe had been installed in the villages and fishing nets had been distributed at heavily subsidized prices to those villagers needing help in obtaining food for their crocodiles. The results, in terms of crocodile growth rates and output of skins, has been disappointing, with perhaps 15% of the "farms" rearing crocodiles satisfactorily. The problems confronting simple village folk in remote settlements and with no tradition of animal husbandry are of course manifold, but two of the most intransigent problems have been the extreme seasonal fluctuations in water supply and the difficulty of obtaining an adequate supply of crocodile food in some areas. In the Sepik, in the north of PNG, the spread of the aquatic weed *Salvinia molesta* has totally prevented fishing on formerly productive lagoons.

Government Farms and Live Crocodile Buying

It became apparent that, if most of the villagers were not to lose interest in the policy of harvesting and keeping small live crocodiles, there would have to be a reliable outlet for them when, for whatever reason, people wished to dispose of young stock. To this end a buying and redistribution service was put into operation based on government crocodile farms in the two provinces (Western and East Sepik) where the need was greatest. During the period June-December 1979 about 5000 young crocodiles were purchased and redistributed under this scheme and, at government prices, the villagers averaged more than double what they would have realized on the equivalent sale of skins. There are still some 7000 crocodiles reared in village farms.

The provincial government farms, however, have been established primarily for demonstration and training in village husbandry, and they are neither suitably located nor equipped for the role of large-scale commercial rearing establishments. In fact, they are vulnerable to the same seasonal feed shortages as the adjacent villages. Clearly, the technically sophisticated farms envisaged at the outset were essential to support the change from skin-hunting to harvesting of live young crocodiles.

Large-Scale Commercial Farms

The first two large-scale farms were approved and commenced operations in mid-1979. Both are associated with large poultry farms and consequently have a reliable and inexpensive supply of crocodile feed in the form of poultry offal. They are located in Port Moresby and in Lae. A third farm, also in Port Moresby and associated with a pig farm, has been approved since then. These three farms now hold a total of 7300 crocodiles, almost all of which have been supplied at government-controlled prices through the government buying scheme.

CROCODILE REARING VERSUS SKIN HUNTING

The advantages of transferring the bulk of the annual harvest from wild-caught skins to farm-reared skins are ecological as well as economic:

1) The main harvest could be taken from the biologically most expendable portion of the wild population, i.e. the younger crocodiles which are more quickly and easily replaced in the wild and most adult breeders would be protected.

2) Because of the greater value of young live crocodiles (as opposed to small skins), the income to the villagers could be increased through a reduced harvest from the wild.

3) The existence of a large stock of captive crocodiles, including stocks in government farms, facilitates the restocking of selected areas in the wild.

4) The serious waste involved in exporting small skins could be virtually brought to a halt, and export earnings for the nation could approach the potential value of the crop of optimum size.

The benefits, as far as can be foreseen, will amply reward the effort and expense of bringing about the proposed restructuring of the skin industry. But perhaps the greatest difficulty will lie in gaining the understanding and cooperation of the villagers when the supportive and essential legislative changes have to be introduced. This point has now been reached because the capacity for farm rearing is such that the villagers need have no difficulty in keeping and/or selling enough live crocodiles under 7" (belly width = 178mm) to earn more than they can expect from the existing annual crop of skins in that size range.

Accordingly, as a first legislative step, it is now proposed to prohibit all trade in skins of less than 7 inches (178 mm) belly width. An explanation of this proposal has been printed in two local languages, as well as English, and a referendum is being conducted throughout the provinces where crocodiles are an economically significant resource.

In 1979, 43,093 skins were exported as follows:

	C. porosus	*C. novaeguineae*
Total skins	7,623	35,470
<7 inches belly width	3,382 (44.36%)	11,745(33.11%)

It will be noted that skins of less 7" belly width (i.e. from crocodiles about 96 cm or less in length) constituted a higher portion of the saltwater harvest than of the freshwater harvest. The reasons for this are not clear, but this difference indicates the significance of the proposed legislation for conservation.

HARVEST REDUCTION AND RESTOCKING

It is expected that the prohibition of trade in small skins will automatically bring about a reduction in the proportion of the wild stock being harvested, because it is more difficult to catch young crocodiles unharmed than it is to catch them by the traditional killing methods. However, the resource will be further protected against overexploitation by the existence of such a large reserve of captive animals.

In Gulf Province, localities have been selected for a trial release of *C. porosus* that have been reared to breeding size in the government's main research farm near Port Moresby. Plans are now well advanced to locate suitable sites and secure the agreement of the local people not to hunt or molest the breeding animals, nor to hold the government responsible for any damage or injury that the crocodiles may cause. The results of this restocking trial will be closely monitored. In the meantime extension workers throughout the country are encouraging villagers to leave breeding crocodiles and nests undisturbed, and there is some evidence that villagers are now realizing the past folly of collecting crocodile eggs for food.

THE MONITORING PROGRAM

Without doubt the crocodile has remained relatively plentiful in PNG because of the low human population density, the vastness of the wetland habitat, and the extraordinary difficulty of human access to some of the major nesting grounds. Had it not been for these factors, the intensive hunting of the late 50's and 60's would have had an even greater impact.

Today these same factors still operate in favor of the wild crocodile populations, but for the same reasons they present a severe practical problem when it comes to census and monitoring work. To compound the problem, both species of crocodiles are cryptic in behavior and frequently invisible from the air.

The well-tried census technique developed in other parts of the world are simply not applicable in PNG, and an experienced FAO monitoring specialist has concluded that "a monitoring system based on direct observation of wild crocodiles for the purpose of measuring population size and structure is rejected as too difficult if not impossible."

Fortunately, direct observation of wild crocodiles is not the only basis for a monitoring system, and the monitoring team is currently developing a program which will make maximum use of the statistics generated by the skin industry itself. These data will be handled by computer in Port Moresby so that an appropriate and thorough analysis will be available each year.

Field work will concentrate on recording the pattern of nesting activity in selected areas, because in both crocodile species the nests are easier (perhaps one should say less difficult) to find than are breeding crocodiles. So far monitoring field work has been most intensive in the Sepik using light, flat-bottomed boats and outboard motors, but it is considered that an acceptable level of efficiency can only be reached with the use of an air boat which has yet to be obtained. In the Sepik and elsewhere helicopter time is also considered essential, as nest surveys with fixed wing aircraft are of very limited value. The problem, of course, is one of funds but the proposals will certainly be given high priority in budgeting.

Meanwhile the policies outlined earlier will be pursued in the belief that the changes they bring about will be in the direction of lighter, more easily sustained and more profitable exploitation, with the added safeguard of a large reserve of captive crocodiles available for selective restocking programs. In future years, with feedback from an ongoing monitoring program available, it should be possible to keep management policy better tuned to the productivity of the resource. Until then, within the economic and socio-political constraints prevailing, policy will seek to err on the side of caution.

INTERNATIONAL ASSISTANCE

The UNDP/FAO programme of assistance is now in its fourth year and include 8 United Nations volunteers, 4 FAO experts, an FAO associate from West Germany, and administrative support. This international team has assisted in all aspects of the national project and is presently heavily involved in village extension work, the organization of live crocodile purchase, and redistribution and the development of the monitoring program. The Wildlife Division continues to experience institutional difficulties in the recruitment and accommodation of national officers, and it is anticipated that UNDP/FAO assistance will continue into 1981.

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CROCODILE FARM PROJECT, EDWARD RIVER, CAPE YORK, QUEENSLAND, AUSTRALIA

J. T. V. Onions

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Applied Ecology Pty Ltd is an Australian company sponsored by the Australian Government (through the Minister for Aboriginal Affairs) engaged in the field of research and development of natural resources capable of commercial development on behalf of Aboriginal and Islander communities throughout Australia. At present the company has projects associated with crocodiles (*Crocodylus porosus*), emus (*Dromaius novaehollandiae*), and tropical oysters (*Crassostrea echinata* and *C. amasa*), with several others under review for suitable communities.

The major development over the past two years at the Edward River Crocodile Farm Project has been the commencement of captive breeding and the continued development of the facilities necessary to investigate the breeding, hatching, rearing, and marketing of crocodiles (*C. porosus*) as an economic resource for the Edward River Aborigines.

Crocodile Stock Situation

The farm had a total of 647 *C. porosus* as of June 1980, which are categorized in Table 1.

Table 1.

	Age Category (Years)						
Source	0-1	1-2	2-3	3-4	4-5	5 plus	Total
Wild Caught	-	-	-	-	-	75	75
Wild Taken Eggs/ Farm Raised	90	27	132	34	18	87	388
Farm Bred and Raised	159	25	-	-	-	-	184
Totals	249	52	132	34	18	162	647

Project Projections

The goal of the project is still to produce 3000 crocodile skins per year at four years of age from 100 active breeding and nesting females. The project should also provide direct employment for at least 15 Aborigines from the Edward River Community.

Breeding Lagoon

The breeding lagoon is a "natural" mangrove and grassed area of 20 ha with a 13 ha water area when full. The area presently holds 111 females (size range 1.8 m - 3.5 m in length when originally tagged and placed in the lagoon in 1978 and 1979).

Based on female saltwater crocodiles maturing at 10 years of age and using snout-vent length as an indicator of age, we estimate that the lagoon should hold 55 sexually mature females by the end of the year 1980, and that this number will rise to 107 in 1983 and 111 in 1985.

Captive breeding performance to date has resulted in one fertile nest (5 nests made) in 1979 and 10 fertile nests (19 nests made) in 1980, giving 87% and 44% hatch respectively for the fertile nests. An average of 40 eggs (range 18-55 eggs) was recorded for all 19 nests. The low egg laying and hatch rate may indicate (1) a lack of successful fertilization, (2) animals, particularly the males, still largely immature or too disturbed to breed , and (3) the breeding lagoon does not meet the animals breeding requirements.

To investigate these matters, it is planned to study breeding in the lagoon next breeding season (October - April) to assess the breeding activity and territorial requirements of the crocodiles. In addition, sperm counts of selected males will be conducted and a series of incubator trials undertaken.

Hatchling Husbandry

The crocodile eggs are hatched, or finish their hatching, in an artificial incubator. The most suitable system is still being investigated and will form a series of trials next season. Hatchlings from the 1978 and 1979 seasons in non-controlled conditions returned survival rates of 65% and 64% at 1-year-old respectively; these relatively low levels of performance prompted the need for research in this area which will continue at least until the 1981 season.

A doctoral student, Steve Garnett from James Cook University of North Queensland, is conducting a series of trials at Edward River into hatchling husbandry, growth and nutrition, comparing foods (pig, beef, and fish [all with vitamins and calcium] and pet-food meat pellets), stock density (4, 8, 16 hatchlings per pen [1.92 m^2]), and handling (weekly or monthly). Results are as yet incomplete, though the pet-food pellets were found unacceptable; pig is giving the most consistent growth rates, and stock density at 15 weeks of age had little effect on growth rates. Survival at 15 weeks of age was 87%. For comparison, a group of hatchlings are also being raised in different conditions in an outdoor "creek system" pen using insects (attracted by light) as feed. This group has grown well with only a little supplementary feeding.

Crocodile Raising Husbandry

From six months of age the crocodiles go through a series of three pen types (one 3 m x 15 m and two types 6 m x 35 m) with a "creek" flow-through water supply systems and vegetative land cover. The crocodiles are kept, insofar as is possible, in peer-size groups, with the largest animals being moved up to the next size stage when obviously larger than their peer group. Finally, the crocodiles are kept in 2 ha enclosures until optimum skin size at 40 cm belly skin width and 1.5 m in body length (about four years of age). The creek systems are drained and swept out six times a week, whereas the enclosures are permanent water areas. The crocodiles are fed wild pig meat or fish six days a week. The system at this stage appears easy to manage with few problems evident.

Crocodile Skinning and Marketing

In June 1980, 40 farm-raised crocodiles were killed and skinned at Edward River Crocodile Farm under licence as part of a feasibility study of their marketing potential. The exercise was largely completed by the staff of Edward River Crocodile Farm, under the guidance of Mr. Brian Venables, a former crocodile skin dealer. All staff were instructed in the skinning of crocodiles, as well as the fleshing, curing, and grading of the skins. The crocodiles ranged in size from 3 feet (0.9 m) to 8 feet (2.4 m) in length. The smaller crocodile skins were used as "horn-backs" and the larger as "belly skins."

The average belly skin width was 37 cm, of which 22 were classed as first grade and 10 as second grade. The 40 skins were divided into eight replicated samples of five skins. Six of these samples were sent overseas, while ten skins were retained in Australia for tanning. This exercise, when complete, will assist in an economic evaluation and planning of the project's future development which is presently underway.

Environmental Impact Statement (EIS)

An EIS to meet the requirements of "The Environment Protection (Impact of Proposals) Act 1974-1975" has been completed and released for public review (Grant and Onions 1979).

Due to the fact that *C. porosus* is on Appendix I of CITES, the EIS only concentrated on a closed-farm system to fully meet CITES requirements rsther than possible future river management programs which were originally part of our research program for crocodile development in the Edward River area.

While the EIS is primarily concerned with the project farm area of about 32 ha and food supplies for the farm when developed, some data on the crocodile situation in the Edward River area was collected (Table 2).

Table 2. Spotlight survey of crocodiles in the Edward River area

South of the Settlement	Actual Sightings	
	*Sept/Oct 1977	Sept 1979**
Chapman River	35	15
Malaman River	21	
Coleman Creek	17	
Munkan River	29	17
Edward River (Breakfast & Christmas Creeks)	26	
Total Sightings	128	
Sightings plus 50%***	192	

* All but three crocodiles estimated to be 1.5 m in length or larger

** Incomplete Survey

*** Number of animals sighted dependent on the state of the tide, moon phase and the total area that could be covered by a 14' dinghy. Allowing for these factors an additional 50% in total numbers present is not unreasonable.

Obviously it is unwise to make anything other than a general observation from this limited data. However, the estimate of 192 crocodiles in 1977 for the survey area of approximately 100 km of tidal wetlands is in excess of Webb's (1978) average density for Queensland of 1.0 crocodile/km. This higher figure may be due largely to the fact that 645 juveniles were released in 1973 in the area by the then Australian National University Applied Ecology Unit.

Some 51 crocodiles (21 males and 30 females) were taken in 1978 and 1979 under permit to stock the breeding lagoon; these ranged in size from 1.8 to 4.95 m in length. More than half of these animals were identified as recaptures of crocodiles previously released. In addition, 14 crocodiles of 1.5 m or greater in length are known to have drowned in fishing nets in the area in the past two years (R. Bredl pers. comm.).

A total of eight nests have been taken under license from the wild over the past two years; 1980 was the last season it is planned to take from the wild. The effects of removing the eggs from the wild is likely to be small when is given to consideration the fact that many of these would have been lost due to flooding. Webb (1978) stated that the area between the Mitchell and Holroyd Rivers (which incorporates the Company's collecting area) is subject to heavy wet season flooding, and thus there is limited chance of successful natural recruitment in *C. porosus* populations.

Technical, Economic, and Social Review

The project is presently the subject of a detailed technical, economic, and social review to plan future research, development, management, and training needs of the project as an eventual Edward River Aboriginal Community controlled and managed venture. The initial study and report is scheduled to be completed in late 1980.

Future Research and Development

The major research effort of the project for the next couple of years will concentrate on:

1) Incubation and hatchling management and nutrition.
2) Crocodile fertility, breeding and breeding lagoon management.
3) Dry season water management and water quality monitoring.

The Edward River Crocodile Farm Development will concentrate on:

a) Continued construction of pens and enclosures.
b) Aboriginal training.
c) The development of management strategies to meet the projects particular needs as a future Aboriginal Community Enterprise.

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AN UPDATE OF CROCODILIAN BREEDING IN UNITED STATES ZOOS

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INTRODUCTION

During the last decade the major emphasis of most large zoo reptile collections in the United States haa evolved from merely housing numbers of single or unpaired representative species for exhibit to the practice of establishing breeding groups of rare and endangered varieties, either on or off exhibit to the general public. Zoo personnel have become aware that the only chance for future acquisition of many species will most probably result from captive breeding rather than from specimens taken from nature. This may be particularly true for crocodilians because of their endangered status and existing wildlife regulations. It is our feeling, therefore, that the captive breeding of crocodilians as well as other reptile groups, has a definite value and an established place in the overall goals of animal conservation, if for no other reason than to assure a supply of specimens for public exhibition and educational and research purposes.

Honegger (1971) presented the first overview of the crocodilian situation in zoological gardens. This report was updated (Honegger 1973) and reports on stocks and breeding from European zoos (Honegger 1975) and from those of the United States (King and Dobbs 1975) followed. This paper gives an update on captive breeding of crocodilians in United States zoos from 1976 through 1979, as well as current information on numbers and breeding potentials of those species maintained in these institutions. Comments are made on the few consistently successful programs. A brief discussion of some of the factors that must be considered by zoos attempting to establish breeding programs is included.

METHODS

The information contained in this report was taken in part from a compilation of more than 50 United States institutional inventories by Slavens (1980). Those zoological parks known to house crocodilians that were not included in Slaven's survey were personally contacted and their inventories added to the results. As mentioned in earlier reports (Honegger 1975; King and Dobbs 1975) survey response was usually incomplete and animal inventories can vary on a day to day or seasonal basis. Additionally, surveys of this nature must rely for the most part on published information for breeding records. To date, the only reasonably reliable source has been the International Zoo Yearbook, either from specific articles dealing with reproduction or from lists of reported breedings located in most recent volumes. In a published list of herpetological titles from the IZY (Tryon 1979) from its inception in 1959 through 1978, only 19 articles have dealt exclusively with crocodilian husbandry and breeding. The lists of reported breedings are less reliable. We personally know of instances where offspring from wild-caught gravid females or egg clutches found in nature have been recorded, probably intentionally, as having been captive-bred. An additional published source of information has been the Newsletter of the American Association of Zoological Parks and Aquariums, where births and hatchings are reported on a monthly basis. These reports are also biased, as some institutions still refuse to make their records available in published form. The problems of sexing and species identification have not improved in spite of available publications (Brazaitis 1969, 1973). Therefore, the information contained in the present report cannot be considered more than an approximation of the current status of crocodilian numbers and breeding potentials.

RESULTS AND DISCUSSIONS

Animal Numbers

Table 1 gives specimen numbers of crocodilians reportedly housed in United States collections. In most cases subspecific names are not used because proper identification could not be determined by reporting institutions. Numbers of known males, females, and unsexed individuals are listed as, for example, *Alligator mississippiensis*, 61 males/38 females/463 unsexed specimens. As expected, *A. mississippiensis* is held in greatest numbers, with a very conservative figure of 563. Substantial figures exist for *Caiman crocodilus crocodilus* (78), *Osteolaemus tetraspis* (75), *Caiman crocodilus yacare* (71), and *Crocodylus moreletii* (62). It is should be noted, however, that these species are bred consistently by one or more institutions (Table 2), and a large percentage of these figures are comprised of hatchling and juvenile age classes. For example, in 1979, the Fort Worth (Texas) Zoo held 36 hatchling and juvenile O. tetraspis, and most of the unsexed C. moreletii were housed at the Atlanta (Georgia) Zoo. With the exception of Caiman crocodilus ssp. (32), all other varieties exist in numbers of 24 (Crocodylus acutus) or less. Nine species number 10 or fewer individuals: Alligator sinensis 8, Caiman crocodilus apaporiensis 3 (misidentification possible, see King and Dobbs 1975), Caiman latirostris 2, Paleosuchus palpebrosus 10, Crocodylus cataphractus 8, C. intermedius 5, C. johnsoni 9, C. palustris 10 and Gavialis gangeticus 2. Every effort should be made to ensure the establishment of breeding situations for these species.

Breeding Potential

Table 1 gives the breeding potential as yes or no, determined by whether or not at least one known sexual pair is housed in the same institution. Again, A. mississippiensis tops the list with 18 of 35 holding institutions reporting at least one sexual pair. Good potential exists for Caiman crocodilus yacare (5 zoos), Crocodylus rhombifer (4 zoos), Osteolaemus tetraspis (7 zoos), and Tomistoma schlegeli (4 zoos). Of the above, only T. schlegeli has not been successfully bred in a United States zoo.

Seven varieties now have breeding potential in only one institution (Alligator sinensis, Caiman crocodilus fuscus, Crocodylus cataphractus, C. intermedius, C. johnsoni, C. novaeguineae, and C. palustris). No known potential exists for Caiman crocodilus apaporiensis, C. latirostris, Paleosuchus palpebrosus, and Gavialis gangeticus. For these, breeding agreements must be established between institutions or individuals housing single or same sex specimens. Breeding potential in most cases is probably better than indicated herein because of the difficulty in sexing juvenile specimens.

Breeding Success

Behler (1978) summarized captive breedings as reported in available literature from 1960 to 1975. During these years, only four species were reported as having been reproduced in United States zoos. These were Alligator mississippiensis (24 breedings), Caiman crocodilus (10 breedings), Crocodylus acutus (2 breedings) and C. morelitii (6 breedings), for a total of 42 breedings in that 15-year period. It is of note that all breedings of C. acutus and C. moreletii during this time occurred at one institution, Atlanta, Georgia.
Table 2 summarizes successful captive breedings from 1976 to 1979 and indicates successful hatchings that have occurred at the time of this writing in 1980. Immediately evident is the fact that not only is there an increase in numbers of species bred, but that more institutions have been successful with at least one species. During this 4-year period, 44 successful hatchings occurred, with 4 species produced in 1976, 4 in 1977, 8 in 1978, and 9 in 1979. Although many of these have been one time breedings, they do demonstrate a potential

TABLE 1. Stocks, sex ratios, and breeding potential of crocodilians housed in United States zoos.

Species	Sex Ratio ♂/♀/Unknown Sex	Holding Institutions	Breeding Potential	Number of Zoos
Alligator mississippiensis	61/38/463	35	yes	18
Alligator sinensis	1/4/3	1	yes	1
Caiman crocodilus ssp.	3/4/25	11	yes	1
Caiman c. apaporiensis	2/0/1	3	no	--
Caiman c. crocodilus	1/1/76	7	yes	2
Caiman c. fuscus	1/1/17	6	yes	1
Caiman c. yacare	14/12/45	12	yes	5
Caiman latirostris	2/0/0	1	no	--
Melanosuchus niger	6/2/3	5	yea	3
Paleosuchus palpebrosus	4/2/4	6	no	--
Paleosuchus trigonatus	5/5/6	6	yes	3
Crocodylus acutus	7/7/10	10	yes	2
Crocodylus cataphractus	4/2/2	3	yes	1
Crocodylus intermedius	3/2/0	2	yes	1
Crocodylus johnsoni	5/2/2	4	yes	1
Crocodylus moreletii	10/20/32	6	yes	2
Crocodylus niloticus	7/9/8	6	yes	3
Crocodylus novaeguineae	8/3/1	4	yes	1
Crocodylus palustris	5/4/1	4	yes	1
Crocodylus porosus	5/4/3	6	yes	2
Crocodylus rhombifer	4/10/3	5	yes	4
Crocodylus siamensis	10/9/3	7	yes	5
Osteolaemus tetraspis	18/10/47	17	yes	7
Tomistoma schlegeli	10/5/3	7	yes	4
Gavialis gangeticus	1/1/0	2	no	--

Table 2. Crocodilian varieties successfully bred in United States zoos, 1976-1979. * indicates successful hatching in August 1980.

Species	Institution	Year(s)
Alligator mississippiensis	Fresno Zoo, California	1978, 1979
	San Diego Zoo, California	1978
	Jacksonville Zoo, Florida	1976
	Busch Gardens, Tampa, Florida	1976
	Honolulu Zoo, Hawaii	1979
	Monroe Zoo, Louisiana	1976, 1977
	Jackson Zoo, Mississippi	1976, 1978, 1979
	Tulsa Zoo, Oklahoma	1977, 1978
	Fort Worth Zoo, Texas	1976, 1978
	Houston Zoo, Texas	1976, 1977
Alligator sinensis	Bronx Zoo, New York	1977
	Rockefeller Refuge, Louisiana	1979, 1980*
Caiman crocodilus fuscus	San Antonio Zoo, Texas	1976, 1978, 1979
Caiman crocodilus yacare	California Alligator Farm, Buena Park	1978
	Fort Worth Zoo, Texas	1977, 1978, 1979
Paleosuchus trigonatus	Cincinnati Zoo, Ohio	1979
Crocodylus intermedius	Dade County Zoo, Florida	1980*
Crocodylus moreletii	Atlanta Zoo, Georgia	1976, 1977, 1978, 1979, 1980*
Crocodylus niloticus	Busch Gardens, Tampa, Florida	1979, 1980*
Crocodylus rhombifer	California Alligator Farm, Buena Park	1978
	Bronx Zoo, New York	1979 (died at pipping)
Crocodylus siamensis	Dade County Zoo, Florida	1978
Osteolaemus tetraspis	Memphis Zoo, Tennessee	1976, 1977, 1978, 1979
	Fort Worth Zoo, Texas	1976, 1977, 1978, 1979
	Seattle Zoo, Washington	1977, 1978, 1979

for continued success and perhaps indicate an awareness that success is possible when correct husbandry techniques are utilized.

In recent years there have been few consistently successful breeding programs for crocodilians. Foremost is the Atlanta Zoo with their program for Crocodylus moreletii (Hunt 1973, 1975, 1977, 1980). Others include the Fort Worth Zoo for Osteolaemus tetraspis (Tryon 1980) and Caiman crocodilus yacare, the Memphis Zoo for O. tetraspis (Beck 1978), the Seattle Zoo for O. tetraspis, and the San Antonio Zoo for Caiman crocodilus fuscus. From records available in 1980, viable programs may be established for Alligator sinensis (Bronx Zoo-Rockefeller Wildlife Refuge), Crocodylus niloticus (Busch Gardens, Florida), and C. siamensis (Dade County Zoo, Florida). For most others a prediction would be premature because single breedings do not necessarily indicate a level of success.

Previous accounts of zoo crocodilian breeding (Honegger 1975; King and Dobbs 1975; Tryon 1980) have stressed the husbandry factors that should be considered in order to establish a successful program. Whereas in the past most breedings have been a matter of luck rather than careful planning, those consistently successful programs listed above have incorporated a number of general maintenance factors that should be, but are not necessarily commonplace in any modern zoo. Foremost, these zoos have begun concentrating on one or more varieties of crocodilians (depending on facilities) and have established species-specific groups per enclosure. It is now uncommon, as opposed to just five years ago, to find large numbers of a variety of species housed together. Although these large aggregations of animals provided for popular exhibits, breeding of any kind was minimal or non-existent.

Within specific breeding groups, attention has been focused upon the elaborate social behaviors exhibited by crocodilians. Hunt (1975) and Tryon (1980), for example, found it impossible to house two sexually mature male Crocodylus moreletii and Osteolaemus tetraspis, together with females without agonistic behavior resulting in injury to one or both males. Agonistic behavior must be considered in any carefully planned program, and more than one breeding enclosure per species may provide an additional measure of success. Females must be given adequate nesting areas supplied with appropriate nesting materials. Quite unbelievably, some zoo personnel still fail to realize this, and as a result eggs are damaged, eaten or laid in pools before they can be recovered. A review of the literature on crocodilian breeding will reveal a multitude of techniques for artifical egg incubation. These range from primitive to sophisticated and show varying degrees of success. We suggest the simple technique of using a vermiculite substrate (Tryon 1975) which has proven exceptional. Hatching rates for fertile eggs have been close to 100 percent, not only for crocodilians but for other reptiles as well. Since temperature-dependent sex determination is common in turtles and has been recently reported in the American alligator (Bull 1980), incubation temperature manipulation could become a major management tool for reptile breeding programs.

Infertility has been a major problem in many zoo programs. If high rates of infertility occur, the diet of the breeding specimens should be examined. When a diet composed largely or exclusively of frozen and thawed fish was given to C. moreletii in Atlanta (Hunt 1973) and A. mississippiensis in Fort Worth, high infertility rates existed for both. A dietary shift to rodents and fowl brought about increased fertility in the eggs of both species. The A. mississippiensis housed in an outdoor enclosure at the Houston (Texas) Zoo have produced several clutches of eggs in consecutive years with a fertility rate of approximately 1 percent. These specimens are given a diet composed entirely of thawed fish. To date a dietary shift has purposely not been attempted but would most likely result in increased fertility rates. Frozen fish should not be utilized, and crocodilian diets including fresh rough fishes should be supplemented with rodents or fowl.

CONCLUSION

Because successful breeding programs began for the most part as a matter of luck rather than planning, certain important factors were not initially considered. Before plunging headlong into a breeding program for any crocodilian, the following questions must be answered. First, what facilities are available which are suitable for crocodilian reproduction? In order for the facility to be suitable, it must be of adequate size in both pool and land area (King and Dobbs 1975); it must provide areas for seclusion, basking, and nesting; and it must be capable of maintaining the proper ambient conditions for temperate or tropical forms. If the program is successful, what facilities are available for the hatchlings? Are these merely holding areas, or will they be suitable as the animals double and triple in size? Most institutions have discovered that they cannot maintain large numbers of any species, and therefore perhaps the most important question of all is what can be done with the offspring? A few specimens may be retained in order to expand the program, but most will have to be transferred to other institutions or individuals interested in establishing additional breeding groups. In late 1979, the United States Fish and Wildlife Service eased restrictions on captive-bred endangered species born in the United States, reducing these from Appendix I to Appendix II, and therefore permission to transport within the United States has been simplified and is less time consuming. The implementation of these regulations was a real boost to zoological institutions.

Recently, the possibility of restocking natural areas with captive-bred crocodilians has received attention. Before this can become a reality, historical and genetic information must be obtained. The origin of most zoo specimens is unfortunately in doubt, and therefore a real concern for gene pools must be expressed before restocking can be considered. Other considerations are transmission of disease, inability of the captive-bred specimens to acclimate, and political or anti-conservationist activities within the natural range of the species.

At the very least, captive breeding programs can assure continued survival of a species in captivity. The potential educational value of captive crocodilians is undeniable and, if properly presented, may impress the general public into an increased awareness of the importance of conservation programs and practices. Zoological institutions can no longer afford to be consumers of wildlife, and it would seem a legitimate goal of any zoo to move toward the establishment of a collection comprised largely of captive-bred specimens.

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REVIEW OF CROCODILE MANAGEMENT OPTIONS AND PRACTICES IN ASIA

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ASIA

Iran (*Crocodylus palustris*)

Though totally protected by law, the small population is threatened. It would be desirable to suggest a management/conservation scheme to the Iranian government consisting of (a) survey, (b) egg collection/rearing/release, (c) protection of suitable habitats, and possibly (d) development of commercial interest in meat and hides once the species is considered numerous and viable enough.

Pakistan (*C. palustris*, *Gavialis gangeticus*)

Both species receive partial protection but their depleted state warrants urgent action. The program suggested for Iran would be applicable to Pakistan. Small populations of both species could exist in sanctuaries now being proposed, but the prevailing attitude is that crocodiles compete with man for fish. There is thus an urgent need for education and development of commercial interest in crocodiles and recognition of their ecological value.

India (*C. palustris*, *C. porosus*, *G. gangeticus*)

The survey/egg collection/rearing/release/research program devised by H. R. Bustard of the Food and Agriculture Organization and implemented by the forest departments of various states is an unqualified success. Public education and involvement of local people at every level of the various projects will hopefully ensure sustained success. These projects provide an excellent model for countries with similar situations (i.e. drastically depleted crocodilian populations and heavy human pressure on the environment).

Sri Lanka (C. palustris, C. porosus)

Both species receive protection but are being pressured in several districts because of (a) lack of protection in the field and (b) lack of interest in crocodiles as a resource by local people. The populations of C. palustris in the two large national parks (Wilpattu, Yala) should ensure survival of this species, but both C. palustris and C. porosus outside the parks will continue to be depleted. A detailed survey and study of the biology of the two species is recommended on the basis of which a management plan for controlled commercial utilization can be drawn up. If the plan were based on royalties payable to villagers under whose jurisdiction the habitat lies, it would provide an incentive to protect the crocodile as a resource. Current uncontrolled illegal exploitation for meat is carried on by itinerant fisherman. There is considerable scope for a large scale commercial crocodile farm based on egg collection, royalties to villagers, and release of a percentage of the offspring, as occurs in the Zimbabwe model.

Nepal (C. palustris, G. gangeticus)

Egg collection and rearing of young gharial is in progress at Royal Chitwan National Park, with releases in the Rapti and Narayani rivers. While both species are assured of protection within the park, survival outside this protected area may depend on developing controlled commercial interest among river dwellers and fishermen, using seed stock from the rearing scheme of Chitwan.

Bhutan (G. gangeticus?)

A farming scheme has been recommended by FAO consultant H. R. Bustard. Stock from India or Nepal could be used and a wild breeding stock established in the Manas River (National Park), the only suitable habitat in the country.

Bangladesh (C. palustris, C. porosus, G. gangeticus)

Similar to the Indian situation, development of crocodiles as an economic and ecological resource would appear to be the best option. While muggers are no longer seen and gharial are fewer than 10, the saltwater crocodile is apparently not uncommon in the Sunderbans. A well organized egg collection and breeding scheme could be not only commercially viable but also help rehabilitate the wild populations. Suitable habitat needs to be protected.

Burma (*C. porosus*)

There is currently interest in village crocodile farming similar to the Papua New Guinea network. Accordingly three delegates of the Burmese Government visited PNG this year. It is important to emphasize that this approach is workable only as a network: village rearing pens as a basis of the rural aspect of the industry and large commercial farms (abbattoir based) to supply expertise and materials and to act as buffers in times of drought and food scarcity. Habitat is being lost to agricultural (rice) development.

Thailand (*C. porosus*, *C. siamensis*, *Tomistoma schlegeli*)

There has been little government action on crocodile management but the well known Samut Prakan Crocodile Farm has been breeding *C. porosus* and *C. siamensis* for a number of years. While they have allowed hybridization, the proprietors maintain that they have large breeding stocks of pure species. In the early 1970's the proprietor offered to restock depleted areas in Thailand once government protection of habitat was assured. This generous offer should be considered on the basis of a survey of suitable habitat and a management plan for initial rehabilitation and, later, a controlled harvest of wild stock. Initial emphasis should encourage breeding and rehabilitation of the rare *Tomistoma schlegeli* and *C. siamensis*. Tourist interest in the Samut Prakan farm suggests that observable populations of crocodiles in national parks would increase visitor attendence.

Kampuchea (*C. porosus*, *C. siamensis*)

Developing crocodiles as a village level resource for meat and skins based on survey work appears to be the best option in the absence of data on the status of the species there.

Vietnam (*C. porosus*, *C. siamensis*)

Same as above.

Laos (*C. porosus*, *C. siamensis*)

Save as above.

China (*C. porosus*, *Alligator sinensis*)

The chinese alligator has apparently been protected since 1958. Dr. Huang Chu-Chien of the Peking Institute of Science is working on the initiation of studies on the ecology and evolution of the species "to establish growing sites and to protect and develop this valuable wildlife resource" (see article this volume). *C. porosus* apparently still exists in small numbers in Kwangtung Province. Following initial surveys and studies, management should first consist of ensuring species survival with possibly a future commercial use. The limited available habitat is a particularly important consideration.

Malaysia (including Sarawak and Sabah) (*C. porosus*, *C. siamensis*, *Tomistoma schlegeli*)

Protection of the three species exists in some areas, but no management of the populations has been implemented. At present the urgent need is for distribution and status surveys followed by conservation management. As Malaysia has had a recent history of small rearing stations, a controlled harvest of young crocodiles for commercial rearing would be a logical approach, if breeding adults still survive in the wild and a percentage of the young are returned to the wild. In Sabah a private farm near Sandakan is rearing about 800 crocodiles, and the proprietor is interested in captive breeding. While creating a controlled commercial management policy on crocodiles, government and/or private efforts towards rehabilitation of the rare *T. schlegeli* and *C. siamensis* should receive priority.

Brunei (*C. porosus*, *T. schlegeli*)

Same as above.

Indonesia (*C. porosus*, *C. siamensis*, *C. novaeguineae*, *T. schlegeli*)

Crocodiles are on the protected list, but exploitation continues to be heavy. In the past, in addition to adults killed for skins, large numbers of young crocodiles were sent to rearing stations in Singapore. It is suggested that Indonesia model a crocodile management program on the PNG farming network, protecting the wild breeding stock and collecting young for rearing and/or supply to large commercial farms. An FAO consultant recently made a survey of the crocodile industry in Irian Jaya; his recommendations are along the above lines.

Philippines (*C. porosus*, *C. n. mindorensis*)

While very little is known about the crocodiles in the Philippines, they are known from several localities in the islands. At present there is an urgent need for a status survey and study, a job now being undertaken by C. A. Ross of the Smithsonian Institution. Based on his findings it will hopefully be possible to identify populations which can be protected and serve as restocking nuclei for the future. The Philippine Government can be made aware of the pressure on the two species of crocodiles and the scientific and ecological value of protecting them. In the long term though, it seems that the eventual controlled exploitation will be a key to gaining significant official involvement in crocodile conservation.

OCEANIA

Papua New Guinea (*C. porosus*, *C. novaeguineae*)

A decade-old crocodile management program is underway and now consists of a rearing farm network of 200 village, 6 government, and 3 commercial farms with over 20,000 crocodiles being reared for skins. Killing of wild crocodiles for skins is to be gradually phased out in favor of capturing of young crocodiles for rearing. The major conservation measure has been protection of a large segment of the wild breeding stock by a law prohibiting the trade in skins over 20" (51 cm) in belly width (equivalent to animals of about 2 m total length). A law prohibiting trade in skins under 7" (18 cm) belly width was recently passed. UNDP/FAO involvement since 1977 has aided village extension work, and technical inputs include the recent formulation of a population monitoring program.

Solomon Islands (*C. porosus*)

Crocodiles are partially protected (see "Status of Asian Crocodiles" in this volume). Though feared by most people, crocodiles could become a valuable resource to villagers interested in rearing them or capturing the young for sale to a commercial farm. Several villagers are in fact rearing small crocodiles. Legislation consistent with neighboring PNG's laws is essential, and technical assistance in a program along the lines of the PNG network is recommended. Tourist viewing of the wild crocodiles could provide another source of income to local villagers.

Western Caroline Islands (Palau) (*C. porosus*)

Though data are lacking, it is reported that islanders have considerable antipathy toward large numbers of crocodiles though a small population is tolerated. A preliminary survey is urgently recommended, and the economic and ecological value of crocodiles needs to be demonstrated to local people.

New Hebrides (*C. porosus*)

Same as above.

SIMULATED POPULATION DYNAMICS OF CROCODILES IN THE OKAVANGO RIVER, BOTSWANA

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ABSTRACT: Growth of the *Crocodylus niloticus* population in the Okavango River, Botswana, and the effects of predation and flooding on eggs, of cannibalism during drought, and of hunting were simulated. Predation on eggs and flooding of nests were significant limiting factors. After growth the population began oscillating around 21,000 in 130-140 years. The nesting female cohort began oscillating around 1400 in 112 years. Tested hunting schemes lowered the population to 1400-2000, and the nesting female cohort to 50-100. Commercially profitable hunting rates appeared unfeasible; egg collection and captive rearing appeared to be a viable management alternative.

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INTRODUCTION

A computer simulation of the population dynamics of the Nile crocodile (Crocodylus niloticus) in the Okavango River, Botswana, began in 1975. We first attempted to find how much time the total population and the nesting female cohort required to reach the numbers believed to have existed prior to 1957, when intensive hunting began. Effects on the population of varied water levels, which would influence hatch and cannibalism on 0-2-year-old animals, of predation on eggs, and of simulated hunting (for skins) were also investigated.

Commercial exploitation, on a sustained-yield basis, is viewed as a motivating force in crocodile conservation. Simulated hunting severely reduced the population, though far below rates considered commercially profitable. It appears that the main method of commercial exploitation is captive rearing from collected eggs.

The crocodiles were overexploited by commercial hunters in the past (see Table 1), but now appear to be recovering in numbers (Graham 1976). S. M. Lurie and Co. (Pty.) Ltd. and B. Wilmot took an estimated 18,900 crocodiles. Of this take, the total of sexually mature females was estimated as, rounded off, 3,200. S. M. Lurie and Co. contributed 1222 and B. Wilmot 1941. Both contributions are based on actual or assumed takes (Table 1), and the roughly 1:1 sex ratio from the kill in 1974-75, which concurs with that of Taylor (1973) and from other areas (Cott 1961, Graham 1968). According to S M. Lurie (1975, pers. comm.) their crocodiles averaged 3 m long in the first year, so all 1000 females were considered sexually mature. In the subsequent two years, the remaining 160 and 62 mature females are guesses (= 40% and 24.8% of total number taken) because the average length for the first of these offtakes can be roughly calculated, from waist measurements, at 2.4 m. B. Wilmot's contribution results from summed values of a curve (Fig. 1) that begins in 1957 at 600 (1/2 of assumed annual take) and drops at the same rate as the numbers in S. M. Lurie and Co.'s kill, to a final value of 60 in 1969.

The senior author began field work in early 1974 in connection with a hunting concession obtained by Botswana Game Industries (Pty.) Ltd. (hereinafter BGI), and concluded in mid-1976. The population had a high percentage of individuals under 120 cm long, which is attributable to the heavy hunting (Bustard 1970, Cott 1961, Pooley 1973a). Viability rates and hatching rates of eggs were 76.4% (concurs with Blake 1974, Blake and Loveridge 1975, and Pooley 1969) and 54.6%, respectively (Blomberg 1977). The monitor lizard (Varanus niloticus) was the important extrinsic cause of egg mortality, and therefore of nesting failure (Blomberg 1977).

The study area (Fig. 2), BGI's former concession area, begins at the Namibian border and includes roughly the upper 30 km of the delta. The area includes roughly 2740 km^2, of which 2350 km^2 consist of marsh, river channels, and lagoons. In the southeast is an area of 390 km^2, most of which is flooded intermittently. Within the marsh are numerous banks and islands which, depending on height, are regularly, irregularly, or perhaps rarely flooded, but their total area at any season is unknown.

Average daily low and high temperatures during the cold season (15 May-15 August) are 8.8°C and 24.0°C and during April and September through December are 16.3°C and 29.2°C. Averages for the seasons are based on 18 and 25 dates, respectively, chosen at random, from records at the weather station in Shakawe, in 1974. Water temperatures ranged from 19°C to 29.5°C. The rainy season begins in October and ends in April and results from rains in the Angola highlands (Earnest 1977), where the Okavango River begins. Eggs on the Okavango River hatch in late December and January, when the water is rising (Blomberg 1977). Simulated flooding of eggs represents unusually early rises in the water level.

METHODS

Pertinent functions of the computer program (see Appendix) described below are derived from the limited data available, sometimes by extrapolation.

Function "F1" (Fig. 3) estimates the percentage of egg mortality due to prematurely high water levels. Its shape is justified by the fact that 68% of the nests will be between 0.8 and 1.8 m above water in normal seasons (mean $\pm$ 1 standard deviation = 1.3 $\pm$ 0.5), as determined by measurements in the field. Function "F2" (Fig. 4) estimates the percent of egg loss caused by monitor lizard predation. The shape of the function is based solely on two data points: apparent lack of nest predation on the 40 nests in 1974 and predation on 23% of 82 nests in 1975 (Blomberg 1977). The difference in nest numbers for the two seasons was real. Additional justification for the general shape of the function is the density-dependent nature of predation in general (Emmel 1973). The predation rate for 1975 may have been somewhat lower if visits to nests could have been very brief or not undertaken, however. The reason is that females tend to leave the nests unguarded if human visits last about 30 min (Graham et al. 1976). The maximum predation rate was set at 28%, which seems reasonable, considering that 20% of nests were robbed at Ndumu (Republic of South Africa) where density was low (Pooley 1969), and 33.8% (Pooley 1969) and 49.4% (Pooley 1973b) at Lake St. Lucia where nest density is high. Nest density was low along the Okavango River.

In their first 3 years, the young crocodiles are susceptible to cannibalism by older crocodiles (Blake 1974, Cott 1971, Pooley 1969). Graham (1968) implied that nearly all young around North and Central Islands in Lake Turkana might be cannibalized, due to the virtual lack of shelter. While we lacked field data on rates of cannibalism and knowledge of its impact on the crocodile population on the Okavango River, we believed that at low water levels the young crocodiles would be forced into the main channels. There they would fall prey in large numbers to older individuals. During floods it is believed that the cannibalism rate will markedly decrease due to formation of extensive sheltered areas. We used an entirely hypothetical approach, namely "F3M1" (Fig. 5). It is a simplified adaptation from Nichols et al. (1976) which computes from a given water level a corresponding multiplier effect on the assumed normal cannibalism rate of 6%. We used the same value (4.65) that Nichols et al. (1976) used for severe drought cannibalism, in F3M1, though for a water level of -1.3 m, hence the slope of F3M1 is only half that of Nichols et al.'s (1976) multiplier function. A multiplier function of some type seems justified in view of the density-dependent nature of predation (Emmel 1973).

Function "PSURV" (Fig. 6) represents the probability of survival from age 0 to age 65. The maximum age span approximates that hypothesized by Graham (1968). For the first four age classes, the increasing portion of the curve is based on derived population structure and thereafter is hypothetical. We assigned ages to lengths based on the growth curve for one free-living specimen in Zimbabwe (reported in Cott 1961 and Graham 1968). More recent calculations show that PSURV gives an individual crocodile a 2% probability of survival to age 20. As the chance of survival to reproductive age is believed to be 1-5% (Blake and Loveridge 1975), PSURV seems realistic.

Function "PERBRD" (Fig. 7) was used to determine the percentage of nesting females for each age class. The earliest a female can mature sexually is age 10 (Cott 1961). By age 37 (length = 290 cm, based on the free-living specimen in Zimbabwe) all females are believed mature, and two-thirds of these will nest in any one year (see Fig. 18 in Cott 1961).

Function "CLUTCH" (Fig. 8) shows the cube root of clutch size (Graham 1968) in relation to the age of the crocodile. (Of course, the cube of CLUTCH is used to calculate the clutch size in the model.) This function is also adapted from Cott (1961).

A condensed flow chart (Fig. 9) shows the general structure of the crocodile population model. It is annotated by the comment cards of the computer program (Appendix) to facilitate understanding of the latter. (The program is written in FORTRAN 4.)

The initial population estimate (for 1975) was made as follows. It was first assumed that BGI's kill of sexually mature females was not intense enough to get the more remote nesting portion, but only that portion which did not nest and which numbered 11. An unbiased sampling of the sexually mature females would have numbered 33, assuming that two-thirds of the mature females nested that year. Thirty-three sexually mature females would increment the female kill, by 22, to 220, of which these 33 females constitute 15.0%. It is then assumed that there were 123 sexually mature females in the population (two-thirds of which were the 82 known nesters) in 1975, and that these 123 females likewise constituted 15.0% of the huntable females (at least 120 cm long). The huntable females in the population would therefore number 820. The huntable cohort, as determined by repeated night counts, constituted 17.0% of the entire population. By use of this percentage the entire female cohort in the study area should equal 4824, and because of the 1:1 sex ratio the entire population is estimated at 9648. We arbitrarily raised this estimate to 9730, an inconsequential 0.8%, to get the numbers of unhuntable crocodiles (under 120 cm) to better fit the structure of the rest of the population, as determined by length-frequency data in the kill.

When hunting was simulated (Fig. 9), a minimum number of huntable crocodiles in the population, below which no hunting could take place, was set. Three minimum numbers used were 300, 400, and 500. Efficiencies, intended to approximately bracket the effectiveness of the hunter on the available animals, were varied at 30%, 40%, and 50%. The minimum number and the efficiency remained constant in any one simulation. Huntable crocodiles in our program were 120-190 cm long, based on current hide prices and the paucity of adults (Graham 1977), and corresponded with 2- to 4-year-old males and 3- to 6-year-old females.

After specification and calculation of a number of variables, the program began its main do loop, consisting of 300 iterations, each of which represented one year. In each iteration, reproduction, growth of the population, and limiting factors, were simulated as follows. If hunting were simulated the do loop began with initialization of a few additional variables.

Weather, because of its effect on water levels, was considered an important influence on survival of eggs and young. A variable, KK, representing water level and ranging from 1 to 10, was obtained by a random number generator. The variable corresponded to the type and severity of water levels (see Fig. 10). Only one of the three possible types of water levels, i. e. premature flood, drought, or normal, could exist in a given year, and these types were represented by values of 2, 1, and 0 respectively, for FLAG, a water level index on which certain decisions in the program were based. The distribution of KK was based on the probability of a drought equal to 0.4, and probabilities of flood and normal levels equal to 0.3 each. In case of flood, function subprogram TABLIE, which calculated consequent egg mortality (F1), was called.

The number of eggs laid depended on the percentage of sexually mature females that actually nested (PERBRD), and the clutch size (CLUTCH), both of which depended on age of the female. Next function subprogram TABEXE, which determined monitor lizard predation on eggs (F2), was called. The simulated hatch of eggs was reduced by premature flooding, when it occurred, and by monitor lizard predation. It was further reduced by a minor extrinsic factor (constant, 0.072) which summed up effects of occasional heavy rain, abandonment of nest, and death of the female, as recorded by Blomberg (1977). The hatch was also reduced by an intrinsic mortality factor (constant, 0.236) which included primarily infertility, also death of the embryo, as observed by Blomberg (1977). The simulated hatch was divided by 2, to produce equal numbers of female and male hatchlings. A separate hatch of males was calculated when hunting was simulated, as age classes of hunted males differed from those of hunted females, due to differential growth rates. (Without simulated hunting the program primarily followed female numbers.) Each age class was then advanced by a year, to give place to the hatchlings in the population. This was done with an array intechange procedure.

Next, if hunting were simulated, the huntable male and female cohorts were calculated from several age classes. The kill of males and females, and total kill, were then obtained. Lastly the cumulative harvest for the year was printed.

If the water level index (FLAG) was not 0, i. e. drought or premature flood occurred, the value of the multiplier that affected cannibalism, F3M1, exceeded or fell below 1, respectively. The actual value of F3M1 was obtained by again calling function subprogram TABLIE. If FLAG equalled 0 however, F3M1 equalled 1, and TABLIE was bypassed. The 0- to 2-year-old crocodiles were subjected to cannibalism by 19- to 65-year-old males and 37- to 65-year-old females; the age difference was due to the males' greater growth rate, yielding an average length of 1.12 times the length of the females in any given age class (see Graham 1968 for probable age classes). In our program, 19-year-old males and 37-year-old females had attained a length of 290 cm. This was chosen as a minimum length of cannibals, because Cott (1961) recorded only 2 of 17 cannibals as under 300 cm long. The predation on the young crocodiles was dependent on the number of cannibals, F3M1, a density factor (M2) of 0- to 2-year-old crocodiles, and the assumed constant rate of 0.06 (NORPRED). (M2 equalled 0 if the 0- to 2-year-old animals numbered less than 500, 1 if they numbered at least 500, and 3 if the number of nesting females reached 1360, a number thought at first to saturate the nesting areas.) The result was divided by 2, as the program primarily monitored the female numbers. (In case of simulated hunting, the number of cannibalized males were set equal to the number of cannibalized females.)

The size of the female cohort equalled the sum of the number of females in all age classes, multiplied by PSURV. The size of the male cohort was, if hunting were simulated, calculated in the same way. In the absence of hunting, the size of the male cohort was simply set to equal that of the female cohort. The hunting kill, whether equal to 0 or positive, was subtracted. Next the total population for the year was figured by adding the female and male cohorts.

Toward the end of the main do loop much of the information that was acquired for the year was printed. In case of simulated hunting, the annual harvest was printed. Then, depending on two decision blocks, or always in the absence of hunting, the following information was printed: number of females in each age class; number of sexually mature females for the year; total number of crocodiles for the year; values for KK, F1, F2, F3M1, M2, and FLAG for the year; and values for the total number of eggs, hatch of females, and total number of 0- to 2-year-old crocodiles for the year. Many simulated years resulted in many pages of print, so one could optionally insert a statement that would make the computer bypass all this output. At this point one iteration of the do loop was complete. When the 300 iterations were completed,the total population (ATPOP) and the number of nesting females (ANNFEM) were listed for each year. Then the program terminated.

After producing a working model, we studied the effects of two sources of disturbance on the population. The first was consecutive years of extreme water levels, and the second was different intensities of hunting.

To simulate consecutive years of extreme water levels, we first induced four consecutive years of droughts every 50 years for the duration of the program. We also ran the model with the inter-drought intervals reduced to 20 years. Finally, we subjected the population to premature floods on the same schedules.

Several runs, to test harvesting strategies consisting of minimum numbers of 300 and 500 at each efficiency, were made. Males and females were killed according to their relative proportions in the 120-190 cm length range, as it is impossible to sex these animals without cloacal inspection (Graham 1976, 1977). The hunting kill in our program was additive to natural mortality.

RESULTS AND DISCUSSION

Simulated Normal Conditions

Patterns generated by the simulation for the total population and for the nesting females, under undisturbed (normal) conditions, are represented by the upper curves in Figures 11 and 12, respectively. The total population grew from 9730 to a consistent oscillation around roughly 21,000 individuals in 130-140 years. This number is comparable to our estimated prehunting population of 29,600, obtained by adding our initial population (9,730) with the kills of Lurie, Wilmot, and BGI (19,840, Table 1). (If B. Wilmot took about 10,000 crocodiles, as believed by Graham [1976, 1977], the prehunting estimate would be a little below 24,000.) Yearly changes exceeding 4000 crocodiles were not uncommon. Nesting female numbers grew to approximately 1400 in 112 years, which would represent 2100 sexually mature females in the population, if two-thirds of the mature females nest in any given year, as is believed. This number is comparable to the 3200 sexually mature females we estimated to have been killed by S. M. Lurie and Co. and B. Wilmot.

Table 1. Hunting history of crocodiles on the Okavango River, Botswana.

Years	Numbers	Enterprises	Source
1957	2,000	S. M. Lurie and Co. (Pty.) Ltd., Bulawayo, Rhodesia	S. M. Lurie (1975, pers. comm.)
1958	800	"	"
1959	500	"	"
1957-1969	15,000[1]	B. Wilmot	Assumed[1]
1973	500	BGI, Francistown, Botswana	Taylor (1973)
1974-1975	440	"	Blomberg and BGI
Total:	19,840		

1 It is only known that B. Wilmot's annual quota of 2,000 crocodiles was seldom filled (Graham 1976, pers. comm.). We have assumed an average of 1,200 annually; Graham (1976, 1977) believed the total to be about 10,000.

In contrast to the total population, the nesting females exhibited relatively less deviation from their apparent mean. The relatively greater fluctuations in the total population may be attributable to the high percentage of juveniles in the population. Crocodiles ranging from 0 to 3 years old normally comprised 50-85% of the total simulated population and have a high mortality rate (Blake and Loveridge 1975, Graham 1968). High mortality of juveniles in any one year causes drastic declines in the total population. Nesting females, however, have grown beyond this vulnerable stage, so their numbers should be more stable.

Another important factor causing total population fluctuations is the hatching rate of eggs. Two phenomena, weather and monitor lizard predation, play a major role in determining this rate. Inclement weather, resulting in floods, can cause extensive destruction of eggs, sometimes eliminating the entire year's production (Pooley 1969). Losses to hatchlings, which generally comprised 20-45% of the total population, would certainly cause severe year-to-year fluctuations in the total population. Monitor predation on eggs over many years is at least as destructive as mortality due to occasional floods.

The upper curves in Figures 11 and 12 resulted after we reduced the maximum rate of predation on eggs to 28%. (We first tested a rate of 56%, approximating that in Kabalega Falls National Park, Uganda [Cott 1968], which severely lowered the population.) From these patterns we concluded that mortality of young, which normally seems to exceed 80% during the first three years of life (Blake and Loveridge 1975) dictates that a hatching rate over 50% is necessary for perpetuation of the crocodile population. This conclusion agrees with the hatching rate (54.6%) on the Okavango River (Blomberg 1977).

Simulated Severe Water Levels

No significant effects on the total population appeared from four consecutive years of droughts every 50 years, nor every 20 years, as seen in Figure 13. The four years of consecutive floods every 20 years resulted in the complete destruction of all eggs laid. The total population, with complete elimination of four consecutive year classes, often dropped noticeably every 20 years, but recovered quickly. The nesting female cohort, as one would expect, appeared unaffected by the drought and flood conditions.

The water level simulations showed that the total population was more responsive to floods than to droughts. Premature floods caused extensive destruction of the eggs, but had little other effect. Droughts, however, mainly affect juveniles by inducing intensified cannibalism and other predation. Although predation may be significant, the number of juvenile crocodiles lost during drought was small compared to the number of eggs lost during severe floods. Thus, our model indicates that factors affecting eggs effect greater changes in the population.

The severe drought and flood simulations we generated for the Okavango area are probably unrealistic. That the crocodile population placed under these unusually harsh conditions maintained itself at close to undisturbed (normal) levels over 300 years implies that the population is relatively insensitive to extreme water levels. The ability of female crocodiles to reproduce from ages 10 to 65 forms a population structure well buffered against recurring large losses of eggs and young.

Simulated Hunting

At a minimum of 300 harvestable crocodiles (120-190 cm long), the total population reacted similarly at all three hunting efficiencies (Fig. 11). Smaller oscillations occurred with increasing efficiency, but all three tended toward a level of 1,400 animals. The nesting female cohort responded similarly (Fig. 12), but oscillated around 50. At a minimum of 500 harvestable crocodiles the total population fluctuated around 2000 and the nesting female cohort around 100. A larger population size at a minimum of 500 huntable crocodiles might be explained by the roughly 60% fewer years of hunting when figures in Table 2 are averaged for both minimum numbers. That the ratio of nesting females to total population should be greater (5:100) at a minimum of 500 huntable crocodiles than at a minimum of 300 huntable crocodiles (3.75:100) is noteworthy. The difference is suspected to be an artifact of the program, changeable by increasing the value for the number of females originally thought to saturate the nesting grounds (CCAP). There is little difference between total harvest averages over 300 years (Table 2).

The best yearly hunt was realized at a 30% efficiency at the 300 minimum, which also gave the fewest years without hunting. However, according to Graham (1976,1977), at least 200 crocodiles per hunting month are needed to make a profit. Hunting would be done from August to perhaps February (5-7 months) when the water level is low, so the crocodiles concentrate in the main channels. This would mean an annual harvest of 1000-1400 crocodiles, which far exceeds our simulated hunting schemes (77-78 crocodiles per year), and therefore appears unfeasible. Furthermore, such annual cropping rates approximate the destructive ones of 1957-1969.

Table 2. Harvests of crocodiles under tested hunting schemes.

Number of years without hunting	Minimum number of huntable crocodiles	Efficiency (%)	Total harvest (300 yr.)	Mean annual harvest
164	500	30	24,670	82.2
192	500	40	23,748	79.2
223	500	50	23,195	77.3
85	300	30	26,046	86.8
137	300	40	24,482	81.6
180	300	50	23,780	79.3

Egg Collection

Egg collection appears to be more acceptable than hunting as a method of utilizing the crocodiles on the Okavango River. Commercial utilization of the crocodiles, on a sustained-yield basis, will motivate conservation; human sentiment alone is not likely to suffice (Blake and Loveridge 1975, Bustard 1970). Graham (1976, 1977) believed that without commercial harvesting the Okavango crocodiles would be treated as pests and eliminated.

Egg collection, followed by incubation and captive rearing, is the basis for the primary method of harvesting crocodiles in Zimbabwe (Blake and Loveridge 1975). The crocodiles are kept for three years, after which most are killed and skinned. The animals not killed (representing 5% of the number of collected eggs) are released to the wild to maintain breeding stock. This percentage is believed to compensate adequately for lost natural recruitment to the population (Blake and Loveridge 1975).

Nearly 80% of the collected eggs can be expected to hatch and about 50% of the hatchlings should reach age three. In the wild, survival to that age is much less. Egg collection allows more production from the population because the high mortality of young is circumvented, and crocodiles of age three in a rearing station are nearly twice as long as those in the wild (Blake and Loveridge 1975). If well fed, crocodiles released at this age can be expected to have a high survival rate.

Blake and Loveridge (1975) suggested that at most 1500 eggs be collected per rearing station annually in Zimbabwe. On the Okavango River, because of the average clutch size of 60.8 (Blomberg 1977), only about 25 nests would have to be robbed. (For this reason and the believed adequacy of the 5% release, we did not incorporate egg collection and release of juveniles into the simulation.) Greater numbers had lower hatching rates, probably because the rearing stations had more clutches than could be carefully managed at hatching time.

CONCLUSIONS

Commercial use of the Okavango crocodiles, on a sustained-yield basis, is viewed as a motivating force in conservation. On the basis of the described computer simulation, hunting can only play a minor role. It is concluded that commercial use should take the form of captive rearing for the valuable skins, and that it should include the release of the number of 3-year-old animals that represent perhaps 5% of the number of eggs collected. To increase income from the rearing scheme, there should be guided public tours.

The computer simulation should, however, be viewed only as a first approximation of the behavior of the crocodile population in the Okavango River. Further work is under way to make the simulation a better approximation. One of two recent corrections has been to raise the initial number of nesting females from 0 to 82, as observed in 1975 (with the result of incrementing each point on the upper curve in Figure 12 by 82); this correction, which appears in the present program, has been to change the subscripts of dummy variable VAL in the function subprograms to be consistent with corresponding dummy arguments in the main program. The effect of this error on output of the program has been negligible.

The collection of data for certain parameters, from the Okavango River, to replace the corresponding data presently in the simulation, is being contemplated. This would make the simulation a better approximation of the crocodile population's dynamics, hence a more reliable guide to sound management. However, field data would be useful in a simulation only if the simulation proved sensitive to changed sets of hypothetical data for the parameters considered. The parameters considered are: survival rates (PSURV), growth rates (as expressed in age spans of vulnerability to cannibalism and hunting, age at which females reach sexual maturity, and age at onset of cannibalistic behavior), percentage of females breeding by age class (PERBRD), and clutch size in relation to age class (CLUTCH). The simulation has responded to changed survival rates, and a set of high rates has caused the total population to level off in about 75 years at about 28,000, which seems more realistic than the upper curve in Figure 11. The curve for number of nesting females responded similarly. Sensitivity to changed growth rates is presently being tested. If the simulation operates realistically, changes in data sets for the percentage of nesting females by age class and changes in data sets for the relation between clutch size and age of female should bring about changes in the curves for total population and nesting females.

Certain other manipulations are needed. The results of delaying the start of hunting for one or more decades, or even waiting until the population levels off, would be useful. The simulation will probably be more realistic if hunting mortality replaces natural mortality (Allen 1962) up to a point. It seems that hunting mortality that falls below natural mortality should be set equal to zero, while that which equals or exceeds natural mortality might replace 95% of it. The effects of making the life span less than 65 years should be investigated, because maximum life spans of wild crocodiles are unknown (Graham 1968). Our simulation assumes that crocodiles reproduce until death. The initial population size will be experimentally lowered. The reason is that the 1975 population of 9730 is possibly an overestimate. In 1975 the 82 nesting females produced an estimated 5002 eggs, 54.6% should have hatched (Blomberg 1977), resulting in 2731 0-year-old crocodiles. A somewhat lower initial population size appears more compatible with this number. The lower population size can be obtained by realizing that half of the 13 females 11-18 years old in the 1974-75 kill could well have been sexually mature, raising the proportion of mature females in the female kill from 0.150 to 0.184. By otherwise using the same method of estimating, the initial population now becomes 7858. According to our estimates for calculation of the original population, 61% of the 4003 0-to 2-year-old females, i. e. 2447, are 0-year-old animals. With a 1:1 sex ratio the total number of 0-year-old animals in the population would be 4894. The same calculations, from an initial population of 7858 would result in 3987 0-year-old crocodiles. The closer agreement with the estimated 2731 hatchlings for 1975 supports the possibility of 9730 crocodiles in the same year being an overestimate.

The number of crocodiles killed from 1957 to 1969 would have a bearing on the estimation of prehunting population size, hence growth rate of the population and the approximate number at which it must level off. Well after the production of this simulation the senior author learned of another estimate of B. Wilmot's kill. Mr. A. C. Campbell, former director of the Department of Wildlife and Tourism in Botswana, and who was acquainted with B. Wilmot, stated in a letter (1973) that the latter killed an estimated 40,000 crocodiles. This by far exceeds the value presented in Table 1. A decision on which figure to use in future work on the simulation must be reached.

Finally, manipulations of certain variables that constitute guesswork merit consideration. An example would be to raise the value of CCAP (the number of nesting females thought at first to saturate the nesting grounds) from 1360 to 2000, and note the results. Certain other variables would be altered or eliminated, or both, experimentally.

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APPENDIX

Listing of the crocodile population simulation. Statements enclosed in dashed blocks are included when hunting is simulated.

```
CROC,JC300,RG3.
FTN,TS,I=X.
LGO.
      PROGRAM CROC(INPUT,OUTPUT)
      DIMENSION PSURV(66), FPOP(66), PERBRD(66), CLUTCH(66), EGGS(66)
      DIMENSION KIL(3), VAL1(12), VAL2(13), VAL3(10), WLEV(11)
      DIMENSION ATPOP(410), ANNFEM(410)
      DIMENSION MPOP(66),MKIL(3),FHKIL(66),MHKIL(66)
      REAL MHKIL, MHUNT,MPOP,MKIL,MHATCH,MINHUNT
      REAL MEEG, IEM, NORMAL1, NORMAL2, NORPRED, M2, KIL, NNEST, M3
      LOGICAL VALUE
      DATA PSURV/42.3,50.4,55.0,63.1,77.3,87.6,98.0,88.8,89.2,90.7,91.6,
     +92.8,94.1,95.0,95.7,96.7,97.3,97.6,97.8,98.3,98.7,30*99.0,92.0,85.
     +0,78.0,71.0,64.0,57.0,50.0,43.0,36.0,29.0,22.0,15.0,9.0,1.0,0.0/
      DATA FPOP/2465.,1043.,525.,280.,216.,56.,34.,26.,2*12.,15.,2*4.,15
     +.,7.,4.,7.,17*4.,0.,6*4.,0.,4.,0.,4.,0.,4.,0.,3*4.,0.,4.,0.,4.,0.,
     +4.,0.,4.,3*0.,4.,2*0.,4./
      DATA PERBRD/10*0.0,.42,.98,1.7,3,4,5.4,7.1,10.2,13.2,16.3,21.1,24.
     +3,28.7,32.6,40.6,44.4,47.9,51.5,54.4,56.8,58.5,59.7,60.9,62.1,63.3
     +,64,4.65.6,29*66.8/
      DATA CLUTCH/10*0.0,2.993,3.0123,3.0216,3.0409,3.0602,3.0795,3.099,
     +3.1181,3.1374,3.1567,3.1760,3.1953,3.2146,3.2339,3.2532,3.2725,3.2
     +918,3.3111,3.3204,3.3397,3.3590,3.3763,3.3976,3.4169,3.4362,3.4555
     +,3.4748,3.4941,3.5134,3.5327,3.5520,3.5713,3.5906,3.6099,3.6292,3.
     +6485,3.6678,3.6771,3.6964,3.7157,3.7350,3.7543,3.7736,3.7929,3.812
     +2,3.8315,3.8508,3.8701,3.8894,3.9087,3.9280,3.9473,3.9666,3.9859,4
     +.0052,4.0245/

C     INITIALIZE THE POPULATION FOR START AT YRS=0.

      DO 121 K=1,66
  121 MPOP(K)=FPOP(K)
      DO 111 K=1,66
  111 FHKIL(K)=MHKIL(K)=0.
      TPOP=0
      DO 16 K=1,66
      TPOP=TPOP+FPOP(K)+MPOP(K)
   16 CONTINUE
      JJ=1 $ ATPOP(JJ)=TPOP $ ANNFEM(JJ)=0.0

C     PRINT RESULTS AT THIS TIME. TPOP,FPOP.

      YRS=0.
      PRINT 200
  200 FORMAT (*1*,*A POPULATION STUDY OF FEMALE CROCODILES IN THE OKAVAN
     +GO, AFRICA.*,///)
      PRINT 207
  207 FORMAT (*0*,130(1H*))
      PRINT 300
  300 FORMAT (*-*,*A FLAG EQUAL TO 0 MEANS THAT A NORMAL YEAR TOOK PLACE
     +.*/,* *,*A FLAG EQUAL TO 1 MEANS THAT A DROUGHT OCCURRED.*,/,* *,*
     +A FLAG EQUAL TO 2 MEANS THAT A FLOOD TOOK PLACE IN THAT YEAR.*)
      PRINT 206
      DO 202 I=1,66
      J=I-1
  202 PRINT 201, FPOP(I), J, I
```

```
201 FORMAT (* *,*THERE ARE *,F8.0,* FEMALE CROCODILES BETWEEN THE AGES
   + OF *,I2,* AND *,I2,*.*)
    PRINT 203, YRS, TPOP
203 FORMAT (*0*,*AT YEAR *,F4.0,* THERE WERE *,F10.0,* TOTAL CROCODILE
   +S IN THE POPULATION.*)
    PRINT 206
206 FORMAT (*0*,130(1H*),//)

C     INITIALIZE PARAMETERS.

      THUNT=0.
      MINHUNT=300.
       EFFIC=.3
      IRNLGTH=300
      NORMAL1=5
      NORMAL2=7
      MEEG=0.072
      IEM=0.236
      NORPRED=0.06
      CCAP=1360. $ BABY=500.
      SMALL1=0. $ DIFF1=.25 $ K1=11
      VAL1(1)=0.0 $ VAL1(2)=0.008 $ VAL1(3)=0.039 $ VAL1(4)=0.07
      VAL1(5)=0.175 $ VAL1(6)=0.48 $ VAL1(7)=0.72 $ VAL1(8)=0.83
      VAL1(9)=0.915 $ VAL1(10)=0.96 $ VAL1(11)=0.98 $ VAL1(12)=1.00
      SMALL2=20. $ DIFF2=10. $ K2=12
      VAL2(1)=0.0 $ VAL2(2)=0.0 $ VAL2(3)=0.0 $ VAL2(4)=0.01
      VAL2(5)=0.05 $ VAL2(6)=0.085 $ VAL2(7)=0.185 $ VAL2(8)=0.235
      VAL2(9)=0.255 $ VAL2(10)=0.275 $ VAL2(11)=0.28 $ VAL2(12)=0.28
      VAL2(13)=0.28
      SMALL3=-1.5 $ DIFF3=.5 $ K3=9
      VAL3(1)=5. $ VAL3(2)=3.6 $ VAL3(3)=2.3 $ VAL3(4)=1.0
      VAL3(5)=.2 $ VAL3(6)=.2 $ VAL3(7)=.2 $ VAL3(8)=.2
      VAL3(9)=.2 $ VAL3(10)=.2
      DO 1 I=1,66
      PSURV(I)=PSURV(I)/100.
      PERBRD(I)=PERBRD(I)/100.
    1 CLUTCH(I)=CLUTCH(I)**3
      WLEV(1)=-1.5
      DO 2 I=2,4
    2 WLEV(I)=WLEV(I-1) + .375
      WLEV(5)=WLEV(6)=WLEV(7)=0.
      DO 3 I=8,11
    3 WLEV(I)=WLEV(I-1) + .6875

C     EXECUTION PHASE FOR 300 YEARS.

      DO 100 M=1,IRNLGTH
      YRS=YRS+1.
      JJ=JJ+1
      HFPOP=HMPOP=0.
      FLAGG=0.
      FFLAGG=0.
      PRINT 206
      PRINT 843, YRS
843   FORMAT(*0*,*YEAR *,F4.0)
```

```
C     RANDOM WATER LEVEL VARIABLE ASSIGNED A VALUE

      RANNUM=RANF(0)
      KK=RANNUM*10+1
      FLAG=0.
      IF (KK.LT.NORMAL1) FLAG=1.
      IF (KK.GT.NORMAL2) FLAG=2.
      F1=0.
      IF (FLAG.NE.2.) GO TO 4
      F1=TABLIE (VAL1,SMALL1,DIFF1,K1,WLEV(KK))

C     NUMBER OF EGGS FIGURED.

    4 TEGGS=0.
      TOT=0.
      VALUE=.FALSE.
      DO 5 K=1,56
      EGGS(67-K)=FPOP(67-K)*PERBRD(67-K)*CLUTCH(67-K)
      TOT=TOT+(FPOP(67-K)*PERBRD(67-K))
      IF(TOT.LE.CCAP)GO TO 5
      M2=3 $ M3=.1
      VALUE=.TRUE.
      GO TO 18
    5 TEGGS=TEGGS+EGGS(67-K)
   18 ACLUTCH=TEGGS/TOT
      HOLD=TEGGS-(TEGGS * F1)
      NNEST=HOLD/ACLUTCH
      F2=TABEXE (VAL2,SMALL2,DIFF2,K2,NNEST)
      ANNFEM(JJ) = TOT

C     TOTAL HATCH MINUS MORTALITY.

      HATCH=TEGGS-(TEGGS * (IEM + MEEG + F2 + F1))
      IF (VALUE) HATCH=(HATCH-(HATCH * M3))
      MHATCH=FHATCH=HATCH/2.
      IF (FHATCH.LT.0.) FHATCH=0.
      IF(MHATCH.LT.0.)MHATCH=0.
      SAVE=MPOP(1)
      MPOP(1)=MHATCH
      DO 115 K=2,66
      HOLD=MPOP(K)
      MPOP(K)=SAVE
  115 SAVE=HOLD
      SAVE=FPOP(1)
      FPOP(1)=FHATCH

C     EACH AGE CLASS IS NOW ADVANCED ONE YEAR.

      DO 15 K=2,66
      HOLD=FPOP(K)
      FPOP(K)=SAVE
   15 SAVE=HOLD
```

```
      DO 112 K=4,7
  112 HFPOP=HFPOP+FPOP(K)
      DO 1111 K=3,5
 1111 HMPOP=HMPOP+MPOP(K)
      PRINT 1112, HMPOP, HFPOP
 1112 FORMAT(*0*,*HMPOP= *,F7.0,6X,*HFPOP= *,F7.0)
      THPOP=HMPOP+HFPOP
      IF(THPOP.GT.MINHUNT)GOTO420
      FHKIL(4)=FHKIL(5)=FHKIL(6)=FHKIL(7)=0.
      HUNT=0.
      MHKIL(3)=MHKIL(4)=MHKIL(5)=0.
      GOTO 413
  420 HUNT=THPOP*EFFIC
      IF(HFPOP.GT.0.)GOTO 411
      FHUNT=0.
      FHKIL(4)=FHKIL(5)=FHKIL(6)=FHKIL(7)=0.
      FLAGG=1.
  411 IF(HMPOP.GT.0.)GOTO 412
      MHUNT=0.
      MHKIL(3)=MHKIL(4)=MHKIL(5)=0.
      FFLAGG=1.
      IF (FFLAGG.EQ.1.) GO TO 4133
  412 MHUNT=(HMPOP/THPOP)*HUNT
      IF(MHUNT.GT.HMPOP)MHUNT=HMPOP
      DO 117 K=3,5
  117 MHKIL(K)=(MPOP(K)/HMPOP)*MHUNT
 4133 IF(FLAGG.EQ.1.)GOTO 413
      FHUNT=(HFPOP/THPOP)*HUNT
      IF(FHUNT.GT.HFPOP)FHUNT=HFPOP
      DO 116 K=4,7
  116 FHKIL(K)=(FPOP(K)/HFPOP)*FHUNT
  413 CONTINUE
      THUNT=THUNT+HUNT
      PRINT 421, THUNT
  421 FORMAT(*0*,* TOTAL HARVEST OF CROCKS IS *,F8.0)
      IF (FLAG.NE.0.) GO TO 6
      F3M1=1.
      GO TO 7
    6 F3M1=TABLIE (VAL3,SMALL3,DIFF3,K3,WLEV(KK))

C     PREDATION FIGURED ON THE 0-2-YEAR OLD CROCODILES

    7 AMPOP=AFPOP=BCROCKS=0.
      DO 8 K=38,66
    8 AFPOP=AFPOP + FPOP(K)
      DO 9 K=20,66
    9 AMPOP=AMPOP+MPOP(K)
      DO 10 K=1,3
   10 BCROCKS=BCROCKS+FPOP(K)+MPOP(K)
      PREDPOP=AMPOP + AFPOP
      IF (VALUE) 12,11
   11 IF (BCROCKS.LT.BABY) M2=0
      IF (BCROCKS.GE.BABY) M2=1
   12 TOTKIL=(PREDPOP*F3M1*M2*NORPRED)/2.
      KIL(1)=TOTKIL * .6
```

```
      KIL(2)=TOTKIL * .3
      KIL(3)=TOTKIL * .1
      MKIL(1)=KIL(1)
      MKIL(2)=KIL(2)
      MKIL(3)=KIL(3)
      DO 135 K=1,3
      IF((FPOP(K)*PSURV(K))-KIL(K)-FHKIL(K).LT.0.) GOTO 13
      FPOP(K)=((FPOP(K)*PSURV(K))-KIL(K)-FHKIL(K))
      GO TO 135
   13 FPOP(K)=0.
  135 CONTINUE
      DO 14 K=4,66
   14 FPOP(K)=FPOP(K)*PSURV(K)-FHKIL(K)

C     FIGURE TOTAL POPULATION FOR THE YEAR.

      DO 123 K=1,3
      IF((MPOP(K)*PSURV(K))-MKIL(K)-MHKIL(K).LT.0.) GOTO 113
      MPOP(K)=(MPOP(K)*PSURV(K))-MKIL(K)-MHKIL(K)
      GOTO 123
  113 MPOP(K)=0.
  123 CONTINUE
      DO 124 K=4,66
  124 MPOP(K)=MPOP(K)*PSURV(K)-MHKIL(K)
      TPOP=0.
      DO 17 K=1,66
      TPOP=TPOP+FPOP(K)+MPOP(K)
   17 CONTINUE
      ATPOP(JJ)=TPOP
      GO TO 100

C     PRINT INFORMATION AND RESULTS FOR YEAR PROCESSED.

      PRINT 1361, HUNT
 1361 FORMAT (*0*,*HUNT= *,F7.0)
      IF (M.LE.10) GO TO 136
      IF (M/50*50.NE.M)  GO TO 100
  136 DO 205 I=1,66
      J=I-1
  205 PRINT 201, FPOP(I), J, I
      PRINT 204, TOT, YRS
  204 FORMAT (*0*,*THERE WERE *,F6.0,* SEXUALLY MATURE FEMALES NESTING I
     +N YEAR *,F4.0,* .*)
      PRINT 203, YRS,TPOP
      PRINT 303,KK
  303 FORMAT (*0*,*THE RANDOM NUMBER FOR THIS YEAR WAS *,I2)
      PRINT 306,FLAG, F1, F2, F3M1, M2
  306 FORMAT (*0*,*THE VALUE OF THE FLAG WAS *,F3.0,/,*0*,*THE VALUE OF
     +F1 WAS *,F7.3,/,*0*,*THE VALUE OF F2 WAS *,F7.3,/,*0*,*THE VALUE O
     +F F3M1 WAS *,F7.3,/,*0*,*THE VALUE OF M2 WAS *,F4.0)
      PRINT 304,WLEV(KK)
  304 FORMAT (*0*,*THE WATER LEVEL FOR THIS YEAR WAS *,F5.2)
      PRINT 305,TEGGS, FHATCH, BCROCKS,PREDPOP,TOTKIL
```

```
305 FORMAT (*0*,*THE TOTAL NUMBER OF EGGS FOR THIS YEAR WAS *,F8.0,/,*
   +0*,*THE TOTAL FEMALE HATCH WAS *,F8.0,/,*0*,*THE TOTAL NUMBER OF B
   +ABY CROCODILES WAS *,F8.0,/,*0*,*THE TOTAL NUMBER OF OLDER CROCODI
   +LES PREYING ON THE YOUNG WAS *,F8.0,/,*0*,*THE TOTAL KILL ON THE B
   +ABY CROCODILES WAS *,F8.0)
    PRINT 206
100 CONTINUE
    PRINT 339
339 FORMAT (*-*,2X,*TOTAL*,9X,*NESTING*,/,* *,*POPULATION*,6X,*FEMALES
   +*,/,* *,10(1H-),6X,7(1H-),//)
    PRINT 340, (ATPOP(I), ANNFEM(I), I=1,JJ)
340 FORMAT (* *,2X,F7.0,7X,F7.0)
    END


C     THIS FUNCTION WILL CALCULATE VALUES FOR PERCENT MORTALITY
C     DEPENDING ON THE WATER LEVEL FOR A GIVEN YEAR. IN FLOOD YEARS
C     THIS MORTALITY WILL AFFECT THE NUMBER OF EGGS PRODUCED. IN
C     DROUGHT YEARS THIS MORTALITY WILL AFFECT THE HATCHLINGS AND THE
C     ONE-AND TWO-YEAR OLD CROCODILES.


      FUNCTION TABLIE(VAL,SMALL,DIFF,K,DUMMY)
      DIMENSION VAL(13)
      DUM=AMIN1(AMAX1(DUMMY-SMALL,0.0),FLOAT(K)*DIFF)
      I=1.0+DUM/DIFF
      IF(I.EQ.K+1) I=K
      TABLIE=(VAL(I+1)-VAL(I))*(DUM-FLOAT(I-1)*DIFF)/DIFF+VAL(I)
      RETURN
      END

C     THIS FUNCTION WILL CALCULATE MONITOR LIZARD PREDATION ON EGGS,
C     DEPENDING ON THE NUMBER OF NESTS IN ANY GIVEN YEAR.

      FUNCTION TABEXE (VAL,SMALL,DIFF,K,DUMMY)
      DIMENSION VAL(13)
      DUM=DUMMY-SMALL
      I=MIN0(MAX1(1.0+DUM/DIFF,1.0),K)
      TABEXE=(VAL(I+1)-VAL(I))*(DUM-FLOAT(I-1)*DIFF)/DIFF+VAL(I)
      RETURN
      END


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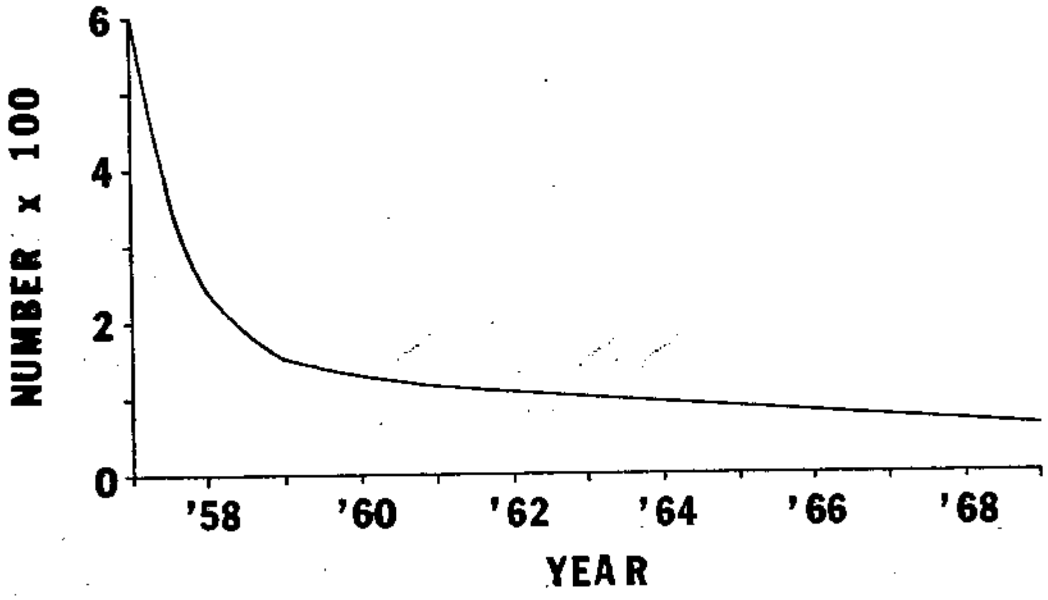

Figure 1. Curve used to estimate B. Wilmot's take of sexually mature females. It begins with half of the assumed annual take, i.e. 600, and for the next two years drops at the rate estimated for the mature females taken by Lurie and Co.

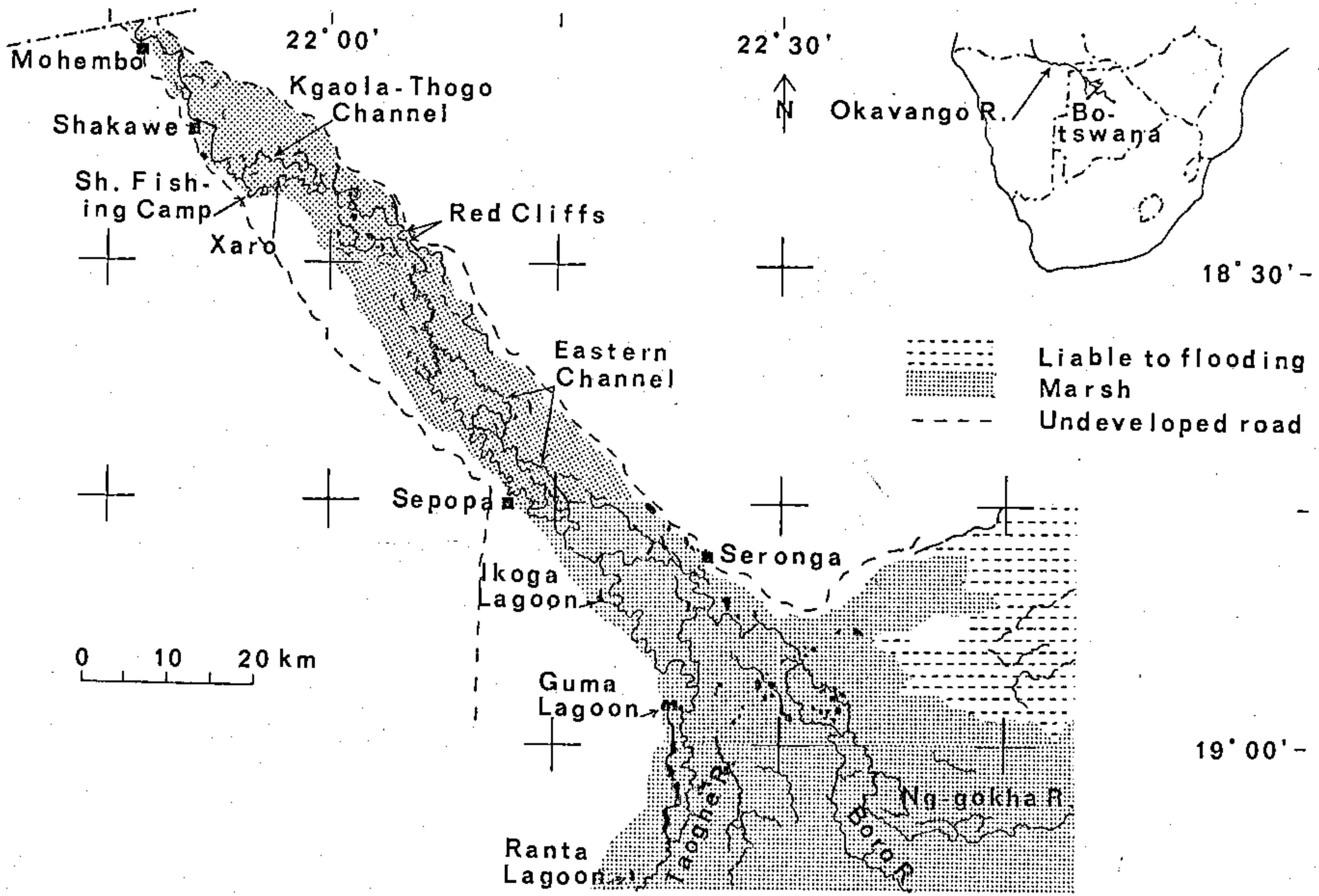

Figure 2. Map of study area.

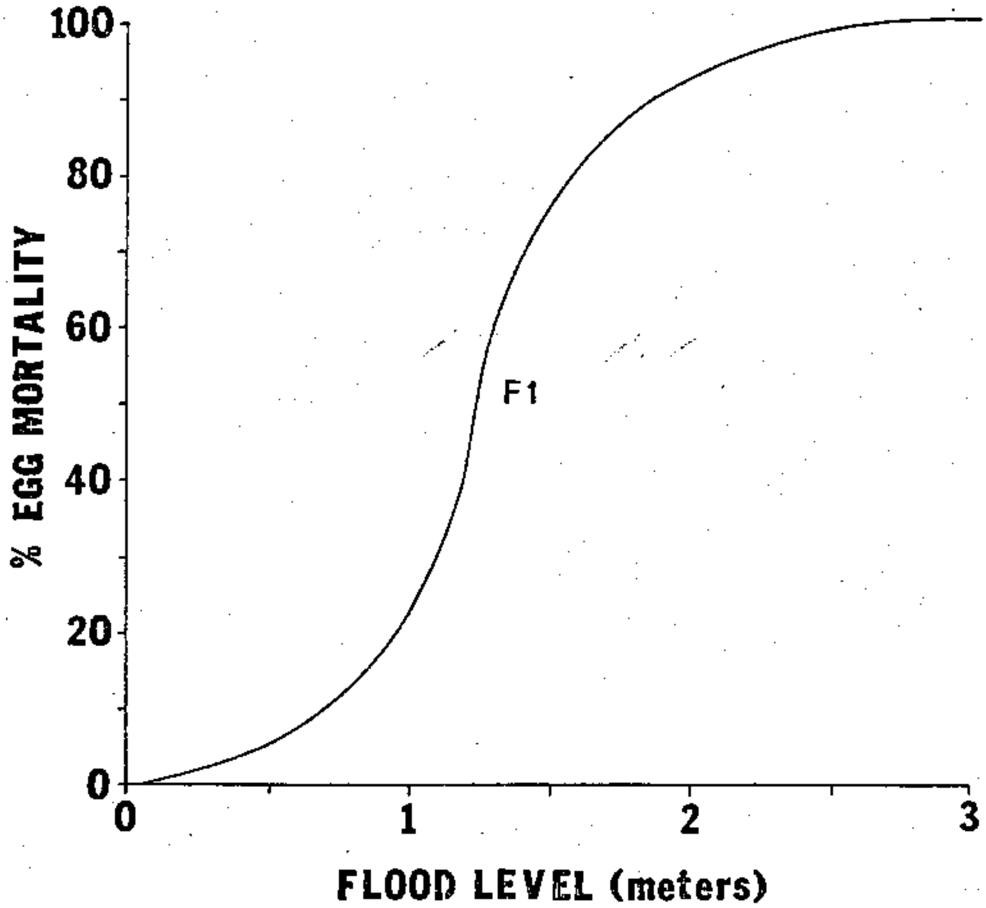

Figure 3. Relation of percent egg loss to flood level (Fl).

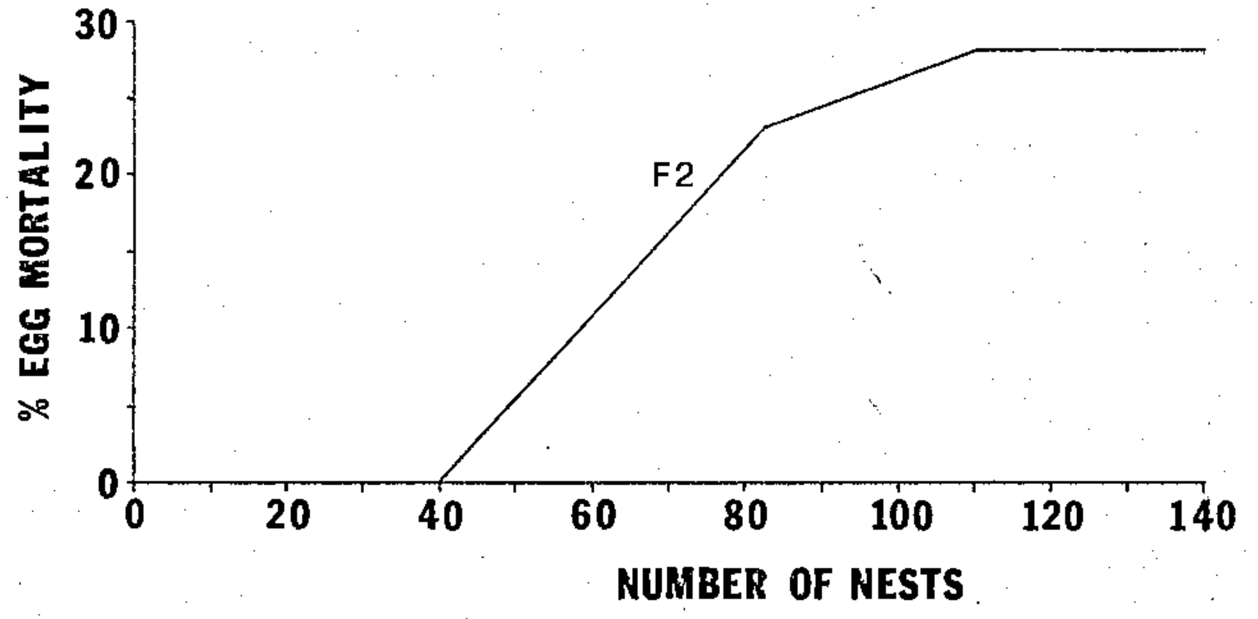

Figure 4. Relation of percent egg loss by monitor lizard predation to number of nests available (F2).

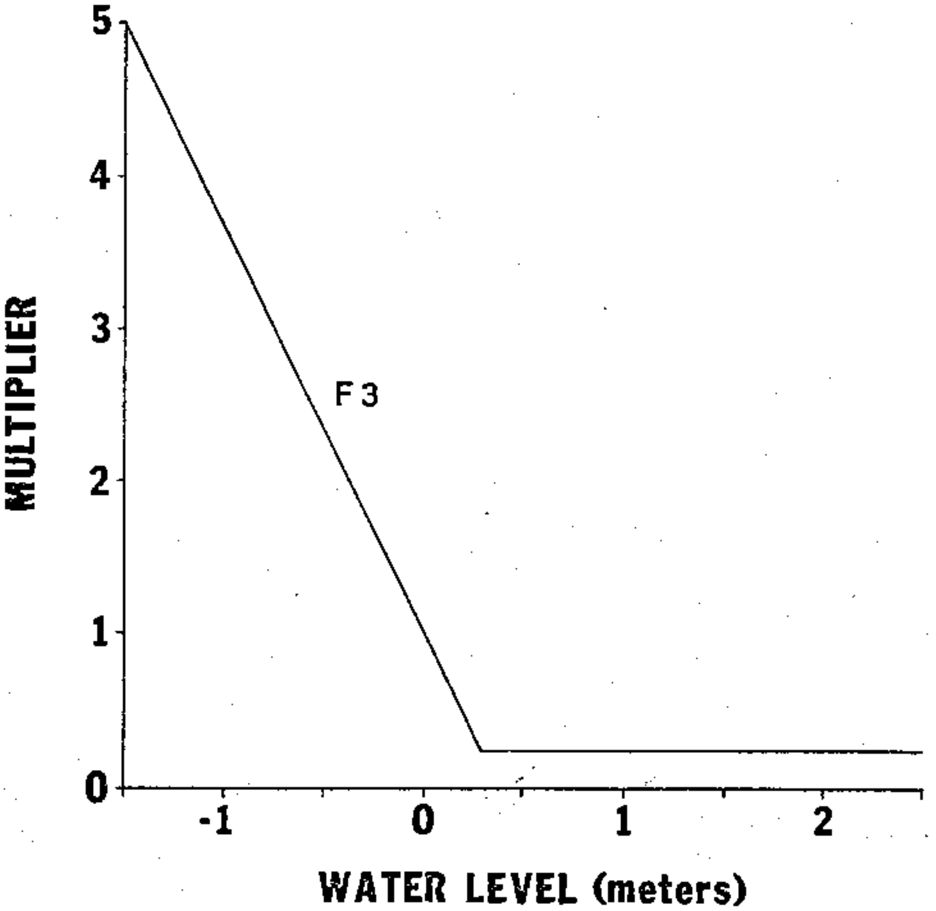

Figure 5. Multiplier function for the cannibalism rate on young crocodiles, in relation to water level (F3M1). The normal water level is designated by 0, where the multiplier equals 1.

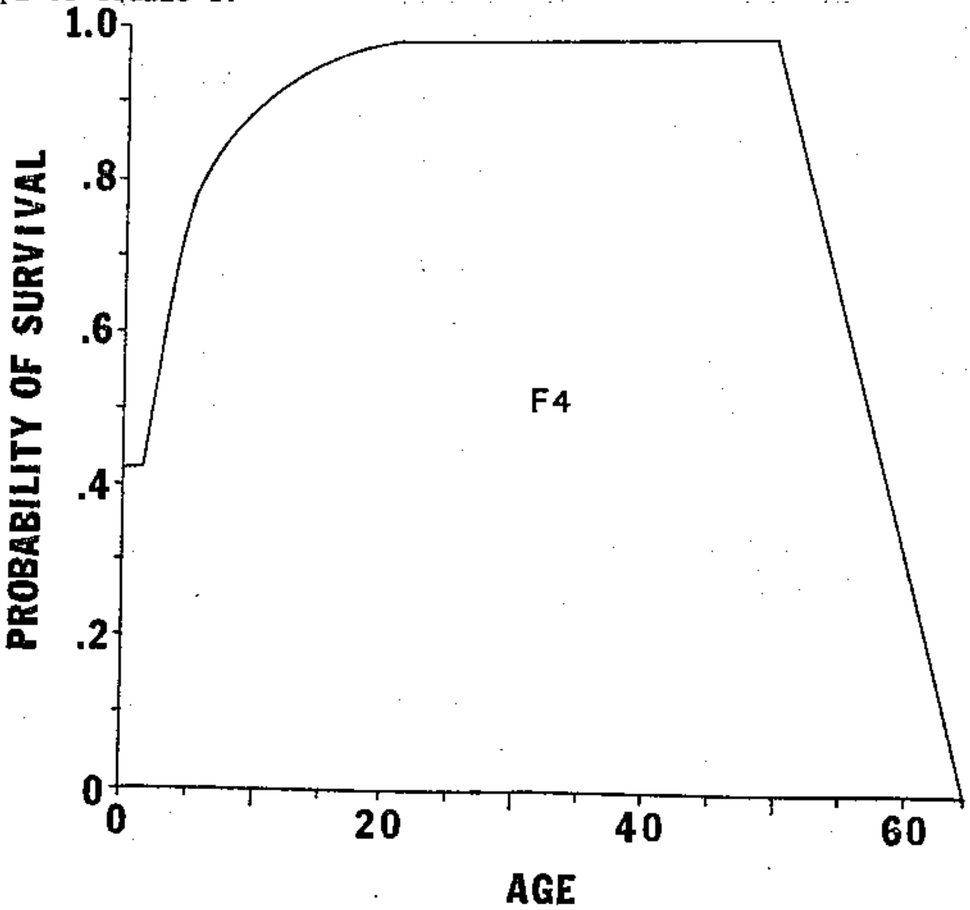

Figure 6. Survivorship curve for Okavango crocodiles (PSURV), based on the assigned age structure of the 1974-75 kill and hypothetical points.

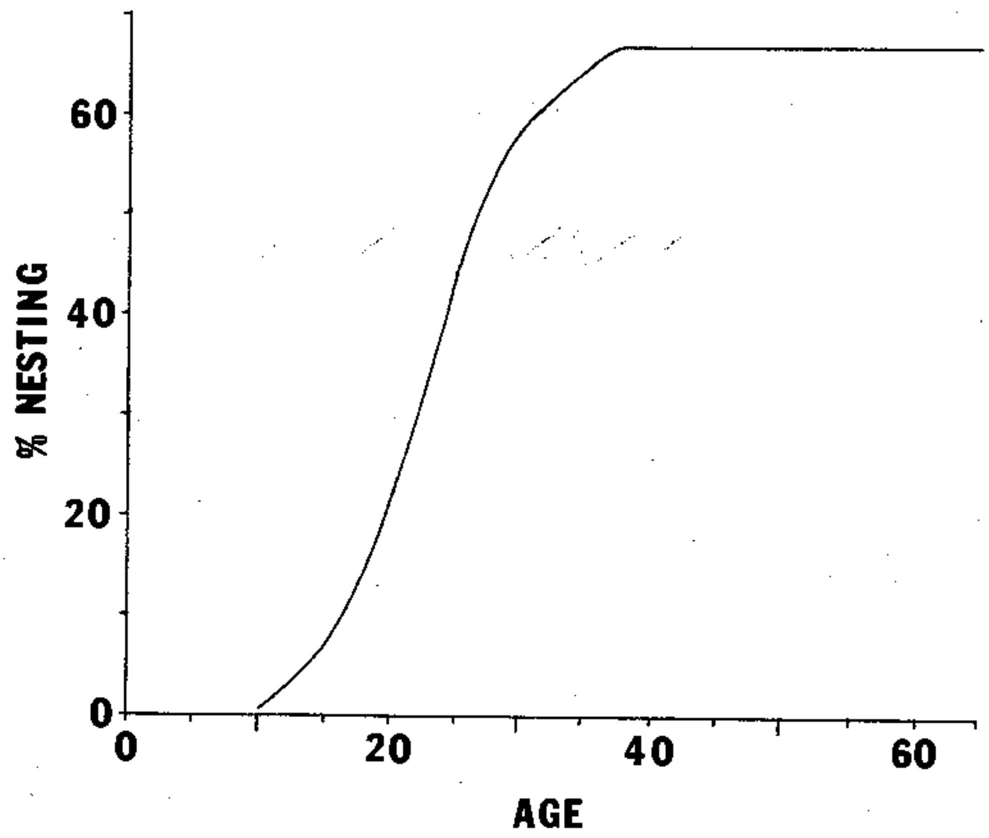

Figure 7. Percent of female cohort nesting as a function of age (PERBRD).

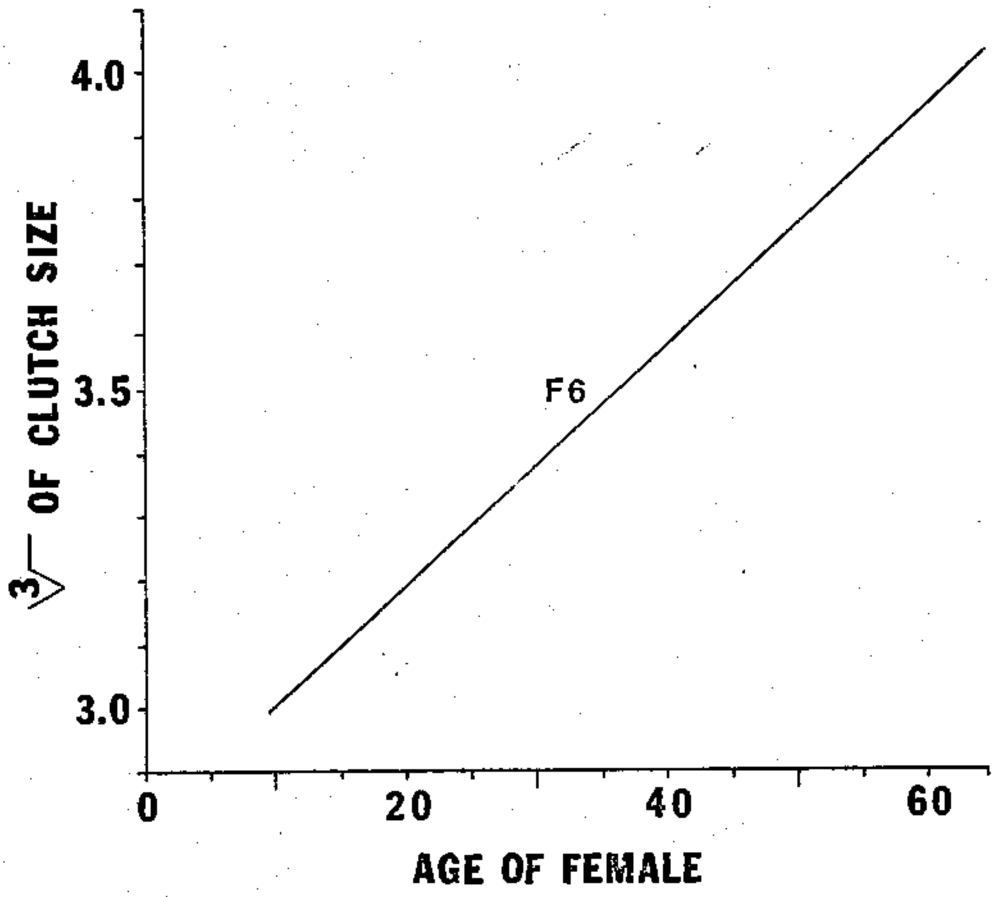

Figure 8. Relation of cube root of clutch size to age of female (CLUTCH).

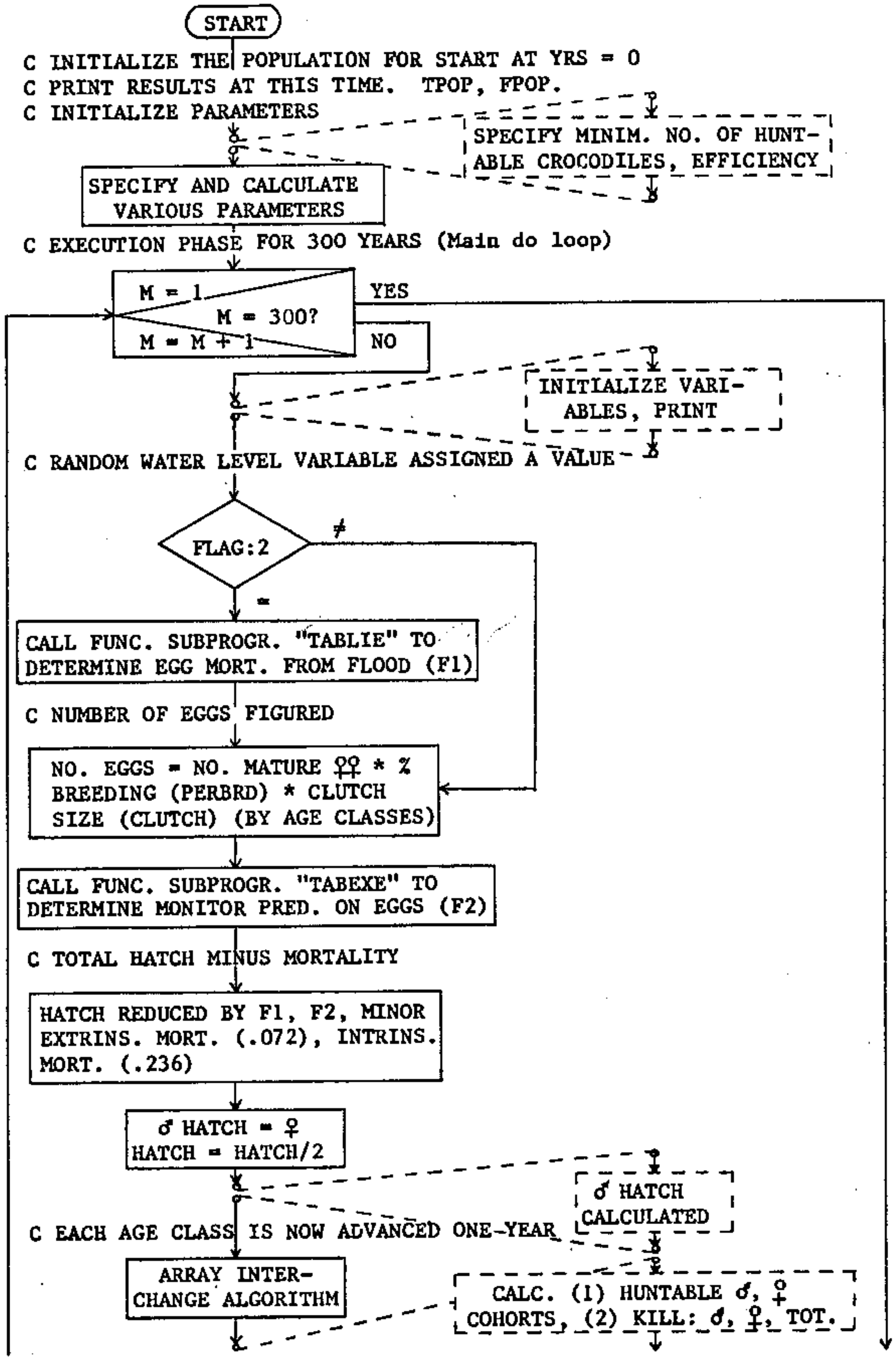

Figure 9. Condensed flow chart of the crocodile population simulation. Dashed blocks are included when hunting is simulated. With an assumed sex ratio of 1:1, and primary emphasis on female members, separate calculation of the male cohort is done only when hunting is simulated, because the age classes of hunted males are not the same as those for hunted females. Without simulated hunting the female hunting kill is set at 0. TPOP and FPOP (second comment) represent size of total

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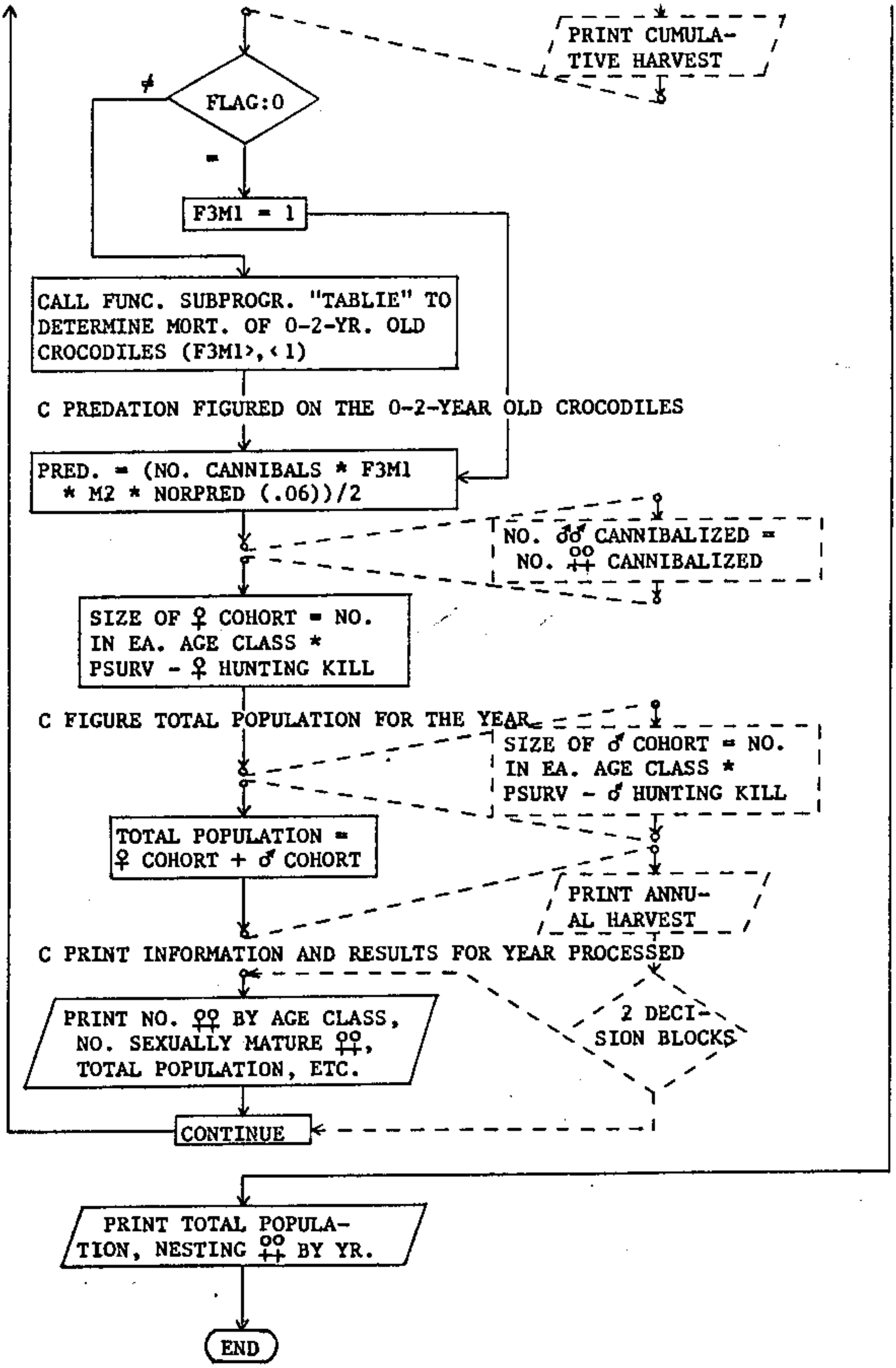

population and female cohort respectively. M at the start of the main do loop represents its number of iterations. FLAG, the water level index, varies, depending on a variable obtained by a random number generator, at 2, 1, and 0. These values represent premature flood conditions, drought (low water levels), and normal water levels, respectively. Where predation on young by the older animals is figured, M2 is a variable representing density of the young, and NORPRED is an assumed constant rate of cannibalism.

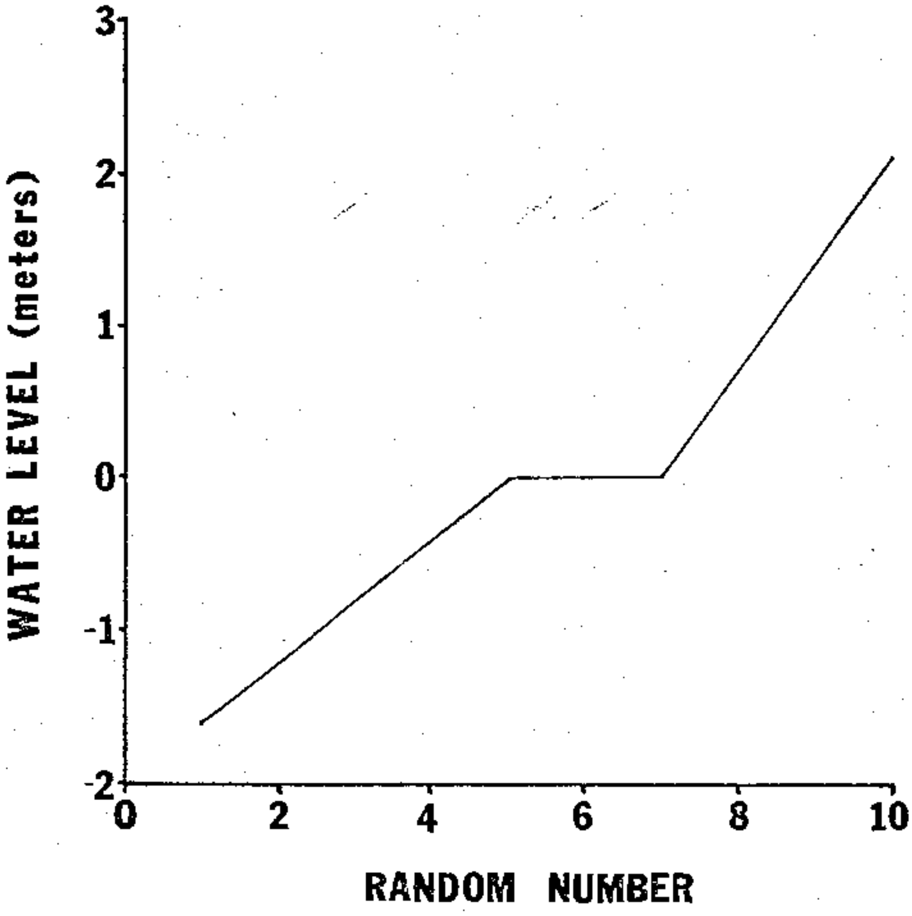

Figure 10. Water levels generated by random numbers. The normal water level is designated by 0.

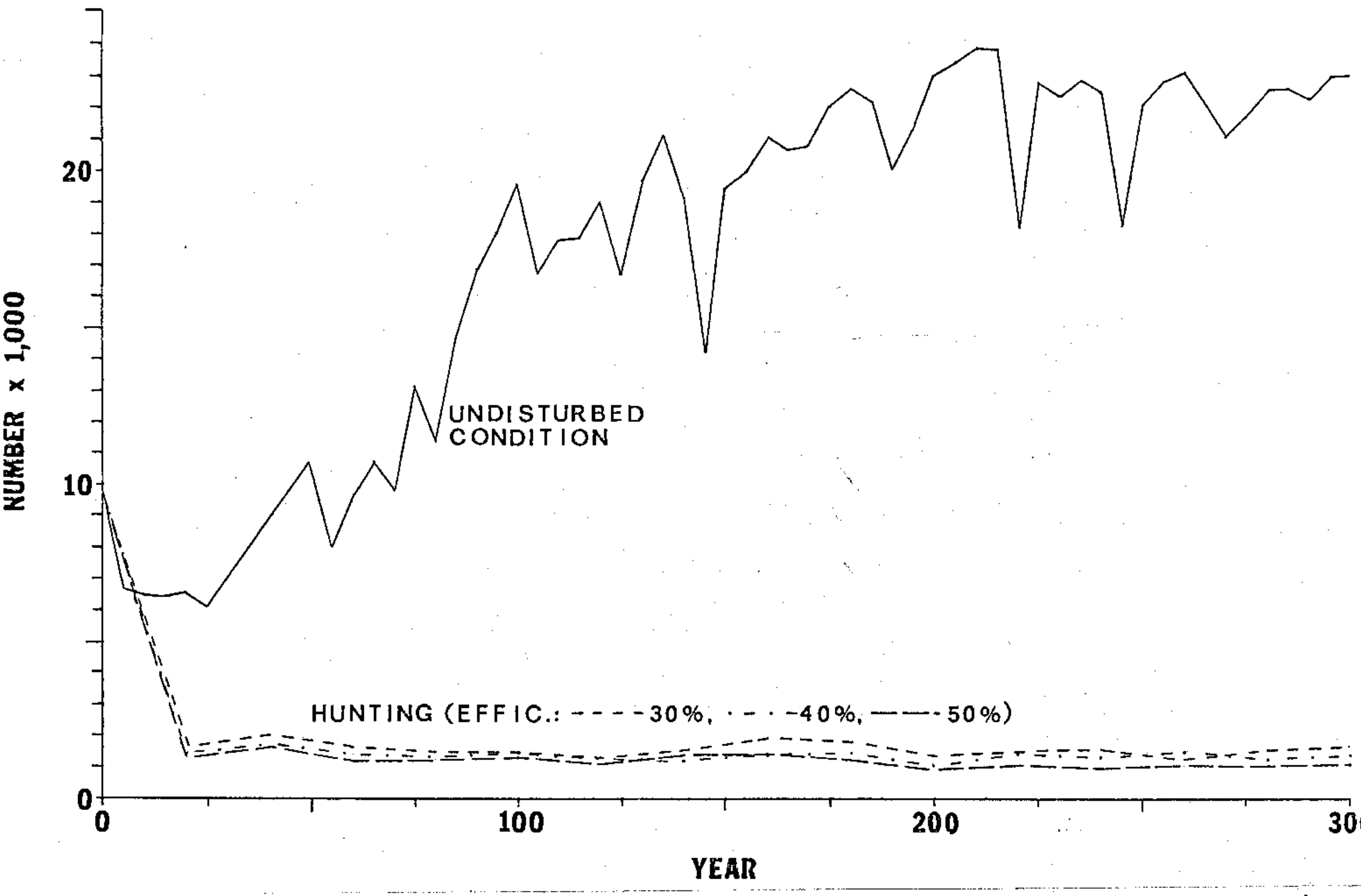

Figure 11. Trend of the total population without unusual environmental disturbance, and the population's reaction to various levels of hunting efficiency at a minimum of 300 harvestable crocodiles.

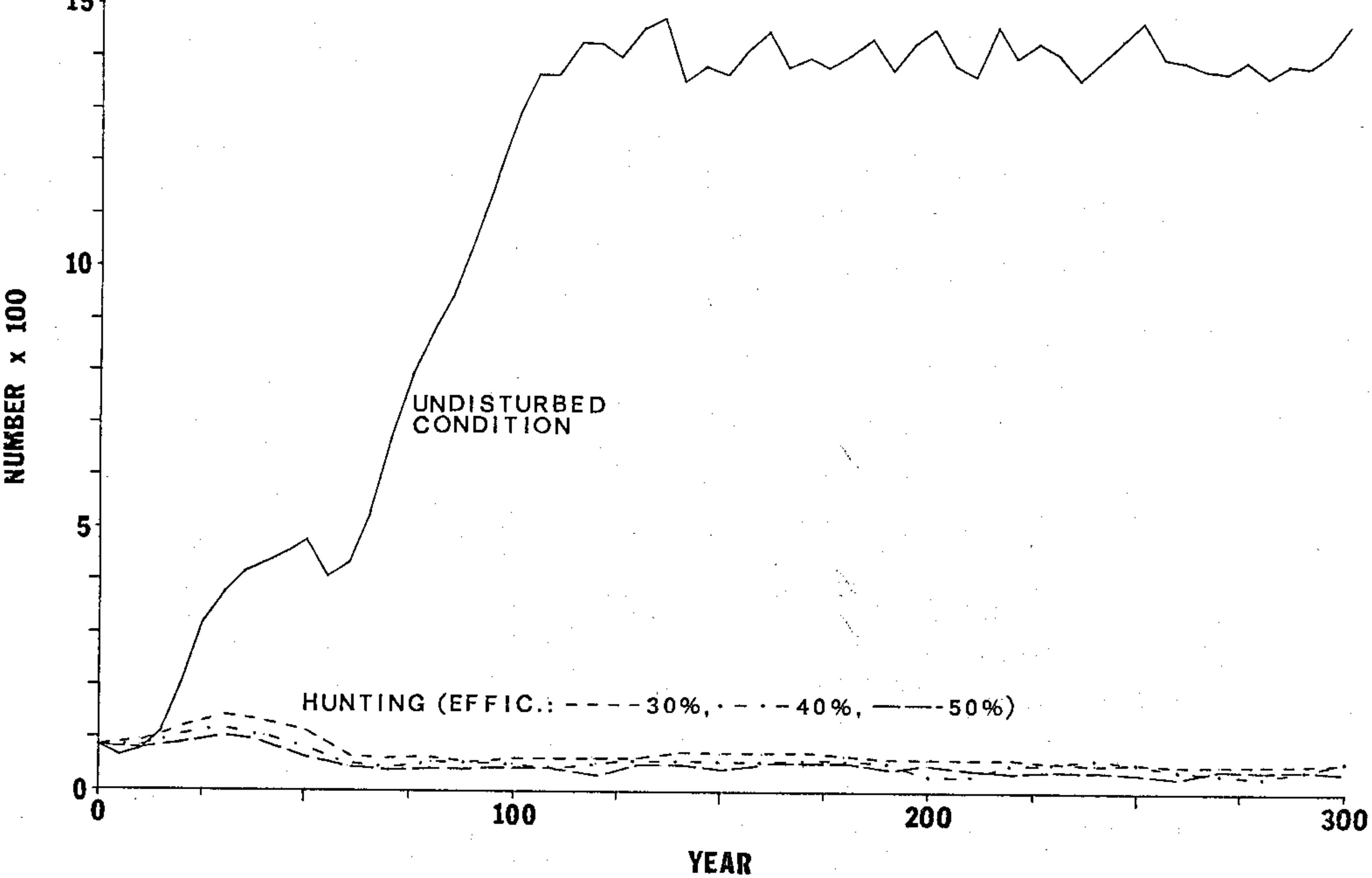

Figure 12. Trend of the nesting female cohort without unusual environmental disturbance, and the cohort's reaction to various levels of hunting efficiency at a minimum of 300 harvestable crocodiles.

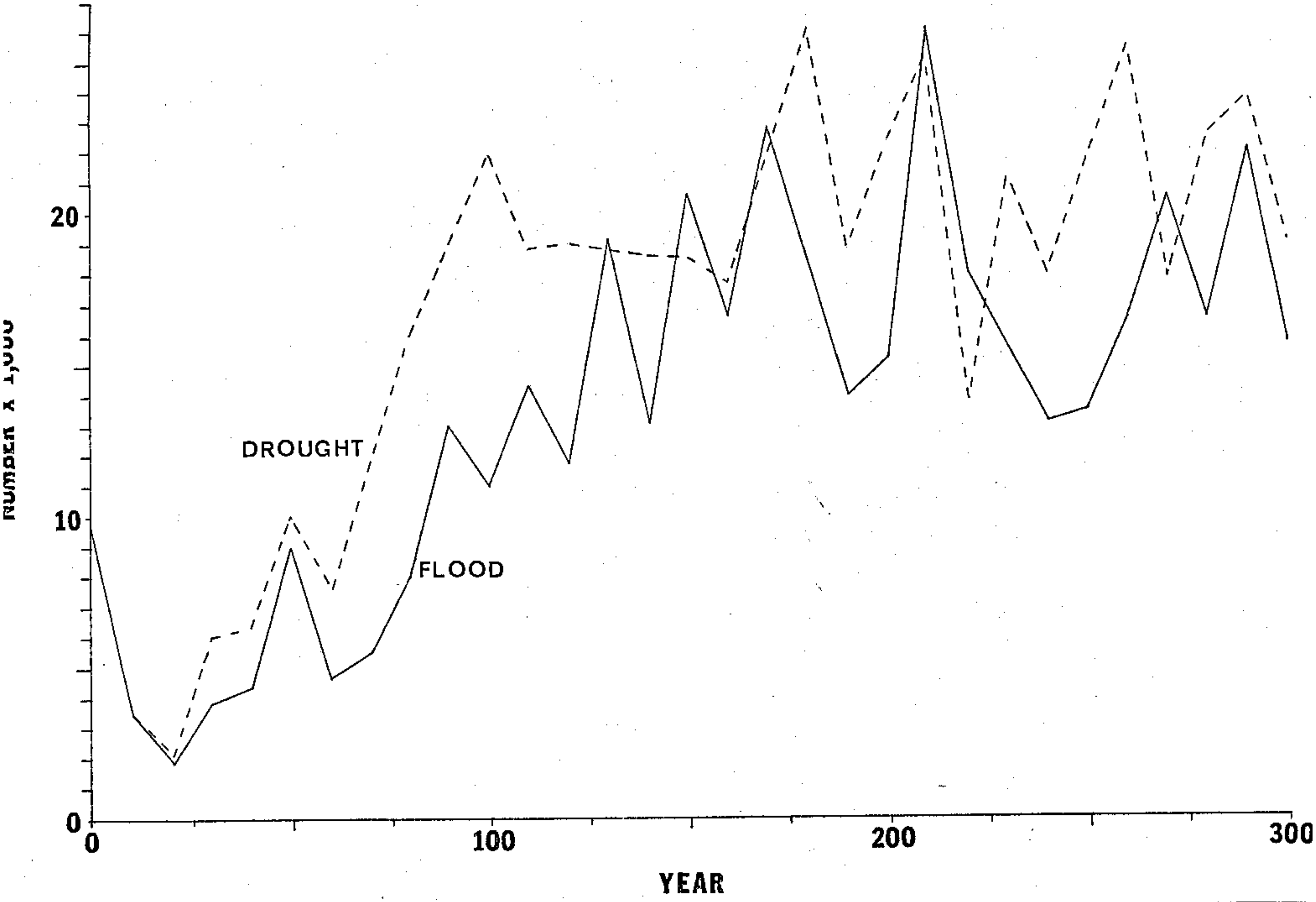

Figure 13. Effects of 4 consecutive years of droughts and floods every 20 years on the total population.

APPLIED ECOLOGICAL STUDIES OF THE AMERICAN ALLIGATOR AT THE SAVANNAH RIVER ECOLOGY LABORATORY: AN OVERVIEW OF PROGRAM GOALS AND DESIGN

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ABSTRACT: The alligator research program at the University of Georgia's Savannah River Ecology Laboratory operates as an integral component of the laboratory's general research program in the area of thermal ecology. As such, the program has been primarily directed toward assessment and prediction of impacts resulting from the introduction of heated effluents from operating nuclear reactors into natural aquatic ecosystems of the southeastern United States. Early studies concentrated on an assessment of the movement, behavior, and population dynamics of the alligator population inhabiting Par Pond, an 1120 ha reactor cooling reservoir located on the Department of Energy's Savannah River Plant near Aiken, South Carolina. Later studies utilized multichannel radiotelemetric techniques and dealt with body temperature profiles and thermoregulatory behavior of free-ranging alligators in the Par Pond reservoir. In 1976, adult alligators experienced increased mortality levels following routine trapping and handling operations. Subsequent studies suggested that increased levels of the bacterium *Aeromonas hydrophila* in the reservoir were at least partly responsible for these stress-related deaths. However, the present lack of control studies in unheated reservoirs makes it difficult to differentiate the ecological effects of water temperature elevations *per se* from the general ecological responses of the resident alligator population to the possibly marginal reservoir habitat.

The Savannah River Plant (SRP) is a 750 km^2 protected area located near Aiken, South Carolina (USA). This area was closed to public access in 1952 when it was first designated as a nuclear production and research facility by the United States Atomic Energy Commission (now the United States Department of Energy). The research program of the Savannah River Ecology Laboratory (SREL), which is located at the site, is primarily directed toward evaluating and predicting the environmental impacts of nuclear- and other energy-related industrial activities at the SRP. An important component of this research deals with the effects of aquatic stress, particularly increased water temperatures resulting from the introduction of reactor cooling effluents, upon natural aquatic ecosystems and their inhabitants. A general overview of these research efforts (Gibbons and Sharitz 1974, Gibbons, Sharitz, and Brisbin 1980) indicates that this program of "thermal ecology" is directed at a variety of levels of biological organization and at species occupying a variety of trophic levels within the SRP aquatic ecosystems, including top carnivores such as the American alligator (*Alligator mississippiensis*).

Early studies of the fauna of the SRP site (Freeman 1955, Jenkins and Provost 1964) have indicated that the American alligator has always been resident on the SRP site, although it was probably not commonly encountered until after the closure of the area to public access reduced hunting pressures and other forms of human disturbance.

Alligator research activities at the SRP have mainly focused upon the population of animals resident in the Par Pond reactor cooling reservoir (Fig. 1). The Par Pond reservoir system was created by damming a natural stream watercourse on the SRP site in 1958, forming a major reservoir of over 1100 ha of open water and two smaller reservoirs of 67 and 81 ha. These reservoirs currently receive and have received throughout their past, varying levels of heated water input from the site's reactors. Heated waters leave the reactors at temperatures often in excess of 70°C, although the highest temperatures in those portions of the reservoirs inhabited by alligators seldom exceed 35-40°C (Murphy and Brisbin 1974, Murphy 1981). Detailed studies characterizing Par Pond habitats have been published elsewhere by Park, Hirshfield and Gibbons (1973) and Lewis (1974). A general overview of the status of the alligator in the Par Pond reservoir, as well as in other aquatic habitats of the SRP, has recently been compiled by Murphy (1981).

Systematic scientific studies of the SRP alligators began in 1968, with a four-year distributional survey of the locations of alligator sightings throughout the main body of the Par Pond reservoir (Murphy and Brisbin 1974). These studies suggested, but did not conclusively prove, that at least some of the alligators in the reservoir showed a tendency to move with the falling temperatures of autumn into the portion of the reservoir where heated reactor effluents maintained warm water temperatures throughout most of the colder months of the year. The alligators wintering in the so-called "Hot Arm" of the reservoir (Fig. 1) remained active and were observed capturing and feeding on migratory waterfowl during the colder winter months, while alligators that remained in other parts of the reservoir, which experienced ambient winter temperatures for the region, became inactive and seemed to enter torpid states.

The later development of an efficient technique for capturing alligators with baited trip-snares (Murphy and Fendley 1975) allowed the initiation of surveys and radio-telemetric movement studies by Murphy (1977). These studies indicated that most of the reservoir alligators tended to have different winter and summer "core areas" of activity, with these areas being, in many cases, constant and predictable in location between years. Shuttling long-distance movements back-and-forth between winter and summer "core areas," often a distance greater than 3 km, began in the spring when ambient water temperatures exceeded 15°C or when ambient water temperatures fell below 25°G in the autumn. Two major winter "core" areas were identified in the reservoir, one being the site of entry of the heated effluents and the other being a cove along the southeastern shore of the reservoir's "North Arm" (Fig. 2). More than 10 adult alligators were found in the latter area from late October to

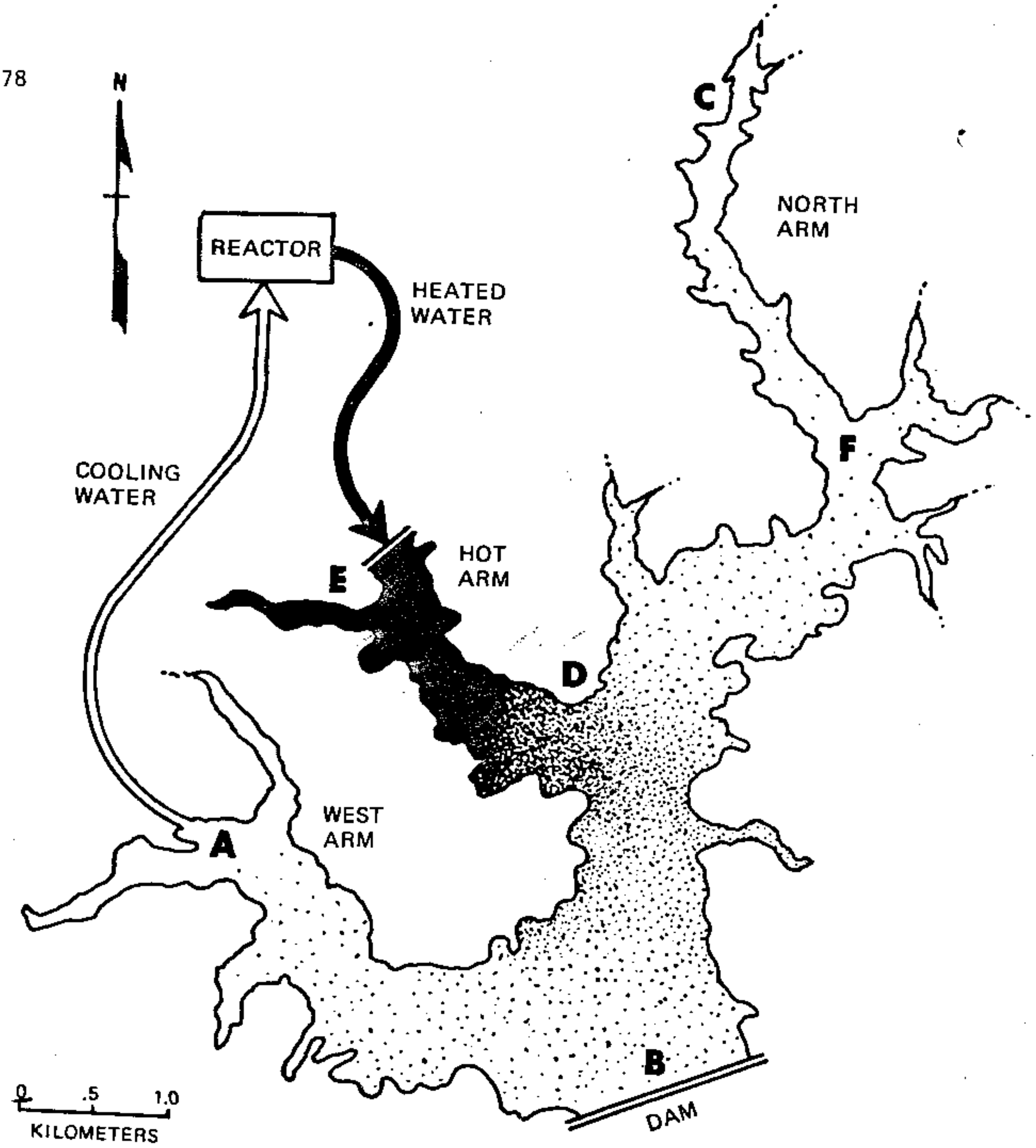

Figure 1. Map of the Par Pond reservoir at the U. S. Department of Energy's Savannah River Plant, showing locations mentioned in the text. Heated reactor effluents from an operating nuclear production reactor currently enter the reservoir at point "E" and pass southward to the main body of the lake (points "D" and "B"). Ambient temperature water is then pumped back through the reactor from point "A," forming a closed cooling loop. In earlier years, a now-abandoned reactor similarly introduced heated water into the reservoir at point "C." The heated water from this abandoned reactor also moved southward through the reservoir and at the present time, the region encompassing points "C," "F," and through "D" may be thought of as being in a state of post-thermal impact recovery. The intensity of stippling is roughly proportional to the degree of present thermal impact produced by the remaining operating reactor.

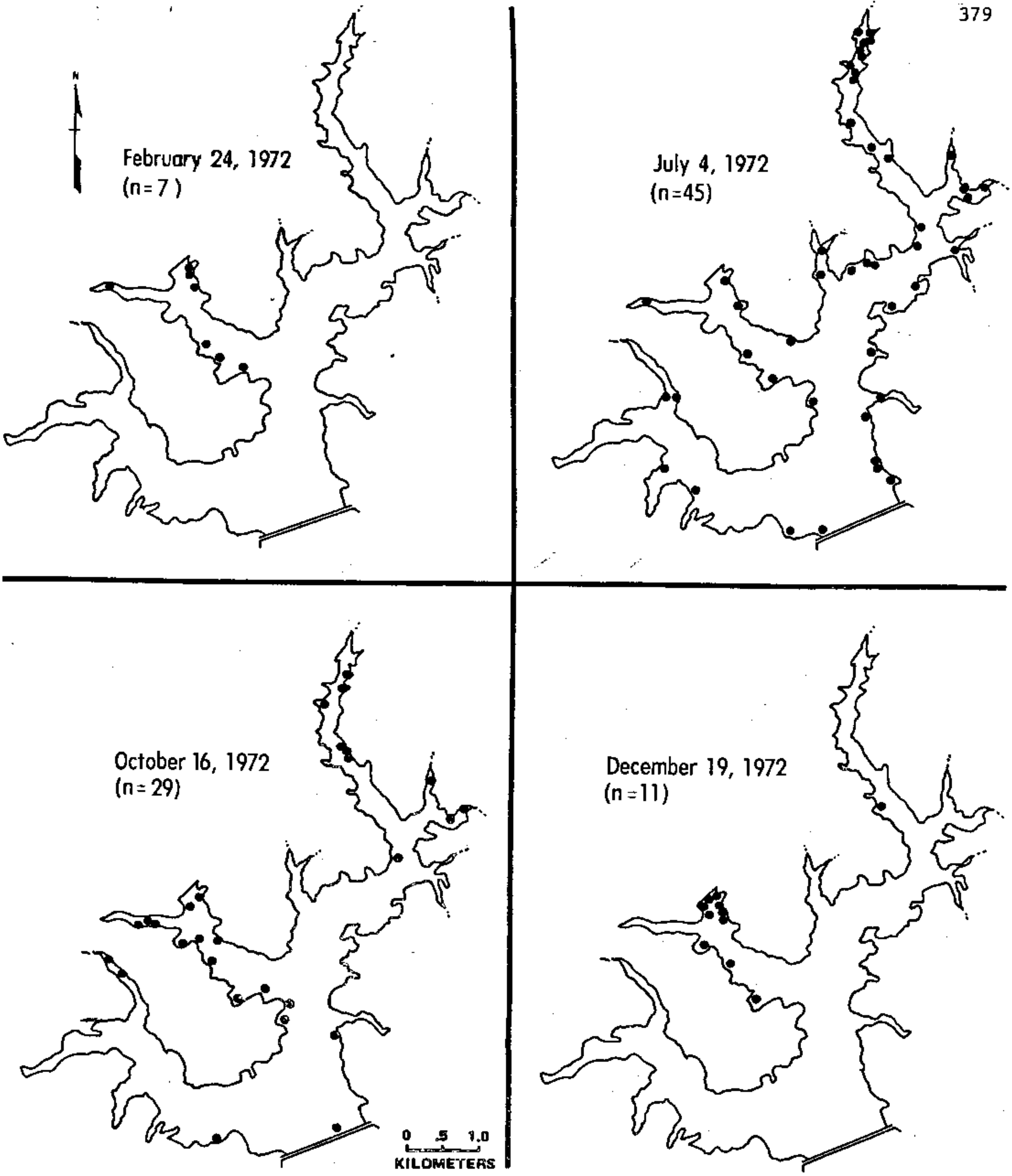

Figure 2. Seasonal changes in the distribution of American alligators sighted during four night census cruises in the Par Pond reservoir of the U. S. Department of Energy's Savannah River Plant. Each dot represents the sighting of a single individual, whose location may be related to the water temperature gradients of the reservoir by comparing with Figure 1. (From Murphy and Brisbin 1974).

mid-March, during which period of time they were usually in a generally dormant state, as opposed to those active animals that wintered and remained active in the reservoir's "Hot Arm."

In addition to providing information on the seasonal movements and behavior of the Par Pond alligators, Murphy (1977) also utilized several census methods to estimate the number of alligators residing in the Par Pond reservoir. This work yielded estimates of 40 juveniles and between 62 and 70 adults in the resident population. Even more important however, this work provided a means of quantitatively comparing the population estimates derived from mark-and-recapture procedures, including the Schnabel and Lincoln index methods, with those provided by the Hansen plot-removal method (Hansen 1968). The latter method provided population estimates that were in close agreement with those of the mark-and-recapture methods and should eventually prove to be a particularly useful method for estimating population numbers of crocodilians, as it is especially suited to the census of animals that can only be sighted (as for example by their eye-shine in a night spotlight survey) but not marked or individually identified. In addition to population censuses, Murphy (1977) also estimated juvenile growth

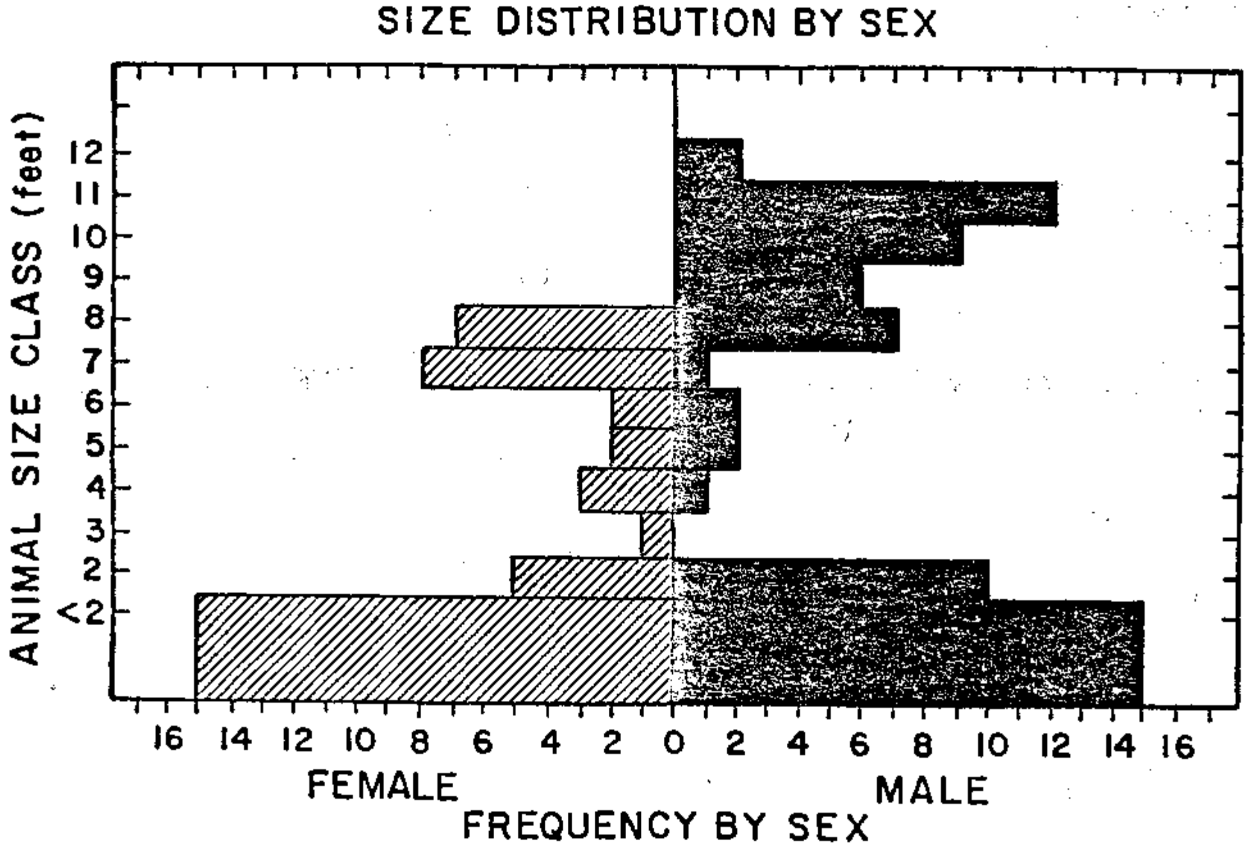

Figure 3. Frequency distribution of size classes of male and female alligators from the Par Pond reservoir of the U. S. Department of Energy's Savannah River Plant. Adjustments of frequency distributions were made so as to conform to actual population estimates (see Murphy 1977, 1981 for details). (From Murphy 1981).

rates, sex ratios, and size-class frequencies for the Par Pond population. This information indicated that, although juvenile alligators in the reservoir's "Hot Arm" grew more rapidly than those from the "North Arm," the growth rates of juveniles from all parts of the reservoir tended to be generally lower than those reported for alligators from Louisiana (McIlhenny 1935). The Par Pond population also showed a greater excess of males than any other population of alligators reported in the literature, as summarized by Nichols and Chabreck (1980). The Par Pond population was also characterized by a top-heavy pyramid of size-structure, with relatively few if any individuals in the juvenile size classes (Fig. 3). This information suggested that the Par Pond reservoir may represent submarginal habitat for alligators, and that reproduction and population recruitment may be considerably less than optimal. Specifically, Murphy (1977, 1981) has used the calculation procedures of Chabreck (1977) to demonstrate that the estimated number of alligator nests on Par Pond (2.3 per year) is 85% lower than the number of nests that should be expected on the reservoir if the female residents there showed the same reproductive potential as those studied by Chabreck (1966) in Louisiana.

Concerns regarding the apparently low rate of reproduction in the Par Pond population and the possible involvement of water temperature changes, prompted Murphy (1977, 1981) to undertake surveys of the dates of sperm production by male alligators in the reservoir. The importance of this information was based on the fact that those alligators residing within the heated waters of the "Hot Arm" during the winter months, including a disproportionately high number of larger males, would presumably be the individuals likely to dominate the breeding activities during the following spring (Joanen and McNease 1980). Periodic recaptures of marked individuals during the winter and spring of 1975 and 1976 revealed that the males residing in the "Hot Arm" of the reservoir first showed the presence of sperm in the penile groove 30 and 12 days, respectively, before the first appearance of sperm in the males of the nearby "North Arm" in the same years. Although dates of termination of spermatogenesis were not documented by this study, these findings suggested the possibility of the development of some degrees of reproductive asynchrony between the large males, which spent the winter in the heated waters of the "Hot Arm," and the reservoir females, which had a greater tendency to spend the winter months in water of more ambient temperatures.

As indicated by Joanen and McNease (1980), Louisiana male alligators produce sperm for a period of about 43 days each year. If this is also true of Par Pond animals, the time of sperm production could be shifted for "Hot Arm" resident males by as much as 70% of the total period of sperm production! Spermatogenesis was initiated in Par Pond males, from both heated and ambient portions of the reservoir, between 26 March and 17 May, while the earliest date for spermatogenesis in Louisiana males, which actually inhabit a more southerly portion of the species' range, was 9 May (Joanen and McNease 1980). These preliminary data suggest that the movement patterns of the larger Par Pond male alligators, and their consequential winter residency in the heated waters of the reservoir's "Hot Arm," may be significantly related to the reduced reproduction as described earlier. Further studies are needed, however, to determine the total duration of spermatogenesis for males residing in various portions of the Par Pond thermal gradient.

In addition to population surveys of the Par Pond alligators, the SREL alligator research program has also emphasized studies of thermoregulatory behavior and thermal energetics. These studies have made extensive use of multi-channel radio-telemetric techniques which were designed to continually monitor both the experienced microclimatic temperatures of air and/or water, and the body temperature profiles from several locations throughout the bodies of large free-ranging alligators, as they moved about through the water temperature gradients of the Par Pond reservoir (Standora 1977). Although much of the data collected in this program has not yet been analyzed and published, preliminary analyses have suggested that such data may provide field verifications of previously published theory and laboratory models of crocodilian thermoregulation and biophysical ecology (Spotila, Soule, and Gates 1972, Spotila 1974, Smith and Adams 1978, Smith 1979). The first two studies, for example, indicate the significant role of water in the body temperature control of larger alligators, and this relationship can now be examined under field conditions where a gradient of water temperatures is available.

The SRP is located along the northwesternmost inland limits of the species' range in this part of the southeastern United States (Kellogg 1929). With the possible exception of the range of the Chinese alligator (A. sinensis), this site thus provides an opportunity to examine thermoregulatory behavior and body temperature profiles under what may be some of the coldest winter environmental conditions ever naturally experienced by any living crocodilian. In studies presently submitted for publication, deep body temperatures have been remotely recorded from free-living alligators during periods when air temperatures dipped as low as -3.1°C and ice several cm in thickness formed on the reservoir above the torpid animals. These studies have suggested that the selection of an appropriate microhabitat, located in close proximity to deep water which may act as a heat source to the animal during cold periods, may be of critical importance to the survival of Par Pond alligators during such winter cold spells. The physical properties and thermal inertia of the bodies of such large alligators, when placed in appropriate microclimates, seemed to be sufficient to explain the general patterns and levels of body temperature changes observed, without invoking any significant degree of homeothermy such as has been suggested for some species of dinosaur (Desmond 1976).

A major research effort has also been undertaken at the SREL concerning the ecological genetics of fish and wildlife populations--particularly emphasizing the use of horizontal starch-gel electrophoresis as a means of determining levels of genetic variability and degree of genetic relatedness between populations of endangered species in a general sense and larger reptiles in particular (Smith et al. 1978, Chesser, Smith, and Brisbin 1980). A study of biochemical variation in the American alligator has recently been completed as a part of this program (Adams, Smith, and Baccus 1980) and compares levels of genetic variability and degree of genetic relatedness between alligator populations found on or near the SRP with those of other alligator populations from Florida and Louisiana. Briefly, this work has confirmed the relatively low level of genetic variability which had been reported for the alligator by earlier studies in the literature (e.g. Gartside et al. 1977). Furthermore, while alligator populations from the three states were shown to have differing allele frequencies, the degree of overall genetic divergence between populations was found to be small (Fig. 4). These findings suggest that, if low levels of genetic variability are found in either captive or wild populations of crocodilians, it may not necessarily indicate that such species have been genetically "bottlenecked" to the point where recovery of viable population levels is no longer possible. American alligator populations have survived very well and have been restocked and restored to abundance in their former habitats without displaying a great deal of genetic variability during their recovery (Gartside et al. 1977, Adams, Smith, and Baccus 1980).

With the possible exception of the creation of reproductive asynchrony in some Par Pond male alligators as a result of thermal gradients created in the reservoir, the majority of the studies of this species on the SRP have failed to show any noticeable negative effects upon the animals as a result of ongoing nuclear industrial activities at the site. In fact, the security and protection from disturbance or harrassment by the public must certainly be beneficial. One significant exception, however, was the discovery of low levels of sublethal infections of the bacterium *Aeromonas hydrophila* in certain Par Pond alligators during 1975 and 1976. During this period, nine large adult alligators died shortly after routine trapping, handling, measuring, and radio-collaring operations. Since most of these animals had been similarly captured and handled a number of times during the preceding two to three years with no ill effects, the presence of some additional stressor agent was suspected. Autopsies were conducted, resulting in the isolation and identification of the bacterial agent as the probable cause of the mortality observed (Gordon et al. 1979).

This work, together with related studies by Classman and Bennett (1978) also suggested that thermal stress, imposed by the heated effluents being introduced into the reservoir, may have acted synergistically with the stress of capture and the bacterial infections, to produce the observed mortality--particularly during the warmer summer months. Other studies being conducted at the SRP have independently demonstrated a similar synergistic relationship between thermal stress and *Aeromonas hydrophila*-associated red-sore disease of large-mouthed bass (*Micropterus salmoides*) in the Par Pond reservoir during the same general period (Esch and Hazen 1978). Similar stress-related deaths, involving associations with *Aeromonas* infections, have also been reported

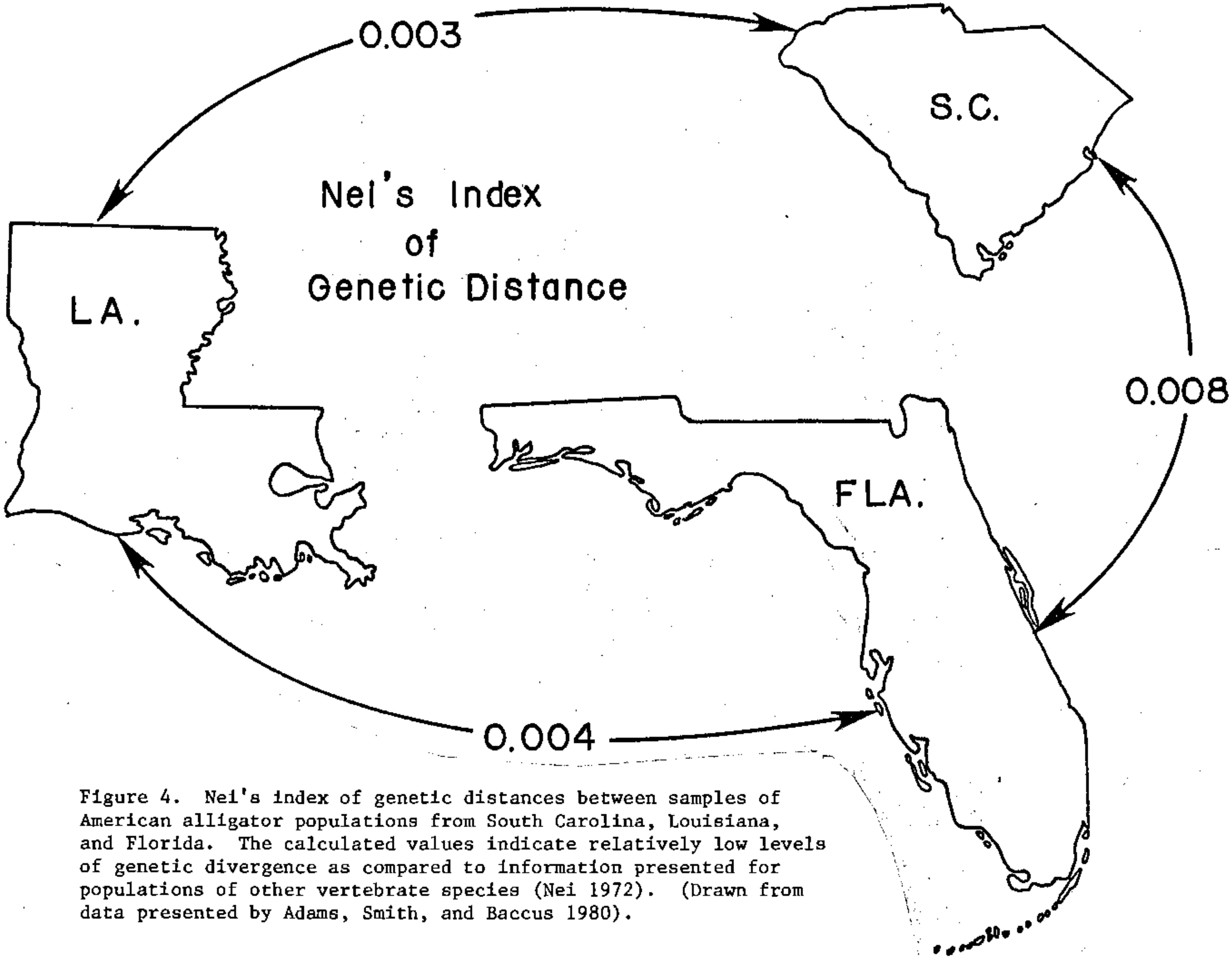

Figure 4. Nei's index of genetic distances between samples of American alligator populations from South Carolina, Louisiana, and Florida. The calculated values indicate relatively low levels of genetic divergence as compared to information presented for populations of other vertebrate species (Nei 1972). (Drawn from data presented by Adams, Smith, and Baccus 1980).

for fishes, alligators, and other reptile species from other lakes in the southeastern United States (Shotts et al. 1972). Other SRP research, currently being prepared for publication, has used laboratory studies to further describe the synergistic relationships between thermal stress and Aeromonas infection and mortality in alligators, with special attention being focused upon modes of bacterial transmission and the possible use of prophylactic agents to reduce the incidence of stress-related deaths.

The Aeromonas-related deaths of the Par Pond alligators suggest that further studies are needed to determine the role of water temperature gradients and the reactions of alligators to them. Such studies would be of importance beyond their immediate application to the situation on the SRP, because alligators are known to be attracted to the vicinity of heated-water outfalls from operating power plants in Florida and several other southeastern states (H. W. Campbell, pers. comm.).

In order to precisely determine the role of heated-water effluents in the ecological relationships of Par Pond alligators, control studies must be initiated in similar southeastern reservoir systems in which there is no introduction of heated waters. The studies of the Par Pond alligators represent the only systematic study of the ecology of this species in a man-made reservoir system. It is therefore not possible at this time to determine which, if any, of the ecological relationships of these alligators are attributable to the effects of heated water, as opposed to the ways in which alligator populations might respond to a protected man-made reservoir habitat. Considering the characteristics of optimal habitat for this species throughout its range, it is possible that relatively open and deep man-made reservoirs, such as the Par Pond system, may represent marginal alligator habitat in a number of respects. Studies of such reservoir habitats should become an important concern to all crocodilian biologists, because it appears that a number of crocodilian species from various parts of the world have shown a tendency to colonize and remain within such habitats. In this respect, the alligator studies being undertaken at the Savannah River Ecology Laboratory may suggest some useful approaches for such future investigations.

ACKNOWLEDGEMENTS

The alligator research program at the Savannah River Ecology Laboratory is supported under a contract (EY-76-C-09-0819) between the University of Georgia and the United States Department of Energy. The author is grateful to Mr. Robert Morgan and Mr. Nathaniel Stetson (retired) of the Savannah River Operations Office, United States Department of Energy, for continued support of and interest in the site's alligator research activities. Mr. Tom Strekal of the Office of Endangered Species provided assistance in obtaining federal permits under which this work is currently being conducted. J. Whitfield Gibbons and Ray Semlitsch provided critical readings of this manuscript. Last but not least, the author is grateful to the many students and technical personnel of the SREL who have participated in various aspects of the alligator research program over the years. Deserving of special mention have been the pioneering research efforts of Tom Murphy and Ed Standora, and the field assistance of Tim Fendley, Clarence Bagshaw, Mike Vargo, Paul Johns, Garfield Keaton, Fred Stone, and last but not least my wife, Pam.

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TECHNIQUES OF SURVEYING FOR CROCODILIANS

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INTRODUCTION

A great number of techniques have been developed for surveying crocodilians, and these vary with regard to the situations in which they are applicable and the type of data they produce. When planning a survey, the first, most important and often the most difficult stage is to link a method of data collection with a method of analysis that will allow a definitive answer to the question being asked. Some questions may not be amenable to study with the time and resources available, and it is best to be aware of this at the start of the study. Two common and important uses of survey techniques are to establish the status or the maximum sustainable yield (MSY) of a population. As many studies to determine the status or maximal permissible levels of exploitation for a population are based on one survey, their titles are probably misleading. Neither the status, nor the maximum sustained yeild of a population can be determined from a single survey. One survey can at best determine that: (1) the species was very difficult to observe; or (2) large numbers of animals were seen in the area. Result (1) translates into: the species requires urgent study (conservation organization) or the species is too rare to consider for exploitation (management authority). Result (2) translates into: in the absence of other information the species can be given low priority for research in comparison with other species (conservation organization), or the species <u>may</u> be sufficiently common to support some form of exploitation (management authority).

These results are very general and in most instances could have been predicted before the survey. Fairly obviously, if surveys are to be cost-effective, they must recognize the dynamic aspect of the population under study. This is not to say that a survey to investigate the status of a population should be undertaken only if money is guaranteed for future surveys. Rather, care must be taken to ensure that the results are collected in such a way that will allow comparisons if and when the opportunity for follow-up studies occurs. In the case of attempts to take sustained yields from populations the situation is stated clearly by Caughley (1977): "The calculation of an MSY must be treated as a first approximation and the effect of the harvesting must be followed carefully to allow fine adjustment towards the optimum."

All too often the results of a survey are presented as the number seen, or sometimes, more ambitiously, as the absolute number of animals present. Even if the results are taken at face value, their significance is likely to be hotly debated. Except in the case of extremes (e.g. none or millions), we need more basic biological information in order to make informed decisions:

(1) population age/size structure;
(2) distribution of population, stratified by size and sex, amongst habitats;
(3) distribution of habitats in the area surveyed.

When the biology of the species is already fairly well known we can sometimes streamline the follow-up surveys by concentration on a critical, or representative, segment of the population. This can be useful as it may allow us to use artifacts (such as nests or tracks) to monitor the population, so reducing interference and/or expense. In general, the collection of additional biological information adds very little cost to the survey (often as little as extra ink and a few notebook pages) but may be critical to the interpretation of results. Consider the case of an isolated population occupying only one hectare. The population is considered endangered and a proposal to create a 10,000 hectare reserve for the species is made. It may be that the population was limited by lack of a particular resource, perhaps habitat with cover for juveniles. In that case a 10,000 hectare reserve not containing more of the resource would have only half the potential for recovery as a 10,001 hectare reserve that contained an additional one hectare of the resource. Alternatively, a 5 hectare reserve of a different shape might be equally effective and more likely to gain legislative approval.

Basic to any sampling program is that surveys be objective, unbiased, and replicated. Objective means as independent of the observer as possible. Unbiased means not subject to systematic error. Replicated indicates that a variance estimate can be made. In reality no system of survey is totally objective or unbiased, and it is often difficult to achieve sufficient replication, especially when it is necessary to stratify by habitat. Nevertheless, a little thought at the planning stage can save a lot of headaches later on and greatly increase the utility of the results.

In the following section I will review most of the techniques that have been used in surveying for crocodilisns. None is necessarily better than the others, though some are applicable over a wider range of conditions. The would-be surveyor needs to look for similarities between his situation and that described in terms of habitat, resources, and the biology of the species. A more general discussion of planning the survey is given in the final section.

METHODS OF SURVEY

Interviews and Opportune Personal Observations

Interviews and opportune personal observations are usually the least preferred methods of obtaining information, as both methods are likely to be subjective, biased, and unreplicable. However, they are cheap and are frequently used by biologists to obtain information while visiting an area for other reasons (Moore 1953; Charnock-Wilson 1970; Abercrombie 1978; Whitaker and Whitaker 1978) or to augment more detailed studies (Parker and Watson 1970). Sometimes the results are so dramatically obvious that decisions can be based directly on them. Joanen (1974) was able to establish the general distribution and trends in numbers of alligators in the southern U.S.A. from a detailed questionnaire sent to all wildlife agencies in the area; Morgan and Patton (1979) established, on the basis of lack of records, that *C. acutus* had been extirpated from the Cayman Islands; and the staff of the Madras Snake Park were able to show by 5000 miles of survey (interviews and opportune observations) which revealed only 6 animals that the gharial had been reduced to critical levels (Whitaker 1975). Often interviews are useful to expose public attitudes to crocodilians and have been used solely for this purpose (Hines and Scheaffer 1977).

Whatever their merits as survey techniques in some situations, interviews and opportune personal observations will generally be used by researchers addressing a specific problem only as a means to identify appropriate study areas in preparation for the use of one of the following, more detailed, techniques.

Daylight Ground Counts

Daylight ground (foot, boat, or car) surveys of crocodilians generally reveal only a small percentage of the population (Graham 1968). Chapman (1970) has estimated that percentage as 20-50% for *Crocodylus niloticus*, but there have been no detailed studies and it will surely vary between species and habitats. In general such techniques are used only when some aspect of the biology of the animal makes the population, or a subset of the population, abnormally indifferent to exposure. *C. niloticus* in some areas is exceptionally easy to count during the breeding season, as all mature adults congregate on a few beaches. Modha (1967) gave details of nesting congregations on Central Island, Lake Rudolf, and Pooley (1969) described the concentration of mature crocodiles in Lake St. Lucia (45 miles long) onto 1 1/2 miles of nesting beaches. Inchaustegui et al. (1980) reported similar breeding aggregations of *C. acutus* in the Dominican Republic. Thompson and Gidden (1972) counted *Alligator mississippiensis* basking during the first spring warm spell in northern Florida. Cott (1968) reported ground counts of nesting *C. niloticus* but presented data that indicate counts from the air (fixed-wing aircraft) reveal a greater proportion of the population. The only carefully controlled daylight ground surveys of crocodilians repeated over a number of years seem to be those of Pooley (1969) in Ndumu Game Reserve between the years 1962 and 1968. His data also demonstrated the importance of taking the biology of the species into account during such surveys. Counts during winter when a greater proportion of the crocodiles were basking on mud banks were consistently much higher than those undertaken during summer.

In summary, daylight ground counts generally reveal only a fraction of the population, but may be used effectively by a biologist who already has a fairly intimate knowledge of the biology of the species.

Daylight Surveys from Aircraft

Most of the same comments apply to this technique as to daylight ground surveys. The technique has its greatest value in habitata without tall vegetation that hides crocodilians from view. The only direct comparison of daylight ground counts with counts from the air seems to be that of Cott (1968) which indicates that aerial counts are more effective. Where applicable, aerial counts would probably always be preferable because of their speed and replicability. Data from Graham (1968) and Parker and Watson (1970) indicate that daylight counts from aircraft record only a small proportion of the animals that are revealed by night spotlight counts,and that the daylight counts from aircraft are strongly biased against small animals. Graham attempted to use aerial photography to census but found that suitable weather conditions were not sufficiently frequent to justify its use. Parker and Watson (1970) successfully surveyed part of the Victoria Nile using aerial photography and by use of standardized length markers anchored near shore were able to estimate the sizes of the crocodiles appearing in the photographs. Unfortunately there was an obviously very large, but unmeasurable, bias against some size classes, making their postulated size structure of the population so hypothetical as to be of little practical use.

The choice between use of a helicopter or a fixed, high-wing aircraft largely depends on cost. One would expect to see more animals at slower speeds but this must be weighed against the more frequent maintenance, less personal safety, and higher operational costs in a helicopter. In any case Parker and Watson (1970) reported no significant differences in the counts obtained from light aircraft and from helicopters surveying the same areas for *C. niloticus*. General aeronautical aspects of survey by fixed-wing aircraft have been reviewed by Grigg (1979).

Night Counts

Counting at night, usually from a boat, with the aid of a spotlight is the most widely used method of censusing crocodilians. The reflective tapetum of a crocodilian's eye glows red in a spotlight and can be seen for a considerable distance. This is the method most commonly used for intensive poaching, and therefore the method directly measures the hunted population. The biases due to animals learning to avoid the spotlight under heavy hunting pressure may reduce the number seen, but this is important mainly with older, more experienced, age groups.

The method frequently has been used to monitor hunted populations (e.g. Chabreck 1976; Onions this volume) and for surveys of status (e.g. Campbell 1972; Graham 1968; Messel et al. 1978; Parker and Watson 1970; Pernetta and Burgin 1980). The proportion seen varies with habitat, water level, and weather conditions. Messel et al. (in press) estimated 60-70% for tidal river systems in northern Australia, but frequently the researcher "feels" that he is seeing a very high percentage (e.g. Graham 1968; Chapman 1970). For some age groups and some situations the percentage seen may be very high (e.g. Staton and Dixon 1975; Magnusson 1981), but generally it is safer to assume that a significant proportion is being missed and to try to keep this constant by standardizing procedures (e.g. Chabreck 1966; 1977). Mark-recapture techniques are likely to be of use only in limited circumstances (Chabreck 1966). Messel et al. (1978) discussed factors affecting the sightability of *Crocodylus porosus* in tidal rivers of northern Australia, and Woodward and Marion (1979) evaluated the factors affecting night counts of *Alligator mississippiensis* in lakes in Florida, U.S.A. Different methods of survey are applicable in different areas. Magnusson (1979) and Staton and Dixon (1975) used foot rather than boat surveys, and Parker and Watson (1970) surveyed areas of thick papyrus at night from a helicopter. Whatever the mode of transport, the northern Australian and Florida studies give the factors most likely to bias the results.

Surveys for Artifacts

The two most obvious artifacts that crocodilians leave are marks in the mud or sand and nests. Some species, notably *A. mississippiensis*, call during the breeding season, and on those occasions when the animal is not seen the call also can be regarded as an artifact.

Estimates of numbers and sizes of crocodilians can be made from footprints (Mitchell 1969; Joanen 1969) and tail scute marks (Bustard and Singh 1977), but the utility of these methods is limited. The proportion of animals basking on a suitable substrate, the effects of season and disturbance on basking behavior, and the number of times and places an animal will leave the water on a given day are largely unknown for most species. The greatest use of the method is in determining the presence (but not absence) of a particular individual or class of individuals which are not amenable to other methods of survey. Obvious examples are large "light shy" animals. Webb et al. (1977) used tracks to infer the presence of an attendant adult with a group of hatchlings even though the adult was not actually seen with the young.

Chabreck (1966) suggested that calls of male A. mississippiensis could be used to give an index of population density but this technique does not seem to have been used extensively. Probably, calls, like tracks, are most useful to indicate the presence of large animals that cannot be surveyed by other means.

In contrast to marks on the bank, nests of mound nesting species are easy to see and in some circumstances can be related to a known or estimated proportion of the population. Ogden (1978) estimated the number of C. acutus in Florida Bay, U.S.A., from the known number or nests that had been located over a number of years. Chabreck (1966) estimated the number of A. mississippiensis on Rockfeller Refuge, Louisiana, from the number of nests found during 1966. Probably the main advantage of nest counts is that for some species, in some habitats, they can be done from the air (e.g. Chabreck 1966; Joanen 1969; Goodwin and Marion 1978; Kushlan and Kushlan, 1981). In many cases surveying for nests may be the only feasible method of monitoring the population (Kwapena and Bolton this volume). It is possible to estimate the absolute number of nests in an area by various statistical methods even when sightablility is not 100% (e.g. Magnusson et al. 1978), but it is unlikely that this information is normally required. The number seen may be used as a minimum number present but in any case allows trends in the breeding section of the population to be monitored. The timing and intensity of nesting may vary between years, depending on the weather (McNease and Joanen 1978), and allowance must be made for this in the evaluation of long term trends in population size. To date the only application of the technique for direct management has been the monitoring of alligator populations in the Louisiana marshes (Chabreck 1966; Palmisano et al. 1973; McNease and Joanen 1978).

Biological Data That Can Be Collected During Surveys

Except in the case of total absence it is often very difficult to interpret the significance of numbers of crocodilians without further information. One of the simplest and most important pieces of information that can be taken during surveys is the size distribution of the population. Most experienced biologists feel that they can estimate sizes of crocodilians with about 90% accuracy (Chapman 1970), but this is experience and species specific. Various rules of thumb have been put forward for estimating sizes of crocodilians, such as that the distance from the eye to the snout in inches equals the length in feet (Chabreck 1966), but in reality most biologists probably estimate sizes from some "Gestalt" combination of size and shape. Only experience allows accurate estimation for each species. Nonetheless, most relatively naive observers can group crocodilians as being hatchling, small, and large (Messel et al. 1978), hatchling, small, medium, and large (Pernetta and Burgin 1980), or young, juvenile, and adult (Woodward and Marion 1979). The hatchling-medium boundary is reasonably easy to determine but the medium-large boundary will vary with species. It is best to place it at lower breeding size for females of the species being investigated if this is known. Data from Pooley (1969) illustrate the importance of size stratification in determining the effect of hunting on a population. The drastic decline he demonstrates in the larger size classes would have been masked considerably if he had lumped all sizes together. Magnusson (1979) reported large numbers of Paleosuchus trigonatus in a number of habitats sampled, but examination of the size frequency distribution revealed a total lack of animals less than one year old. This apparently healthy population therefore probably lacked some resource essential for breeding or for growth of young and was maintained by recruitment from elsewhere. The relative proportions of animals of each size also can be important for estimating population sizes from surveys of particular segments of the population, such as nesting females (Chabreck 1966; Palmisano et al. 1973; Nichols et al. 1976).

Another aspect that may be important is the distribution of sexes. Joanen and McNease (1972), McNease and Joanen (1974), and Goodwin and Marion (1978) discussed sex-related differences in movements of alligators, and Palmisano et al. (1973) discussed how this relates to possible strategies of harvesting. Webb and Messel (1978a) discussed sex-related differences in movement of C. porosus in northern Australia. Unfortunately, crocodilians usually have to be captured to be sexed. This takes the exercise from a pure survey into a long-term study. Chabreck (1963) and Webb and Messel (1977a) gave details of various capture methods that have been developed for crocodilians. It is well to remember that different species vary in their habitat preferences, behavior, and temperment. Methods used for capturing one species may well be useless for another. Loveridge (1979) reviewed methods of immobilizing crocodilians with drugs if this is necessary (it rarely is in the context of surveys). The crocodilian can then be sexed by methods described by Brazaitis (1968), Chabreck (1963), or Joanen and McNease (1978). Most crocodilians older than six months can be sexed with a fair degree of accuracy, but A. mississippiensis may not be sexually differentiated until more than 12 months old (Joanen and McNease 1978; Nichols and Chabreck 1980). The most effective method is direct observation of the penis or clitoris by gently opening the cloaca, though inserting a finger and feeling for the penis is reliable for larger animals.

Once the animal is in hand it is worthwhile to weigh, measure,and mark it, and hence increase its value if caught again. Webb and Messel (1978b) discussed morphometric data that are commonly taken,and Chabreck (1963) and Whitaker (1978) discussed marking techniques. It may even be considered worthwhile to take other biological data, such as stomach contents (Taylor et al. 1978), record marks and injuries (e.g. Webb and Messel 1977b), and external parasites.

While capture of animals under survey conditions is difficult and hence subsequent data difficult to obtain, making estimates of sizes is not. It is difficult to see how not making size estimates during surveys could be justified as the potential gains are so great.

Habitat Data

Details of habitat are easy to record and may be critical to the interpretation of results. Differential use of habitat by particular sexes and ages has already been discussed (Parker and Watson 1970; McNease and Joanen 1978; Webb and Messel 1978a). Sometimes a detailed habitat description will allow the area to be recognized on future surveys, and presentation of results stratified by area and habitat allows more detailed analysis (Graham 1968; Parker and Watson 1970) as well as facilitating comparison with follow-up surveys (see Pernetta and Burgin 1980 for an excellent presentation of survey data).

Sometimes a detailed knowledge of habitat use by a species may allow information to be gained from a survey of that habitat alone. Hines (1979) discussed the extent of habitat suitable for *A. mississippiensis* in Florida, and McNease and Joanen (1978) established the relative suitability of various marsh types for alligator nesting in Louisiana. Their study formed the basis of population estimates for alligators in Louisiana and their subsequent harvest (Palmisano et al. 1973). Magnusson (1980) established the suitability of a range of habitats for nesting by *Crocodylus porosus* in Arnhem Land, Northern Australia, and this formed the basis of aerial surveys of suitable nesting habitat in Arnhem Land (Magnusson et al. 1978), Cape York Peninsular (Magnusson et al. 1980), and the Alligator Rivers region (Grigg and Taylor 1980).

PLANNING A SURVEY

There is no single survey plan applicable to all species and conditions. If there were, the variety of techniques alluded to in the foregoing sections would not have been developed. However, there are a number of basic aspects that will enter into all surveys:

1. *Know your animal*.-- Despite the method used, the basic truth is that the quality of the survey is directly proportional to the experience of the researcher. If planning a survey and lacking a great deal of experience with the animal in question, try to spend some time with another researcher who has experience with similar species *in similar habitats*. This may avoid repetition of a lot of mistakes that have been made before.

2. *Use local knowledge with care*.-- A researcher arriving in a new area is usually impressed with the detailed knowledge of the local people,

and rightly so. The problem lies in translating this knowldge into data interpretable by the researcher. For example, initial studies on crocodile nesting habitat in northern Australia indicated a strong preference by crocodiles for a particular grass, Ischaemum australe. Most nests were located by aboriginal hunters with detailed knowledge of the area. It was only in the second year of the study that the hunters realized the researchers were interested as much in the range of habitats used as in the number of nests found and demonstrated that the crocodiles use a range of habitats in proportion to their availability (Magnusson 1980). While accepting the extent of the local peoples' knowledge, researchers should always question their interpretations of what they are being shown.

3. Research the history of the population to be studied.-- Before commencing try to deterimine historical, present, and predicted land use patterns in the area, the past and present levels of exploitation of crocodilians, and what research has already been carried out on the species which might allow special types of survey.

4. Be familiar with the geography of the area.-- Determine the amount and distribution of the various habitats that the crocodilians might be using and do replicate sampling in each, even if this reduces the number of crocodiles seen. Try to cover as representative a number of areas as possible and avoid the common tendency of concentrating on areas in which it is easy to find animals. Detailed maps or aerial photographs are invaluable.

5. Collect data on population structure.-- A minimum requisite for interpretation of results is the size structure of the population, stratified by area and habitat. If necessary, practice making size estimates on zoo animals.

6. Decide how to analyze the results before starting.-- How, where, and when to collect data will depend on what the study is attempting to demonstrate. Be sure the question or premise is clear before starting. Treat all surveys as if they were the first of a series, whether funds are presently available for repeat surveys or not. Any elementary statistics book will give a range of analyses for making tests for differences between areas and/or surveys. Be sure that data are collected in such a way that they can be plugged into some such test. Basic requirements for all analyses are replication and stratification.

7. Standardize conditions as far as practicable.-- It is not always possible to standardize all factors, but be aware of the probable causes of bias and record enough data regarding them that sensible decisions can be made as to their probable effect on the final results.

8. Allow sufficient time for the survey.-- How much time is required will vary according to the area to be covered, the researcher's previous experience, and the support facilities. In developing countries it is well to allow one week of dealing with the bureaucracy for each two weeks

of attempted survey, and, to expect one week of ineffectual survey (transport, equipment difficulties) for each week of effective survey. Most people unfamiliar with an area underestimate the time required to survey. Even a small area usually requires several months (or several years of experience leading to several weeks of survey). Often a biologist visits a country for several weeks and produces a "status report." In fact such studies do not give data on the status, they establish the urgency (priority) for determining the status of the population. A true status report for even a tiny country requires many months, if not years of work. For this reason the advantage of persons resident, or with regular access to the area, being included in the survey team cannot be overestimated.

The following people are experienced in crocodilian surveys and are currently working in the field:

Alistair Graham - C. niloticus, C. noveaguinae, C. porosus (Papua New Guinea)

Gordon Grigg - C. porosus (aerial survey of habitat, Australia)

Ted Joanen and Larry McNease - A. mississippiensis (Louisiana)
James Kushlan - A. mississippiensis, C. acutus (Florida)

William Magnusson - C. porosus (Australia), M. niger, C. crocodilus, P. palpebrosus, P. trigonatus (Brazil)

Harry Messel - C. porosus (Australia)

Tony Pooley - C. niloticus (South Africa)

Grahame Webb - C. johnsoni (Australia)

Alan Woodward and Tommy Hines - A. mississippiensis (Florida)

The following people can give details of monitoring programs now in effect:

Tommy Hines, Florida, U.S.A.
Sixto Ichaustegui, Dominican Republic
Robert Jenkins, Australia
Ted Joanen, Louisiana, U.S.A.
Navu Kwapena, Papua New Guinea
Tony Pooley, South Africa
Romulus Whitaker, India

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SUGGESTIONS FOR STANDARDIZATION OF DATA COLLECTION TECHNIQUES AND TERMINOLOGY USED IN STUDYING CROCODILIAN NESTING

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ABSTRACT: Although there are many excellent studies of ecological and behavioral factors affecting crocodilian nesting, the nonuniformity of terminology, measurement, and observational techniques used renders the making of intra- and interspecific comparisons difficult. These variations may limit the use of computerized statistical analyses to evaluate factors significant in nesting success. I am herein suggesting measurements to be made and protocols to be followed. The ideas expressed in this paper should not be construed as a mandate, but rather suggestions open to discussion.

NESTING DATA

Data taken at the nest may be divided into four major categories: (1) nest stage, (2) ecological factors, (3) nest and egg measurements, and (4) information about the adult (presumed or known female), other adults, and/or immature animals at the nest site.

1) Nest stage information requires an evaluation of the state of completion and/or survival of the nest. A completed nest contains crocodilian eggs (see Table 1 for stage determination). Dates of nest construction and stage on observation dates, date of egg laying, and, for hatched nests, date of hatching, should be noted. False nesting attempts, in the form of partial or complete mounds for mound-building species, including size of mounds and information regarding the female that built the mound, should be noted.

2) Ecological factors include, for example, the habitat type in which the nest is located, nest construction material, proximity of the nest to standing water (best taken from the central point of the nest where the two widest axes intersect), and average depth of water surrounding the nest. Highest and lowest water levels should also be taken. These data also include basic climatological factors, i.e. temperature, rainfall, relative humidity, water levels, barometric pressure, etc., which should be continually monitored.

3) Nest and egg measurements are listed in Table 2. In species that build both hole and mound nests, the type of nest should be noted. Note

if a nest site has been used before and the material of which the nest is constructed. All measurements should be metric. Because additional material may be added to mound nests as incubation proceeds, and wind and rain tend to compact these nests, only length, width, and height measurements taken within the first several days of incubation would have comparative statistical value. This caveat also holds for hole nests that may be compacted by the parent or by meteorological factors. The nest should be measured once it is completed, and the approximate age of the nest from the date of oviposition should be noted. Width and length measurements should be taken from the two widest, near-perpendicular axes, and should be multiplied by each other. As length and width are arbitrary designations, the figure l x w, which is an estimate of area (nests not necessarily being perfectly circular) should be used in statistical analyses. Height should be measured from the actual base of the nest, whether it be on land or under water, to the highest point of the nest. If a nest is located partially under water, the longest vector should be used. Height should be measured perpendicualr to the substrate, as should depth of the uppermost layer of eggs from the top of the nest and height of the lowermost layer of eggs above the base of the nest. Mean and maximum high water in relation to the egg cavity should be noted.

Egg cavity measurements should be made at both the widest and deepest portions of the cavity. Disjunction of the cavity should be noted.

If measurements of eggs are taken, first mark the top of the eggs with a non-water soluble, non-toxic substance, such as animal marking paint, and take care not to turn or roll the egg as turning can result in death of the embryo during early stages of development (see Ferguson 1980 for more information on eggs and embryonic development). Counting of eggs and noting conditions of eggs and width of central band are other standardized measurements that could be taken. The band width should increase with the stages of development (Ferguson 1979, 1980). In general, if egg measurements are to be done, the sample size should be limited to 10 randomly selected eggs per nest. This should give a sufficient sample size, especially if many nests are observed, and minimize destruction of embryos due to handling.

4) Information about the adult. Noting only the presence or absence of an adult or defensiveness versus passivity of an adult near the nest in response to human intrusion, does not yield sufficient information about the parent. Multiple visits to a nest area along with observation periods of 30 minutes or longer, especially if visits are randomly distributed around the clock, give a more complete picture of the role of an individual adult at the nest.

I have divided nest tending behaviors of *Alligator mississippiensis* observed at Okefenokee National Wildlife Refuge into five categories (Watanabe 1980):

1) Constant vigilance--adult always present at nest; always defensive;

2) Temporal defense--adult sometimes present at nest and sometimes defensive;
3) Constant tending--adult always present at the nest and never defensive;
4) Temporal tending--adult sometimes present at nest and never defensive; and
5) Adults that are never seen, but evidence, such as fresh crawl marks, wet and/or new vegetation, etc., indicates that they have been at the nest.

The above categories may not be sufficient to describe behavior of adults at nests in all situations; however, they are a starting point for determining other possible behaviors. Actual defensive behaviors of a female American alligator at a nest were described by Kushlan and Kushlan (1980). Use of their terminology, some of which was adopted from Garrick and Lang (1977) and Garrick, Lang, and Herzog (1978), will aid in maintaining uniformity of descriptions of behavior.

Presence of young from previous year classes should be noted, as should the presence of other adults or other species of crocodilians in the nest area.

If it is not possible to measure the size of the female directly, estimated size, based on either estimated nares to anterior eye length or actual measurement of hindfoot print--longest digital tip to base of palm--should be noted. All estimated measurements should be clearly designated as such.

Nest destruction and suspected (or actual) means of destruction should be noted, and destroyed nests should be visited for several days after destruction to check for presence of adult and for any rebuilding activity. Rebuilding is often evidenced by fresh vegetation and/or wet fresh spoor on an otherwise destroyed nest.

For behavioral observations, data collection may disturb a tending or guarding adult; thus many of the measurements suggested are inappropriate at such nests. Nest measurements have already been made for many species. Additional measurement data may be unnecesary for the species and/or population being studied. A careful search of the literature beforehand may spare unessential work and avoid unnecesary disturbance.

I now have available a multivariate statistical program (SPSS) that is easily adaptable for use with standardized data on crocodilian nesting. Use of this program will help analyze differences and similarities between populations. However, it is only valid if measurements and measurement techniques are comparable and standardized.

TABLE 1. Nest stage evaluation for mound nests (based on data for *Alligator mississippiensis*).

Stage 1	Pull - small clump (not 1 m in diameter) of freshly torn vegetation in area with many spoors (trails), especially spoors intersecting at pull.
Stage 2	Incomplete nest - larger than a pull, perhaps as large as a completed nest, but contains no eggs.*
Stage 3	Fresh complete nest - (24 hrs or less) eggs have fresh clear mucus coat; may not have central banding.
Stage 4	Less than 1 week old - eggshells white; narrow banding.
Stage 5	Greater than 1 week old - eggshells colored from decaying vegetation; banding of eggshell increasing in width.
Stage 6	Near hatching - eggs at top are swollen with longitudinal cracks and some flaking of shells.
Intact	Eggs present.
Destroyed	Evidence of eggs or egg fragments. Flattened top or irregular large opening. If destroyed by fire ants, only shell fragments will remain. If destroyed by flooding, the nest will be intact but all embryos will be dead.
Hatched	Female (or male) excavated - horseshoe-shaped opening or large hole at top of nest.
	Unexcavated - no horseshoe-shaped openings, but several small round openings at top and sides of nest. Eggs, embryos, and/or shell fragments should remain.

* Some researchers (McIlhenny 1935; Joanen 1969; Neill 1971; Metzen 1977; Deitz 1979) found an empty egg cavity in the nest several days before the eggs were laid.

NOTE: This table is adaptable for use with hole nesters, beginning at Stage 3. Eggs may not be discolored by vegetation, but use of Ferguson's (1980) band width ratios may aid in determining age of nests.

TABLE 2. Measurements to be taken at the nest.

Nest	(based on Joanen 1969):	
	height*	
	length*	
	width*	
	depth from top of nest to top of eggs**	
	egg cavity depth	
	egg cavity length	
	egg cavity width	
	number of cracked eggs	
Eggs	(based on Deitz and Hines 1980):	
	egg length	
	diameter at widest point	
	weight	
	width of band (follow formula of Ferguson 1980)	

* May not be available for hole nesters.
** For hole nesters, depth from substrate surface to top of shallowest egg layer.

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