CROCODILES

Proceedings of the 14th Working Meeting of the Crocodile Specialist Group

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

convened at

Singapore, 13 – 17 July 1998

(Unedited and Unreviewed)

CROCODILE
SPECIALIST GROUP

IUCN - The World Conservation Union

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Cover: Chinese alligator *Alligator sinensis* A critically endangered species and top CSG priority for conservation. Current captive breeding and habitat protection efforts underway in China will be crucal for this species survival (see Wan Zi-ming, Gu Chang-ming, Wang Xiao-ming & Wang Chao-lin Pages 80 –100). R. Godshalk photo.

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World Trade in crocodilian skins. Current events and trends.

Evaluation of re-introductions of crocodilians as a conservation tool.

Physiology of reproduction in captivity.

Methods and techniques.

Miscellaneous papers.

* Indicates papers not presented at the meeting.

CROCODILE SPECIALIST GROUP

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

FOREWORD

Once again CSG members have convened from around the world to address current urgent conservation issues of crocodilians. This meeting was deliberately located in S.E. Asia to highlight the high diversity of crocodilians and the severe threats facing them in this region. Rapid economic development, including an intense interest in crocodile farming and trade, provides us with the opportunity to ensure that use of crocodilians in the region is sustainable and provides conservation benefits to the wild populations and their habitats. At this meeting we have seen the benefits derived from highlighting one species, *Tomistoma schelegelii*, which has resulted in funding and an intense survey effort. We are confident that we can now change the conservation assessment of this species from Data Deficient to Endangered. This is the way the CSG works, identify the problem, conduct the research, provide the information to direct policy and conservation action. We express our great thanks to our friends in Singapore and throughout the region for providing the venue and platform and the vital support on which our efforts rely.

Professor Harry Messel, Chairman CSG.

SUMMARY OF THE MEETING

About 140 CSG members convened in Singapore between 14 and 17 July 1998 for our biennial worldwide meeting. The facilities and arrangements of the meeting hosts, Singapore Reptile Skin Trade Association, were impeccable and participants were quickly made to feel comfortable among Singapore skyscrapers. The meeting was opened by Dr. Ngiam Tong Tau, Director, Primary Production Department, Ministry of National Development, after welcoming comments by Mr. Koh Choon Heong representing the hosts, Singapore Reptile Skin Trade Association, and Professor Messel, Chairman of the CSG.

The working part of the meeting began with a series of presentations on recent work on *Tomistoma* in Sarawak, Sumatra and Kalimantan, followed by vigorous discussion by participants. In the afternoon, colleagues from China presented results and information on the rapidly developing situation there and Gerry Ortega of the Crocodile Farming Institute gave a comprehensive description of the many advances made with the captive population of the Philippine crocodile.

The meeting continued in high gear with a session detailing the newly recognized problem of sub-lethal levels of pollution affecting reproductive hormones in alligators. The recent similar phenomena observed in Lake Griffin, Florida, were described and in discussion the possibility that such effects might be widespread in both wild and captive situations was presented. That afternoon a series of presentations on world trade detailed the current depressed state of the crocodile skin market and led to a discussion of more active measures CSG might take to promote the conservation value of crocodilian use .

The combination of in-depth papers and extensive discussion continued the following day with sessions evaluating reintroduction as a conservation tool and more presentations on the situation of SE Asian crocodiles. Quite striking contrasts between results of reintroductions obtained in different situations and by different workers were reported. Therefore each particular situation should be analyzed rigorously. An introduction to general principles of reintroduction programs by Pritpal Soorae of the IUCN Reintroduction Specialist Group provided a valuable framework for discussion. New information from Cambodia and Vietnam and an update on the situation in Thailand further broadened our understanding of the need for conservation action in the region to harness the energy of developing commercial interests to ensure conservation of wild crocodilians.

In a special session, participants used the IUCN criteria to re-assess the status of SE Asian species. New information available on *Tomistoma* as a result of the activities promoted by declaring this species our first priority in 1992 were evaluated and the meeting concluded that the correct status for *Tomistoma* was Endangered. The current evaluations of crocodilians in the Asian area were confirmed. *Alligator sinensis*, *Crocodylus siamensis* and *C. mindorensis* remain Critically Endangered, and *C. porosus*, *C. johnsoni* and *C. novaeguineae* remain Low Risk of Extinction. However, it was noted that *C. porosus* may be Endangered in many parts of its range, but is secure in Australia, PNG and Indonesia. This led to a detailed discussion of the applicability of the criteria to long-lived species like crocodilians.

On the final day of the meeting Val Lance chaired a session on physiological basis of reproduction in captivity and gave a comprehensive review of 20-years research. Additional contributions on the recent mycoplasm disease outbreak in St. Augustine Alligator Farm and research on captive husbandry in Queensland rounded out this useful practical session and again prompted extensive discussion. After a brief closure and expression of thanks to the organizers, participants went on field trips to the Heng Long tannery and Long Kuan Hung Crocodile Farm where again they received the generous hospitality of our Singapore hosts.

Papers published in this volume include those presented at the meeting, extended abstracts of several posters displayed at the meeting and a number of relevant papers submitted by authors who were unable to attend. As customary for CSG Proceedings these are presented as they were submitted by the authors without review or correction and serve as a ready source of current and new information on crocodilian research management and conservation.

Perran Ross, Executive Officer CSG, Managing Editor 14th Proceedings.

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INTRODUCTION

Though known for over a century as museum specimens, the false gharial, *Tomistoma schlegeli*, has remained somewhat of a mystery in terms of its distribution and abundance. A cryptically coloured and secretive species, the inaccessibility of its swampy habitat makes it difficult to detect, while its non-aggressive disposition does not betray its presence by conflict with humans. There have been no surveys in Sarawak devoted exclusively to the species, although Cox & Gombek (1985) included it in their general survey of crocodiles. There have been few field surveys since, partly because traversing *T. schlegeli* habitat is both difficult and time consuming. Lack of interest could also be caused by the species having no local cultural importance nor any significant economic value (the skin is not traded locally). Thus the distribution and status of *T. schlegeli* in Sarawak is yet to be properly documented, and the species has received little attention despite its listing among Sarawak's protected wildlife (Anon, 1990).

DISTRIBUTION

The historical distribution for the false gharial was from southeastern China, Thailand and Burma, Peninsular Malaysia, Sumatra and Borneo. Its current distribution in Malaysia-

Indonesia includes a small portion of Peninsular Malaysia (Tasek Bera), eastern and southern Sumatra, and the island of Borneo (Sebastian, 1993). De Rooij (1915) listed Sadong and Muka in Sarawak, and Singkawang, Pontianak, Banjarmasin, Lake Lamuda (?), Kapuas River and Muara Tebeh (=Teweh) as localities for the species in Borneo. Sebastian (1993) added Kutai National Park[1], Gunung Palung (surrounding swamps), Tanjung Puting and Danau Sentarum (Kapuas) in Kalimantan. Cox & Gombek (1985) reported that in Sarawak, false gharials could be found in the upper Rejang, Tutuh, Suai, Tisak, Seterap, Kelauh and Dor Rivers and the Ensengei Baki River. Sebastian (1993) added the lower Baram River, Loagan Bunut and Maludam swamp forest to the Sarawak list.

If plotted on a map of Borneo, many records lie within a geological stratum known as the Kuching Zone (Figure 1; van Bemmelen, 1949), which follows the northern edge of the ancient Sunda Shield (H. Hazebroek, pers. comm.; Hall and Blundell, 1996). This zone extends through western Sarawak into West Kalimantan in the vicinity of the Danau Sentarum (Kapuas Lakes), then curves in a northeasterly direction to enclose part of the ulu Barito and ulu Mahakam. *T. schlegeli* has been reliably reported from most of these sites apart from Singkawang, the Gunung Palung area and Tanjung Puting National Park. The sum of these records seems to reflect a formerly continuous, now fragmented distribution for *Tomistoma* in Borneo, in interior wetlands.

Firsthand reports from western Sarawak are numerous, most of them from swampy tributaries of the Lupar and the Sadong Rivers, such as the Sg.[2] Ensengei Baki (Fig. 2; Table 1). This vegetation-choked tributary of the Sadong, meanders through peat swamps for about 20-25 km, often obstructed by floating mats of vegetation. Cox and Gombek's (1985) only sighting of the species occurred in the Ensengei Baki, where one of us (EL) reconfirmed the existence of the species during a 1996 survey. In late March, 1998, residents of Kampung Ensengai Baki related firsthand sightings of *T. schlegeli*, despite the permanent lowering of water levels by two metres, because of a recent drainage project.

Another recent record of *T. schlegeli* originates from a site near the town of Engkelili (1° 12 N, 111 ° 40 E) and in the Sg. Tisak, also a Lupar tributary. In August, 1994, at Sg. Runjing, Engkelili, two adult false gharials were sighted, and about two weeks later, a three-meter female was captured at her nest by Sarawak National Parks and Wildlife staff (Lading and Stuebing, 1997). In the Sg. Tisak on Christmas day, 1996, an Iban woman bathing at the jetty of a log pond was seized (probably by a *Crocodylus porosus*) and killed. Her remains were found the next day about one kilometer upriver. Several days after the incident, an approximately 3 m long *T. schlegeli* female, with 20 partially developed eggs, was caught on a hook and killed in revenge for the woman's death. Its stomach was found to contain a small amount of human remains (nose, lips, some hair). The most recent locality in Sarawak is was reported in April, 1998 from the upper Sg. Mayeng, a tributary of the Sg. Kakus (M. Gumal, pers. comm.). A compilation of the most recent information on the distribution of the species in Sarawak is given in Table 1.

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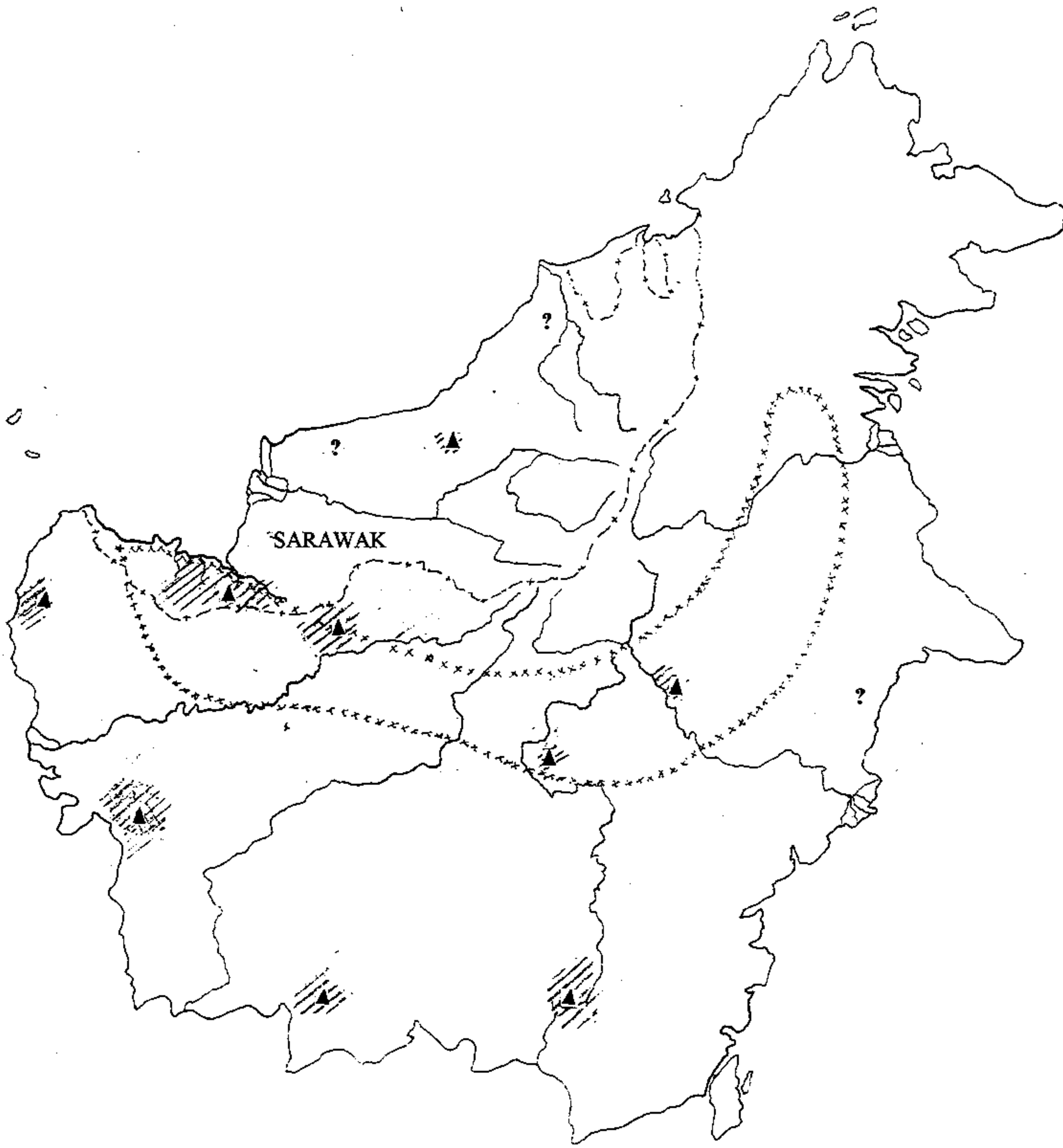
[1] Apparently an error (R. Blouch, pers. Comm.)

[2] Sg. = Sungai (river)



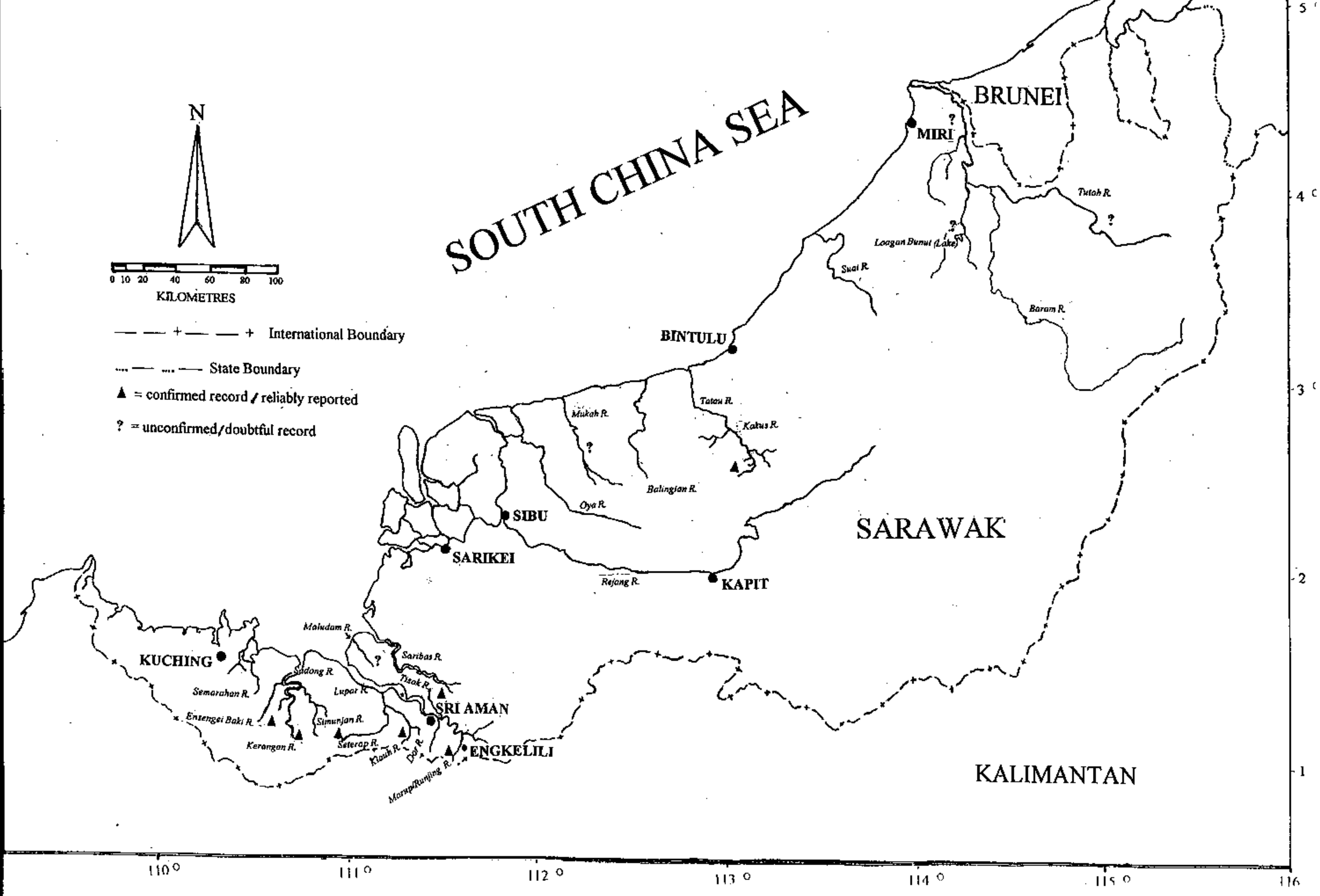
▲ = confirmed record

? = unconfirmed, doubtful record

x x x x x x = Outline of the Kuching Zone

Figure 1. Approximate distribution of *Tomistoma schlegeli* in Borneo in relation to a geological feature, the "Kuching Zone" of Van Bemmelen (1949).

Figure 2. **Known localities for *Tomistoma schlegeli* in Sarawak (revised from Cox and Gombek, 1985).**



Cox & Gombek's (1985) records of *T. schlegeli* from the lower Baram in the northwest, including the seasonal lake, Loagan Bunut (also mentioned by Sebastian, 1993), are doubtful. and may represent either small non-viable populations, or vagrants, in shrinking pockets of habitat. A visit by one of us (EL) in 1996 could not confirm its existence there via direct surveys, and comments from local people were vague. Both of the Mukah records are based on old museum specimens, one from the Sarawak Museum and De Rooij's from Leiden. There have been no reports of *T. schlegeli* from the Mukah area for many years (C. Tyller, NPWO, pers. comm.). There are few reliable reports of the species occurring beyond the Maludam River near the Lupar River. The only recent confirmed breeding population of false gharials from eastern Sarawak exists in the above mentioned Sg. Mayeng.

Table 1. Localities for *Tomistoma schlegeli* in Sarawak

Locality/River	Source*	Status**	Comments
Sg. Ensengai Baki	1,6	A, B	Adults and juveniles
Sg. Kerang	6	B	Adult caught and released, 1997
Sg. Seterap	1, 2	B	*Crocodylus porosus* present
Sg. Kelauh	1	B	*Crocodylus porosus* present
Sg. Dor	1	B	
Sg. Runjing	4	A	Nesting female, two adults
Sg. Tisak	2,3	A	*Crocodylus porosus* present
Sg. Mayeng (Kakus)	6	A	Flying fox survey
Sg. Mukah	1,2	C	Extinct?
Loagan Bunut	2	C	*Crocodylus porosus* present
Sg. Baram & trib.	2	C	*Crocodylus porosus* present

* 1 = DeRooij, 1917; 2 = Cox & Gombek, 1993; 3 = Surveys by Lading, 1996-97; 4 = Lading and Stuebing, 1997; 5 = M. Gumal (pers. comm.); 6 = 1998 surveys

** A = Confirmed sighting; B = Reports by local people; C = Second hand reports (presence doubtful)

HABITAT

The majority of records of *T. schlegeli* in Sarawak are from peat swamps formed in the interior tributaries of the Sadong, Lupar and Tatau/Kakus rivers. Vegetation is composed of a giant species of *Pandanus*, and the river channels are often blocked debris and by large floating mats of *Hanguana malayana*, and now with exotic water hyacinth. Based on the intensive fishing practiced in these coffee-coloured rivers, fish evidently remain extremely abundant. Fish species harvested from three rivers with known populations of *T. schlegeli* are listed in Table 2.

For nesting areas, conditions observed at the Sg. Runjing nest suggest that forest cover is an important feature of nesting areas. Unlike *C. porosus*, *T. schlegeli* apparently avoid the sun, and if given the opportunity, choose to rest in the shade when out of the water.

NESTING

In July, 1994, a farmer near Engkelili, Sarawak (1° 08' N, 111 ° 39' E) was clearing a plot for wet rice and came upon a *Tomistoma schlegeli* guarding a mound of leaves and other debris on a bank of the Sg. Runjing. Details of this nest have been reported elsewhere (Lading and Stuebing, 1997), but the basic features will be mentioned here. The nest was constructed under an approximately 5 m high canopy in disturbed peat swamp forest, at the base of a tree

Table 2. Fish species of economic significance in three rivers where *Tomistoma schlegeli* is known to occur

Species	Local name	Sg. Ensengei Baki	Sg. Kerang	Sg. Seterap
Channa sp.	Blau	+	+	+
Channa striata	Udun		+	+
Cyclocheilichthys apogon	Boeng		+	+
Hampala macrolepidota	Adong		+	
Helostoma sp.	Biawan	+	+	
Hemibagrus spp	Baung		+	+
Macrobrachium rosenbergii	Udang galah (prawn)		+	+
Osphronemus gourami	Kalui	+	+	+
Osteochilus sp.	Bantak		+	+
Oxyeleotris marmorata	Betutu		+	+
Puntius collingwoodi	Kepiat		+	+
Rasbora spp.	Enseluai	+	+	+
Wallago sp.	Tapah	+ **	+	+

about 2 m from the stream bank about 1 m above a small stream. The nest materials differed from that of *C. porosus*, because no grass was used, and the main materials were dry leaves and woody debris. The false gharial nest was not built as a isolated mound (like nests of most *C. porosus*), but was constructed at the base of a tree in relatively deep shade. This situation, if it proves consistent, may mean that the heat generation and dissipation characteristics of *T. schlegeli* nests differ significantly from those of *C. porosus* nests. The Sg. Runjing nest resembled that of a megapode (*Megapodius cummingii*) seen on Pulau Tiga, in Sabah. The *T. schlegeli* clutch size was 16, and after the eggs were removed in mid-August, the relatively docile female was captured by staff of the Wildlife Section and transferred to Matang Wildlife Centre near Kuching.

The Jong Crocodile Farm on the outskirts of Kuching, Sarawak currently holds 39 false gharials, most of which were obtained from tributaries of the Sadong River, including the Ensengei Baki, Kerang(an) and Simunjan. Several males have been in captivity for 30 years, while several of the females have been kept for about 18 years. Interestingly, *Tomistoma schlegeli*, unlike *Crocodylus porosus* can be kept in mixed groups (size and age) with minimal aggressive interaction.. This difference in captive animals may imply differences between the two species in the wild in terms of social interactions and territorial defense.

In the farm, the *T. schlegeli* have survived well, and have been observed courting and mating. Of a total of five nests over the last four years, all have been constructed), between May and July (1994-1997) by a single pair, a 2.6 m female and a 3.2 m male. Nest construction commenced about six months after the farm enclosure was modified to simulate conditions seen in the 1994 Engkelili nest. Eggs were subsequently laid in four out of five nesting attempts, with from 12-23 eggs per nest, but only one hatchling was produced. The reason for the low fertility is not known, although the relatively young age of the male might be a factor. The hatchling that was produced grew to a length of 64 cm in approximately one year.

LEGAL STATUS

Tomistoma schlegeli is listed as a Protected Species under Schedule II of the Sarawak State Wildlife Protection Ordinance (Anonymous, 1995). Under this regulation, no person may "hunt, kill, capture, sell, offer for sale, import, export or be in possession of the live animal, trophy or flesh/organ except under an accordance with the terms and conditions of a license" issued under the Ordinance. The penalty is a fine of RM10,000, and imprisonment for one year. License fees to export or to hold in captivity are RM10.00/head/yr. Export of *T. schlegeli* also requires CITES certification.

THREATS

Hunting

False gharials are not as likely to be hunted as *C. porosus*, as the skin currently has little value in the local market. Hatchling or juvenile *T. schlegeli* used to be sold, however, in the Balai Ringin area. Cox & Gombek (1985) remarked that the trade at that time probably numbered "less than ten animals". It was probably substantially more than that then, and perhaps even now. Only careful surveys and cooperation from local people can shed light on this. The Jong farm keeps a substantial number of *T. schlegeli* under license obtained 20-25 years ago from the ulu Sadong area, possibly from the Sg. Ensengai Baki and the Sg. Kerang.

Fishing

Cox & Gombek (1985) expressed concern over intensive fishing in rivers such as the Ensengei Baki. Fishing is carried out via the use of deep *selambau* nets up to 30 metres in length, which are commonly opened across main river channels or mouths of tributaries. These nets entirely block a channel, and if the villagers report that numerous *T. schlegeli* are drowned as a result. The *belat* net takes advantage of tidal fluctuations, an though less likely to trap an adult *T. schlegeli*, could trap juveniles. Some fishermen regard false gharials as a nuisance, killing them and discarding the carcasses. Others will release the animals out of a superstitious belief that crocodiles should not be disturbed. Hatchlings are not as likely to be released, however.

The use of pesticides for fishing has occurred in recent years near Serian, within *T. schlegeli* habitat (A. Fong, Pers. Comm.). This practice has not been directly linked to any decline of *T. schlegeli* populations, but the long-term effects could be serious.

CONSERVATION

Until intensive surveys in Sarawak prove otherwise, *Tomistoma schlegeli* should be regarded as threatened. From the most recent spotlight surveys and interviews with local people, densities of false gharials seem rather low, though admittedly the animals are always difficult to detect. A matter of great concern for long-term survival *T. schlegeli* populations is the impact of land development on peat swamps and their associated rivers in Sarawak. The main area of concern is specifically the area from Serian to Engkelili. Existing government lands still contain small forest reserves, but the remaining areas are likely to undergo development for agriculture, and drained via the construction of long, parallel channels. *T. schlegeli* populations existing in privately held lands (mostly under native title) may face a bleak future as well, since many peat swamps are now targeted for conversion to oil palm plantations.

Currently, there are no gazetted parks or protected areas lying within the core distribution for *T. schlegeli* in Sarawak. The Maludam Wildlife Sanctuary (8,700 ha), where *T. schlegeli* may occur, has been on the proposed list for several years, but as of early 1998 had not yet been gazetted[3]. This proposed Sanctuary may, in fact, lie outside the areas historically having the highest density of *T. schlegeli* in Sarawak.

To reiterate, most of the areas where *T. schlegeli* has historically been abundant are unlikely candidates for protection, since they already fall under other categories of land use. A multiple use arrangement is probably the best solution to this dilemma, involving active management fishing practices.

Considerable conservation effort has been underway during the last few years, to promote legislation to discourage all forms of hunting in Sarawak. Unfortunately, species such as *Tomistoma schlegeli* will benefit more from guidelines on sustainable use of resources and wise land use, rather than a ban on killing. The disappearance of false gharial habitat must be halted, followed by involvement of both government and local communities in management of this unique wildlife resource.

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[3] Maludam has, in fact been proposed primarily for the conservation of birds and primates (Gumal and Ahmad, 1995).

Department), Safuan Ahmad (National Parks and Wildlife Office), Michael Megang, Ahmad Ampeng and Stephen Sungan (Sarawak Fisheries Department).

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The False Gharial (*Tomistoma schlegelii*) in Sumatra

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Abstract

The False Gharial (Tomistoma schlegelii) *is one of the world's least-known crocodilians and is considered to be globally endangered. This paper presents the results of a research project undertaken from 1994 to 1996 to assess distribution, abundance and ecology of the species in Sumatra. The species is currently distributed from North Sumatra to South Sumatra Provinces, with an isolated population in Lampung Province. Historically, the species occurred in freshwater ecosystems throughout most of eastern Sumatra, and its current distribution represents a range decline of some 30-40%. Local people report a decline in distribution and abundance over the last 30-40 years, coinciding with increasing loss of nesting habitat and hunting for the skin trade in the 1950s-70s. It has always been considered that the species occurred in low densities. The highest recorded densities (0.21/km and 0.26/km) were on the Merang River (South Sumatra Province) and Berbak National Park (Jambi Province) respectively, where breeding populations were confirmed to occur.* Tomistoma schlegelii *was found to forage and nest in at least two forest categories in Sumatra, peat swamp forest and lowland secondary forest. Nest and egg dimensions are presented. Of significance, egg mass is almost double that of every other crocodilian species. The global IUCN status of the species is Data-Deficient, but within Sumatra the species may be considered to be Endangered or Critically Endangered.*

Introduction

The False Gharial (*Tomistoma schlegelii*) is one of the world's least-known crocodilians, and is listed as the fifth-highest priority species for conservation action by the IUCN-SSC Crocodile Specialist Group (CSG) (Thorbjarnarson 1992). Originally widely distributed in South-East Asia, the only populations are now known from Sumatra and Kalimantan (Indonesia), Sarawak and Peninsular Malaysia (Malaysia). The formal status of the species is 'Data-Deficient' under the IUCN (1994) criteria. Sebastian (1994) recently emphasised the need for clarification of the current status and distribution of the species.

In 1994 the CSG initiated a project to assess the conservation and management needs of *T. schlegelii*. Wildlife Management International (WMI) agreed to co-ordinate a cooperative research project on the species on behalf of the CSG, with funding from the Global Guardian Trust, WMI, the German Leather Industry Association (Internationaler

Reptillederverband-IRV), CSG and the Asian Conservation and Sustainable Use Group (ACSUG). Additional staff and resources were provided by WMI.

With the largest remaining populations thought to exist in Sumatra and Kalimantan (Cox 1987), research efforts were directed at Indonesia. A co-operative project was initiated with the Directorate-General of Forest Protection and Nature Conservation of Indonesia (PHPA), which has identified *T. schlegelii* as one of the most endangered crocodilians in Indonesia (Ramono and Raharjo 1993). Fieldwork was restricted to Sumatra in order to maximise the amount of information obtained from a single, large area.

The aims of the project were:

- to locate areas with breeding populations of *T. schlegelii*;
- to obtain a broad overview of the current and historical distribution, abundance and status of *T. schlegelii* in Sumatra;
- to conduct surveys for *T. schlegelii* in river systems in eastern Sumatra; and
- to collect as much additional information as possible on the ecology of *T. schlegelii* in Sumatra, including nesting biology, morphometrics and scalation, diet, historical trade and local beliefs.

This paper describes the results of the project, undertaken from 1994 to 1996. Conservation and management of *T. schlegelii* in Sumatra is discussed.

Study area

Sumatra, the second largest island of Indonesia (after Kalimantan), extends from 5°40'N, 95°10'E (northern tip of Aceh Province) to 5°55'S, 106°00'E (south-eastern tip of Lampung Province). The island is divided into eight provinces (Fig. 1). Western Sumatra is dominated by the Barisan Mountain Ranges, a large chain of mountains which extend from the northern to southern tips of Sumatra. In many areas of western Sumatra, only a narrow strip of coastal plain separates the mountains from the Indian Ocean. Rivers in western Sumatra are relatively short, rocky and drain west into the Indian Ocean. In contrast, eastern Sumatra is dominated by large plains of low elevation, characterised by long, meandering rivers which drain east into the Malacca Strait. Mudflats and extensive mangrove systems dominate the eastern coast.

The climate of Sumatra varies considerably due to its varied topography. Average annual rainfall is 2500 mm, but ranges from 1500 mm (some areas of eastern Sumatra) to 6000 mm (west of the Barisan Mountains) (Whitten *et al.* 1984). Eastern Sumatra is characterised by a poorly defined wet season lasting 7-9 months (October-April) and a dry season lasting 3-5 months (May-September). Mean annual temperatures in eastern Sumatra range from 23°C to 31°C and mean annual relative humidity is 85% (Whitten *et al.* 1984). In eastern Sumatra there is usually one tidal cycle per day, but can be two per day during neap tides. Tidal range can be up to 5 m in some areas, but is highly variable; tidal influence extends well upstream into totally fresh water areas (Hadi *et al.* 1977).

Methods

Field surveys were conducted in Sumatra from 1994 to 1996. In 1994, preliminary field trips and interviews were conducted in Sumatra and East Kalimantan Province (Ramono 1994). In March 1995 a trip was made to South Sumatra Province to ascertain fieldwork logistics and identify areas for research (Bezuijen *et al.* 1995a). Two extensive field trips to Sumatra were undertaken from August-October 1995 and July-October 1996 (Bezuijen *et al.* 1995b, 1996). Fieldwork and methods are described in Bezuijen *et al.* (1995a, b, 1996) and are summarised below.

Interviews. Interviews with fishermen, former crocodile hunters, Forestry officials, reptile skin traders and crocodile farms were a key source of information. Provincial Department of Forestry records of *T. schlegelii* sightings were accessed. A comprehensive interview (consistent format) covered *T. schlegelii* distribution (current, historical), abundance (changes in number and size structure over time), taxonomy (different colour forms), nesting biology, local customs and beliefs and historical trade. Interviews were conducted in all provinces of Sumatra and information was obtained on a total of 27 river systems. Historical and current distribution was defined as records prior to 1990 and after (and including) 1990 respectively.

Surveys. Surveys for *T. schlegelii* were conducted on several river systems in eastern Sumatra, by speedboat or canoe using a spotlight (12 V battery) or torch (6 V battery) respectively. 'Eyeshines' were assumed to be *T. schlegelii* unless they were within a few kilometres of the sea and in brackish water, where they were assumed to be *Crocodylus porosus*.

Capture, morphometrics, scalation and diet. Attempts were made to capture all individuals sighted. Scale counts and morphometric data were recorded. Stomach contents were removed following Webb *et al.* (1982). To aid with analyses of *T. schlegelii* stomach contents, fish and crustaceans were collected from the Merang River in South Sumatra Province. Incidental observations of mammals, reptiles and amphibians were recorded.

Nesting biology. Sidecreeks and mainstream banks were searched for nests. Nest dimensions, nest habitat, clutch size and egg dimensions were recorded. Where possible, one egg from each nest was opened, preserved and embryo age estimated.

Habitat quantification. To quantify the foraging and breeding habitat of *T. schlegelii*, forest type, structure, dominant tree species, river length, depth, temperature, salinity and pH were recorded on most rivers surveyed.

Results and Discussion

Historical distribution in Indonesia

In Indonesia, the species is known historically from Sumatra and Kalimantan. The species was formally described from Kalimantan by Muller (1838) and later Boulenger (1889), and the first *T. schlegelii* was brought to the Zoological Gardens of Amsterdam in 1890 (de Lange and de Rooij 1912). There are no historic records from elsewhere in Indonesia, except for a museum specimen with the collection locality as 'Java', although the specific locality is unknown (Strauch 1866, as cited by de Rooij 1915). Strauch did not see any on Java (de Rooij 1915) and it has never been reported there since. Mountain ranges and oceanic isolation may have prevented dispersal to other Indonesian islands (e.g. the Nusa Tenggara island chain east of Java).

In Sumatra, *T. schlegelii* has only been reported from provinces on the eastern side of the Barisan Mountains: Aceh, Jambi, Lampung, North Sumatra, Riau and South Sumatra Provinces (Fig. 2). Most historical records of *T. schlegelii* are from the central and southern provinces of Jambi, Riau and South Sumatra (de Rooij 1915, de Lange and de Rooij 1912, Sudharma 1976). There are no records west of the Barisan Mountains in West Sumatra and Bengkulu Provinces, as this mountain range probably prevented dispersal from eastern Sumatra. It is unlikely that the species has ever occurred in western Sumatra.

Prior to the 1950s, *T. schlegelii* appears to have occurred from south-eastern Aceh to Lampung Province, almost the entire length of eastern Sumatra (Bezuijen *et al.* 1996). A sighting in Aceh Province by a Forestry warden in 1993 was the most northerly record reported (Bezuijen *et al.* 1996). A record from the 1960s in North Sumatra Province near the border with Aceh Province indicates that until 20-30 years ago, *T. schlegelii* occurred in northern Sumatra. If the 1993 record from Aceh Province is confirmed, this would extend the historical (and possibly current) range by approximately 400 km north. There are no mountain ranges extending to the coastal plain in southern Aceh which might have restricted dispersal, and it seems possible that the species may have occurred in southern Aceh Province. In contrast, a narrow coastal plain is present in northern Aceh, bounded by the foothills of the Pusat Gayo Mountain Range, and it seems unlikely that the species would have occurred this far north, due to a lack of upstream, freshwater habitat.

In Kalimantan, there are historic records from Central, East and West Kalimantan Provinces, where the species appears to have been widely distributed (de Rooij 1915, Frazier and Maturbongs 1990).

Current distribution in Indonesia

The only known breeding populations currently in Indonesia are in eastern Sumatra and central, eastern and western Kalimantan. There are unsubstantiated reports from the early 1980s from north Sulawesi (Thorbjarnarson 1992), although the occurrence of a breeding population on the island seems unlikely, given its isolation from Kalimantan. There are no records of the species from Java and the Nusa Tenggara islands.

In Sumatra, post-1990 reports of *T. schlegelii* were recorded from local fishermen and others from all eastern provinces: Aceh, Jambi, Lampung, North Sumatra, Riau and South Sumatra (Bezuijen *et al.* 1996). Seventy-eight records of *T. schlegelii* were reported by interviewees (24 pre-1990 and 54 post-1990) (Bezuijen *et al.* 1995b, 1996). The majority of post-1990 records were from Jambi (26), Riau (11) and South Sumatra Province (8). Records of *T. schlegelii* sightings in Sumatra held by Asian Wetland Bureau-Indonesia are from Riau (8), Jambi (5), South Sumatra (2) and Lampung Province (1), of which 10 are pre-1990 and 6 are post-1990 (AWB-Indonesia Database, September 1995, unpubl. records). Records of *T. schlegelii* obtained by other researchers are most commonly from Jambi, Riau and South Sumatra Provinces (J. Cox, FAO-PHPA Crocodile Resource Management Project unpubl. data, Muin and Ramono 1994, Ramono 1994, Sebastian 1993b, 1994).

Currently, *T. schlegelii* is thought to occur from south-eastern North Sumatra Province to southern South Sumatra Province, with an isolated population in Way Kambas National Park in Lampung Province (Fig. 2) (Bezuijen *et al.* 1996, Sebastian 1994), which probably represents the southern-most extent of the species' current range in Sumatra. The furthest west the species has been recorded is the eastern foothills of the Barisan Mountain Ranges in West Sumatra Province (Bezuijen *et al.* 1996), which is probably the western limit of its range in Sumatra.

Based on a synthesis of the above information and by comparing the approximate areas encompassed by the historical and current range (Fig. 2), it is estimated that the distribution of *T. schlegelii* in Sumatra has contracted by 30-40% in the last 30-40 years. Jambi, Riau and South Sumatra Provinces are the strongholds of the species in Sumatra.

Status in Sumatra

The IUCN-SSC status of *T. schlegelii* is 'Data Deficient', due to insufficient information to enable an assessment of the global risk of extinction, based on IUCN (1994) criteria. This situation is largely unchanged on a global basis, but data from Sumatra indicates that the species may meet the IUCN criteria for Endangered, and possibly Critically Endangered within Sumatra. Data from the surveys confirms the high priority listing given by the CSG to the species:

- there has been a documented decline in the distribution of *T. schlegelii* in Sumatra over the last 30-40 years, during which the species' total range has contracted by an estimated 30-40%;

- there has been a documented decline in the extent and quality of habitat for *T. schlegelii* in Sumatra in the last 30-40 years;

- the number of mature individuals and subpopulations within Sumatra has declined in the last 30-40 years;

- *T. schlegelii* populations within Sumatra and Kalimantan are separated by mountain ranges and ocean and may be isolated from each other.

Abundance in Sumatra

Prior to the 1950s, the species was considered relatively abundant by former crocodile hunters. There are no quantitative data to indicate the species' historic abundance, but interviews with fishermen and former crocodile hunters suggest they have always occurred at low densities, although this may be partly because *T. schlegelii* is not known to form large aggregations and appears to be a particularly shy crocodilian. De Rooij (1915) found that *T. schlegelii* was 'not rare' in Sumatran rivers and Muller (1838) stated that it was 'fairly abundant' in Kalimantan.

Surveys were undertaken on 10 rivers and their tributaries in Jambi, Riau and South Sumatra Provinces in 1995 and 1996 (Table 1, Figures 3 and 4). *Tomistoma schlegelii* were recorded on only two rivers, in Jambi and South Sumatra Provinces. The highest mean density of *T. schlegelii* recorded during surveys was 0.26 individuals/km on the Air Hitam Laut River in Berbak National Park (Jambi Province) in 1996 (Table 1). No *T. schlegelii* were recorded during spotlight surveys elsewhere in South Sumatra, Jambi or Riau Provinces (Table 1). However, survey conditions were not ideal on several occasions (e.g. high water levels after rain). Local people reported that *T. schlegelii* occurred at low densities on all 10 of these river systems.

Table 1. Spotlight survey results in South Sumatra (SS), Jambi (J) and Riau (R) Provinces, Sumatra, 1995-1996. Results refer to *Tomistoma schlegelii* unless marked with '*' (*Crocodylus porosus*). ES = Eyeshine. Ahl = Air Hitam Laut River and Simpang Melaka Creek (Berbak National Park). Btg = Batang Hari River. From Bezuijen *et al.* (1996).

Yr	River (km surveyed)	Prov	Size classes (ft)						ES	Total	Density
			<2	2-3	3-4	4-5	5-6	>6			
95	Merang (0-45)	SS	-	2	-	2	-	-	3	7	0.16
95	Merang (46-66.5)	SS	-	2	-	-	-	-	5	7	0.34
96	Merang (0-45)	SS	-	1	-	-	-	-	1	2	0.04
96	Merang (46-66.5)	SS	-	2	2	-	1	-	5	10	0.49
95	Medak (0-53)	SS	-	-	-	-	-	2	-	2	0.03
95	Medak trib's (32 km)	SS	-	-	-	-	-	-	-	0	0
95	Lalan (0-160)	SS	-	-	-	-	-	-	-	0	0
95	Kepahyang (0-16.5)	SS	-	-	-	-	-	-	-	0	0
96	Benu (0-38)	SS	-	-	-	1*	-	-	2*	0	0
96	Ahl (0-27)	J	-	1	1	-	-	1	4	7	0.26
96	Btg (325-465)	J	-	-	-	-	-	-	-	0	0
96	Alai (4-9.5)	J	-	-	-	-	-	-	-	0	0
96	Teso (0-14)	R	-	-	-	-	-	-	-	0	0
96	Kubu (26.5-34)	R	-	-	-	-	-	-	-	0	0

The Merang River (South Sumatra Province) was surveyed in 1995 and 1996. Spotlight-count densities on the Merang River ranged from 0.04-0.49 individuals/km.

In the downstream section of the Merang River (km 0-45), densities were lower in 1996 than in 1995, but in the upstream section, were higher in 1996 than in 1995 (Table 1). The overall densities of *T. schlegelii* seen along this river (sections combined) were 0.21/km in 1995 and 0.18/km in 1996. The Merang River is tidally influenced along km 0-45, where banks are often clear of vegetation and the mainstream is more than 30 m wide, providing good survey conditions. Along km 46-66.5, the banks are densely vegetated and often only several metres wide, and survey conditions are poor. The survey densities presented here provide an index to population fluctuations, rather than an indication of absolute population size. Caution is required when interpreting these data, due to the low numbers. One other survey of the Merang River was conducted in 1990, by J. Cox, who recorded the same density of *T. schlegelii* along km 0-23 (0.04/km) as that recorded along km 0-45 in 1996 (Tables 1 and 2).

The few data with which to compare the above densities are unpublished records or are included in the results of broader crocodile surveys, and do not present specific densities of *T. schlegelii*. The raw data from these reports have been extracted and, where possible, the specific densities of *T. schlegelii* calculated. Table 2 summarises *T. schlegelii* densities recorded in other crocodile surveys in Indonesia and Malaysia. Densities of *T. schlegelii* recorded by other researchers are of similar magnitude to those in Table 1, and most densities appear to be low. Immediately apparent is that the highest densities of *T. schlegelii* are from three locations: the Merang River, South Sumatra Province (highest overall density of 0.21 *T. schlegelii*/km in 1995), the Air Hitam Laut River, Jambi Province (highest overall density of 0.34/km in 1990) and Danau Sentarum National Park, West Kalimantan (0.12/km in 1994) (Tables 1 and 2).

Table 2. Summary of *T. schlegelii* densities recorded by other researchers during crocodile surveys in Indonesia and Malaysia. Ahl=Air Hitam Laut River, NP=National Park. CK, EK and WK=Central, East and West Kalimantan Provinces, SS=South Sumatra Province. ES=Eyeshine (assumed to be *T. schlegelii* for this summary). Km = total kilometres surveyed.

Location	Survey date	No. *T. schlegelii*	Km	Dens	Source
Sumatra					
Merang River (SS)	Sep 90	1	22.75	0.04	J. Cox, in litt.
Medak River (SS)	Sep 90	2 (ES)	36	0.06	J. Cox, in litt.
Lalan River (SS)	Sep 90	2	150	0.01	J. Cox, in litt.
Ahl (Berbak NP, J)	Oct 90	7	20.5	0.34	J. Cox, in litt.
Kalimantan					
several rivers (EK)[1]	Aug-Sep 90	5	156.8	0.03	Frazier & Maturbongs (1990)
several rivers (CK)[1]	Sep-Oct 90	19	802.5	0.02	Frazier & Maturbongs (1990)
Danau Sentarum NP (WK)[2]	Aug 94	6	51.9	0.12	Frazier (1994)
Sarawak					
several rivers[3]	Jul-Sep 85	3	102	0.03	Cox & Gombeck (1985)

[1]Total survey length derived by adding all km surveyed by F&M (1990) *except* for 'Tidal-Mangrove Nypa habitat' (assumed to be unsuitable habitat for *T. schlegelii*). 4xES in East Kalimantan were assumed to be *T. schlegelii* for this calculation.

[2]4xES were assumed to be *T. schlegelii* for this calculation. All six crocodiles were seen on a 7.6 km span of one river (=0.79 crocodiles/km).

[3]All 3 *T. schlegelii* were seen on a 13 km span of one river (=0.23 *T. schlegelii*/km).

Tomistoma schlegelii is a species which appears to occur at low densities throughout its current range in South-East Asia. The highest recorded densities are from three river systems in Sumatra and Kalimantan: the Merang and Air Hitam Laut Rivers (South Sumatra and Jambi Provinces) and Danau Sentarum National Park (West Kalimantan).

Nesting biology and habitat

Breeding populations were located on the Merang River (South Sumatra Province) and confirmed to exist in Berbak National Park (Jambi Province). The presence of a breeding population in Berbak National Park has previously been noted (Atmosoedirdjo 1993, MacKinnon 1982, Silvius *et al.* 1984).

Sixteen sites where *T. schlegelii* nests were present or had been present were examined in 1995 and 1996 (Bezuijen *et al.* 1995a, 1996). All except one site had been previously located by resident fishermen and were shown to the survey team. Fifteen sites were on the Merang River and one, a site from the early 1970s (shown to the team by the fisherman who originally located it, and which no longer contained any traces of a nest) was on a tributary of the Medak River (South Sumatra Province). Only three sites contained intact nests with eggs. The fifteen nest sites on the Merang River were from the following nesting seasons: 1996 (n = 2), 1995 (n = 7), 1994 (n = 1), 1992 (n = 1) and 1987 (n = 4). Nest information from seasons prior to 1995 was supplied by local fishermen. Of the seven nests from the 1995 nesting season, six were intact when located by fishermen and five contained eggs, although all five had been predated when visited by the survey team 1-5 weeks after discovery by fishermen. One site contained an unfinished nest (scratchings).

Tomistoma schlegelii is a freshwater, forest-nesting species. Nest sites on the Merang and Medak Rivers were in peat swamp forest. Reports of juvenile *T. schlegelii* and nests from local fishermen on all other river systems surveyed were in lowland secondary forest, a widespread forest category distinct from peat swamp forest. Structural differences between these forest types was quantified. Peat swamp forest was characterised by the presence of well-defined peat mounds along the banks (formed by gradual deposition of organic matter around tree roots), poorly-defined river channels and a myriad of short waterways adjacent to the mainstream, low pH and very low elevation. This forest category was only recorded on the Merang River and Air Hitam Laut River (Berbak National Park, Jambi Province). Lowland secondary forest was characterised by well-defined river channels and river banks, absence of peat mounds, dry land adjacent to the river channel (i.e. few waterways adjacent to the mainstream), a higher pH and higher elevation. This forest type was termed 'secondary' as virtually all forest visited had been logged at some time. All river systems were freshwater (although some were tidally influenced) and all interviewees stated *T. schlegelii* inhabited freshwater.

The 16 nest sites had the following characteristics.

- All were situated at the base of a large tree on a distinct peat mound (Fig. 5). Nests were made of peat and were compact.

- Nest sites were directly adjacent to (fifteen sites) or 100 m away from (one site) the mainstream, surrounded by a system of small, shallow sidecreeks (Fig. 5) with a mean depth of 0.4 m and mean length of 18 m in July 1996 (n = 228). All nest sites were within 2-4 m of a waterway.

- Nest sites were in mostly shaded areas, with all nests in shade at least 50% of the day, and 13 nests which were in shade 80-100% of the day.

Three nests were intact and contained eggs (1 in 1995 and 2 in 1996). Nest height (top of nest to bottom egg) was 33, 37 and 59 cm. Nest basal diameter was 1.2-1.4 m and the bases were 1 m above water level. Egg and embryo dimensions are summarised in Table 3.

Table 3. Summary clutch data for 3 intact nests and dimensions of 2 semi-intact eggs from a predated nest, Merang River (South Sumatra Province). Measurements are with ± standard deviation (range, n). TCM=Total Clutch Mass, NT=Nest Temperature, EHL=Embryo Head Length, EA=Estimated Age of embryo (days). From Bezuijen *et al.* (1995b, 1996).

Nest	Clutch size	Egg mass (g)	Egg length (mm)	Egg width (mm)	TCM (g)	NT °C	EHL (mm)	EA
1 ('96)	34	244±13.17 (221-276, n=32)	98.15±2.73 (92.30-104.82, n=32)	64.99±1.12 (63.01-67.90, n=32)	8300	31.8	13.23	24-25
2 ('96)	29	231±4.67 (215-236, n=29)	97.19±1.89 (94.76-102.06, n=29)	63.39±0.70 (61.82-64.82, n=29)	6692	32.4	34.39	52-53
8 ('95)	35	278±9.82 (253-295, n=34)	102.83±2.44 (97.63-109.45, n=34)	64.85±0.67 (63.47-66.00, n=34)	8759	31.4	35.88	57-58
5 ('95)	Predated nest		96.44, 95.11	57.67, 55.46	-	-	-	-

The nesting data from Sumatra are similar to data collected by other researchers. Witkamp (1925) recorded three *T. schlegelii* nests in freshwater swamp forest on upstream tributaries of the Mahakam River in East Kalimantan Province. Nests were on dry river banks 2-3 m above the water and between thin saplings and moderate-sized trees. Two nests were within 500 m of each other. Nests were 1.2-1.4 m diameter, 0.6 m high and contained 33, 34 and 41 eggs. Internal nest temperatures were 31°C (n = 2) and 33.5°C (Witkamp 1925). Witkamp (1925) measured the dimensions of one egg as 103.5 mm diameter, 61.5 mm width and 206 g mass, and noted egg mass to be almost double that of *C. porosus* eggs recently measured by another researcher in the region.

Habitat, proximity to a stream and dimensions of a single *T. schlegelii* nest in Sarawak described by Lading and Stubing (1997) were similar to the nest sites on the Merang River, although the Sarawak nest was located at the edge of a rice field. Clutch size and egg dimensions were notably smaller than those recorded on the Merang River.

Of significance is the finding that mean egg mass is almost double that for every other species described by Thorbjarnarson (1996) within the Order Crocodylia.

Nesting success

The most significant natural factor affecting *T. schlegelii* egg mortality on the Merang River appeared to be predation by non-indigenous wild pigs (*Sus scrofa*). Five of seven nests (71%) from the 1995 nesting season on the Merang River had been predated by wild pigs. Nests had been pulled open by pigs and eggshells were strewn around the site when visited by the survey team. The extent of nest flooding is unknown and no flooded nests were reported by any of the fishermen interviewed. Habitat loss and modification by fire is probably a significant factor influencing the availability of nesting habitat for *T. schlegelii*: extensive areas of swamp forest in eastern Sumatra were burnt by human-induced fires in 1994 and 1997.

Human pressures

The habitat utilised by *T. schlegelii* is also extensively utilised by local people. Fishing and logging are the two primary human activities within *T. schlegelii* habitat. Most river systems in eastern Sumatra are populated and forest areas adjacent to waterways are regularly searched for fish and turtles. All river systems surveyed except those in Berbak National Park (Jambi Province) had been logged at least once and all were fished to some extent, including the uppermost, remote creeks. *Tomistoma schlegelii* is widely recognised by local people as having little economic value and is not usually deliberately captured or hunted. Local people in most river systems surveyed were familiar with the species and considered it to be harmless and shy. Human-induced mortality of *T. schlegelii* listed by interviewees was incidental drowning of young individuals caught in fish traps and, at two rivers in Jambi Province, occasional egg consumption.

Tradition and local culture

There is a diverse range of cultures and socio-economic conditions at regional and local scales in eastern Sumatra, which would need to be identified for conservation of *T. schlegelii* on specific river systems. For example, in South Sumatra Province, a unique system of river ownership exists ('*lebak lobang*'), whereby local heads of villages gather once a year and bid, on behalf of their village, for exclusive fishing rights to sections of a river or a whole river. At a local scale, fishermen on the Merang River have private agreements as to where each fisherman may harvest fish, turtles and snakes. Such agreements vary on neighbouring rivers. Tributaries or sections of a river are often fished by a family, and the feeling of communal support is strong.

Other

Information obtained on the diet, morphometrics and scalation, local beliefs and former skin trade in *T. schlegelii* is summarised below.

Diet. Based on interviews with former crocodile hunters and fishermen, *T. schlegelii* has a broad diet and is not a specialist fish-eater. The most frequently reported food items by interviewees were monkeys, wild pigs and snakes. Birds, other mammals and reptiles were also listed. Stomach contents were removed from six wild *T. schlegelii* (total lengths 66.6-190.0 cm) captured on the Merang River and included shrimp and *Pandanus* leaves. At least two stomach contents contained numerous nematodes. Galdikas and Yeager (1984) observed a *T. schlegelii* predate a Crab-eating Macaque (*Macaca fascicularis*) in Tanjung Puting Reserve (Central Kalimantan Province) and noted that the local people in the Reserve traditionally used macaques as bait to catch *T. schlegelii*. Muller (1838) stated the diet of *T. schlegelii* consisted of fish, monitor lizards (*Varanus* spp.), waterbirds and mammals.

Morphometrics. From 1995 to 1996, morphometrics and scalation was recorded from a total of 70 *T. schlegelii* (55 captive and 15 wild individuals, all from the Merang River in South Sumatra Province except one captive individual from the Alai River in Jambi Province) (Bezuijen *et al.* 1995a, b, 1996). Snout-vent lengths ranged from 32.4-188.8 cm. The largest individual measured was a nesting female captured on the Merang River (total length 343.0 cm). The largest *T. schlegelii* sighted was estimated to be 4.8-5.2 m (16-17 ft), on the Merang River in 1995 (Bezuijen *et al.* 1995b).

Scalation. Twenty patterns of precaudal scalation were recorded from 70 individuals. Thirty-six individuals had a single precaudal pattern ('Type 1', Bezuijen *et al.* 1996), and the remaining individuals had 'Types 2-20'. All *T. schlegelii* except the single individual from Jambi Province were from the Merang River, thus no conclusions can be inferred as to geographical differences in morphometrics and scalation that may exist.

Local beliefs. No specific local beliefs were associated with *T. schlegelii* amongst interviewees. Some former hunters used chanting and prayer prior to hunting to ensure a successful crocodile hunt. Specific beliefs are associated with *Crocodylus porosus*.

Historic skin trade. The majority of crocodile hunting in eastern and south-eastern Sumatra was in the 1950s-70s. *Crocodylus porosus* skins were of higher value than *T. schlegelii* skins and all former hunters agreed that *C. porosus* skins were of better quality. Hunters sold *T. schlegelii* skins for about half the price of *C. porosus* skins. *Tomistoma schlegelii* is still widely recognised as having little commercial value and no evidence of commercial hunting of *T. schlegelii* was recorded. Specimens are occasionally captured in fish traps and sold by fishermen to crocodile farms, who keep them (Bezuijen *et al.* 1996, Webb and Jenkins 1991). Cox (1990) notes that skin traders relate the presence of osteoderms in the ventral scales of *T. schlegelii* as the reason for its low economic value, although the species lacks osteoderms (King and Brazaitis 1971). The large size of the ventral scales (relative to crocodile species with smaller ventral scales e.g. *C. porosus*) may also contribute to the low economic value (Brazaitis 1987).

Conclusions

1. In Sumatra, the largest remaining populations of *T. schlegelii* are in Jambi, Riau and South Sumatra Provinces, where the species is widely distributed, although probably in low densities.

2. The primary threats to the foraging and nesting habitat of *T. schlegelii* in eastern Sumatra are outright loss of nesting habitat (logging, fire), modification or disturbance of nesting habitat (logging, fishing, regular human visitation of nesting areas, motorised boat activity) and egg predation by wild pigs. The extent of nest flooding is unknown.

3. Rivers with the highest recorded densities of *T. schlegelii* and which are confirmed to support breeding populations are in Berbak National Park (Jambi Province) and the Merang River (South Sumatra Province).

4. Berbak National Park is the only protected area in eastern Sumatra which is currently known to hold a viable breeding population of *T. schlegelii*. The flora, fauna and management requirements of Berbak National Park is well-documented (e.g. de Wulf 1982, Giesen 1990, Santiapillai 1989, Silvius *et al.* 1984) and a framework for management and research thus exists.

5. *Tomistoma schlegelii* also occurs in Way Kambas National Park (Lampung Province). However, given the widespread deforestation, clearance of river bank vegetation and intensive fishing in the Province, this population is probably small and isolated.

6. The Merang River is not protected and is currently under a logging concession. From 1996 to 1998, km 50-60 of the river were logged to within 250 m either side of the river (Indonesian law prohibits logging any closer); this is the section where the majority of *T. schlegelii* nests were recorded. Upon expiry of the logging lease, the Indonesian Government will decide the river's future.

7. Protection of some viable breeding populations on selected river systems may be the most effective interim and long-term method for ensuring the long-term conservation of the species. This strategy would need to incorporate upstream, freshwater forested areas with suitable breeding habitat.

8. A harvesting program involving *T. schlegelii* individuals or eggs, and which provides direct financial incentives for local people to protect foraging and nesting habitat, may be an effective long-term conservation strategy.

9. Most areas inhabited by *T. schlegelii* are also utilised by humans and conservation will only be possible with the support and involvement of local people, as has been suggested for conservation in Danau Sentarum National Park, West Kalimantan

(Jeanes *et al.* 1995, Jensen *et al.* 1995). The socio-economic conditions of local people living on a river with a breeding population of *T. schlegelii* would need to be assessed.

Recommendations

10. Conservation of *T. schlegelii* in Sumatra should focus on river systems in Jambi, Riau and South Sumatra Provinces.

11. The following strategy is recommended for optimal use of conservation funds for the species in Sumatra.

    - Annual spotlight and nesting surveys on selected river systems. These will provide baseline data on population size, structure and fluctuations.

    - Formulation of management plans for selected rivers which are currently not protected. Management plans should be specific to each river and describe and identify: data on distribution, abundance and nesting of *T. schlegelii*; threats to foraging and nesting habitat; existing socio-economic conditions; local attitudes towards the species; optimal methods for protection of nesting and foraging habitat.

    - Identification of other river systems which support breeding populations of *T. schlegelii.*

12. Annual surveys should be conducted in at least one representative river system in each of Jambi, Riau and South Sumatra Provinces. Based on the data collected from 1994 to 1996, recommended rivers are: Air Hitam Laut River and tributaries in Berbak National Park (Jambi Province), Teso River (Riau Province) and Merang River (South Sumatra Province).

13. Baseline surveys should be conducted in Way Kambas National Park (Lampung Province) to assess the status of the species.

14. Nesting and foraging habitat for *T. schlegelii* in Berbak National Park is secure. Aside from annual surveys, no active management of the species is considered necessary at this time.

15. It is recommended that the Merang River be given high priority as a site for a management plan for *T. schlegelii*, for the reasons listed below.

    - Baseline data on densities and nesting now exist from 1995 and 1996.

    - Until recent years, the river has been subjected to relatively low levels of human disturbance; most other rivers in the region have been extensively burnt, cleared or fished.

- Local people on the Merang River are interested in the species and possess extensive knowledge on *T. schlegelii*. They have indicated their interest in the conservation of the species and were involved in field work in 1995 and 1996.

- As a result of the project, the Provincial Ministry of Forestry is aware of the conservation significance of the Merang River for *T. schlegelii*. Preliminary discussions on conservation of the species in the Province were held with Provincial officials in 1996 (Bezuijen *et al.* 1996).

- The river is one of few remaining in the north-east region of the Province with peat swamp forest and which supports a variety of other threatened fauna.

- A regional conservation strategy incorporating areas near to the Merang River has been produced (see below) and a framework for conservation already exists.

16. The international importance of the mangrove and swamp forest ecosystems of eastern Sumatra has been recognised for many years. Regional socio-economic conditions and land uses have been described (e.g. Danielsen and Verheugt 1990, GOI-World Bank 1995). A regional strategy for integrating conservation and development of forested coastal wetlands in South Sumatra and Jambi Provinces has recently been formulated (Davie and Sumardja 1997, GOI-World Bank 1995) and is centred around Berbak National Park. The Sembilang River catchment (east of the Merang River) is proposed for protection as an extension of Berbak National Park (Davie and Sumardja 1997). The proposed extension currently does not incorporate the Merang River. A formal proposal to National authorities describing the conservation value of the Merang River for *T. schlegelii* and proposing that the river be incorporated in this regional strategy may be the optimal method for initiating conservation of *T. schlegelii* in Sumatra.

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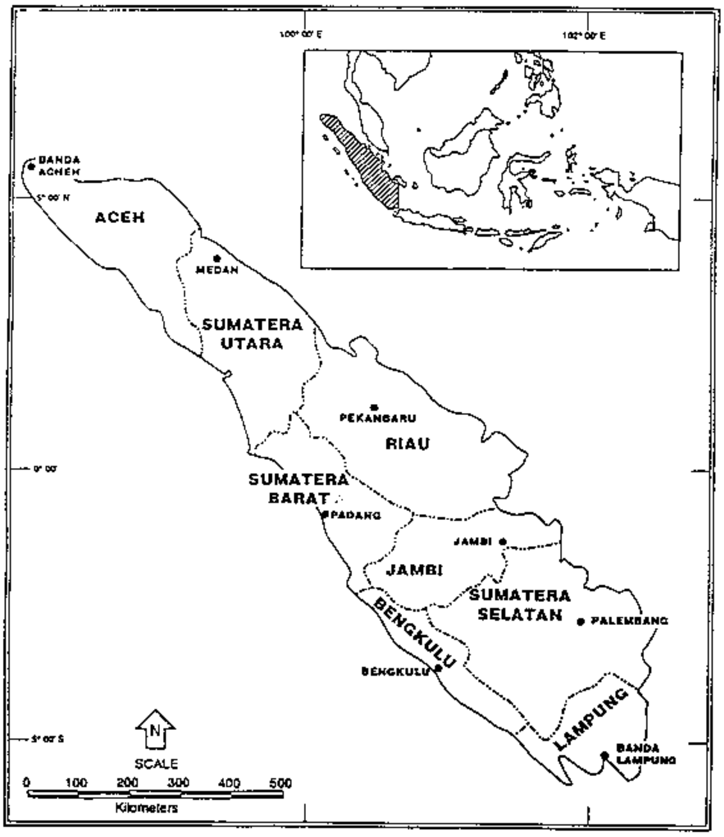

Fig. 1. Sumatra. Dots represent provincial capital cities.

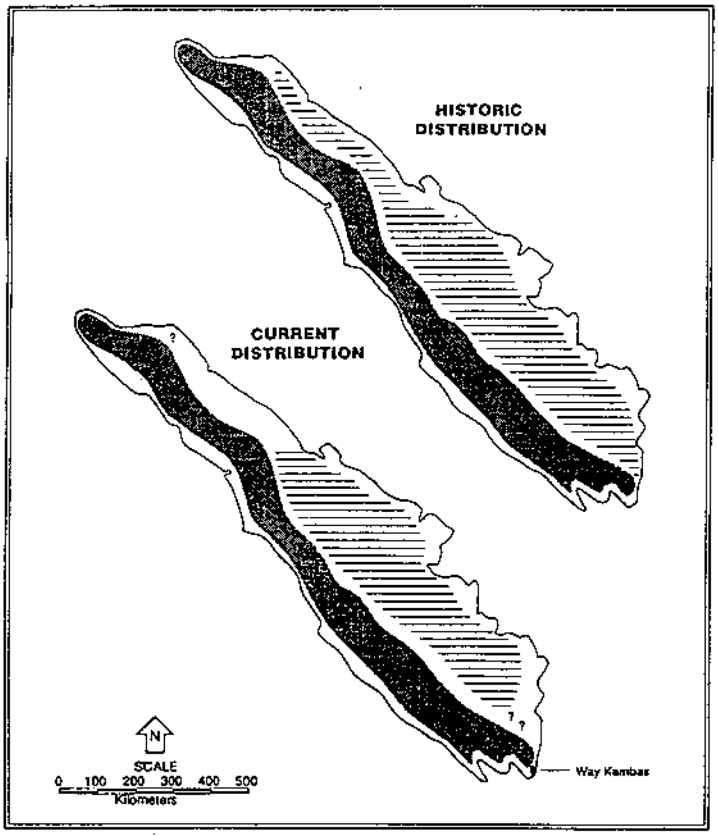

Fig. 2. Historical & current distribution of *Tomistoma schlegelii* in Sumatra. ? = a single 1993 sighting from Aceh. ? ? = populations may still occur in southern South Sumatra Province. A single population is known from Way Kambas National Park, Lampung. Dark shading represents the Barisan Mountains.

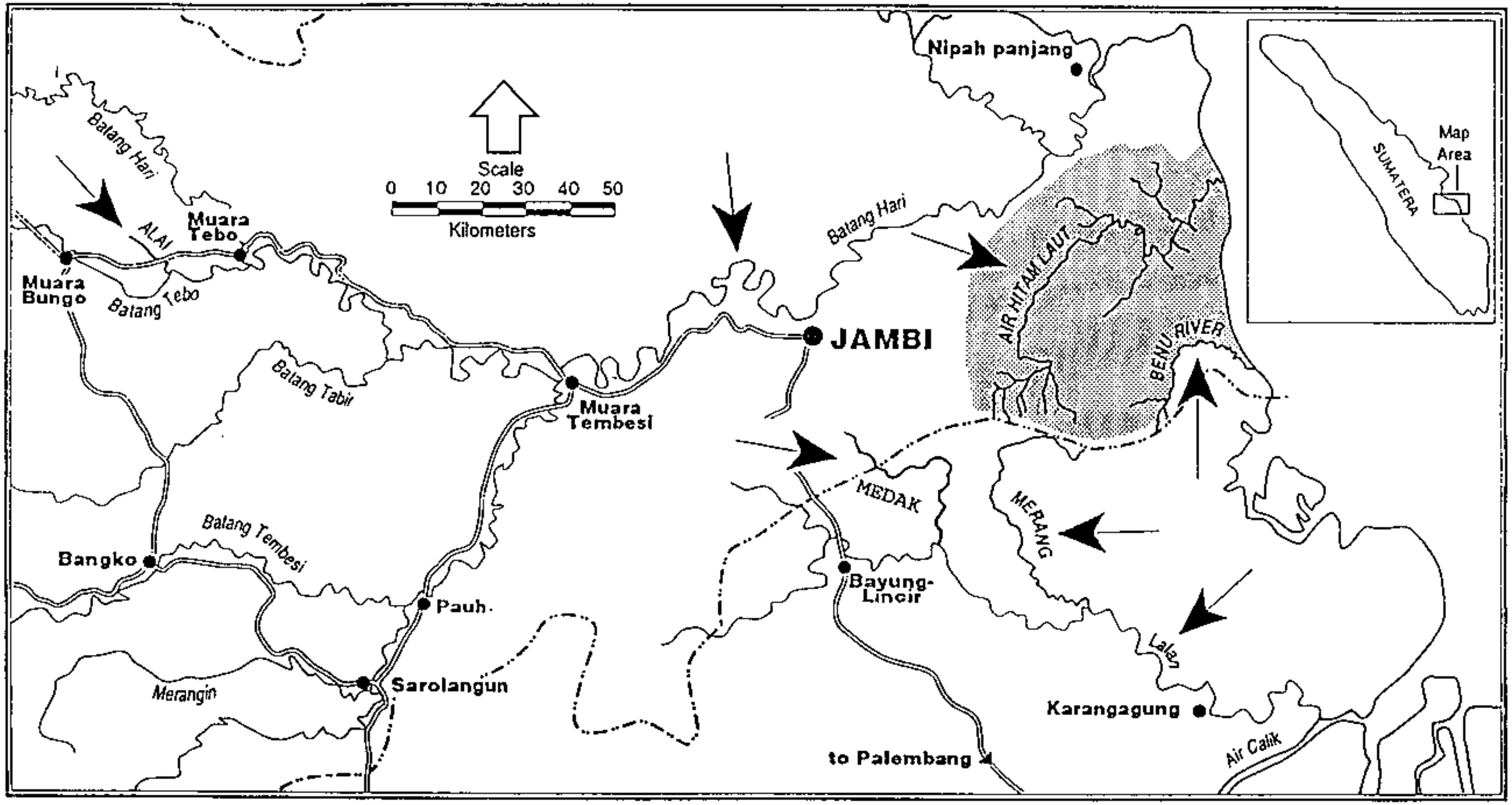

Fig. 3. Jambi and north-east South Sumatra Provinces.

- Study rivers
- Town
- Road
- Province boundary
- Berbak National Park

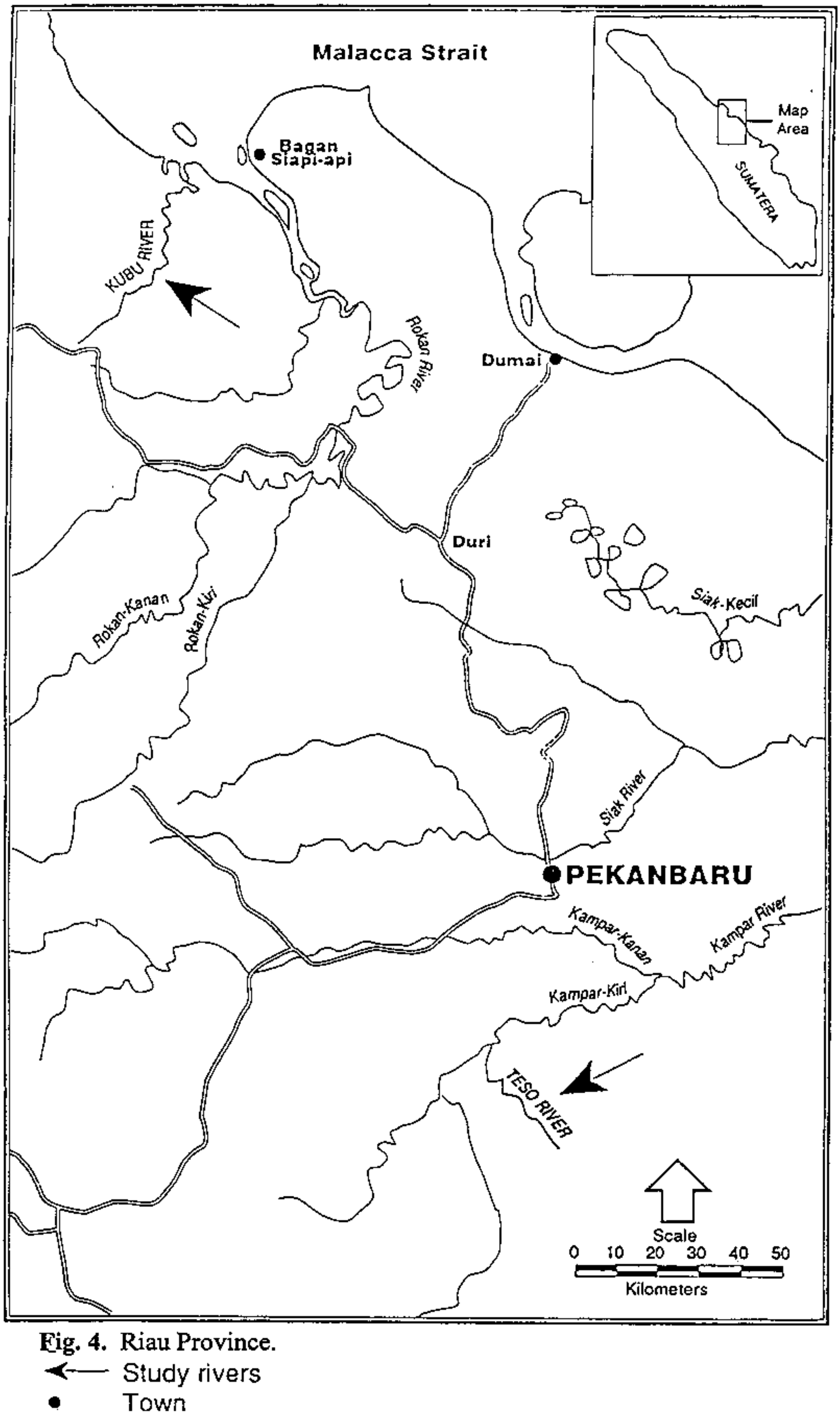

Fig. 4. Riau Province.

←— Study rivers

• Town

═══ Road

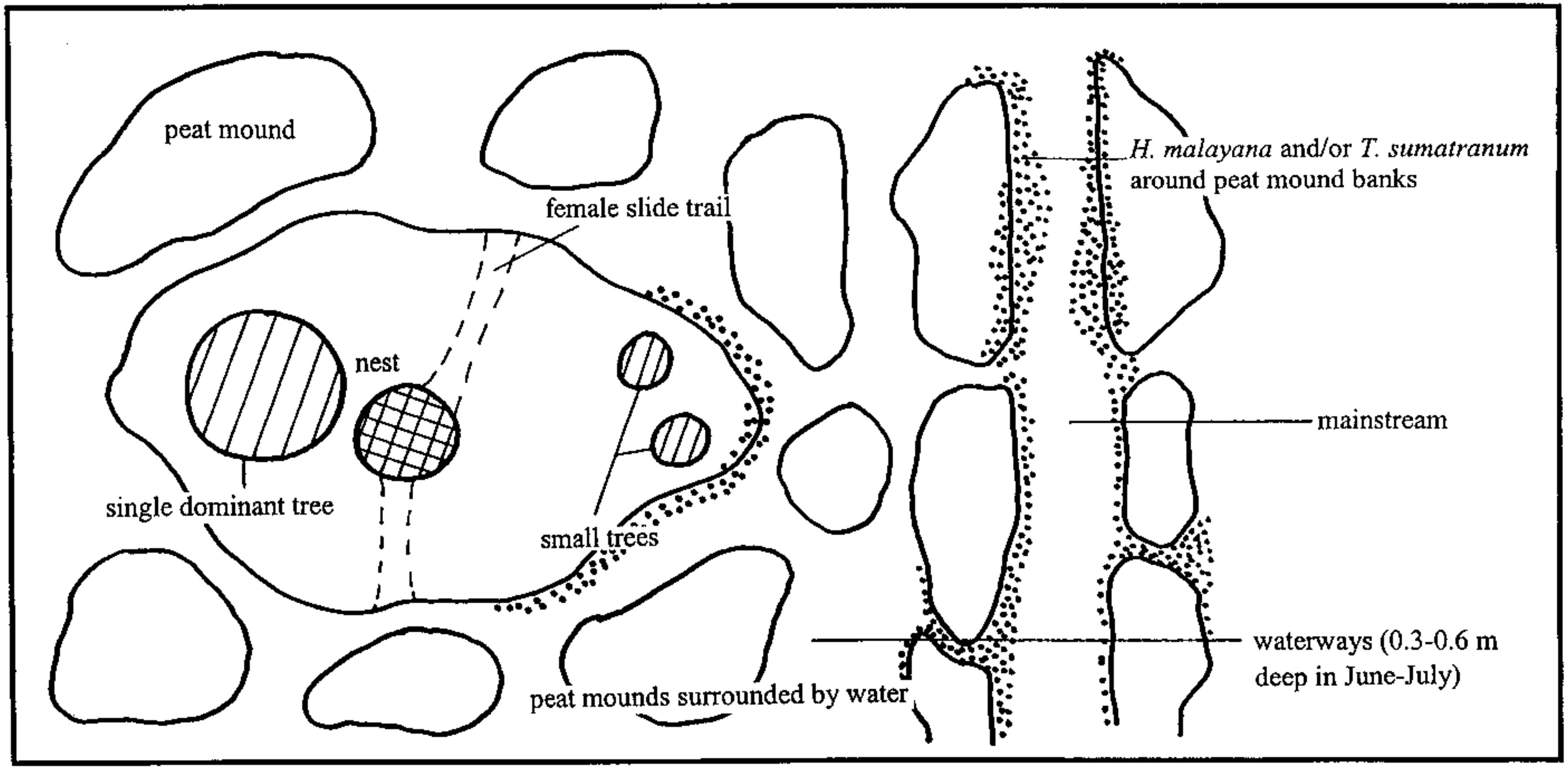

Fig. 5. *Tomistoma schlegelii* nest on a peat mound within peat swamp forest along the Merang River, South Sumatra Province, Sumatra. *Hanguana malayana* (Family Hanguanaceae) is a floating macrophyte and *Thoracostachyum sumatranum* (Family Cyperaceae) a sedge. Not to scale.

Tomistoma (*Tomistoma schlegelii*) at Tasek Bera, Peninsular Malaysia.

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Abstract

As part of the management plan for Tasek Bera, Malaysia's first Ramsar site, spotlight surveys for *Tomistoma* were conducted over 12 nights in the swamp and surrounding rivers. No crocodiles or "eyeshines" were sighted in 92.8 km surveyed. Local residents reported commercial hunting of Tomistoma for skins in the late 1950's and early 1960's, where all sizes were taken and the population greatly reduced. Nests have not been reported in recent times, although historically they were seen along the banks of the Bera, Jelai and Tasek Rivers (but not in the swamp itself). Some *Tomistoma* still occur in the swamp, but are seen infrequently.

The loss and alteration of large tracts of forest habitat due to logging, oil-palm and rubber plantations may have hindered the recovery of *Tomistoma* after the hunting period. The area has also seen a large influx of people living and working in the area over the last 15 -20 years, with recreational activities becoming popular. Fish poisoning and netting of some waterways still occur.

Several tributaries of the Pahang River in Peninsular Malyasia reportedly contain *Tomistoma*, and nests have been reported over the last 5 years. *Tomistoma* and *C. porosus* may occasionally be hunted for meat in these areas. Extensive surveys are needed in Peninsular Malaysia to confirm and consolidate the scattered reports of this species, which is clearly endangered.

INTRODUCTION

The Malayan False Gharial or *Tomistoma (Tomistoma schlegelii)* is a large, slender-snouted crocodilian growing up to 5 m in length; it is considered to be one of the least known of all crocodilians. The Species Survival Commission of the IUCN has identified it as a crocodilian species with the highest priority for research and conservation action (Thorbjarnarson 1992). Historically the species may have ranged from south-eastern China through to Indonesia. *Tomistoma* is now thought to be confined to Indonesia (Sumatra, Kalimantan) and Malaysia (Peninsular Malaysia, Sarawak) where it is found in the freshwater upper reaches of rivers and swamps (Sebastian, 1994). The species is thought to be extinct in Thailand.

Tomistoma is currently listed as 'Data Deficient' in the IUCN Red Data List (IUCN, 1996), due to the lack of information. Published information on *Tomistoma* is meagre and scattered throughout the literature. In Peninsular Malaysia, *Tomistoma* have only been confirmed from a few locations: The North Selangor Peat Swamp Forest (Butler 1905, Prentice 1990, Sebastian 1994), Perak River (Boulenger, 1896) and historically, the Tasek Bera Swamp. The Pahang and Setiu River Basins and the Southeast, Jemaluang and Beriah Swamp Forests are all possible sites where *Tomistoma* may exist or areas of unconfirmed reports (Sebastian, 1993). *Tomistoma* are now legally protected throughout Malaysia but there have been no systematic crocodile surveys carried out in the Peninsula.

Tomistoma surveys were undertaken at Tasek Bera, by Wildlife Management International (WMI) under the auspices of the IUCN Crocodile Specialist Group. These surveys were conducted in conjunction with The Tasek Bera Project and had the following objectives:

- Assess crocodilian species presence; historically and currently.
- Assess the status of species: their historical distribution and abundance (in relation to habitat types) relative to their current distribution and abundance.
- Determine habitat conservation priorities for *Tomistoma* and identify current or potential threats.
- Collect information on breeding status and reproductive biology if possible

The Tasek Bera Project

The Tasek Bera Project involves the development and implementation of a management plan for Malaysia's first Ramsar site: the freshwater swamp ecosystem at Tasek Bera (Lake Bera). The project is being developed by Wetlands International - Asia Pacific (WIAP) in conjunction with the Institute of Advanced Studies (IPT) of the University of Malaya, and aims to integrate wetland conservation, recreation and ecotourism. The initiative will be carried out with the Pahang State Government and involves the indigenous people of the area, the Semelai.

During the initial stages of the project, numerous flora, fauna and hydrology surveys were being conducted to provide information for the development of the management plan. The core zone of the Ramsar site covers 26,000 hectares and includes the lake, surrounding swamp and lowland forests. A further 27,500 hectares is a buffer zone comprising part of the catchment area.

Study Area
Tasek Bera is a large alluvial peatswamp forest situated approximately 100 km east of Kuala Lumpur in central Peninsular Malaysia (Fig. 1). It consists of a dendritic complex of meandering tracts of swamp forest some 35 km long by 25 km at its widest point, though each arm of swamp may only be a kilometre or two wide. The swamp covers over 60 square kilometres between areas of raised lowland forest. Water flows into the swamp throughout the year and it drains northward through a single confluence, into the Tasek River, which in turn drains into the Jelai and Bera Rivers.

During the dry season water is restricted to a single narrow channel which flows through the heart of the swamp forest. The water is usually less than 1.5 m deep at this time of the year, but the channel is interspersed with many deep, wide pools or lubuks. Channel width is usually between 3-7 m, but widens into an open lake at the northern end of the swamp which is approximately 3.5 km long by 500 m wide.

The most common habitat, which occupies two thirds of the swamp, is peatswamp forest, composed of *Eugenia* trees with *Thoracostachyum* sedge fringing the waterways and forming an understorey. This forest type dominates the dendritic arms and waterways of the southern swamp. The northern reaches are dominated by *Pandanus* clumps and *Lepironia* reed beds which make up the remaining third of the swamp area. This habitat fringes the open lake which is dotted with many *Pandanus* islands.

The wetlands of Tasek Bera are surrounded by dry lowland Dipterocarp forests, characterised by *Dipterocarpus* and *Shorea* trees. Most of this forest has at some time been logged, cleared or altered, and very little (if any) primary forest remains. Large tracts of this forest have been cleared under the government's Federal Land Development Authority (FELDA) scheme, which develops and allocates large oil-palm and rubber plantations to new settlers. Such schemes have resulted in the isolation and enclosure of the wetland of Tasek Bera, leaving only a small strip of dry lowland forest of about 10 000 ha, surrounding the swamp.

METHODS

All fieldwork at Tasek Bera was carried out over 2 weeks (26 June - 11 July 1997) using local guides and boat drivers.

Surveys

Surveys were undertaken at night from a 4.2 m fibreglass boat, powered by a 15 HP Yamaha outboard motor. In some survey units, the motor was not used and the boat was paddled. Spotlighting procedures followed that outlined by Messel *et. al.* (1981). A 12 V spotlight or a 6 V 'Dolphin' torch were used, depending on the width of the stream being surveyed. Four narrow water holes, of varying lengths (100-400 m), were surveyed by foot from the banks, using torches

Interviews

Interviews with local residents were carried out to assess local knowledge on various aspects of *Tomistoma*. Most interviews were conducted in and around the 14 villages of Tasek Bera (Fig 2) and the majority of interviewees were known to have had dealings with *Tomistoma* at some time. Most of the people residing at the swamp had lived in the area all their lives and were only familiar with the Tasek Bera region.

A standardised questionnaire (Bezuijen *et al.* 1995b) covered current and historical prospectives on: species presence, distribution, abundance, nesting biology, hunting and trade, and other information. 'Recent sightings' of *Tomistoma* were classified as those which had occurred in the last five years (ie from 1993-1997). All pre-1993 sightings are referred to as 'Historical Sightings'. As *Tomistoma* sightings are quite well known throughout the community, 'Recent sightings' of the *Tomistoma* also include secondhand information: that is, reports made by the interviewee who knew of someone else who had seen a *Tomistoma*.

Mapping

Broad scale habitat type was recorded for vegetation adjacent to the navigable channel running south-north in the Tasek Bera swamp. Channel depth was measured and width estimated visually every 2-3 km. Deeper waterholes, or lubuks, were recorded with the aid of a Garmin GPS 40 Global Positioning System. Lubuk depths were measured using a weighted cord with 1 m graduations. Local names for the lubuks were recorded and the width and length estimated. Water temperature and pH were measured in a number of locations throughout the swamp.

RESULTS

Surveys

All navigable waterways within the swamp, from the Jelawat Bridge to Pathir village, were surveyed twice over 8 nights (57.4 km). A further four waterholes, the Tasek and part of the Jelai and Bera Rivers were also surveyed (35.4 km) over 4 nights. No crocodiles or eyeshines were sighted during any of the spotlight surveys (Simpson *et al.* 1997).

Interviews

A total of 19 people were formally interviewed from 8 villages (or areas) in Tasek Bera and the surrounding region (Simpson *et al.* 1997). An additional number of people from the villagers of Kuin, Benal and Bukit Gegerish reported that their village had no information on *Tomistoma*. Most of those questioned had spent their entire lives at Tasek Bera or in the region.

Recent Sightings

Twelve reports of *Tomistoma* were recorded within Tasek Bera and associated rivers to the North over the last five years (Fig. 2). Sightings have occurred throughout the swamp from Jelawat village in the South, to the Bera River in the North. Most *Tomistoma* were seen in the deeper waters of the lubuks, and where the size was known, they were estimated at greater than 3 m long. Large individuals were said to dive immediately on being seen. One exception was a small individual (< 1 m long) seen basking on a log. Usually 3-4 sightings of *Tomistoma* are reported from the Tasek Bera region each year.

Historical Sightings

Sightings of *Tomistoma* prior to 1993 were reported by 16 of the 19 people questioned, with nine of these people being involved in some form of hunting. Of the people interviewed who were over 50 years of age, most had been directly involved in hunting or had personally seen *Tomistoma* in the Tasek Bera region during that period. Some interviewees reported seeing "many" *Tomistoma* in the 1950's and early 1960's, with all size animals being reported (hatchlings to animals 6 m long).

The greatest number of reports came from the Tasek, Jelai and Bera Rivers directly to the North of the Tasek Bera swamp (Fig. 2). "Many" *Tomistoma* were seen along these rivers, and were reportedly found all along the Bera River from the Tasek Bera swamp to the confluence with the Pahang River, a distance of approximately 50 km. Within the swamp itself, the majority of sightings occurred in the northern half, from Benal village to Pathir village

Saltwater Crocodiles, *Crocodylus porosus*, were also reported from the Tasek Bera area, mostly in the 1930's and 1940's. Only two old hunters had seen *C. porosus* in the region. Most reports came from sightings made by the parents or grandparents of interviewees. Saltwater crocodiles have not been reported in the region since the 1950's.

Nesting

There were no historical reports of *Tomistoma* nesting within the swamp itself. All historical nests reported were found outside the Tasek Bera Swamp, on the banks of the Tasek, Jelai and Bera Rivers. Numerous nests were sighted prior to the 1960's, but reports since have been sporadic. Nesting was said to occur all along the Bera River, on the banks of the dry lowland/secondary forest. Of those interviewed (n=19) the latest sighting was of an old flattened nest in 1980, in Lubuk Perah, off the Tasek River.

Nest and egg descriptions were similar to previously published reports from other regions (Bezuijen *et al.* 1995b; 1997, Lading and Stuebing 1997). Interviewees reported nests to be composed of leaves and small twigs raked into a mound, 30-60 cm high and about 1 m in diameter. Clutch sizes were reported as 15 - 30 eggs, each approximately 10 cm long. Nests were reported to occur in the dry season, from June to August. Females did not defend the nest which was usually within 20 m of the river. Wallows or depressions beside the nest were not reported.

Diet

Tomistoma was reported to eat a variety of prey items, including fish, mouse deer, dogs, pigs, snakes, monkeys and stones. One old hunter reported that all *Tomistoma* caught greater than 15" in circumference [approximately 1.2 m long] had stones in their stomach.

Hunting and Trade

Tomistoma were commercially hunted for their skins over a 3-4 year period from approximately 1958-1962. Hunting occurred in the Jelai, Tasek, Bera and Serting Rivers (north of Tasek Bera), as well as the northern reaches of the swamp, from Benal village to Pathir village (Fig 2). From those interviewed, it was estimated that up to 150 *Tomistoma* may have been taken from the Tasek Bera Swamp and the surrounding rivers during this period. *Tomistoma* may have also been taken by hunters who were not canvassed in these interviews.

The majority of *Tomistoma* were reportedly caught using a pointed stick 30 cm long which was baited, usually with fish or pig, and attached to a length of dried rattan vine. The bait was set 15-30 cm above the water edge. After the crocodile had swallowed the bait and swam off, the floating vine could be tracked down and the crocodile pulled to the surface with the pointed stick lodged in it's stomach. This method usually caught crocodiles larger than 1.5 m long. Teams of 2-4 professional crocodile hunters used this method and worked during the dry season. Hunters mostly worked the Tasek, Jelai, Bera and Serting Rivers and did very little hunting in the Tasek Bera swamp itself, where the *Tomistoma* numbers were too low to produce good returns.

Villagers also caught *Tomistoma* on an opportunistic basis, catching them by hand, in fishing nets or spearing them. Most of the opportunistic catches occurred within the Tasek Bera swamp and continued infrequently after commercial hunting had ceased.

Tomistoma of all sizes, from hatchlings to 6 m animals were caught, killed and sold. Animals greater than 1.2 m had the belly skin taken, while smaller animals were sold whole or as hornback skins. Most of the *Tomistoma* caught came from the Tasek, Jelai and Bera Rivers to the North. Within the swamp proper, the number of crocodiles caught during the hunting period from 1958-1962 was estimated at 20-30. By the end of 1962, *Tomistoma* numbers were greatly diminished (in all size classes) and prices were low, bringing an end to serious hunting in the Tasek Bera area.

Skin prices varied during the period of hunting, but generally the price for a belly skin was RM2.00-3.50/inch After the main hunting period, the price in the mid-1960's increased to approximately RM5.00/inch. Smaller crocodiles up to one metre in length could be sold whole, and would bring prices of around RM15.00.

A *Tomistoma* skull was inspected at Papak village which had been obtained from a fisherman about 20 years ago. The skull was 61.0 cm long (Head Length), which, using regression equations derived by Bezuijen *et al.* (1995a; b), equates to a *Tomistoma* with a total length of about 3.76 m (12'4").

Tasek Bera Swamp

The navigable swamp channel within Tasek Bera measures approximately 20 kms from the Jelawat bridge to Pathir village. Channel width is usually between 3-7 m, with the depth usually less than 1.5 m. The water level at Tasek Bera during the field trip (26 June - 11 July 1997) - the dry season, was quite low. The standard water depth scale at the Tangung Kuin Jetty (Fig. 2) measured approximately 80 cm for the duration of depth measurements. The water level did rise to 110 cm with rainfall in the area during the last 4-5 days of the trip.

There are 38 deep waterholes, or lubuks, which intersperse the dry season channel from the Jelawat Bridge to Pathir village (Simpson *et al.* 1997). Nine of these are in the open water of the northern swamp. Most of the lubuks in southern part of the swamp, from the Jelawat bridge to Benal village usually measured less than 3 m deep. Those lubuks from Benal village north to Pathir village were usually 4-6 m deep. Lubuk sizes varied but were usually 100-300 m long, although some measured only 20 -30 m; lubuk width was between 20-100 m.

Water temperature was lower in the faster flowing areas of shallow channel (26 C) than in the deeper lubuks (27.5 - 28.5 C). Water pH was the same throughout the swamp (5.5).

DISCUSSION

Tasek Bera

The population of *Tomistoma* at Tasek Bera and in the Tasek, Jelai and Bera Rivers has been clearly reduced over the last 40 years, and only a few individuals may remain. The commercial hunting of all sizes of *Tomistoma* for the skin market was the most obvious reason. It appears hundreds rather than thousands of *Tomistoma* may have been removed from the region during that period (1958-1962), but such losses probably represented a large proportion of the population. Very few animals remained after the commercial hunting had finished in 1962. The species is now legally protected and in conjunction with very low densities, is not the subject of deliberate hunting in the area.

The loss or alteration of the natural habitat throughout the area is a factor which threatens the recovery of *Tomistoma* populations. The remaining dry lowland forest at Tasek Bera has been subjected to varying degrees of clearing and alteration. Forest has been logged to varying degrees, and subjected to shifting swidden agriculture. The large oil-palm and rubber plantations of the and Federal Land Development Authority (FELDA) schemes further isolate the swamp. These schemes result in large tracts of forest being cleared for agriculture and greatly increase the potential for fertiliser run off which can impact on the swamp in many ways.

The increasing number of people to the area, through tourism and FELDA schemes, may also impact on the *Tomistoma's* ability to recover. An increase in the number of powered recreational and fishing boats on the Bera River has occurred over the past few years, with river cruises increasing in popularity. The increase in human activity since the main FELDA settlements in 1983 has also resulted in an increase in fishing intensity, especially netting and poisoning of the Bera River. These fishing activities are real threats to *Tomistoma* and the aquatic fauna generally. The use of traditional root poisons (which have a limited effective range) have been overshadowed in recent times by the use of pesticide poisons and cyanide-based industrial chemicals. Such chemicals indiscriminately kill and affect all aquatic life forms. Fish netting occurs frequently along the Bera River, with large nets stretched across the river width. These catch all sizes of fish, restrict the movement of *Tomistoma*, result in individuals drowning, and may decrease food availability.

No *Tomistoma* were seen during the surveys, but information from villagers indicated that some individuals are still present in Tasek Bera. These have been infrequently sighted over the past several years, with most reporting large animals greater than 3 m long. It is probable that there are only a few individuals which are seen as they move within the swamp. The report of a small *Tomistoma* may suggest successful nesting somewhere in the region, within the last 5 years or so. It is possible that breeding still takes place, although clearly infrequently. All previous nesting reports indicate that the lowland forest of the Tasek, Jelai and Bera Rivers provide suitable nesting habitat for *Tomistoma*, although no nests have been reported in nearly 20 years.

Peninsular Malaysia

Information obtained during the Tasek Bera surveys indicate that *Tomistoma* can still be found in tributaries of the Pahang River. The Department of Wildlife and National Parks (PERHILITAN) at Temerloh have four *Tomistoma* in their minizoo. One was confiscated from a fishermen in 1995 from the Jengka River (Fig. 3). The 3 others were obtained since July 1997. Two small individuals came from Tasek Chini, while the other from another tributary of the Pahang River (Fig, 3).

Information from Menchupu village (near the Rasau River) indicates that all sizes of *Tomistoma* (as well as *C. porosus)* are frequently seen at night in the Rasau, Lepar and Pahang Rivers (Fig. 3). The Luit and Rompin Rivers were also said to hold populations of *Tomistoma*. Batin Kandol of Menchupu reported seeing *Tomistoma* nests during the dry season on the banks of the Rasau and Lepar Rivers 4-5 years ago. A 40 kg [estimated at 2.4 m long] *Tomistoma* was caught in a net in 1996. The lower jaw was examined and the dentition noted as 4/15 (Simpson *et al* 1997), in accordance with other described *Tomistoma* specimens (Iordansky 1973, Bezuijen *et al.* 1995a). *Tomistoma* caught as incidental catch in fishing nets in the Rasau River area can still be reportedly sold for RM5/kg, but during the Chinese festive season prices can reach RM40/kg: *Tomistoma* (and *C. porosus*) are sometimes hunted at this time.

The *Tomistoma* surveys at Tasek Bera were the first such surveys to be carried out in Peninsular Malaysia although *Tomistoma* have been known from the Peninsula for more than 100 years. Historically reported from the Perak, Pehang and Selangor Rivers (Fig. 3) (Boulenger 1896, Butler 1905), *Tomistoma* have only been recorded from the North Selangor Peat Swamp Forest in recent times (Prentice 1990, Sebastian 1993). As the current status and distribution of *Tomistoma* within Peninsular Malaysia is unknown, comprehensive surveys are urgently needed. *Tomistoma* may still be under some hunting pressure in some areas.

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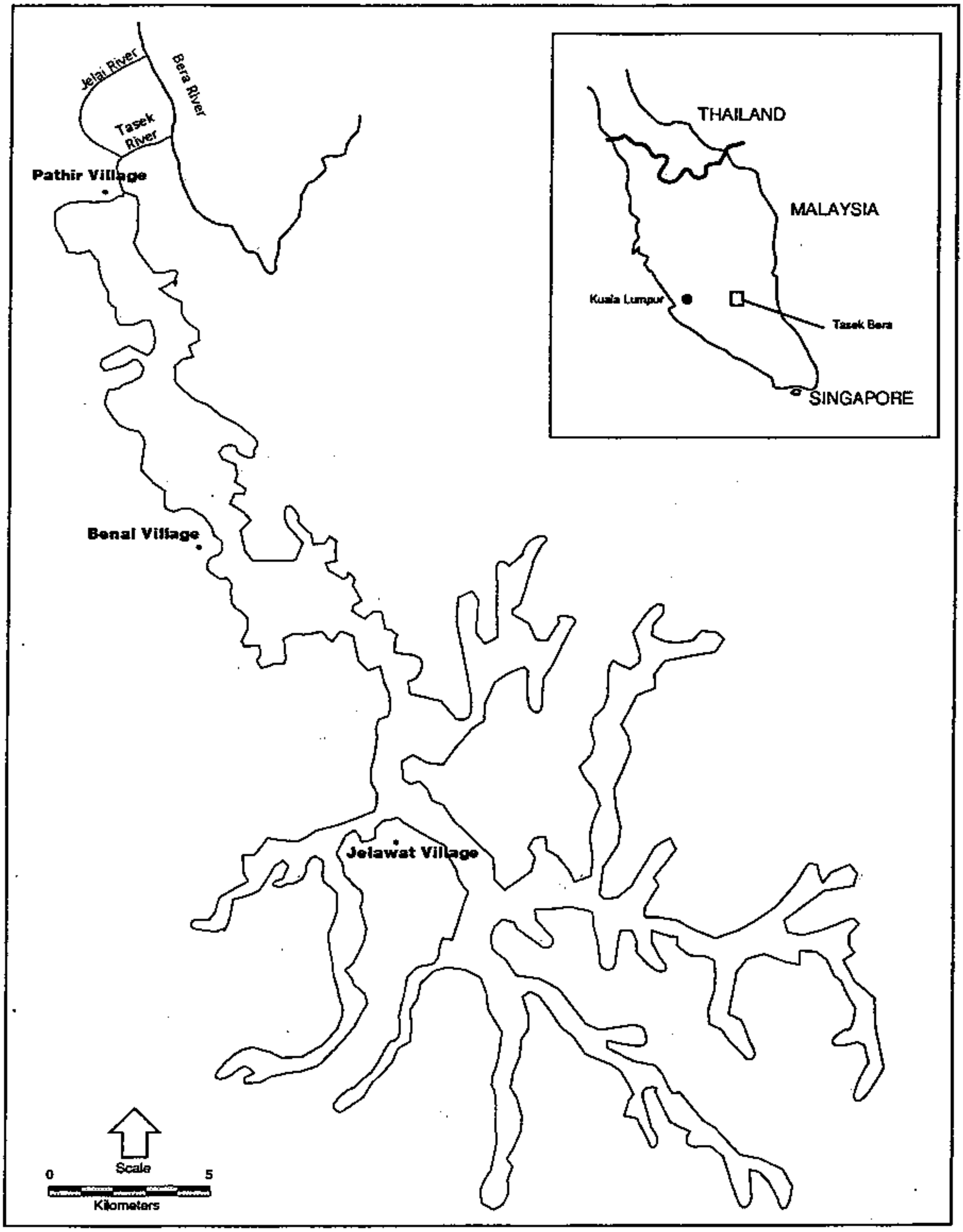

Figure 1. Tasek Bera Swamp and associated northern rivers

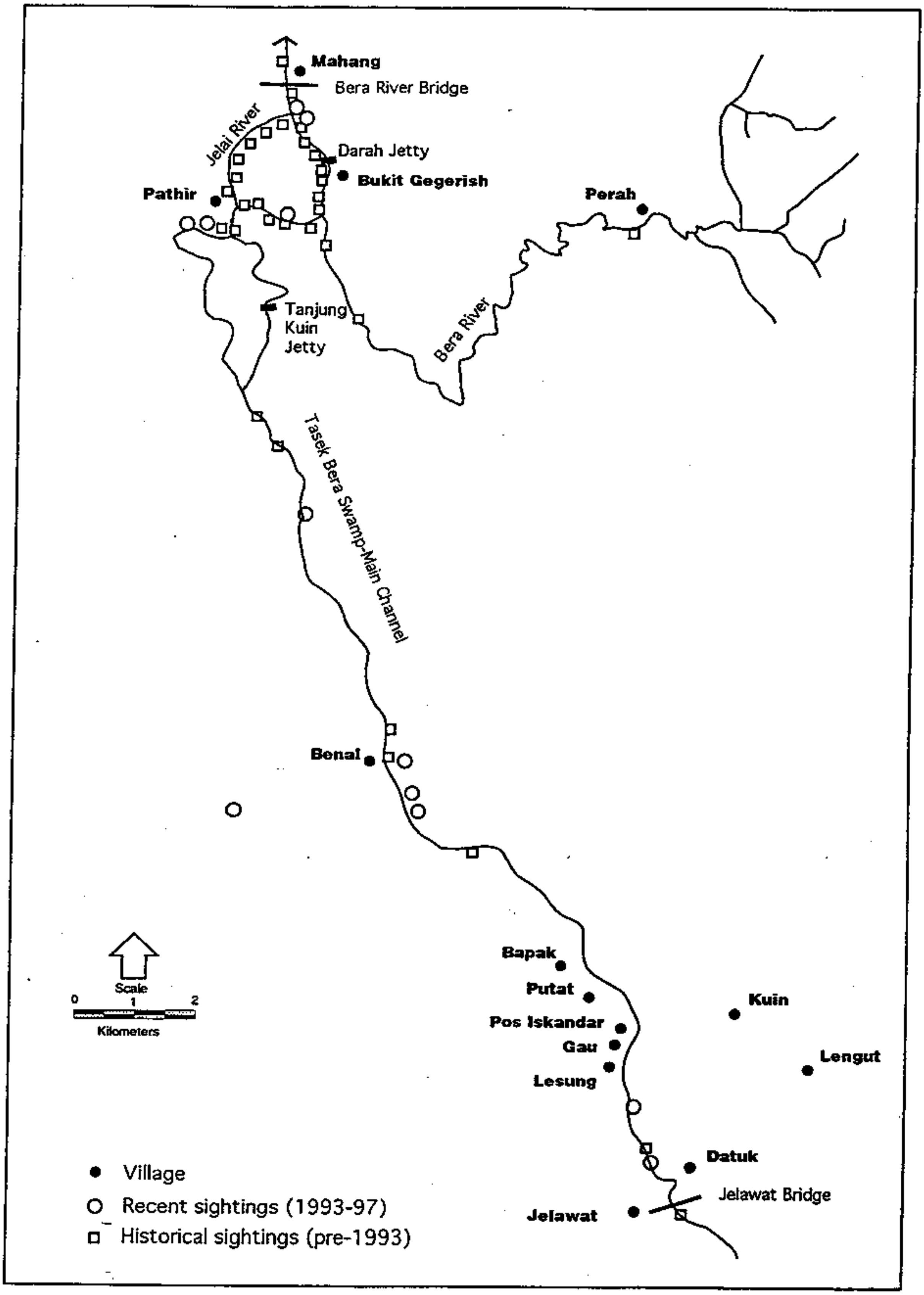

Figure 2. Sightings of Tomistoma and associated villages at Tasek Bera

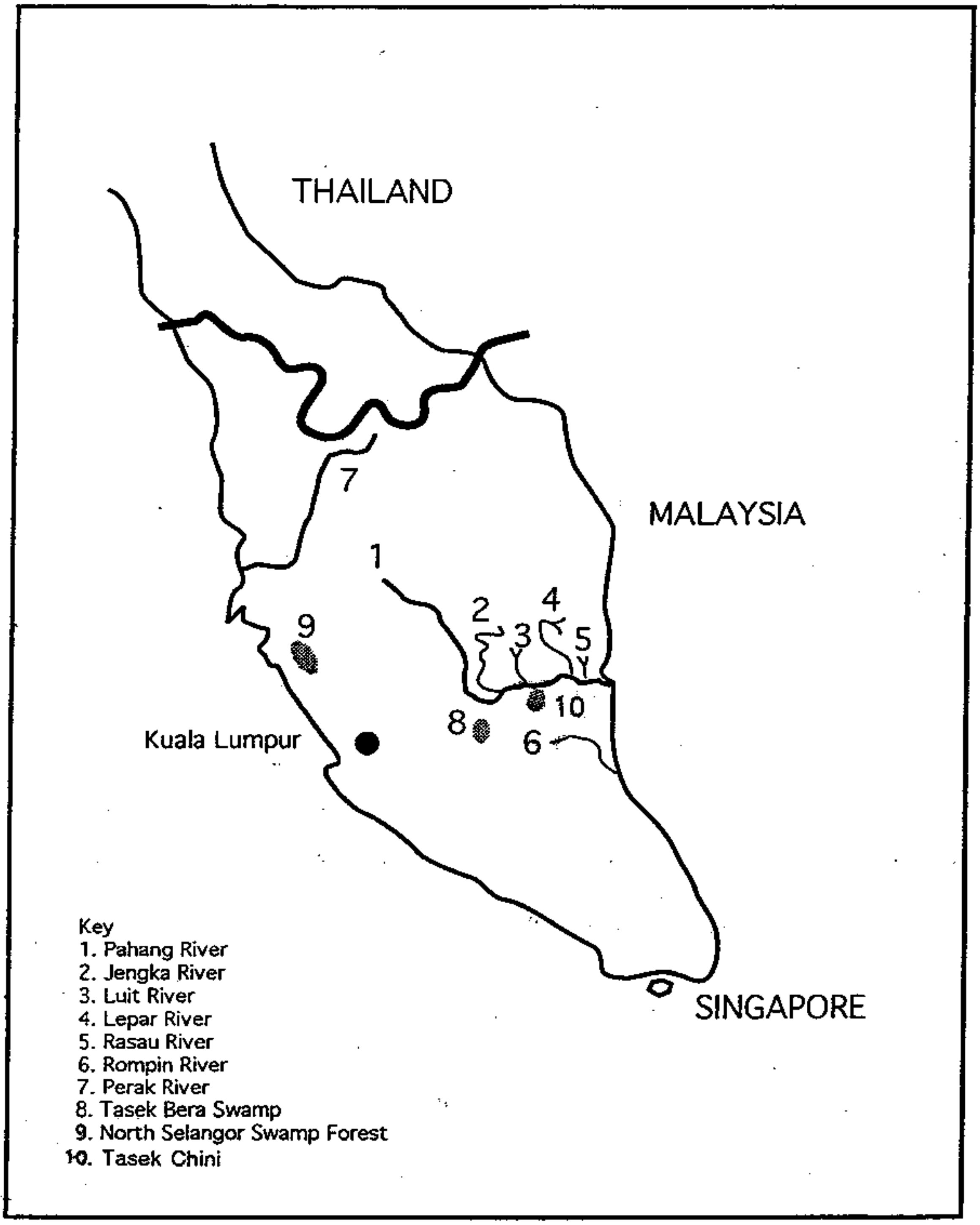

Figure 3. Areas in Peninsular Malaysia with reported sightings of Tomistoma

Preliminary Surveys of Palustrine Crocodiles in Kalimantan

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Abstract

Three species of palustrine crocodilians reportedly occur in Kalimantan (Indonesian Borneo): Crocodylus raninus*, an apparent Bornean endemic,* C. siamensis*, and* Tomistoma schlegelii*. A fourth species,* C. porosus*, also inhabits freshwater river systems, but is more commonly known from coastal habitats, and was not a focus species in this study.* Tomistoma schlegelii *and* C. siamensis *are considered highest priority species for conservation action by the IUCN/SSC Crocodile Specialist Group (CSG). The most recent evidence of* C. raninus *is a juvenile specimen collected* ca. *1878.*

Surveys were conducted in two phases during 1995 and 1996 as part of a joint Smithsonian Institution (SI)-Indonesian Institute of Sciences (LIPI) research project. Main objectives were to document an extant population of C. raninus *and occurrence in the wild of* C. siamensis*; and to obtain specimen series for taxonomic study. Specimens of* T. schlegelii *and* C. porosus*, and data on distribution, habitat and nesting of all four crocodilians, were collected on an opportunistic basis. An evaluation of population status was not a project objective.*

In 1995 a wild population of C. siamensis *was confirmed in the Mahakam River system of East Kalimantan. Two individuals of a* raninus *group crocodile were examined on a farm in South Kalimantan, and tissue obtained from one. Phase 2 in 1996 emphasized searches for* C. raninus *in the Arut and Jelai river systems of Central Kalimantan, the general area where the* raninus *group individuals were said to originate, but yielded no evidence of the species. Mahakam surveys produced additional specimens of* C. siamensis *and inspections of two active* T. schlegelii *nests, one on land and the other on floating vegetation. Three nests with spoiled clutches were also attributed to* T. schlegelii.

Night counts in eleven lakes and rivers of West and Central Kalimantan totaling 199 km were likely compromised by flooding (d=0.01/km). The only eyeshine recorded was from a juvenile T. schlegelii *and an assumed* C. porosus*. In East Kalimantan, eight* T. schlegelii *juveniles were recorded from Sungai Kedang Rantau (d=0.11/km). Captive* T. schlegelii *were frequently encountered at the village level (80 individuals at 20 sites), and is obviously the common palustrine crocodilian of Kalimantan.*

Wetland sites appraised to comprise critical habitat for palustrine crocodilians in Kalimantan are described and recommended for formal protection.

Introduction

Kalimantan (Map 1) is a region of special interest for crocodilian research and management. Four species: *Crocodylus porosus, C. raninus, C. siamensis* and *Tomistoma schlegelii* have been recorded, the most of any area in the Asia-Pacific region. The presence of two species (*C. siamensis* and *T. schlegelii*) in high-priority need of status surveys according to the IUCN/SSC Action Plan for crocodilians (Thorbjarnarson 1992), and a third little known species, *C. raninus*, led two of the authors (Ross and Cox) to formulate a research proposal addressing a suite of biological and conservation problems.

The main objectives of the project were: 1) to document or disprove an extant population *C. raninus* and confirm the occurrence in the wild of *C. siamensis*; and 2) obtain specimen series of whole animals, skulls and tissue samples for taxonomic study. Specimens of *T. schlegelii* and *C. porosus*, and data on distribution, habitat and nesting and other ecological aspects of all four crocodilians were collected on an opportunistic basis. Assessment of population status was outside the scope of this study.

Grant money obtained by Ross through the Smithsonian Institution allowed the proposal to be submitted to the Research and Development Centre for Biology (Puslitbang), a division of the Indonesian Institute of Sciences (LIPI). After discussions with LIPI and Puslitbang officials, the proposed project was revised to facilitate fieldwork by expanding the duration of surveys to two seasons or phases, and was approved. Prior to the start of field work, Kurniati agreed to join the project as a co-implementor on behalf of LIPI and Museum Zoologicum Bogor (MZB), and arrangements were made for collaboration with the CITES Management Authority in Indonesia: the Directorate General of Forest Protection and Nature Conservation (PHPA), Ministry of Forestry.

One of the most intriguing aspects of the research involved attempts to document survival of *C. raninus*. Commonly referred to as the Borneo crocodile, the species was initially described as a palustrine variant of *Crocodilus biporcatus* Cuvier (= *Crocodylus porosus* Schneider 1801) from the type series of a skull obtained from the Banjer (=Barito) River in 1836, and a juvenile preserved in alcohol, collected between 1836 and 1844 by Diard from the Pontianak area of West Kalimantan (Müller and Schlegel 1844). The series is deposited at the Nationaal Natuurhistorisch Museum, Leiden (RMNH). Two additional specimens attributed to *C. raninus* are known. One is a skull ostensibly from "Borneo" in the American Museum of Natural History, New York (AMNH). The other is an alcoholic juvenile collected by W.T. Hornaday, and is housed at the Museum of Comparative Zoology, Harvard University (MCZ). The only data associated with the juvenile specimen is "Borneo, Hornaday", but it was likely collected by him in 1878 while collecting orangutãns in southern Sarawak (see Hornaday, 1885).

Despite the existence of museum specimens, confusion long reigned regarding the unequivocal identity of this palustrine crocodile. Inclusion of one *C. porosus* and two *C. siamensis* skulls among Müller and Schlegel's syntypical series of five specimens was the principal reason. In 1992 the confusion was resolved by designation of the Diard juvenile from Pontianak as the lectotype of *C. raninus* Müller and Schlegel 1844 (Ross 1992). In addition to distinctive skull morphology, squamation was amended to include a ventral pattern that places the species in a "large scale" group (22-27 transverse rows) of crocodilians (*idem* 1992). The taxon was therefore "resurrected" as a valid species, and to date no attempt has been made to refute its status.

Methods

Series of specimens for taxonomic research were assembled from animals whose origin was considered indisputable. Most juvenile *T. schlegelii* and *C. siamensis* were obtained from holding cages at villages and huts in the immediate vicinity of crocodile habitat. One specimen, a juvenile *Tomistoma* was hand captured on a night survey. Additional *C. siamensis* material was obtained from ranch stock in Balikpapan that originated from the Mahakam River system, East Kalimantan. Collected individuals were pithed and preserved in 15% formalin, then transferred to MZB, where the preservative solution was replaced with 75% ethanol. *Tomistoma schlegelii* skulls were collected where made available by local residents. Distribution records were accepted for species in river systems where captive individuals or skulls were observed, and where wild individuals were sighted or captured.

Interviews were conducted with owners, managers and staff of most crocodile farms in Kalimantan, and with persons professing knowledge of crocodiles at the town and village level. At captive locations information was sought on species present, numbers of stock, age groups, origin, and breeding activity. A separate standard procedure was followed at the village level, where questions were asked regarding the number of species present, distribution by habitat type, historical and current abundance, exploitation patterns, and nesting biology/ecology. During Phase 2 a laminated sheet of *Crocodylus* photographs showing neck and body squamation without written species names was used to assist identification of species by informants citing local names.

Night counts, conducted primarily to document species occurrence and obtain specimens, followed standard methodology. A bright beam of light was projected along the surface of lakes and waterways, with particular care taken to cover shoreline indentions and 'cul-de-sacs'. The observer scanned from the bow of various vessels: speedboats equipped with 40 h.p. outboard motors, *ketintings* (narrow wooden vessels powered by shallow longshaft propellers) and, less frequently, from small boats and paddled sampans. Unavailability of large scale maps precluded calculating precise distances of some surveys, particularly in West Kalimantan.

Morphometric data was collected from live animals by direct measurement of total length and ventral squamation. In addition, 35 mm film and Sony Hi-8 mm video were used to record dorsal lateral and ventral scale patterns. Clutch data were recorded with a triple beam balance and vernier calipers, accurate to within 1 gr and 0.2 mm respectively.

Global Positioning System (GPS) coordinates were taken for villages where interviews were conducted, nest sites, survey waypoints and crocodile eyeshine/capture points. Coordinates of important map points were also recorded to assist speedboat navigation when travelling via the sea between river systems.

Results and discussion

Phase 1 fieldwork in Kalimantan was conducted from 20 September through 13 December 1995. Most crocodile farms in Kalimantan were examined for species present and to collect morphological data. Information on the purported origin of stock was used to plan for intensive surveys in Phase 2 of selected river systems. As time allowed, river journeys were undertaken to village holding facilities in the interior of West, Central and East Kalimantan provinces to collect specimens and additional data on occurrence. In conjunction with these excursions, night counts and daytime assessment of habitat were conducted in lakes and rivers where crocodilians were said to persist.

Phase 2 activities were carried out from 17 July to 21 September 1996. The research team was joined by Frazier for surveys with Kurniati in West Kalimantan. On the basis of Phase 1 results, priority was given to searches for *C. raninus* in the Arut and Jelai river systems of Central Kalimantan and the Kapuas River system in West Kalimantan. Continued investigation of *C. siamensis* in the central Mahakam River of East Kalimantan was carried out by Cox and local counterparts to fully document the occurrence of a breeding population, and to collect data on basic breeding biology and ecology. Incidental observations on *T. schlegelii*, including nesting biology and ecology, were made as time and limited funds permitted.

Species accounts

Crocodylus siamensis

Historical distribution of *C. siamensis* was until recently considered to be the mainland Southeast Asian countries of Thailand, Cambodia and Vietnam (Groombridge 1982), but skulls from Java (Ross, 1992; Ross *et al.* 1995) suggest that the range extended at least to that island. Until 1992 *C. siamensis* was reported as virtually extinct in the wild, but a substantial extant population (several thousand?) is now known from Cambodia, remnants of *ca.* 100 each persist in Vietnam and Lao DPR, as do a few individuals in Thailand (Ross, 1998).

In 1990, an unusual 2 m captive *Crocodylus* was photographed at Muara Ancalong in the Mahakam River, East Kalimantan (Frazier and Maturbongs 1990). Although ventral squamation data was unavailable, the dorsal characters were consistent with *C.*

siamensis. Two years later, juvenile *C. siamensis* were documented on farms in East Kalimantan, and were reportedly acquired as small juveniles from the central Mahakam (Cox *et al*. 1993).

Morphology. During Phase 1, morphological data were recorded from 42 captive specimens that originated from the Mahakam River system. Most of these were farm stock at C.V. Surya Raya, Balikpapan, but nine were juveniles (seven of which were examined) from village holding facilities in the central Mahakam, and deduced to be offspring from at least two, possibly three or more breeding crocodiles. Full squamation data was obtained from 28 captive individuals using Hi8 video. Tail scute clippings were taken from the same group for DNA studies. An additional five adult *C. siamensis* (from total stock of *ca*. 15 individuals) were photographed at P.T. Alas Watu Utama crocodile farm near Banjarbaru, South Kalimantan. Origin of these animals is less certain, but purported to be Central Kalimantan.

Table 1. Morphometric comparison of mainland Southeast Asian and East Kalimantan *C. siamensis*. Measurements include ±standard deviation (range,n). Mainland data are from Ross (1990).

Sample	Transverse ventral scale rows	Transverse throat scale rows	Basal caudal irregularity
Mainland SE Asia	31.3 ±1.14 (29-33,n=14)	50.3 ±1.49 (49-53,n=15)	yes (n=15)
East Kalimantan	32.7 ±1.23 (30-35,n=35)	52.2 ±1.78 (47-55,n=35)	yes (n=35)

In the East Kalimantan sample, the number of transverse throat scale rows, of which *C. siamensis* exhibits the highest number of in *Crocodylus*, and the number of transverse ventral scale rows, typical of "small scale" *Crocodylus* were very similar to those from mainland individuals sampled by Ross (1990). Small differences in the two data sets are probably due mainly to variation in sample size. All 35 individuals from East Kalimantan from which ventral data were recorded showed median basal caudal irregularity as reported by Brazaitis (1973).

No *C. siamensis* skulls were examined in Kalimantan, but few of the sub-adult and adult captive individuals showed the extreme raised squamosal ridges characteristic of mainland animals in Thailand and Vietnam (Ross, pers. obs.), and many did not clearly exhibit the unique light coloration of these ridges. These characteristics are ontogenetically influenced, and further study is required before assessing the importance, if any, of these observations (Ross 1996).

The character data sets clearly show, however, that individuals inspected in East Kalimantan during Phase 1 are morphologically consistent with *C. siamensis* known from mainland

Southeast Asia (Thailand and Vietnam) (Ross, 1990; Ross, unpubl. data), and individuals in Kalimantan examined by Cox *et al.* (1993).

Occurrence in the wild. Results of a recent crocodilian survey in the Danau (=Lake) Sentarum area, Kapuas River system of West Kalimantan, included a photograph of an unusually patterned juvenile *Crocodylus* (Frazier, 1994). Interviews with village residents in the Kapuas drainage, in particular Danau Sentarum and vicinity, showed no indication of *C. siamensis* inhabiting this large river system. Visual inspection of stock at the P.T. Cipta Khatuslistiwa Mandiri crocodile farm outside Pontianak also failed to yield any evidence of the species.

From information in reports by Muin and Ramono (1994), Frazier and Maturbongs (1990) and Cox *et al.* (1993), and a wealth of information provided by Messrs. Tarto Sugiarto (C.V. Surya Raya) and Welly Makawang (P.T. Makmur Abadi Permai), surveys in East Kalimantan were conducted in areas of the Mahakam River system where wild *C. siamensis* was reported to occur.

At Sungai (=river or stream) Bongan in the lakes region of the central Mahakam (Map 2), Mr. Saleh, a former crocodile hunter and supplier of *C. siamensis* juveniles for captive breeding, guided the survey team to several sites where young and nests of "buaya kodok" (frog crocodile), as *C. siamensis* is commonly referred to in the region, were said to have been harvested.

Four juveniles (59.5-80 cm total length [TL]) being reared by Mr. Saleh in October 1995 reportedly came from nearby Danau Belibis. This is a largely overgrown, shallow (dry season depths of *ca.* 1.5 m) lake that is fringed with floating mats of reeds *Phragmites* sp., hanguana *Hanguana malayana* and *Leersia hexandra*. Dense, boggy vegetation restricted an unproductive search for nests to the outer edge of the lake.

Another reported area of *C. siamensis* breeding habitat, Danau Tanah Liat, is connected to Sungai Bongan by a 2 km channel. This relatively isolated lake is densely fringed with tall hanguana, reeds, and broadleaved thickets draped with lianas. Water hyacinth *Eichhornia crassipes* occurs as patches in open water and is braided in the floating fringe. Since its introduction 20-30 years ago the aquatic weed has apparently accelerated growth of the fringe and constricted the area of open water by almost half.

Danau Tanah Liat has some non-floating shoreline where *C. siamensis* were said to occasionally bask. A large individual reportedly destroyed a *bubu* (rattan fishtrap) *ca.* two months earlier, about the same time another villager, interviewed at this lake, claimed to have seen a large crocodile floating in the water. Although more than 100 *bubus* were placed in the floating fringe, no reports were received of young crocodiles having been trapped. Furthermore, juveniles and active nests have not been observed for several years, suggesting poor nesting success and/or recruitment.

Two evenings were spent conducting spotlight surveys by *perahu* (paddle canoe) in Danau Tanah Liat, but no crocodile eyeshine was observed (see Table 6).

At Danau Mesangat village, in the Kedang Rantau tributary, residents reported *C. siamensis* to be fairly abundant in the adjacent overgrown lake system (Figure 6). A 73.5 cm TL juvenile captured in Danau Mesangat about 10 days earlier was obtained as a locality voucher for MZB.

Although most information indicated that *C. siamensis* preferred permanent marshlands and small isolated lakes, villagers in the vicinity of several large shallow lakes bordering the central Mahakam reported that *C. siamensis* also occurred there. Kampung (=village) Melintang residents said juveniles obtained from Danau Melintang were released in 1986 or 1987 after being informed that it was illegal to keep them. At Kampung Resak two captive juveniles were said by the owner to have been captured at nearby Danau Jempang.

Crocodylus siamensis was said to occur at Danau Sekentang, and uninhabited lake that can be reached by foot from Muara Bengkal on Sungai Wahau, and several small lakes or marshlands (including Danau Gendang), associated with Sungai Keteng, and accessed with difficulty by *perahu* from Danau Padam Api. Due to time and funding constraints none of these sites were investigated.

At least some of the captive *C. siamensis* observed at Banjarbaru reportedly came from western river systems of Central Kalimantan (Kasan, farm caretaker, pers. comm.). Surveys there during Phase 2 in the Sungai Kotawaringan and Sungai Jelai drainages found only anecdotal evidence of palustrine *Crocodylus*. Three to four local names were used to described resident crocodilians, among them "buaya kodok". In East Kalimantan the name is referable only to *C. siamensis*, but based on varying descriptions and selections of species photos during interviews in Central Kalimantan, the exact species is less certain. In the Sungai Barito drainage, informants at several villages claimed that "buaya kodok", which as described resembles *C. siamensis*, occurred in the area. At Kampung Buyui on Sungai Ayu, a tributary of the upper Barito, residents said "buaya kodok" was known to inhabit lakes and rivers, but last seen five years earlier.

In West Kalimantan, "buaya kodok" was reported to occur in the southern river systems (Ketapang area) by a former hunter at Kubu. He cited catching two of these crocodiles in 1982 at Sungai Pinggan in the Gunung Palung area, and said that the species lives in freshwater lakes. In other areas of West Kalimantan, in particular the Kapuas River system, there was no mention of "buaya kodok"; however, several reports were received from villagers of a freshwater *Crocodylus* referred to as "buaya katak" (toad crocodile). This crocodile was frequently described as aggressive, dark colored, and distinct from *C. porosus*. On other occasions, "buaya kâtak" was reported from large coastal rivers, sometimes in brackish conditions.

Nesting. In addition to Danau Belibis, where successful *C. siamensis* nesting is inferred as recently as 1993 by the capture of small juveniles in 1995, Danau Tanah Liat was also claimed to be a nesting area for crocodiles, presumably *C. siamensis*. (*Crocodylus porosus* was said to be formerly sympatric there with *C. siamensis*, but the former has been reportedly extirpated for many years). Nesting habitat was described by Mr. Saleh as floating mats of herbaceous vegetation, including hanguana and saplings, found inland from the fringe. He could not recall the months when active nests were seen.

Mr Saleh also reported that Danau Pekah, a smaller lake S (?) of Danau Tanah Liat, and connected by floating mats of vegetation, was another good *C. siamensis* nesting area. Many years had elapsed, however, since he last visited this secluded site.

The other *C. siamensis* breeding locality recounted by the informant was Danau Panan near Resak village. The lake was said to be a former hunting locality surrounded by forest and smaller lakes. Mr. Saleh said he not hunted *C. siamensis* for its skin for the past decade or so due to low prices and protection by government regulations. Juveniles were no longer pursued, he said, but were occasionally found in *bubus*.

Another former and renowned hunter, Abdullah Rahman, was interviewed at home in the district center of Muara Kaman. He hunted in the central Mahakam and further afield from 1948/1949 until the 1980s. Mr. Rahman reported that *C. siamensis* prefers open lake habitat and commences nesting during August/September. Nests are reportedly constructed on floating mats in lake fringes and permanent mixed herbaceous swamp.

Danau Mesangat, northeast of the central lakes region in the Mahakam, is a diverse mixed swamp woodland interspersed with open pools and herbaceous associations. Floating mats of hanguana, *Leersia hexandra*, *Thoracostachyum sumatranum* and *Scleria* spp. sedges exhibit a patchy distribution. Introduced *Eichhornia crassipes* covers most of the otherwise open water surface. Local fishermen said *C. siamensis* nests exclusively on floating mats of herbaceous vegetation. Clutches began to be laid in August or September, but October was the best time to find eggs as most, if not all, nests were finished by that time.

A nest with a partial clutch of rotten eggs (MKM 001) was shown to the survey team in October 1995 (Table 2). Egg size appears too small for *T. schlegelii* (Bezuijen *et al.*, 1995; *T. schlegelii* section this report). Although well within the range for captive C. *siamensis* in Thailand (Youngprapakorn, *in litt.*), *C. porosus* cannot be rejected because egg size is also within the range of this species (Webb *et al.*, 1979; Cox, 1985). Furthermore, evidence of *C. porosus* in similar upriver habitat in Kalimantan (e.g. Danau Sentarum, Sungai Bila) was found in this study.

Table 2. Measurements of five eggs (in mm) from a nest at Danau Mesangat, Mahakam River, East Kalimantan. October 1995.

Length	Width
88.0	52.0
83.1	51.7
80.2	53.0
81.7	51.5
82.6	53.1
x = 83.1	x = 52.3

Further investigation of nesting in the Danau Mesangat and Muara Kaman areas was carried out during 1996. Local fishermen said the previous year that they could guide survey personnel to *C. siamensis* nests on floating vegetation from July through October, but the only active nests shown during our late August return proved to be *T. schlegelii*. One informant at Danau Mesangat opined that our searches may have been too early because high water levels had not yet receded to prompt nest building. Local residents were requested to report any active nests found on subsequent forays in 1996 to counterparts in Samarinda and Balikpapan, but no response was received.

Conservation. Without intensive surveys emphasizing population monitoring, it is difficult to infer much about the current status of *C. siamensis* in the Mahakam. Considering the apparent extent of suitable habitat in the central Mahakam, probable lack thereof elsewhere in the river system, and the impression that our interviews yielded information on most sites inhabited by the species, the population is roughly estimated at a maximum of a few hundred individuals.

The occurrence of a wild population in Kalimantan is of major importance to crocodilian conservation. The *in situ* biology of *Crocodylus siamensis* and its ecology are poorly known, with few studies of its natural history available (Kimura, 1969; Smith, 1919,1931). The main population of this species is in Cambodia, where continued political instability makes it exceedingly difficult to conduct field research. Peripheral populations in Lao PDR and Vietnam appear similar in size to the one in Kalimantan, but prospects for research and conservation are unclear. By contrast, the Kalimantan population occurs in an area where study, protection and management is currently feasible

Trade in C. *siamensis* has evidently ceased in East Kalimantan. Although small clusters of captive animals were examined at Sungai Bongan and Muara Muntai, area farm owners acknowledge the protected status of the species, and report they no longer purchase wild stock. Observations by the survey team of farm stocks in Balikpapan and Samarinda supported this claim. The greatest threat to the wild population is habitat degradation and disturbance. Intensive fishing with nets and traps, and to a lesser extent, fires that sweep across wetland habitat in times of severe drought, are the main causes for concern.

A fortunate aspect of live juvenile trade in the recent past is that a breeding nucleus, and if eventually needed, a potential founder population, is secure at C.V. Surya Raya in Balikpapan. Total stock of 37 subadults were obtained directly from the central Mahakam as small juveniles (T. Sugiarto, pers. comm.), and are separated from potentially hybridizing *C. porosus*.

About half of the 15 *C. siamensis* reared at P.T. Alas Watu Utama near Banjarbaru, Central Kalimantan are adults. A pair of them reportedly nested in January 1996, but no hatchlings were produced from a clutch of 30 eggs (Kasan, pers. comm.). To assure the homogeneity of wild populations, *C. siamensis* reared at Banjarbaru should be isolated from *C. porosus*. Communal stocks at P.T. Makmur Abadi Permai outside Samarinda evidently include hybrids, some of which are adult size. Species there should be segregated and all suspected hybrids culled. The practice of mixing *C. siamensis* and *C. porosus* in common pens has been strongly discouraged (Webb and Jenkins, 1991; Ross *et al.*, 1996).

Conservation of known breeding areas in the central Mahakam also merits priority. There is pressing need to link Danau Mesangat, and additional sites associated with Sungai Kedang Rantau as confirmed, with nearby Muara Kaman Strict Nature Reserve (62,500 ha). This degraded mixed swamp is the only protected area in the central Mahakam and a probable nesting area for *C. siamensis*. A strict nature reserve of *ca.* 200,000 ha (Perairan Sungai Mahakam) has been proposed for the region to conserve distinctive lake habitat, swamp forests and the rare freshwater dolphin *Orcaella brevirostris* (MacKinnon, 1996). The reserve may require re-classification to reflect the economic dependence on fisheries of local communities, but the lakes region is one of the most important freshwater wetland habitats in Kalimantan, and the presence of breeding *C. siamensis* underscores an urgent need for conservation action.

Development of a management plan for *C. siamensis* in East Kalimantan should take into account the "classic skin" commercial value of the species. Harvests of eggs from wild nests, rearing, and eventual restocking of a percentage of offspring may provide an effective local incentive to protect wild breeders and nesting areas, as well as a mechanism that contributes to quantification of population status (Ross, *et al.*, 1996).

At present most individuals removed from the wild population of *C. siamensis* are small juveniles accidentally caught in *bubus* (rattan funnel traps) used by local villagers for fishing. Artificial incubation of eggs and release of larger young may increase survivorship in the wild, but safeguards against potential tainting of the wild population through *ex situ* hybridization are a prerequisite (Ross, *et al.*, 1996).

In situ management must also contend with more general conflicts in habitat use by local communities and foraging crocodiles. An integrated approach that decreases pressure on overharvested fish stocks by emphasizing development of alternative sources of income may ultimately provide the most effective protection for *C. siamensis* in the wild.

C. raninus

During Phase 1 no crocodiles identifiable as *C. raninus* were observed on crocodile farms or in holding facilities in West, Central and East Kalimantan. Interviews of villagers, farm personnel and others in these provinces yielded no information specifically referable to *C. raninus*.

In South Kalimantan, however, a visit by Cox in December 1995 to P.T. Alas Watu Utama crocodile farm in Banjarbaru revealed two individuals that were identified, on the basis of ventral squamation, as *raninus* group crocodiles[1] (Ross *et al.*, 1996). These crocodiles were captured, photographed (see Figures 1-4), sexed, and measured for total length and ventral squamation. Tail scute tissue samples from the male were obtained on a subsequent visit by Kurniati.

Table 3. Measurements of two captive *raninus* group crocodiles at P.T. Alas Utama, Banjarbaru, South Kalimantan. Total length in meters.

Total length	Sex	Transverse ventral scale rows	Transverse throat scale rows
1.8	♀	24	37
1.38	♂	23	37

Farm staff were repeatedly and carefully questioned regarding the origin of these crocodiles. The caretaker, Mr. Kasan, was adamant that these animals were obtained, separately over a two year period, from a logging camp foreman posted at or near Pangkalanbun, Central Kalimantan.

The female was reportedly received in early 1991 as one of five crocodiles in a group that included two *C. porosus* and two *C. siamensis*. Mr. Kasan recalled that the unusual crocodile measured 53 cm TL when it was received.

The male reportedly arrived in 1992 as part of a second shipment, again hand-carried by the foreman, that included 22 juvenile *C. porosus*. At the time of purchase the crocodile

[1]taxa of Indo-Pacific *Crocodylus* that exhibit "large scale" ventral pattern: *raninus*, *mindorensis*, *novaeguineae* and *johnsoni*.

measured 33 cm TL. It has since died (Moelyono, farm manager, *in litt.*), apparently from wounds inflicted by other crocodiles, and has been preserved as a whole skin (Ross *et al.*, 1996).

Our current taxonomic knowledge of *C. raninus* requires examination of cranial sutures to positively identify the species, because the only whole specimens known are small and inadequately preserved, and comparative DNA studies of *raninus* group species are lacking. Even so, identifiable morphological characters (i.e. ventral squamation and post-occipital pattern) have been used to predict that *C. raninus* closely resembles *C. mindorensis* and *C. novaeguineae* (Ross, 1990).

One interview during Phase 2 suggested that *C. raninus*, or a crocodile very similar to it, may persist in the wild. The information was received in July 1996 from Mr. Jamain, a former crocodile hunter and trader, at Kampung Pandulang, Sungai Kotawaringan, Central Kalimantan. He recognized four types of crocodiles in the Sungai Arut/Kotawaringan system: *T. schlegelii*, which he referred to as "buaya sapit", a common local name for the species; *C. porosus*, or "buaya toman", a name that refers to the species in areas of Central Kalimantan; *C. siamensis*, alluded to as "buaya kodok", and correctly selected from the photo sheet; and "buaya salak", for which Mr. Jamain picked the head/neck shot of the *raninus* group crocodile, and the less distinctive body photo of *C. siamensis*. "Buaya salak" was said to formerly inhabit Sungai Sebingit, but may now be locally extinct.

DNA analyses of the *raninus* group individuals at Banjarbaru may be instrumental in species identification, although this requires a comparative series of material from *C. mindorensis* and *C. novaeguineae* (north and south coast populations of the latter due to differences in morphology and reproductive biology; Cox, 1985; Hall, 1989; Hall and Johnson, 1987).

Tomistoma schlegelii

Commonly referred to variously as the false gharial, false gavial, and Malayan false gavial, *Tomistoma schlegelii* is one of the most taxonomically distinct yet least known crocodilians. Historically, the species was widely distributed in Southeast Asia, but is currently reported only from Sumatra and Kalimantan, peninsular Malaysia and Sarawak (Ross, 1998). Its long held "Endangered" status (Groombridge, 1982) was recently revised by the IUCN to 'Data-Deficient' (IUCN, 1994). The species is of special concern to the CSG. In 1994, "Project Tomistoma" was formed to coordinate an assessment of conservation and management needs of the species, and has undertaken field studies in peninsular Malaysia and Sumatra. To not assist this effort while conducting *Crocodylus* studies in sympatric habitats of Kalimantan would have been neglectful on our part.

Observations were made on captive and wild *T. schlegelii*, and data collected on the ecology, reproductive biology and status of this species. In addition, a representative series of whole specimens and skulls was assembled, primarily to assist studies of variation in geographic isolates of *T. schlegelii*.

Occurrence in the wild. Captive *T. schlegelii* were observed in villages of all three provinces where fieldwork was conducted (West, Central and East Kalimantan). Eighty individuals were recorded, usually singles or pairs, ranging from small juveniles (55 cm TL) to adults >3 m TL. Most of these (47) were found at Kampung Batambang in December 1995 on a circuit of tributaries in the Barito River, Central Kalimantan (Map 3). Proof of *T. schlegelii* (captives, skulls, direct sightings), or reports of its occurrence by local residents, was found throughout all nine areas of reconnoitered river systems: upper Kapuas, Kendawangan/Balaban, Simbar, Pawan, Air Hitam Kecil, Jelai/Berais/Mapam/Bila, Kotawaringan/Arut, Barito and Mahakam).

Almost all captive animals were maintained in semi-submerged crates at the littoral of waterways, usually adjacent to floating residences of villagers and townspeople. Some had obviously been reared for many months if not several years. In the Kapuas system, villagers surmised that captive *T. schlegelii* would eventually be sold to itinerant traders for glands and skins. This may explain why relatively large stocks were reared in two villages (47 at Kampung Batambang in the Barito; eight at Muara Anggalam in the Mahakam), although apparent length in captivity suggested that trade in the species had ceased 2-3 years earlier. Most of the other individuals were said to be kept exclusively as pets or exhibition curiosities. The species appears suitable for these purposes, owing to its more docile character, compared to sympatric *Crocodylus*, and peculiar appearance.

Captive *T. schlegelii* were frequently reported to have been acquired as incidental catch (usually small juveniles) in fishing nets or *bubus*. Some evidence of pursuit was seen - a juvenile with a spear wound, a prepared skin, and a skull with a mortal blow from a *parang* (machete)- but the intensive level of fishing in many waterways visited, and lack of commercial demand for *T. schlegelii*, lent credence to much of the information.

In the Kapuas River system, *T. schlegelii* was observed at three villages near Danau Sentarum Wildlife Reserve. At Kampung Meliau, another village in the vicinity, local guides said that *T. schlegelii* occurred at Danau Semati. This is a small lake fringed with floating pandan *Pandanus sp.* that usually anchors during the dry season. No crocodilians were sighted on a night spotting circuit of the flooded lake. *Tomistoma schlegelii* was also reported to occur at Danau Lintang (partial floating pandan fringe), and to be sympatric with *C. porosus* at Danau Merbong (swamp forest border). Sungai Leboyan, a known locality for *T. schlegelii* (Frazier, 1994) was said by Kampung Meliau residents to contain "many" *T. schlegelii* in the upper reaches during the dry season, but disperse to adjacent swamp forest when flooded.

Surveys were also conducted in remote tributaries of West Kalimantan that are part of the proposed 150,000 ha Muara

Kendawangan Nature Reserve. The area was recently assessed as important for conservation of mangrove, freshwater and peat swamp forest, and unlike all other existing and proposed reserves in lowland Kalimantan, "not threatened" (MacKinnon, 1996). Sungai Kendawangan and Sungai Balaban showed moderate-serious habitat disturbance from logging and intensive use of waterways and adjacent lakes for fishing. *Tomistoma schlegelii* was said by local residents to inhabit the rivers, but no crocodile eyeshine was recorded in either system (Table 6). Sungai Air Hitam Kecil, a pandan and hanguana fringed small river that wends through peat swamp, was also said to harbor the species, although none had been seen in many years. The lower and middle reaches of this narrow tributary have been seriously disturbed by recent extraction of timber. A night count there yielded no eyeshine (Table 6).

Extensive and fairly intact habitat for *T. schlegelii* was found in tributaries of Sungai Jelai bordering West and Central Kalimantan. Sungai Mapam (Fig. 5), and its upriver branch, Sungai Bila, comprise perhaps the least disturbed habitat in the system. A large *T. schlegelii* was sighted during the day on an excursion up the Bila, and a small juvenile was captured on a night count in the Mapam under flooded conditions. Nests were said to be easily found in swamps adjacent to Pondok Palas in the middle Mapam. An informant at Kampung Buntar, Sungai Berais, suggested that *T. schlegelii* was fairly plentiful in that lengthy, narrow tributary. Mr. Nuan estimated that 10-20 individuals congregate during the dry season in a section of deep channel from Buntar to the confluence with the Jelai.

In addition to the many captive *T. schlegelii* observed in the Barito River system of Central Kalimantan, substantial anecdotal evidence of the species' occurrence was collected in the Arut and Lamongan rivers in the western part of the province. Reports of captures in 1995 near Kampung Pangkut, and recent nesting at Danau Bau and Sungai Jampau were related to the survey team. In the lower reaches, Sungai Sebingit was said to be good for *T. schlegelii*.

Tanjung Puting National Park (300,400ha) in Central Kalimantan was not surveyed, but is reported as an important area for *T. schlegelii* and *C. porosus* in Kalimantan (MacKinnon, 1996), with the former species fairly abundant (Abdul Muin, pers. comm.).

Habitat. Information from interviews and observations of individuals in the wild indicates that *T. schlegelii* is broadly distributed in the lowland river systems of Kalimantan. The species was most often encountered, or reported to occur, in sluggish freshwater tributaries and stagnant lakes, usually associated with peat swamp forest. Waterways and lake margins are typically fringed with pandan-hanguana associations. No information was received suggesting that *T. schlegelii* occurs in brackish or saline waters.

Crocodylus siamensis is sympatric with *T. schlegelii* in the central Mahakam river system, but evidence of habitat partitioning was suggested by informants familiar with both species. These were almost invariably experienced hunters who said that *T. schlegelii* is found in lakes, streams and rivers, while *C. siamensis* is more likely to be occur in static environments: permanent herbaceous swamps and lakes.

Nesting. During Phase 2 four *T. schlegelii* nests were inspected, and one other, freshly raided nest was attributed to the species. All nests were located in the central Mahakam except one in a captive facility at Tengkiling Recreation Park, north of Palangkaraya, Central Kalimantan.

Hatching data from these nests (Table 5) and information from interviews in West, Central and East Kalimantan consistently indicated that the nesting period for this species is from July/August through October. This overlaps the normal dry season in East Kalimantan, affording land nests the opportunity to avoid flooding in most years.

Three types of nesting habitat were noted:

1) Mixed freshwater swamp. Composed mainly of fire-climax herbaceous vegetation, mostly in floating mats of grass, sedge and short fern. Includes patches of trees, standing deadwood and thickets.

2) Secondary forest. Lowland tropical rainforest dissected by small steams and logged for large trees in the past. Ground vegetation is typically sparse.

3) Peat swamp. Nests constructed at tree bases on peat hummocks as described by Bezuijen *et al* for *T. schlegelii* nesting in Sumatra (1995, 1996). Trees at a Kalimantan nest site (MKM 006) were heavily draped with lianas. Surrounding herbaceous vegetation was hanguana, sedges and water hyacinth. Subject to flooding.

Table 4. *T. schlegelii* nest data, 1996. Only nests in the wild included. NR=Not Recorded due to disturbance of nest from egg collection.

Nest code	Habitat	Height (cm)	Width (cm)	Distance to water (m)	Material
MKM 003	Secondary forest	52	145-150	7.2	leaves & twigs, clay-lined clutch chamber
MKM 005	Floating mats in permanent swamp	55	135-165	at base	*Leersia* & ferns
MKM 006	Peat swamp mound/forest	N/R	N/R	*ca.*0.2	leaves & twigs

Nest MKM 003 (Fig.7-8) was located at 0°32'20" N 116°41'49" E on 24 August 1996 at the edge of an overgrown channel. The site was mostly overhung with small trees, and the channel overgrown with water hyacinth and *Leersia* grass with flooded thickets nearby. The egg chamber was lined with finely speckled, orange-white clay, that was conspicuously different than the other nest material. A tail groove was present on the nest top. Although no adult was seen during examination of the nest, water nearest the nest was recently disturbed. About 300 m away was another nest (MKM 004) that had been active a month earlier, but since raided by a wild boar (spoor present). All that remained of the clutch were egg shell fragments.

Nest MKM 005 (Fig. 9) was located at 0°31'01" N 116°41'40" E, also on 24 August 1996. The mound was a soggy mass of decaying herbaceous vegetation constructed on a flimsy floating mat. The informant assumed the species to be *C. siamensis*, because *T. schlegelii* was said to nest exclusively on land. No reports of floating *T. schlegelii* nests were received during the study, and none are known from the few studies of the species in the wild.

Nest MKM 006 (Fig. 10) was located at Danau Ngibun (encompassed by Danau Mesangat), 0°32'15" N 116°41'12" E on 26 August 1996. The informant was unsure of the species but said that only *C. siamensis* nested in the area. Eggs had been translocated several weeks prior for artificial incubation in wood shavings, but none were alive when inspected later in the day.

Data for all clutches examined are presented below:

Table 5. *T. schlegelii* clutch data from Kalimantan, 1996. Measurements are with standard deviation (range, n). Clutch temperatures not recorded. Hatching followed incubation at 30°C.

Nest code	Clutch size	Egg mass (g)	Egg length (mm)	Egg width (mm)	Hatching dates
MKM 003	32	188.2±9.81 (166-214, n=24)	93.1±4.00 (83.3-100.0, n=29)	60.0±0.78 (58.5-61.8, n=29)	1-2/10
MKM 005	23	187.2±9.48 (169-211, n=16)	92.8±3.22 (88.3-101.3 n=20)	59.8±0.87 (58.3-61.3, n=20)	23-30/9
MKM 006	27	209.5±10.43 (195-238, n=26)	97.4±3.52 (93.0-106.5, n=26)	61.8±0.83 (59.5-63.0, n=26)	eggs dead
Tengkiling, Central Kalimantan	30	193.5±7.43 (178-213,	93.6±3.10 (88.5-101.5,	59.7±0.59 (58.7-60.8,	infertile &/or dead

Nesting information collected in other localities (including additional river systems) suggest that *T. schlegelii* clutches are commonly predated by wild boar and monitor lizards. One woman in the Sungai Arut area told of finding a nest the year before and taking the eggs to eat.

Conservation. Tomistoma schlegelii has apparently declined in all provinces of Kalimantan, although elder hunters assert that the species was distributed in relatively low abundance (compared to *Crocodylus*) prior to the commencement of hunting in the late 1940s (A. Rahman, Ibrahim, Saleh, pers. comm.). A broad yet thin distribution across freshwater habitats complicates the logistics of ecological/biological research and conservation of the species. The apparent preference of *T. schlegelii* for small secluded waterways, often choked with floating vegetation and in flood stage, makes direct population studies even more problematic.

Challenges to conservation and management are also compounded by intensive utilization of habitat by local communities. Freshwater habitats were heavily fished in all areas reconnoitered. Villagers in the lakes region of the central Mahakam, Jelai and Danau Sentarum areas cited overharvesting (declining size of fish and total catch) as the main threat to their economic livelihood. Combined with severe drought and forest fires in 1997, many villagers in the Danau Mesangat area are said to have turned to gold mining in the Mahakam headwaters to generate basic income (T. Sugiarto, pers. comm.).

The low skin value of *T. schlegelii* (Bezuijen *et al.*, 1996) hinders employment of a commercial utilization strategy to conserve the species. Inability of *T. schlegelii* harvesting to compete with other land uses probably means that any effective strategy to conserve remaining habitat will have to rely on community development interventions that generate alternative means of income (to reduce the pressure of intensive fishing and logging), and persuading government authorities to set aside key areas of habitat from extraneous, non-renewable development schemes.

Conclusions

A wild population of *Crocodylus siamensis* was documented in the Mahakam River system of East Kalimantan. Based on recent capture of small juveniles in the vicinity of reported nesting areas, a breeding population was inferred to exist as recently as 1993. Considering the apparent lack of hunting for skins, breeding crocodiles very likely persist in the central Mahakam.

The possibility that C. siamensis observed by Frazier and Maturbongs (1990) and Cox *et al.* (1993) may have originated from farms or other facilities in Java or mainland Southeast Asia was disproved. As noted in Ross *et al.*(1996), the hypothesis that this population was translocated through 16th or 17th century trade is unlikely for several reasons:

1). Several, evidently endemic, local names exist for *C. siamensis* in the Mahakam River system. If this population was a product of introduction, common names should reflect such a phenomenon.

2). Evidence is lacking that early traders in the region transported crocodiles, either as a commercial item or tribute (Andaya, 1981).

3). Historical distribution of *C. siamensis* in the Mahakam and possibly other adjacent river systems, some comprising different watersheds, is reasonable from zoogeographic patterns of freshwater fishes (Inger and Chin, 1962; Roberts, 1989) and Pleistocene sea level variations in the Sunda region (Inger, 1966; Umbrove, 1949). The paleozoogeography of the Sunda region is critical to understanding current, and possibly relictual, distributions of crocodiles and other fauna (Ross *et al.* 1996).

Although the project accumulated substantial anecdotal evidence of *C. siamensis* in Central Kalimantan, and to a much lesser degree from southern West Kalimantan, the species could not be confirmed outside the Mahakam river system. Proof of a wild population in Central Kalimantan would further strengthen the likelihood that *C. siamensis* in Kalimantan is naturally distributed. River systems in Central Kalimantan are effectively isolated from those in East Kalimantan by the Meratus mountains. Wild presence of the species in both watersheds would otherwise have to be explained by multiple, exogenous introductions.

No evidence of a wild *C. raninus* population was found in this study, but results of interviews suggest three palustrine crocodilians have inhabited (and may persist in) the Sungai Kotawaringan/Arut river system of Central Kalimantan. All crocodilian populations there have apparently declined in recent decades, but additional surveys may serve to clarify species composition and provide insight on ecological relationships.

If the *raninus* group individuals observed in Banjarbaru did indeed originate from the wild in Central Kalimantan, then their identity as *C. raninus* is highly probable. *Crocodylus mindorensis* is a possibility due to its fairly proximate southern limit of distribution (islands N of Sabah), but *C. novaeguineae* is far too extralimital, unless the species was introduced. This is unlikely as intra-archipelago shipments of juveniles (none of which are known to have arrived in Borneo) began only in the late 1980s.

DNA analyses of tissue samples are needed to clarify the taxonomic relationships of the three *Crocodylus* species in Kalimantan, in particular the identity of the *raninus* group individuals and affinity of the disjunct *C. siamensis* population with those in mainland Southeast Asia.

Tomistoma schlegelii was found in all reconnoitered river systems. Although trade for skins and glands has apparently ceased, numbers of *T. schlegelii* continue to be held in villages. This species was the common crocodilian encountered in surveys of freshwater habitat, but its ecological requirements remain poorly understood. In the upper Kapuas River, *T. schlegelii* was sympatric with *C. porosus*, and with *C. siamensis* in the Mahakam. Although there is pressing need for follow-up studies to provide additional data on distribution, abundance, breeding biology and ecology, *T. schlegelii* in Kalimantan is evidently not Critically Endangered, as defined by IUCN (1994), and is more appropriately categorized as Endangered or Vulnerable.

Several areas that were appraised to comprise critical habitat for the species merit formal protection and active management programs.

- For *C. siamensis*: Danau Belibis, Danau Tanah Liat and sections of Danau Mesangat in the central Mahakam are fairly intact and apparently represent crucial habitat for *C. siamensis*. The species likely inhabits nearby Muara Kaman Strict Nature Reserve, but this mixed swamp of trees, thickets and herbaceous vegetation has been degraded by severe burning in recent years.

- For *T. schlegelii*: Sungai Mapam, Sungai Berais and Sungai Bila, which are minimally-moderately disturbed tributaries of the Jelai river system in West and Central Kalimantan. The relatively large numbers of captive animals observed in the middle Barito in Central Kalimantan suggest that this area may contain important habitat for the species, although exact locations remain unclear. Danau Jeras and small lakes associated with Danau Sentarum (West Kalimantan) and Danau Mesangat (East Kalimantan) are lakes with intact-minimally disturbed peripheral vegetation where *T. schlegelii* was confirmed present.

The entire central Mahakam warrants priority in Kalimantan for future investigation of *C. siamensis* and *T. schlegelii*. The most extensive inland area of palustrine habitat in the four provinces is found in this heavily utilized lakes region. Vast areas of freshwater swamp are found in Central Kalimantan, but large areas are being converted for a huge rice production scheme.

Much of the information obtained on palustrine crocodilians in this study came from local informants familiar with crocodiles. Their reports often constitute important anecdotal evidence, especially where consistency among informants is shown, and where sources are former hunters well-experienced with local crocodile populations. In the absence of written records and reports, such knowledge is valuable for gauging former distribution and status of crocodilians in Kalimantan, and for comparison with current observations and conclusions. Anecdotal evidence from preliminary surveys over an immense study area helps lay the groundwork for more intensive future surveys by identifying key sites, support personnel, timing and logistic considerations that save substantial time, effort and limited funds.

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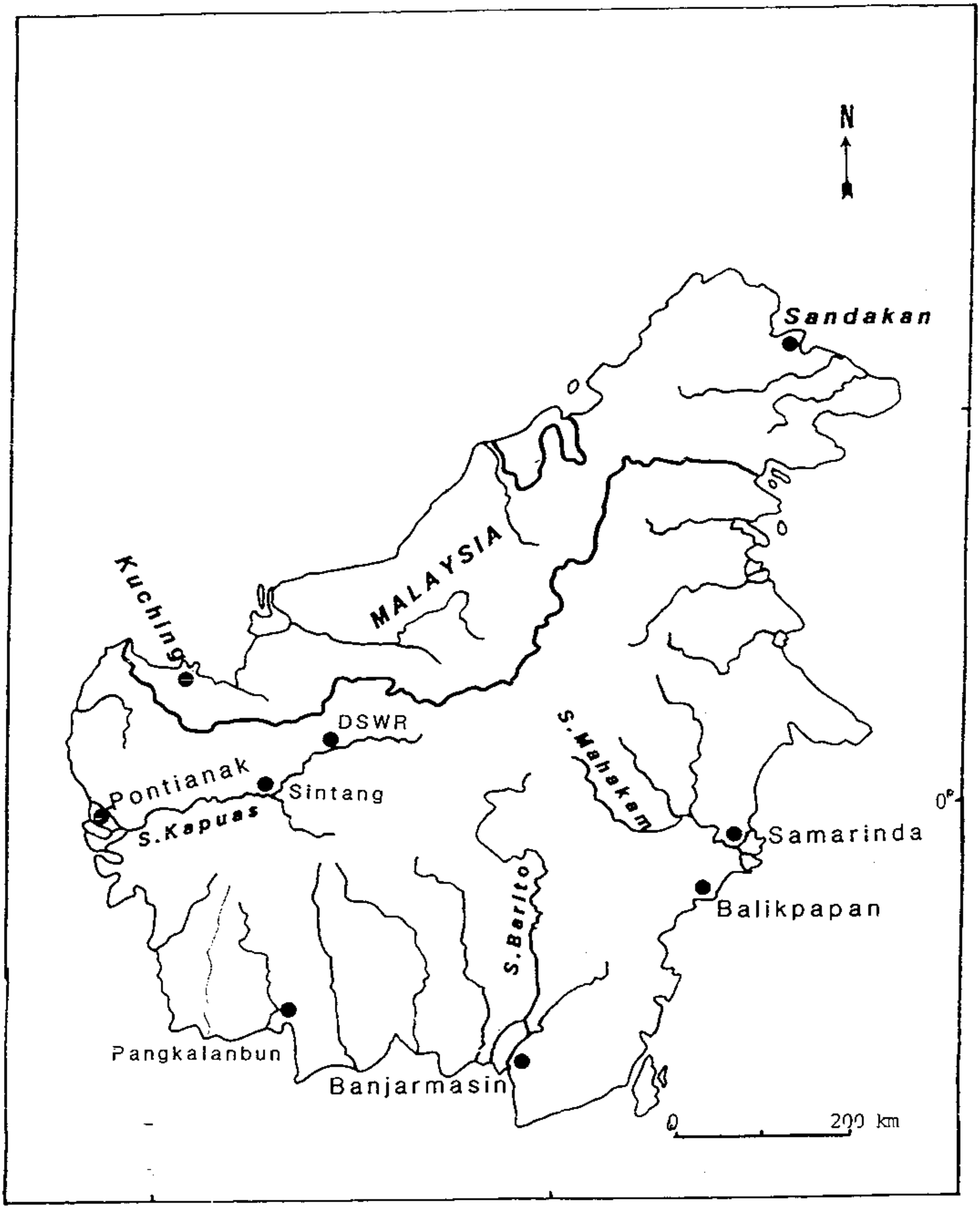
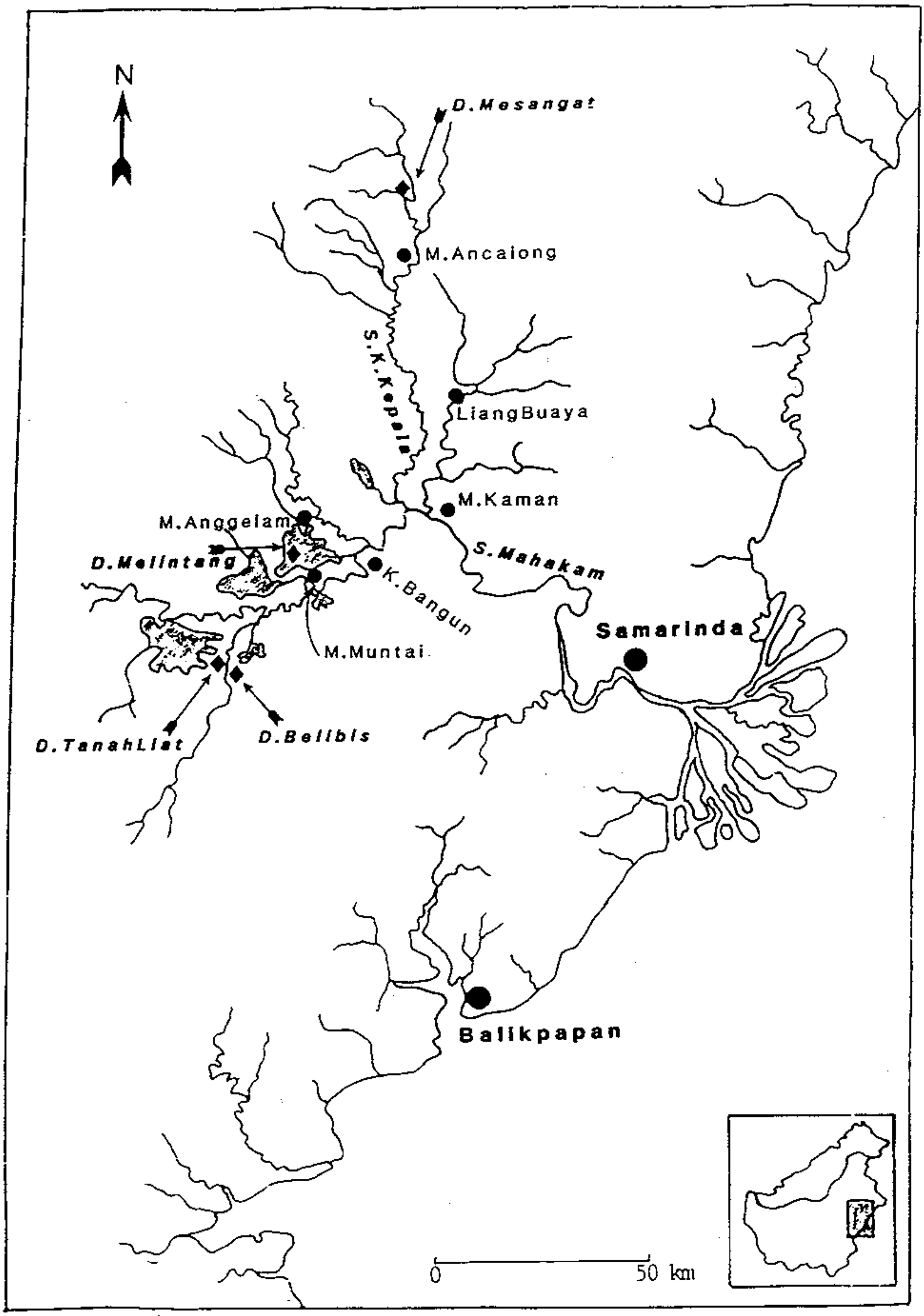
Table 6. Night counts of crocodilians in West (WK), Central (CK) and East (EK) Kalimantan provinces, 1995-1996. TS=Tomistoma schlegelii. CP=Crocodylus porosus. CS=C. siamensis. *= assumed TS. ○= assumed CP. H=hatchling. J=juvenile.A=adult. EO=eyes only.

Date	Survey site	Prov.	Species	Start/end coordinates	km surv'd	H	J	EO	Density
15-8-96	S. Kapuas	WK	TS/CP	0°51'10" N 112°51'48" E/ 0°03'55" S 109°21'39" E	10				0
16-8-96	S. Sibau	WK	TS/CP	1°04'38" N 113°02'00" E/ 0°03'55" S 109°21'39" E	20				0
18-8-96	D.Termabas	WK	TS/CP	0°46'40" N 112°30'16" E/ 0°46'50" N 112°30'39" E	20				0
25-8-96	S. Pawan	WK	TS/CP	1°48'31" S 110°09'49" E 1°51'11" S 109°58'15" E	15				0
28-8-96	S. Belaban	WK	TS/CP	2°23'03" S 110°30'37" E/ 2°27'45" S 110°26'46"E	25				0
28-8-96	S. Simbar	WK	TS/CP	2°44'53" S 110°14'05" E/ 2°43'03" S 110°17'37" E	7				0
22-9-95	D. Pengembung	WK	TS/CP	0°29'20" S 112°15'48" E/ (circuit)	4.1				0
24-9-95	D. Basaulaut	WK	TS/CP	0°39'10" S 112°15'50" E (circuit)	6.7				0
5-9-95	D. Tanah Liat	EK	CS?/TS?	0°29'20" S 112°15'48" E	3				0
6-9-95	D. Tanah Liat	EK	CS?/TS?	0°29'20" S 112°15'48" E	3				0

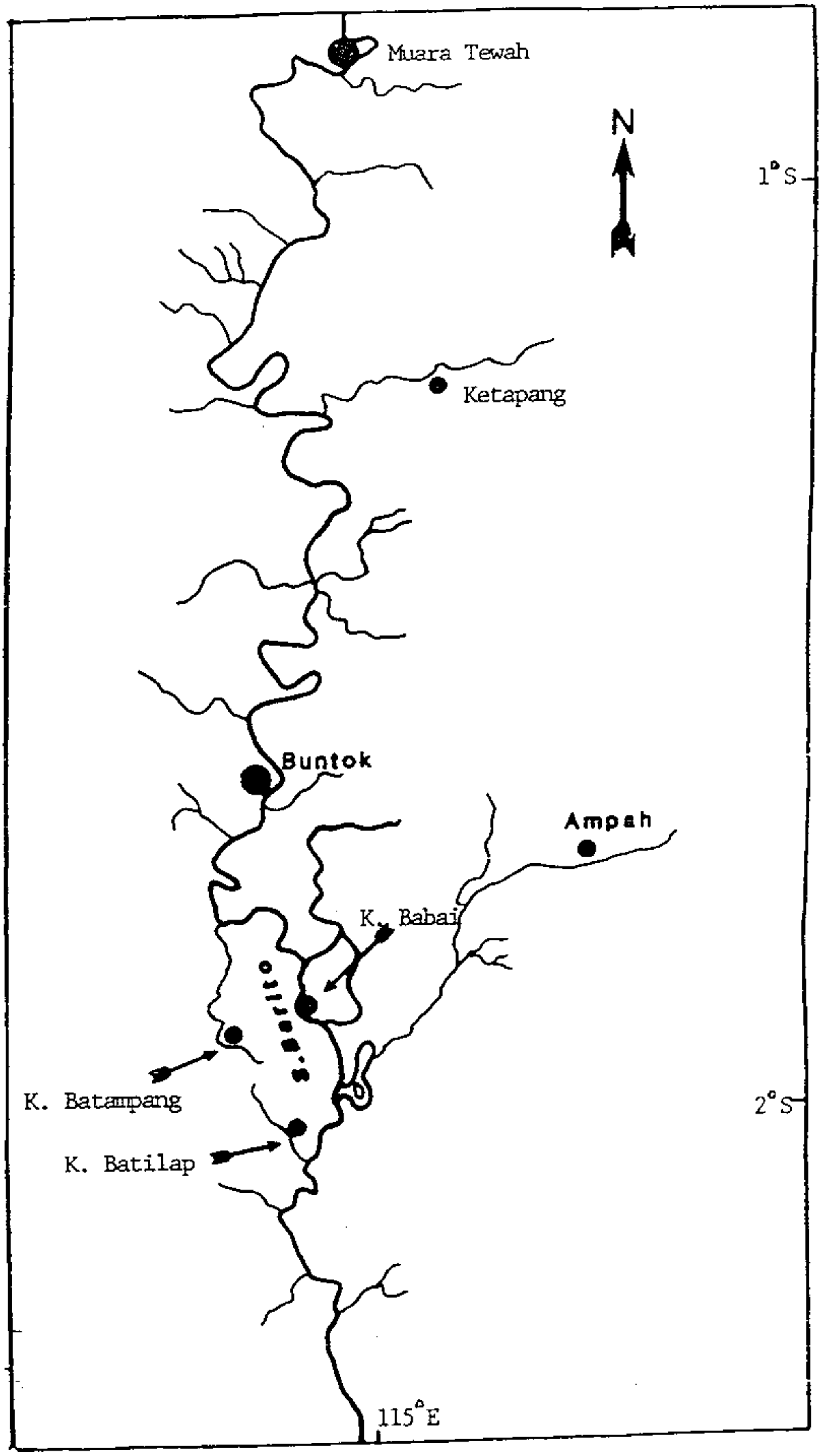
Date	Survey site	Prov.	Species	Start/end coordinates	km surv'd	H	J	EO	Density
16-9-96	D. Belida- S. Belida- S. Jelai	WK/ CK	TS/CP/CS	2°50'03" S 110°58'08" E/ 2°59'08" S 110°44'12" E	42.5			1*	0.024
29-9-96	S. Kedang Rantau	EK	TS/CP?	0°13'46" S 116°42'49" E/ 0°08'50" S 116°43'23" E	72	1	6	1□	0.11
13-9-96	S. Mapam	WK/ CK	TS	2°29'04" S 111°12'27" E/ 2°42'30" S 111°10'06" E	32			1	0.03
17-9-96	S. Air Hitam	WK CK	TS	2°47'59" S 110°23'53" E/ 2°54'57" S 110°23'24" E	17				0



Map 1. Island of Borneo showing major features.



Map 2. Mahakam River system. East Kalimantan.



Map 3. Barito River system. Central Kalimantan.

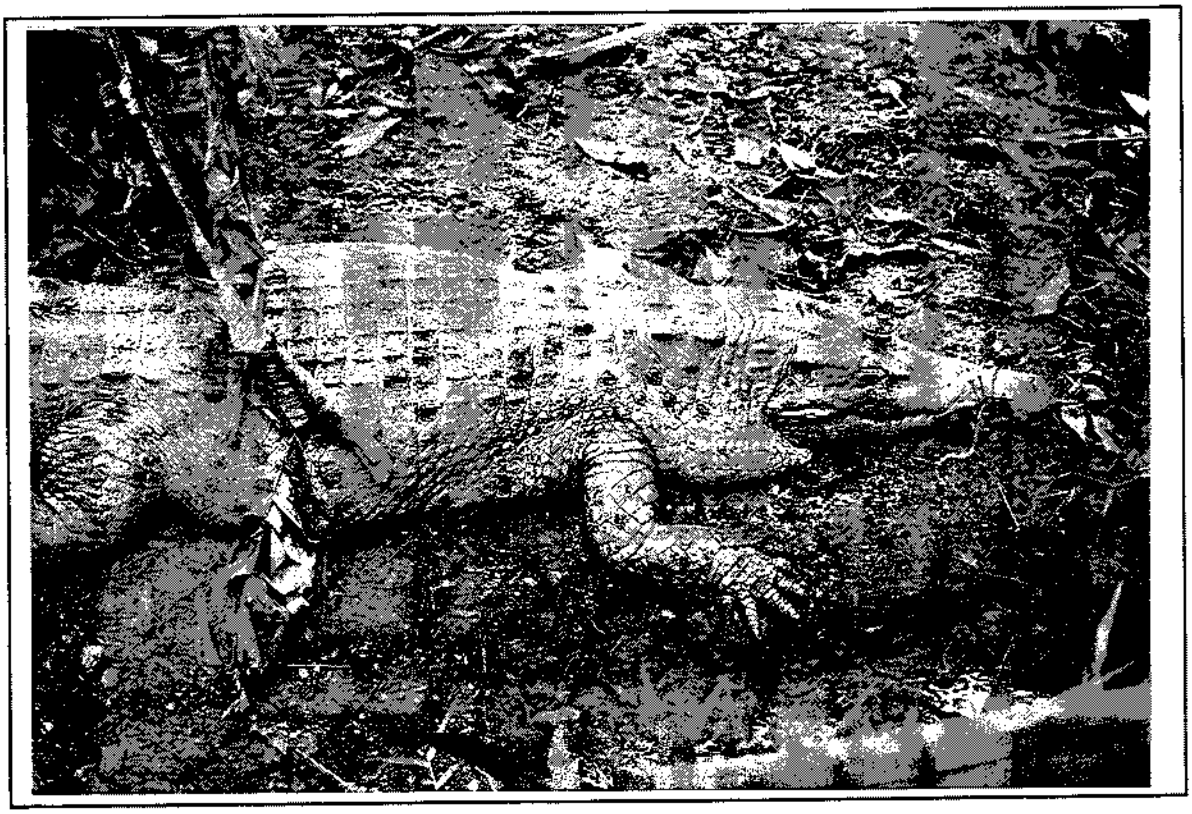


Figure 1. Dorsal view of ca. 1.8 m TL *raninus* group crocodile. P.T. Alas Watu Utama, Banjarbaru, Kalimantan Selatan.

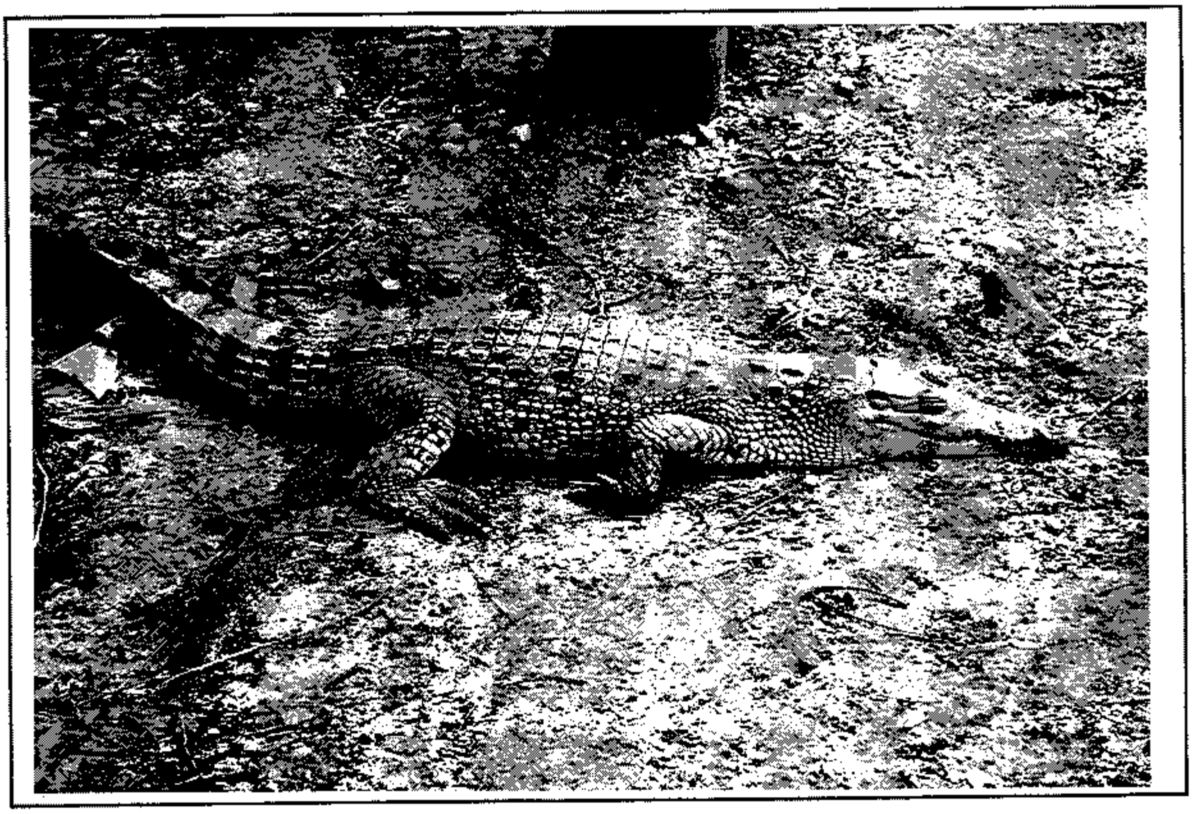


Figure 2. Lateral view of 1.4 m TL *raninus* group crocodile. P.T. Alas Watu Utama, Banjarbaru, Kalimantan Selatan.

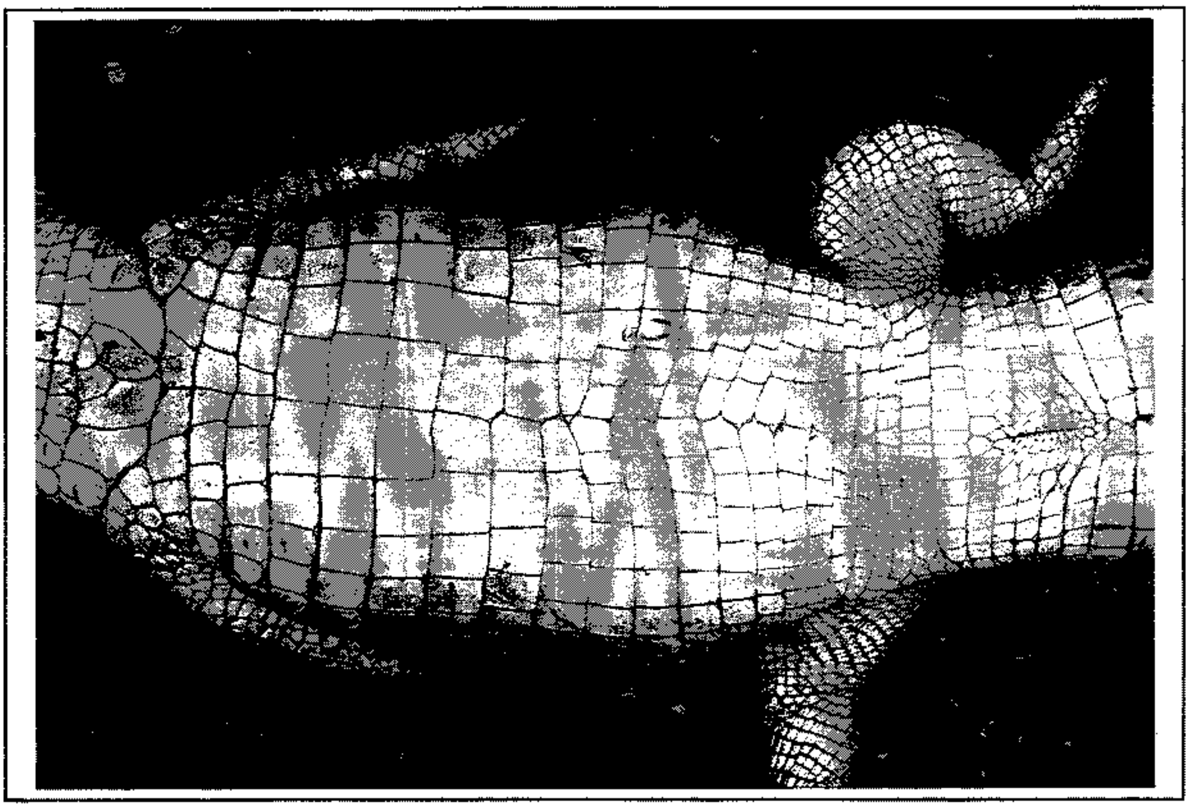


Figure 3. Ventral view of 1.4 m TL *raninus* group crocodile. P.T. Alas Watu Utama, Banjarbaru, Kalimantan Selatan.

Figure 4. Dorsal neck view of 1.4 m TL *raninus* group crocodile. P.T. Alas Watu Utama, Banjarbaru, Kalimantan Selatan.

Figure 5. Hanguana fringed Sungai Mapam. Good foraging habitat for *T. schlegelii*. Border of West and Central Kalimantan provinces.

Figure 6. *Crocodylus siamensis* habitat. Herbaceous patches and thickets in Danau Mesangat. Mahakam River system, East Kalimantan.

Figure 7. *T. schlegelii* nest at secondary forest edge. Danau Mesangat, East Kalimantan.

Figure 8. Clay-lined clutch chamber of nest in Figure 7. Danau Mesangat, East Kalimantan.

Figure 9. Recording data at a *T. schlegelii* nest on floating vegetation. Danau Mesangat, East Kalimantan.

Figure 10. *Tomistoma schlegelii* nest on land in peat swamp forest. Danau Ngibun/Danau Mesangat, East Kalimantan.

CONSERVATION, MANAGEMENT AND FARMING OF CROCODILES IN CHINA

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ABSTRACT

The Chinese Alligator (*Alligator sinensis*) is restricted to China and is generally considered one of the most endangered crocodilians in the world. Since the 1970's, Chinese Government has paid high attention on the conservation of Chinese Alligator and carried out a range of effective measures in succession to strengthen the management of Chinese Alligator with considerable achievements being made. However, the wild population of Chinese Alligator is still on the verge of extinction and it urgently needs much concerns from national and international conservation community. With the fast development of national economy, the activities related to import and export, farming, manufacture and utilization of crocodilians and their products in China become more and more frequently. It is of great significance for the protection of global crocodilians to enhance the conservation and management of crocodiles in China.

INTRODUCTION

China locates in the eastern part of Asia and western bank of Pacific Ocean with a total land area of 9,600,000 square kilometer. It is a country with both coastline and land border, which are 18,000 kilometer and 20,000 kilometer in length respectively, neighboring 15 countries(e.g. Vietnam) with 6 countries(e.g. Japan) to its east and southeast across the sea.

China is divided into 33 provinces, autonomous regions, municipalities and special administrative region. According to the census in 1994, the population of China is

1.1985 billion (excluding the population of Hongkong).

With vast territory and diversified natural environment, China is one of the countries in the world with the most diverse varieties of wildlife resources. There are 6,347 species of vertebrate, accounting for over 14% of the world total, and 32,800 species of higher plant, taking up over 12% of the world total. Among the wildlife species listed in the appendixes of CITES, 1,700 were found in China.

CROCODILES IN CHINA

There are three crocodilian species ever known to be occurred in China. The Saltwater Crocodile(*Crocodylus porosus*) and the Malayan False Gharial(*Tomistoma schlegilii*) once lived in south coast region of China. However, Both of them have not been found in China since 1922. Only the Chinese Alligator has fortunately survived to now. Since 1993, many species of crocodilians such as Nile Crocodile(*Crocodylus niloticus*), Siamese Crocodile(*Crocodylus siamensis*), Mississippi Alligator(*Alligator mississpiensis*) and Saltwater Crocodile have been introduced or re-introduced into China for farming, education or tourism purpose.

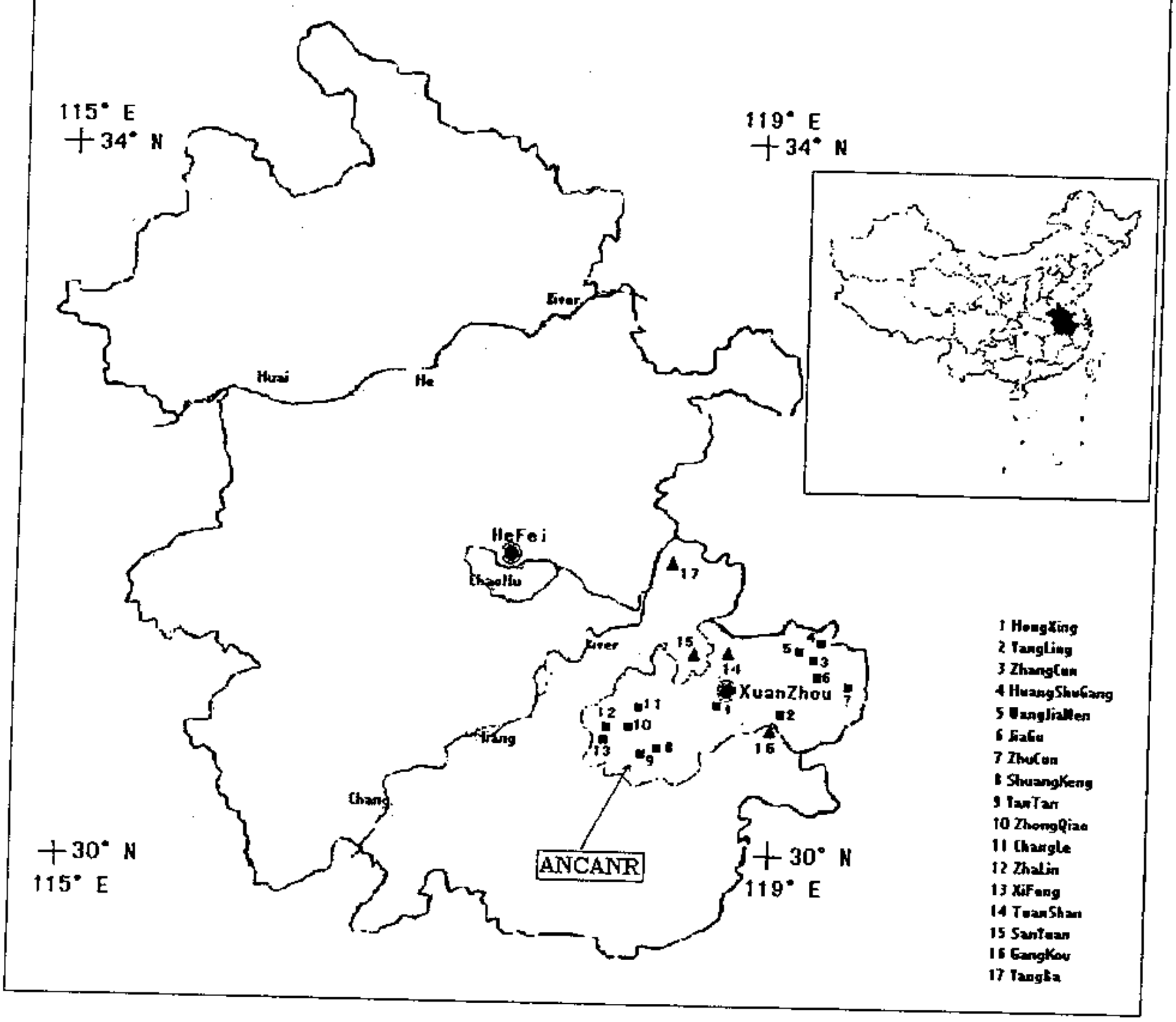
STATUS OF CHINESE ALLIGATOR

1. DISTRIBUTION

The Chinese Alligator is the most endangerd of the world's 23 species of crocodillians (Groombridge,1982; Thorbjarnarson, 1992). The species is a relatively small crocodilian with a maximum length of approximately 2.5 m (Wang C.L., pers. observation). In China, local people uses the name Yangzi E (means Yangzi alligator) or Tu Long (means muddy dragon) to designate the species. The local name indicates that the alligator was once widespread along the lower Yangzi river valley. It was recorded in the ancient Chinese books that the Chinese Alligator distributed densely over the middle and lower reaches of the Yangtzi River in the 14th century. However, with the dramatic climatic change and the increase of the human population, the range of Chinese Alligator was sharply shrank to the lower reaches of the Yangtzi River in the 19th century.

From the beginning of this century to 1960's, due to lake drainage, land reclamation, use of farm chemicals and excessive capture and killing, the habitats of Chinese Alligator had been destroyed very seriously, resulting that the population size declined year by year and its range continuously decreased. The investigation conducted in the 1950's indicated that its range had been shrunk to the area of junction of Anhui, Zhejiang and Jiangxi provinces. The surveys in the 1970's and early 1980's documented an even greater shrinking of the range within the three provinces. In recent years, the wild Chinese Alligator has not trace in Jiangxi province and hardly to be found in Zhejiang province. It seems that the remaining wild population is almost confined to the counties of Jingxian, Nanling, Xuanzhou, Langxi and Guangde in the southern area of Anhui Province and sporadically distributes in the small irrigation ponds and reservoirs. In addition, small number and sites of chinese alligator are also reported as being found. in Wuhu and Ningguo counties. In lowland habitat north towards the Yangzi river small alligators are still reported in Maanshsn and Dangtu counties of Anhui province. For example, in 1995, an adult male alligator was found in village of Maanshan (see figure1).

Distribution of Chinese Alligator in Anhui Province, China



In Zhejiang province, a small number of alligators remain in Yinjiabian village of Changxing county. The village became a alligator reserve in 1979. In August 1982, one male and one female alligator were captured from this village and sent to the reserve. As no survey in the reserve, we do not know that how many individuals remain in the field although the habitat is very nice to alligator. Huang et al (1987) reported that alligators were captured in Huzhou and Anji counties from the 1970's to 1980's, but now no reports of alligators are from the area. The Changxing forest bureau staff guessed the alligators had extirpated in the area.

In fact, most alligators are found in agricultural field or in isolated reservoirs in tree farm, The three principal habitat types are riverine and swampy areas, low-elevation agricultural villages, and agricultural and tea farm villages up to 100m above sea level (Watanable and Huang,1984).

2.ABUNDANCE

Alligators are extremely secretive and hard to count. Night spotlight counts reveal a small number, but many may be hidden in dens and not visible. Some of the best information currently avaiable comes from local residents that live around the alligator ponds. Chen Bihui estimated 300-500 alligators remained in the Anhui National Chinese Alligator Nature Reserve based on survey with Dr. Watanable in 1981 (Anon., 1991). From then to now, five investigations were made in ANCANR, Zhou (1997) presented these results: wild population number was estimated 378-421 individuals,407-463 individuals, 690-740 (including 150 alligators released from the breeding center),674-747 individuals and 667-740 individuals in 1985, 1987, 1990, 1992 and 1994, respectively. In 1997, the ANCANR estimated that the total wild population within the Reserve was decreased to about 400 animals. However, there are no firm data on the status of the wild population, for example, their ages and sex (Thorbjarnarson, 1992).We need to further and systematic work for confirme these population estimates.

In our view, the main factors led to declining of the remaining wild population are as follows.

1. Loss of habitats.

The Chinese Alligator lives in one of the most human dense area. From the late 16th century to the early 20th century, there was a large migration of people from the north into the lowland Yangzi region (Huang,1982;Chen,1990,Thorbjarnarson and Wang, submitted to Oryx), and many alligator habitats have been developed as the agricultural land. In fact, these areas are now under cultivation (Watanable,1982). Today, habitat is still being lost. From the 1950's to the 1980's, it was estimated that the total area of lakes in China was reduced by 11%(Scott, 1989). The reserve consists of small ponds set in a matrix of valleys cultivated with a variety of crops, mostly rice. In a few areas, protected sites consist of small reservoir in low hills covered by pine and tea plantations. The land-use right within the ANCANR doesn't belong to the management authority of ANCANR. Such situations have brought great pressures to the conservation and management work of wild population of Chinese Alligator. Though many of the alligator's former habitats, which can be used for reintroduction, have been developed to establish the factories and mines or developed into farmland, ANCANR is unable to stop those activities. From the viewpoint of the local governments, the first problem is to strongly develop their economy so that the people are able to make a good living as soon as possible. From the viewpoint of ANCANR, it is impossible to immigrate the local people (over 1 million) to other places, and it is unrealistic to ask the local governments stopping their developing activities without any compensation. In all areas, the principal contradiction between human benefit and alligator conservation is increasing because of habitat loss.

2. The low initiative of local people on conservation .

The habits of preying on the domestic poultry and burrowing the dams and banks of rivers, ponds and reservoirs make the local people considering the Chinese Alligator as vermin. They do not like to see its population increasing and its territory expanding to their productive lands. In addition, the fact that the local people can not get the economic benefits from the conservation of Chinese Alligator also hampers the smooth implementation of the conservation and management program

3. Habitats destruction .

The loss of natural vegetation throughout eastern China has also exacerbated periods of drought and flooding. Flood and drought force alligators to move overland where they easily captured or killed （Chen, 1990） .In dry weather, the farmers always use the water of some ponds where the wild individuals inhabit to irrigate their crops. This undoubtedly will damage the surviving environment of alligator, and even run out of their food animals. For example, only about 20 individuals remained, and 80 individuals were died in Shuming village of Langxi county because of drought in 1987 （Zhou, 1997） .The alligators were not tolerated by local people because they prey on domestic animals（for example ducks） and their burrowing interferes with the complex water control structures that are vital for rice cultivation.

4. Environment pollution .

Most of rivers, ponds, reservoirs and lakes are polluted by the fast development of the industry. Such pollution and the wide use of fertilizer and insecticide in the countryside are detrimental not only to the reproduction and survival of Chinese Alligator, but also to its food animals. In addition, since the snail fever ever occured in southern Anhui Province, the chemical matter which was used to kill the snails also polluted the survival of Chinese Alligator.

5. Financial difficulty .

Due to lacking of funds, the reserve authority is unable to carry out conservation programs such as monitoring and reintroduction. The funds allocated by the central and provincial governments each year are so limited that they are not enough for the normally running of the reserve.

LEGISLATION

China acceded to the Convention on International Trade in Endangered Species of Wild Fauna and Floral (CITES) on April 8, 1981 and Chinese Alligator is on Appendix I of the CITES at the time China acceded.

Early in 1972, the Chinese Alligator was listed as class I protected animals by Chinese Government. Afterwards, it was listed as class I special protected animals under the Law of Wild Animals Protection of the People's Republic of China going into effect on 1 March 1989. In addition, the exotic animals species listed in CITES Appendix I and Appendix II are also included in the list of China's special protected wild animals in 1993 by the Ministry of Forestry(present name is State Forestry Bureau, SFD) in accordance with the law. In other word, all the crocodile species imported into China are managed as state special protected animals and controlled by the conservation departments at various levels in China.

CROCODILE FARMING IN CHINA

In China , it may be permitted to raise the native or exotic crocodiles if a farm has land, water surface, farming techniques and enough funds because China has adopted the market economy policy and the governments can not interfere the operations of a farm if its activities satisfy with the requirements of international conventions and domestic laws. At present, nearly 60 operations are involved in the farming of crocodiles with a total stock of about 14,000 individuals. Majority of them is located in the provinces of south and central China. Most of the captive-held crocodiles are Chinese Alligator, Siamese Crocodile, Saltwater Crocodile and Nile Crocodile .According to our analyze, there is a trend that more and more farms in China will engage in farming of exotic crocodile species.

The farming of Chinese Alligator started at 1979. In order to prevent the Chinese Alligator from extinction and protect them by captive-bred method, the first crocodile farm, Anhui Research Center for Breeding Chinese Alligator (ARCBCA), was set up in Xuanzhou city by Anhui Provincial Government. Since 1993, several zoos, farms and tourism companies have engaged in raising exotic crocodile species for the exhibition or commercial purposes. So far, it is only one .

Crocodile farm in China, ARCBCA, which has registered at the CITES Secretariat as a commercial captive breeding operation.

The main species domesticated in China are as follows.

1. CHINESE ALLIGATOR

Nearly 50 units are involved in farming of Chinese Alligator with a total stock over 8,000 animals in China. Many a lot have succeeded in breeding. ARCBCA is the largest one and Zhejiang Yinjiabian Chinese Alligator Farm(ZYCAF) is larger one too. The former has a stock over 7,000 alligators and the latter has a stock of more than 200. Almost all of the original stocks of other farms, zoos, gardens and research centers in China come from those two farms, especially from the ARCBCA.

1.1. ARCBCA

This farm is situated within the ANCANR. It was established in 1979, specifically for preventing Chinese Alligator becoming extinction through farming of and research on it. It was a joint project between the SFB and APFD, and mainly managed by the APFD.

Two hundred and twelve heads of live alligators were collected from the wild as the foundation stock by ARCBCA at the time of its establishment. It succeeded in producing F1 generation in 1982 and F2 generation in 1988. At present, ARCBCA covers an area of 100 hectare with 3 big and 2 small breeding ponds, more than 10 rearing ponds, an incubation building, a hatchling care building and a hibernation building. In order to collect funds to maintain itself , ARCBCA has allocated and transferred 714 individuals to 42 zoos, farms, gardens and research centers, and opened itself to public for wildlife education and tourism. The data in Table 1 shows the total egg production (F1 only) and the fertility and hatching rate of animals incubated through to hatching. The production of F2 generation eggs is summarized on Table 2.

Table 1. Records of Chinese Alligator egg production, fertility and hatching rates at ARCBCA.

Year	Nests	Total Eggs	Mean Clutch Size	Fertility Rate(%)	Hatching Rate(%)
1982	10	224	22.4	/	65.6
1983	12	264	22.0	88.9	58.7
1984	20	501	25.0	90.4	83.7
1985	30	809	26.9	90.5	90.3
1986	29	801	27.6	90.4	82.0
1987	37	1045	28.0	84.0	92.4
1988	42	1219	29.0	91.9	95.0
1989	34	955	28.0	92.1	94.0
1990	34	942	27.7	95.4	85.3
1991	35	901	25.7	80.0	90.2
1992	42	1145	27.3	86.2	91.0
1993	42	1206	28.7	85.1	90.5
1994	69	1659	24.0	86.2	92.3
1995	45	987	21.9	91.2	91.1
1996	63	1440	22.9	92.3	85.0
1997	90	2531	28.1	89.8	90.4
total	634	16629	26.2		

Table 2. The F2 Chinese Alligator egg production, fertility and hatching rates at ARCBCA.

Year	Nests	Total Eggs	Mean Clutch Size	Fertility Rate(%)	Hatching Rate(%)
1988	1	25	25	96.0	88.0
1989	5	143	28.6	91.2	82.0
1990	4	109	27.3	89.7	76.1
1991	9	219	24.3	82.6	71.4
1992	10	264	26.4	84.9	73.4
1993	12	353	29.4	90.4	70.2
1994	30	709	23.6	85.1	86.0
1995	22	540	24.5	86.7	87.2
1996	40	919	23.0	74.5	81.9
1997	62	1610	26.0	73.4	86.6
Total	185	4613	24.9		

After twenty years' developments, ARCBCA not only has possessed the capability of annually producing thousands of hatchlings and satisfying with the domestic and international demands for live Chinese Alligator, but also can provide enough individuals for future reintroduction.

However , ARCBCA still faces many difficulties: As the tanning techniques of the skin of Chinese Alligator have not been developed , ARCBCA is unable to collect enough funds from the commercial utilization of the captive bred alligators to maintain its operation and carry out the reintroduction program; thousands of annual hatchlings have become a heavy burden and brought great pressures to ARCBCA; due to financial difficulties and lacking of habitats, they are unable to return their captive-bred alligators to the wild to release their burden. Such problems have made ARCBCA being in hobble where they can not further develop their captive breeding stock and return the alligator to the wild. In a word, they are in urgent need of financial and technical supports from the international community for expanding their farming scale, tanning alligator skins, implementing reintroduction and monitoring programs.

1.2 ZYCAF

ZYCAF was set up by the villagers at Yinjiabian Village in Changxing County in 1979. Its size is 0.69 hectare with a building for accommodation and hibernation, 2 breeding ponds and several raising ponds. The original stock was 11 wild adults, of which 8 adult died before 1982. In 1984, one of the two adult females began to breed in captivity. In 1997, the F2 generation was bred at the farm successfully.

In general, ZYCAF adopts a method of nature breeding that is different from that in ARCBCA. The eggs are hatched in the alligator's own nests just like their nature environment. In addition, ZYCAF feed alligators with a kind of ball-shaped fodder which is cheaper and better than fish and frog and they find out that the growth rate of the alligators who feed on the above fodder can increase from 5.22 cm to 16.11 cm per year. This research result will provide the scientific basis for reducing their food costs.

ZYCAF has drafted a reintroduction program aims at re-establishing a wild population at Zhejiang Changxing Chinese Alligator Nature Reserve(ZCCANR), but we are worry about that if they can collect enough funds to implement it.

2. SIAMESE CROCODILE

Three operations are involved in raising of Siamese Crocodile. All the original stocks were imported from Thailand under the authorization of CITES Management of China. Among of them, Fujian Fuzhou Aofeng Crocodile Park has imported 1320 live individuals in 1998, Heilongjiang Xinfa Crocodile Farm has imported 300 in 1998, Guangdong Panyu Xiangjiang Wildlife Safari Co., Ltd. imported 1,000 in 1997 and will import 3,505 in 1998.

3. NILE CROCODILE

Hubei Guangshui Yinhua Mississippi Alligator Farming and development Co., Ltd. has been approved by CITES Management Authority of China to import 2,500 hatchlings of Nile Crocodile from South Africa in 1998.

4. SALTWATER CROCODILE

Six units have been involved in farming of Saltwater Crocodile since 1993. The total original stock is more than 1,000 animals. Among of them, Shenzhen Wildlife Safari imported 160 individuals from Thailand in 1993 , Hainan Dongshanhu Wild Animal Garden imported 60 from Malaysia, Guangdong Zhuhai Baitenghu Tourism Development Company imported 100 individuals from Malaysia, Guangdong Panyu Xiangjiang Wildlife Safari Co., Ltd. imported 260 from Thailand in 1997 , Guangdong Dongguan Tianbao Crocodile Farm imported 170 from Singapore in 1997, Guangdong Panyu Xiangjiang Wildlife Safari Co., Ltd. has imported 22 from Malaysia in 1998 and Fujian Fuzhou Aofeng Crocodile Park has imported 180 from Thailand in 1998.

5. MISSISSIPPI ALLIGATOR

Hubei Honghu Bohua Chinese Softshell Turtle Farm Co., Ltd. imported 50 live Mississippi Alligators into China from United States of American in 1996 and intended to import more than 1,000 in the near future.

REGULATION OF TRADE

According to the Law of Wild Animal Protection, hunting and killing of class I state special protected animals is prohibited except for the purpose of scientific research, taming and breeding and exhibition, when a special hunting permit must be obtained from the SFB. Hunting and killing of class II state special protected animals is prohibited except a special hunting permit has been issued by the provincial conservation agency. Over the past ten years, no live Chinese Alligator has been allowed collected from the wild. The domestic trade, transportation, farming, manufacturing and utilization of all the crocodilian species must attach with the relevant permits or obtain the authorization document from the SFB or the provincial conservation agencies. China is a party to the CITES and the stipulations of CITES are applied to the import and export of any kind of crocodilian specimens in China. In addition, China adopts a more strict measure which import of CITES Appendix II listed species should also apply to the People's Republic of China Endangered Species of Wild Fauna and Flora Import and Export Administrative Office (CITES Management Authority of China) for an import permit.

MANUFACTURING OF CROCODILE PRODUCTS

There are several manufacturers involved in importing crocodile leather and re-exporting its products such as wallet, watch belt, handbag and shoes that made from such leather in south China.

TRADE OF CROCODILE

The domestic trade of crocodiles and their products is limited. Most of the trade is confined to the live individual and frozen meat. As mentioned above, about 840 live Chinese Alligators have been sold to around 45 units by the ARCBCA and ZYCAF . To the alligator meat, only two restaurants were permitted to sell the foods made of the meat of Chinese Alligator from May 1998 by SFB. Until now, the alligator skin has not been developed as a commodity and no skin or its products have been put into markets.

The international trade on live crocodile, crocodile meat, leather and its products is in a large number. As we mentioned above, over 9,500 live crocodiles have been imported or are intended to import into China. From 1997 to present, 34,450 kilograms of frozen Siamese Crocodile meat have been permitted importing into China from Thailand and Indonesia. Most of those imported meats are used in consumption at restaurants and hotels. Only a few are processed as health products and re-export to foreign countries. There are hundreds and thousands of crocodile leathers imported into China from Singapore and Hongkong every year. All of them are used to make the crocodile skin products and then re-exported to Hongkong or Singapore. Most of the imported skins came from Caiman crocodile, Saltwater Crocodile, Siamese Crocodile, Mississippi Alligator and Nile crocodile. Consumption of the imported crocodile skin products in China is very limited. No Chinese Alligator skin and its products have been exported for the commercial purpose and only a few live alligator were exported to foreign countries. For example, ARCBCA exported 25 hatchlings to Denmark in 1997.

In recent years, China has found many illegal cases relating to the smuggling of live crocodiles and crocodile meat. Those illegal cases have been handled and many smugglers have been seriously punished. For example, in 1997 , In cooperation with the CITES Management Authority of Malaysia and CITES Secretariat, CITES Management Authority of China investigated and prosecuted an illegal case relating to the forgery of the Export Permit of Malaysia, prevented 200 Saltwater Crocodiles from illegally imported into China; in 1995, 36 Saltwater Crocodiles that were smuggled from Vietnam were confiscated and the offender was seriously punished by CITES Management Authority of China.

NATURE RESERVE FOR CONSERVATION OF CHINESE ALLIGATOR

There are two nature reserves specifically established for protection of Chinese Alligator in China: ANCANR and ZCCANR.

1. ANCANR

ANCANR was established in 1982 by the APFD in 1982 and funded by the Anhui Provincial Government. In 1986, they were declared as a national reserve and funded by both the SFB and APFD together.

ANCANR locates in the southeastern Anhui Province (lat.118°30'-119°35'E,30°18'-31°18'N), covers the counties of Jingxian, Nanling, Langxi and Guangde and city of Xuanzhou, with an total area of 433 square kilometers. However, it is a special reserve because there are 69 mountain towns and semi-mountain towns within the reserve with a human population of at least 1 million. ARCBCA locates in the reserve and coordinates the management of ANCANR under the direction of SFB and APFD. Five stations with 13 special protected areas were set up in above mentioned counties and city by ANCANR. Each station is managed by part-time and full-time officers of conservation agency at the county level and responsible for a group of protected areas. Their main responsibility is to conserve the wild population and its habitats, collect the information on status of wild population and enhance the public awareness on conservation of Chinese Alligator. At the same time, ANCANR has also taken measures for protecting the wild distribution of Chinese Alligator in Ningguo, Wuhu and Dangtu counties beyond ANCANR. The reproduction of the wild Chinese Alligator in ANCANR is summarized on Figure 1. The data in Figure 2 shows the captive incubated hatchlings from the wild collected eggs.

Figure 1. The records of reproduction of the wild Chinese Alligator in ANCANR .

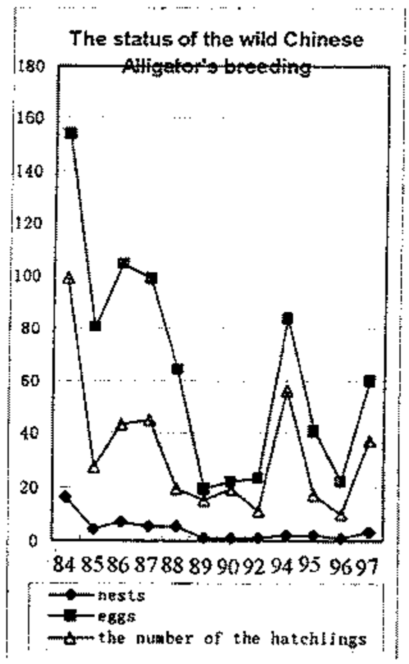
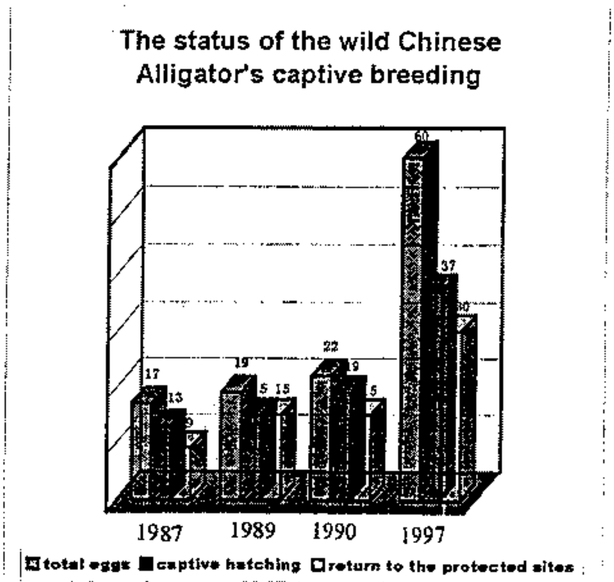


Figure 2. The records of captive incubated hatchlings from the wild eggs collected.



Although the wild alligators especially that in special protected sites have been protected by ANCANR, the population doesn't increase significantly and it is facing the trend of decreasing or extinction. Thus, expanding special protected areas, rehabilitating habitats and carrying out the reintroduction and restocking program of Chinese Alligator in the reserve is of great urgency.

2. ZCCANR

ZCCANR was set up in 1982, locates in Yinjiabian Village, Changxing County, Zhejiang Province. Its size is 122 hectare, including 0.69ha for the breeding center where is 140 individuals. ZCCANR is funded by the local people and Zhejiang Provincial Forestry Department .

ZYCAF is situated within ZCCANR and coordinates its work. However, no alligator has been found living within the reserve since 1982. According to its plan, ZCCANR will use its captive-bred individuals to restock its wild population. The main problem faced by ZCCANR is still the financial difficulty. In our view, it will be relative easy to implement the restocking program in ZYCAF because of the high initiatives held by the local villagers.

Considered the circumstances of these reserves, one of key factors that may determine the ability of alligators to survive in these areas is the presence of islands. Small islands provide a terrestrial retreat that buffers the alligators to some degree from human impacts. It is very necessary and importance to reconvert agricultural areas back into alligator habitat.In order to resolve these problems, further studies on the status of alligator is required to establish better conservation strategy. It is very useful to make the international cooperation on the scientific program such as WCS and us will make systematic investigations of population ecology of Chinese alligator. The project will address the current status and distribution of the wild populations and identify suitable alligator habitat that could be used in reintroduction or restocking programs, and land use by GIS . These information are basically and necessary for alligator conservation. Dr. John Thorbjarnson will present our research plan in detail on behalf of Eastern China Formal University, Anhui Province Department of Forestry and WCS. In addition, reserves are not functioned very well because of lack financial support and trained workers, and it is very difficult to resolve the contradiction between wild population and the economic benefits of the people farming and agricultural land that surrounds and encroaches on the alligator habitat because of no enough financial support . We hope that international organization will provide financial support for Chinese alligator conservation.

RESEARCH

Research on Chinese Alligator in China has been done for several decades by many scientists and institutions and a great deal of achievements have been made in the fields of historical distribution, physiology, morphology, anatomy, ecology, captive breeding, nutrition, diseases, conservation and management. ARCBCA and Anhui Formal University are the main research institutions involving in studying the alligator.
Considering the dangerous situation faced by the wild population of Chinese Alligator, a joint survey program among WCS, APDF and Eastern China Formal University has been approved by SFB in 1998 and will be conducted from this year.

TRAINING

Ten years ago, a training delegation organized by SFB, APFD, Anhui Formal

University and ARCBCA visited Thailand and accepted training on farming of crocodilians at the Samutprakan Crocodile Farm and Zoo Co., Ltd. In 1997, another training delegation organized by SFB, APFD and ARCBCA was invited by Dr. Webb and attended the training course on conservation, management and farming of crocodilians at his Wildlife Management International in Darwin, Australia. Meanwhile, Dr. John Thorjarnarson gave the short training course to local researcher of ANCANR, and will continue to give a threes weeks of training course in July and August 1998. This year, we have been invited to attend this meeting for exchanging experiences. Mr .Wan Ziming will be founded to visit Thailand for learning on the conservation , management and farming of crocodile after the 14th Working Meeting of CSG. Such training and visits have helped or will assist China a lot in its effort to conserve and develop Chinese Alligator.

DISCUSSIONS

Through 20 years hard work, a great deal of achievements has been made. The people conservation awareness has been greatly raised , the illegal cases related to poaching of wild Alligator have almost vanished, the farming techniques of Chinese Alligator have been successfully developed, the captive stock of Chinese Alligator has increased to about 8,000, the crocodile farms have the capability of producing at least 2,000 hatchlings of Chinese Alligator each year and more and more farms, zoos and tourism corporations are interested in farming of crocodilians.

However, there still exist many difficulties and problems. The wild population of Chinese Alligator has begun to decline again , its nature range has a trend of gradually decreasing, the local people doesn't like to protect the wild population, the conservation agencies are lacking of surveying and monitoring techniques and equipment and unable to control the lands, water and foods of the majority of the habitat, the skin tanning techniques have not been successfully developed and the crocodile farms can not collect funds from commercial utilization of captive-bred specimens of Chinese Alligator to support the conservation of the wild population and to compensate to the local people for their loss which are caused by the wild Chinese Alligator, and the smuggling of crocodiles and their products haven't been thoroughly controlled .

Based on above situations, in order to enhance crocodilian conservation and management in China, the following actions are being considered to take.

1. Further enhance the awareness of conservation and strongly encourage the local people involving in the conservation program of Chinese Alligator.

The conservation course will be held in various schools so that it can make more and more people understanding the importance of conservation through the ANCANR instruction. In addition to that, it is important to add value on alligator. In case the alligator has been developed as a commodity with relative high commercial value, the people will actively and conscientiously protect and develop the alligators lived in their lands just like protecting their own property. At the same time, it will also undoubtedly attract a great deal of farmers to participate in the conservation programs such as farming, restocking and reintroducing of alligator and brings financial benefit to the people concerned. In our view, only by relying on the local people can we fully protect and develop the wild population. So, once the condition is ripe, the villagers within the reserve will be encouraged to engage in above activities by the conservation agencies.

2. Prevent the exotic crocodilians from escaping to the wild.

Many crocodile experts are worrying about that it will be detrimental to the survival of native Chinese Alligator if the exotic species of crocodilians escaping from the farm to the wild. We think that this may be a problem. But it seems easy to solve through strengthening the farming management, limiting or forbidding the farming activities in the nature range of Chinese Alligator and controlling the scale of crocodile farming industry. As everyone know, due to the cold weather condition, the exotic crocodilian species except the Mississippi Alligator may not be able to survive in the wild at the nature range of Chinese Alligator. In addition, all of crocodilians species are managed as China's special protected animals and the activities related to crocodile farming are well controlled under the conservation agencies at various level. Even if they escape to the wild, the farmer has the legal responsibility to capture them from the wild in accordance with the related provisions of the Wild Animal Protection Law.

3. Further strengthen the management of import and export of crocodilian.

Though some illegal cases of smuggling of crocodilian and its products have been investigated and prosecuted, there still exists smuggling phenomenon in south China. In order to crack down the illegal smuggling activities on crocodilians, a special national survey on the farming and utilization of crocodilians and their products organized by CITES Management Authority of China will be conducted by the conservation agencies at various level. If a dealer or farmer couldn't show related permits and documents, it will be investigated and prosecuted. Our policy is that once it has been found, it will be seriously handled in accordance with the provisions of Chinese laws and CITES. In addition, a regular communication system is planned to be set up between the CITES Management Authority and the Customs to enhance the examination of permits and imported and exported goods and improve the capability of identifying wild animals and their products.

4. Further promote and strengthen the international cooperation.

The following fields are in urgent needs to be strengthened by international cooperation: reintroduction (restocking, surveying and monitoring) program of the Chinese Alligator, tanning alligator skin program and international marketing of alligator products.

With the kind help of Dr. Grahame and his colleagues, Anhui Provincial Forestry Department has drafted a management program for conservation of Chinese Alligator (see annex 1). We sincerely welcome everyone to discuss about it and any pragmatic and working suggestion would be highly appreciated. Nevertheless, it should be emphasized that such solution must fit in with the realities of life in China. Once the management program is passed and get the financial support at this meeting , it will be implemented soon.

Due to lacking of the skin tanning techniques, the skin of Chinese Alligator have not formed a commodity and the alligator farms are unable to collect funds to support the conservation programs concerned. Thus, one of the urgent tasks at present is to develop the tanning as well as other techniques as soon as possible through international cooperation.

CONCLUSION

China, as the world's largest developing country, is restricted by its less advanced social, economic and technical development, has hundreds of endangered species awaiting for its special protection, will be difficult to allocate more funds to support the conservation of the wild population of Chinese Alligator. In addition, Chinese Alligator is the common heritage of all human beings and it also ought to be cared by the international community. We would like to take this opportunity to invite all of those who are really concerned with the conservation causes of Chinese Alligator, including researchers, conservation professionals, farmers, tanners and international organizations, to support for and participate in the programs mentioned above.

Since ARCBCA is a open tourist site, we hope that it will be built a world Crocodile exhibition center with all species crocodilians in the world by exchanging live crocodilians and their specimens with different countries.

ACKNOWLEDGMENTS

We would like to thank Dr. Grahame Webb and Mr. Charlie Manolis for their long-term assistance to us in conservation of Chinese Alligator. We would especially like to thank Dr. John Thorbjarnarson and Mr. Uthen Youngprapakorn for providing funding to Mr. Wan Ziming and Dr. Wang Xiaoming for their participate in this meeting. At the same time, we would like to thank Wildlife Conservation Society for it's providing funding to us for jointly conducting the survey of wild Chinese Alligator, and Australia-China Council for providing funding to Mr. Wan Ziming for his studying in Australia.

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ANNEX 1

A MANAGEMENT PROGRAM FOR CHINESE ALLIGATOR IN ANHUI PROVINCE

(Drafts)

1. SPECIES SUBJECT TO MANAGEMENT

Class: Reptilia
Order: Crocodylia
Family:Crocodylidae
Species: *Alligator Sinensis* (Chinese Alligator)

2. PROPONENT AND SUPERVISORY AUTHORITY

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3. INTRODUCTION

Chinese Alligator is currently restricted to Anhui Province of China and is generally considered as one of the world's most endangered crocodilians. There are only about 400 Chinese Alligators living in the wild and about 8,000 kept in captivity in 1997.

Chinese Alligator, also called land dragon, was included in Category 1 of the State Protected Species in 1972 and listed in Class I of State Special protected species under the Law of Wild Animal Conservation of the People's Republic of China enacted in 1 March 1989. Capturing and hunting of this species is prohibited except for scientific, taming and breeding purposes, when a special hunting permit must be obtained from the State Forestry Bureau(SFB, former Ministry of Forestry). The farming and commercial use of the captive-bred alligators are permitted, when related permits or documents, such as import and export permit, transportation certificate and dealing and using permit, have been obtained from the SFB.

This program is developed in accordance with the provisions of Law of Wild Animal Conservation, the Regulations on Management of Nature Reserves for Forest and Wildlife Type and the Rules for Implementing the State Law of Wild Animal Conservation in Anhui Province. Its aim is to further conserve and develop the wild population of Chinese Alligator and its habitats and actively save this endangered and endemic species throughout the Anhui National Chinese Alligator Nature Reserve(ANCANR).

Prior to this program, the Anhui Research Center for Breeding Chinese Alligator(ARCBCA) was set up in Xuanzhou city in 1979 and the ANCANR was established in 1982, by SFB. The administration of ANCANR is coordinated through

ARCBCA. Great achievements have been made in conservation of Chinese Alligator by those units. The awareness of the local people within ANCANR for conservation of Chinese Alligator has been greatly raised and the illegal cases related to poaching of Chinese Alligator have almost vanished; the farming techniques of Chinese Alligator have been successfully developed, the captive stock of Chinese Alligator in ARCBCA is about 8,000 and the ARCBCA has the capability of producing of at least 2,000 hatchlings per year .

However, there still exists many problems. The wild population increases very slowly , the distribution area has a trend of gradually decreasing, the local people is not positive to protect the wild individuals because they can not obtain benefits from the protection of Chinese Alligator, the conservation agencies are lacking of surveying and monitoring techniques and facilities, it is unable to control the food and water of the habitats by conservation agencies because the lands and water belong to the local people (including tree farms), the techniques on utilization of captive-bred specimens of Chinese Alligator have not been successfully developed, ARCBCA can not collect funds from commercial utilization of captive-bred specimens of Chinese Alligator to support the conservation of the wild population and to compensate to the local people for their loss which are caused by the wild Chinese Alligator. The present program encompasses a range of strategies through which those problems can be gradually solved in five to nine years.

4. AIMS AND OBJECTIVES

This management program is developed for the purpose of further protecting of the remaining wild population of Chinese Alligator and its habitats, saving this most endangered species through releasing the captive-bred individuals into the wild to restock/re-establish the wild population following IUCN guidelines and further raising the conservation awareness of the local people through bringing economic benefits to the local people .

The management program seeks to realize the following objectives in five to nine years:

1. Strengthen the conservation of remaining wild alligator and its habitats, enlarge it through restocking project;

2. Rehabilitate the nature habitats of alligator and re-establish several wild population through reintroduction project;

3. Enlarge the re-introducing population through ranching project;

4. Enhance public conservation awareness by creating employment opportunities on farming/reintroducing of Chinese Alligator for local people;

5. Summarize the mature experiences on conserving and enlarging the wild population.

5. LEGISLATION

China is a party to CITES and the Chinese Alligator is on Appendix I of CITES. The provisions of CITES should be followed while implementing this program.
All of the existing provincial and national regulations, rules and laws related to the

conservation of wildlife are available to this program. Moreover, any activity related to the killing, trade and commercial use of wild individuals are forbidden.

6. MANAGEMENT OF THE RESTOCK

ANCANR covers five city and counties, including Xuanzhou, Guangde, Langxi, Jingxian and Nanling, with a total area of 433 square kilometers. The using right of the lands and water surfaces within the reserve belong to the local people. The main habitats of the wild alligator are small reservoirs and ponds. No alligator has been found in the rivers and lakes. There are thirteen key protected areas where the wild alligators concentrate in. Each spot has less than 20 wild alligators. All of those areas is monitored by the staff of the reserve.

In order to implement this program, a survey on the wild alligators will be conducted. When the range, number, age and sex of the wild alligators are clear, the reserve will select more than 20 distributing spots for restocking of the wild population. According to the survey results and other related research achievements, ARCBCA will release captive-bred adults into the above distributing areas to enlarge the existing wild population. It is recommended that the sex ratio of 1:3(male:female) in each spot would be appropriate. Those spots will be looked after and monitored by the staff of the reserve.

7. MANAGEMENT OF THE REINTRODUCTION

Considering that the present distributing spots of the wild alligator are limited and the local people should obtain benefits from the protection of this endangered species, ANCANR must call for the local people and related state-owed tree farms to be involved into this reintroduction project. The related local people and tree farms who would like to take part in the reintroduction project should provide ponds, foods, manpower and other necessary facilities to this project. As a compensation means, the reserve will provide necessary techniques and captive-bred alligators and the Anhui Provincial Government will provide certain sum of funding, to the local people and tree farms.

The spots used for this project should be selected by ANCANR, where they are suitable for the living of wild alligator. In order to prevent their escaping and to facilitate the management of the reintroduced alligator, the iron net will be erected around the ponds at the first year when the reintroduction project conducts. The related local people and tree farms should sign contracts with the reserve and the contract should make definite each other's obligations and responsibilities. In general, the local people are responsible for the care of the reintroduced alligators and their habitats. The recommended sex ratio of the reintroduced alligators is 1:3. Four individuals will form a group. About 10-50 groups of captive-bred alligators should be released into selected ponds and reservoirs every year and the groups released into one pond or reservoir should be decided by the conditions of the area.

8. MANAGEMENT OF THE RANCHING

In order to ensure the reintroduced population increasing quickly, the ranching program should be introduced. When the reintroduced females lay their eggs in the wild, the eggs will be collected and incubated by ARCBCA in time. ARCBCA will be responsible for the raising of the hatchlings until they reached 3-4 years old. Then, releases some of them into their original habitats or other places depending on the circumstances of the habitats. The ARCBCA should pay additional fee to the local people for the eggs laid at their lands. The data related to the nesting, eggs, fertility, incubation, hatchlings (number, sex), mortality, etc. should be recorded in detail by the local people and ARCBCA.

9. ROLE OF RELATED ORGANIZATIONS

The ANCANR is responsible for the communicating with the local people and tree farms , signing contracts of reintroduction program with local people and farms, conducting technical instruction and administration of local people and farms, monitoring the development trend of the wild population and compiling the annually report on implementing of this program.

The ARCBCA is in charge of providing captive-bred alligators to the ANCANR for restocking and reintroducing projects, incubating eggs and raising hatchlings and juveniles from ranching project , organizing and holding training seminars on farming of alligator for local people and tree farms and developing the techniques on using of captive-bred alligator .

The APFD is in charge of coordinating the relationship between the reserve and local governments, drawing up or approving the programs on protection and utilization of Chinese Alligator, collecting funding from international community and related government agencies and organizations and providing funds for implementing this program. To some extent, the possibility of success of this program will be mainly depended on the financial supports from the international community.

10. EDUCATION AND RESEARCH

In general, the publicity and education work on conservation of Chinese Alligator has been made great achievements over the past 20 years. In the future, most of the publicity work will be focused on the alligator's commercial value for the purpose of encouraging local people and farms interested in farming of alligator and directly involving in this program. The final goal is to make them regarding the alligator habitats as productive lands and to ensure them gaining economic benefits from this program.

The previous research mainly focus on the biology, ecology and farming of alligator. The future research work should be focused on the development and application of monitoring techniques, reintroducing techniques, the best density for wild population, commercial farming and utilization captive-bred alligator, raising up the rate of nesting, fertility and hatching and reducing the mortality rate of hatchlings.

The foreign crocodile experts are encouraged to involve in this program with their research program, funds, equipments and techniques.

11. MONITORING AND REVIEW

All of the remaining wild population and the reintroduced stocks and their habitats should be taken care and monitored by the local people, tree farms and the reserve. If it is possible, the radio-tracking device and GIS may be used for monitoring part of those individuals. The reserve should identify certain areas as the contracting place for its staff. These staff are responsible for the technical instruction to the local people on rehabilitating, restocking or reintroducing project, designing the food type and amount, monitoring on wild population, collecting the eggs and other related works. The staff of the reserve should submit their working reports to the reserve twice a year. The reserve must summarize the work what they have done at the middle of a year and submit their annual implementing report to the APFD at the end of a year.

When this program is completed , the reserve should prepare and submit a report on the implementation of this program and the proposal about the future management and monitor work to APFD and related funding organizations, and the APFD should formulate another one management program for the conservation of those restocked and reintroduced populations and their habitats based on the situation at that time . The funding organizations and foreign experts are welcome visiting Anhui Province to instruct and inspect the implementation of this program.

12. MARKET FORECASTING

Chinese Alligator seems to be international trade as pets, tourist display or internal trade for meat, skin and possibly medicinal use ,such as fat, oil ,bones.

Another is tourism benefit. ARCBCA and the wild populations are located an easy day's drive from China's largest city. Very close by in southern Anhui province is the Yellow Mountains, a destination visited by hundreds of thousands of Chinese and foreign tourists per year. A good organized tourism program will generate a lot of money for ARCBCA as well as for local people.

PHILIPPINE CROCODILE CONSERVATION
(Comprehensive Report)

by

GERARDO V. ORTEGA, D.V.M.

INTRODUCTION

In 1935, Karl P. Schmidt, curator of herpetology of the Field Museum of Natural History of Chicago, discovered the Philippine crocodile in the island province of Mindoro, thus, it was named *Crocodylus mindorensis*.

In 1982, forty seven (47) years after its discovery, Charles A. Ross of the Smithsonian Institution, estimated its remaining wild population to be between 500-1000 matured individuals. That report alarmed the government which forced it to propose a project that will halt the march of the two endangered species of crocodiles (*C. mindorensis* and *C. porosus*) occurring in the country to extinction.

Finally, on August 20, 1987, the Crocodile Farming Institute was created with a grant-in-aid and technical cooperation from the Japanese Government through the Japan International Cooperation Agency (JICA). It has two (2) main objectives:

1. To conserve the two endangered species of crocodiles in the Philippines; and
2. To promote the socio-economic well-being of the local communities through the development and introduction of a suitable crocodile farming technology.

On March 4, 1988 the project (CFI) officially opened and hired its personnel.

PHILIPPINE SITUATION; CONSERVATION CHALLENGES AND OPPORTUNITIES

The People and the Environment

The Philippines is not only home to 950 species and subspecies of birds, 233 species and subspecies of mammals, and 240 species of reptiles, it is also home to 70 million Filipinos. Majority of these people are living below the poverty line with a per capita income of $1,554.15 per annum. Four million people are believed to be unemployed.

With the country's economy in bad shape, many of the poor, unemployed and destitute Filipinos are forced and will be forced by circumstances to expand their use of nature. As a consequence, people are now encroaching and will be encroaching on the forest lands and wildlife habitats for purposes of livelihood. They engage and will be engaged in hunting, illegal trade of wildlife and its by-products, illegal logging, slash and burn farming, and cyanide and dynamite fishing in order to survive.

On the other hand, misplaced and environmentally non-friendly industries are aggravating the Philippine situation.

The results of these pernicious activities are devastating. Thirty hectares of the Philippine forest cover are being denuded every thirty minutes (or 3,720 hectares a day). In the province of Palawan alone, 954 hectares of its mangrove forest are being exploited every year. The number of wildlife species in immediate danger of extinction is now 189 including the Philippine crocodiles. Not surprisingly, the Philippines is among the top 10 hotspots of most endangered ecosystems in the world.

Sixty three years (63) ago when Karl P. Schmidt first discovered the Philippine crocodile in Mindoro, a vast number of Philippine lakes, rivers and marsh lands were still teeming with crocodiles. However, shortly after the Second World War (1945), hunting and poaching started to diminish their number due to its valuable hide.

Crocodiles in the Philippines have poor public image. They are being viewed negatively in almost all levels of the society. Locally-known as *buwaya*, they are believed by rural folks to be bearers of bad tidings and in the league with the dark forces of nature. Thus they are often referred to as *asuwang* or witches.

Their aggressive nature and dinosaur-like appearance did not endear them to the populace. Reported cases of problem crocodiles attacking hapless victims have reinforced this supernatural belief of the rural people. Crocodile hunters are even being revered and viewed as extraordinary beings in possession of amulet or *anting-anting* and gifted with courage and skill. They are very popular and admired individuals whose slaughter of crocodiles are considered heroic acts and an exemplary service to the community.

Crocodiles are also the most maligned and ridiculed animals in the Philippines. In the Filipino culture, crocodiles or *buwaya* are always associated with corrupt government officials, greedy businessmen, policemen, highway patrolmen, tax and customs collectors, and selfish athletes. In general, common Filipinos are unconcerned and indifferent about their fate. In totality, crocodiles are regarded as useless creatures - a vermin.

Research and Development Challenges

During the early days of the project, everyone was groping in the dark; the level of knowledge was very minimal in terms of crocodilian biology, physiology, anatomy and pathology. The technical staff were inexperienced in terms of capturing, handling, and husbandry. There was no deep understanding about the mission and vision as to how the two objectives of the project can be translated into reality.

Crocodile sourcing was another big challenge. Crocodiles are scattered in different parts of the archipelago, and the extent of its current distribution is not very well known. Survey and trapping activities are often hindered by the prevailing insurgency situation in the habitat areas.

The propriety of introducing crocodile farming in the Philippines while many Filipinos are suffering from the complex social problems and are dying due to protein deficiency and malnutrition is a very sensitive issue. An appropriate approach must be carefully planned so as not to add insult to injury.

To summarize, the causes and solutions to research and development problems and challenges are:

PROBLEMS	CAUSES	SOLUTIONS
1. Sourcing and acquisition of stock	endangered species, peace and order, and habitat conversion and destruction	Appropriate trap development, intensified trapping activities and negotiation to acquire private crocodile collection in favor of the government gained people's support
2. technical know-how	no prior training	acquisition of references and literature, development of institutional linkages and foreign trainings and technical exchange, research and observations
3. social acceptability	negative perception	intensive information and education and communication (IEC) in tri-media
4. bureaucracy	circuitous bureaucratic maze	change the point of view of bureaucrats and gain their support

Status and Distribution

- **Status**

Crocodylus mindorensis, found only in the Philippines, is the most highly endangered crocodilian in the world today. No large population is known to exist in one area. There remain only minor pockets of habitat in which *C. mindorensis* exists today, and none appears to be protected. Informed estimates yield a maximum of 500 animals held in captivity and in the wild. The wild animals are scattered in Mindanao and a few other islands in the Southern Philippines. The species is listed in Appendix I of CITES and is considered endangered by the IUCN - The World Conservation Union (Messel, et al. 1992, Ross 1982).

- **Historical Distribution**

Crocodylus mindorensis has been reported to have thrived in Northeastern and Central Luzon, Samar, Masbate, Mindoro, Negros, Busuanga, Jolo, and Mindanao islands (Ross 1982) (see Fig. 1).

- **Current Distribution**

Based on the acquisition record and information gathered by CFI, *C. mindorensis* is still present in the following areas: Mindoro (Naujan Lake), Mindanao (Agusan Marsh and Liguasan Marsh), Busuanga (Dipuyai River), and Tuguegarao (Fig. 2).

In all of these areas, Mindanao has the most number of crocodiles (N=227), note that in Mindoro only one (1) specimen was obtained which is indicative of its degree of endangerment in this island province where it was first discovered (Ortega and Regoniel 1993). Local residents are now encroaching in Lake Naujan, Oriental Mindoro.

In Busuanga, two rivers, Dipuyai and Busuanga, still contain crocodiles. One *C. mindorensis* was caught in Dipuyai River and several others have been observed by local residents. A local informant reported seeing some small crocodiles farther upstream in Busuanga River. Two crocodiles were also observed near old Busuanga port (1989) although these have not been caught. The upper Busuanga River dries up into isolated water pools located inland. In Barangay Sto. Niño, where Dipuyai River mouth is located, a *C. mindorensis* was caught in 1989 but escaped.—It was estimated at 2-3 m long. Another *C. mindorensis* was brought to CFI on May 30, 1991 from an area called Bogtong. The crocodile was caught by the crew of a fishing boat which happened to pass between Laho island and the Dipuyai River. Sightings have also been reported in Labangan River on the eastern portion of the Busuanga island (Regoniel, Pontillas et al. 1993). In Tuguegarao (northern Luzon) one specimen was reportedly displayed alive in the provincial museum (Ramirez pers com.). Verbal reports have it that scarce and isolated population may still be present in the North Sierra Madre Natural Park in Isabela (Milan, pers com., 1995), Cagayan river system (Tugas pers com., 1995), the Mangyan Heritage Nature Park in Occidental Mindoro (Diaz, pers com., 1992), Ilog River in Negros island, Liguasan Marsh, and in small lakes and rivers of Mindanao (Ortega 1998) .

The absence of report of sightings in formerly known habitats of *C. mindorensis* may indicate two things: that its population is severely depleted, and that it's hardly noticed or it has gone extinct already. Although new efforts are being exerted to survey all the known habitats of *C. mindorensis* to draw a more accurate picture of its present state. Two very recent surveys done in Agusan Marsh in Mindanao yielded negative results, although it has been confirmed during the first survey (year 1994) that *C. mindorensis* is inhabiting the marsh. This was after a live adult specimen was seen on exhibit in the provincial capitol grounds of Agusan del Sur before it died.

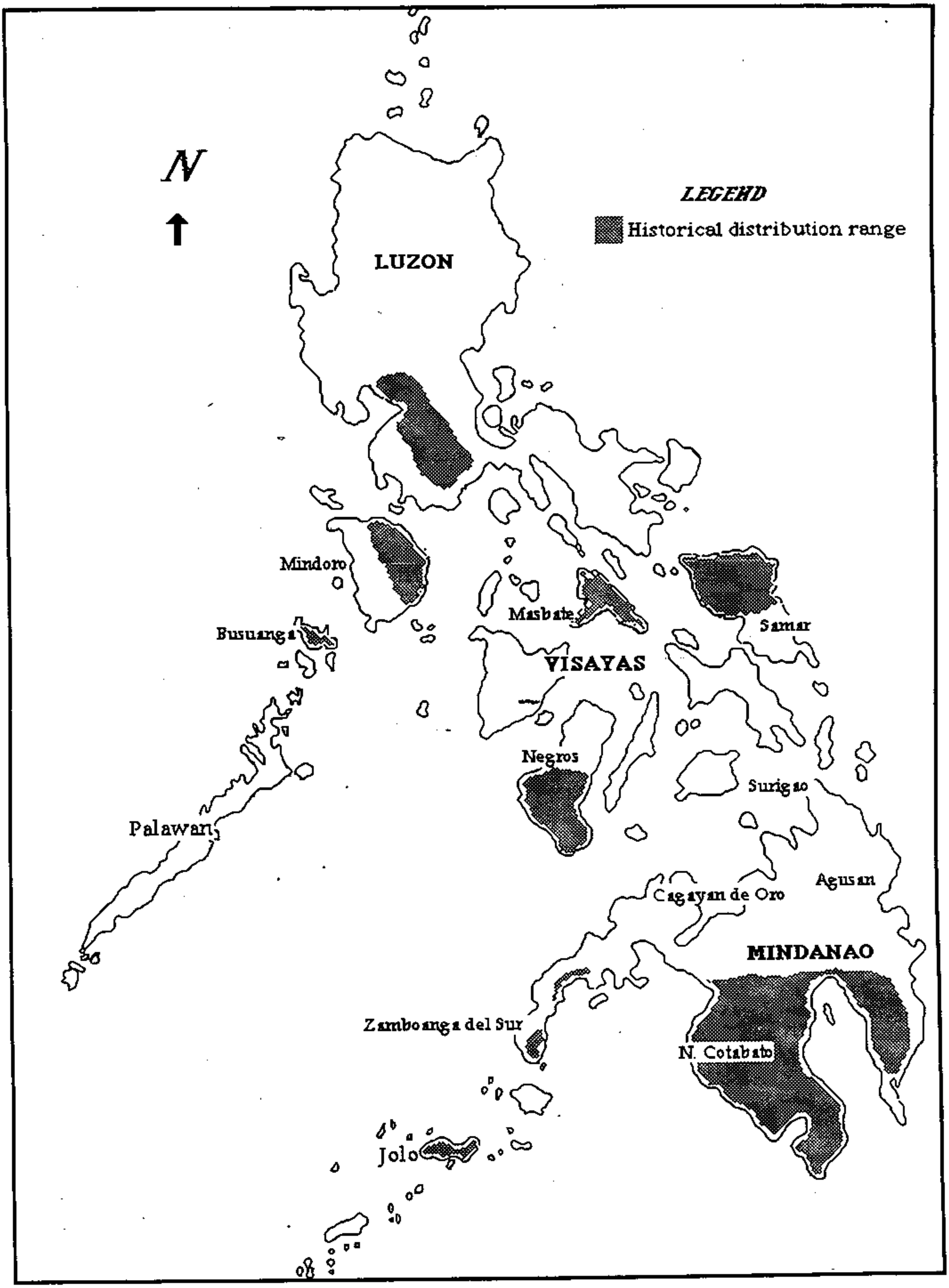

Fig. 1. Historical distribution of C. *mindorensis* in the Philippines (Ross and Alcala, 1982)

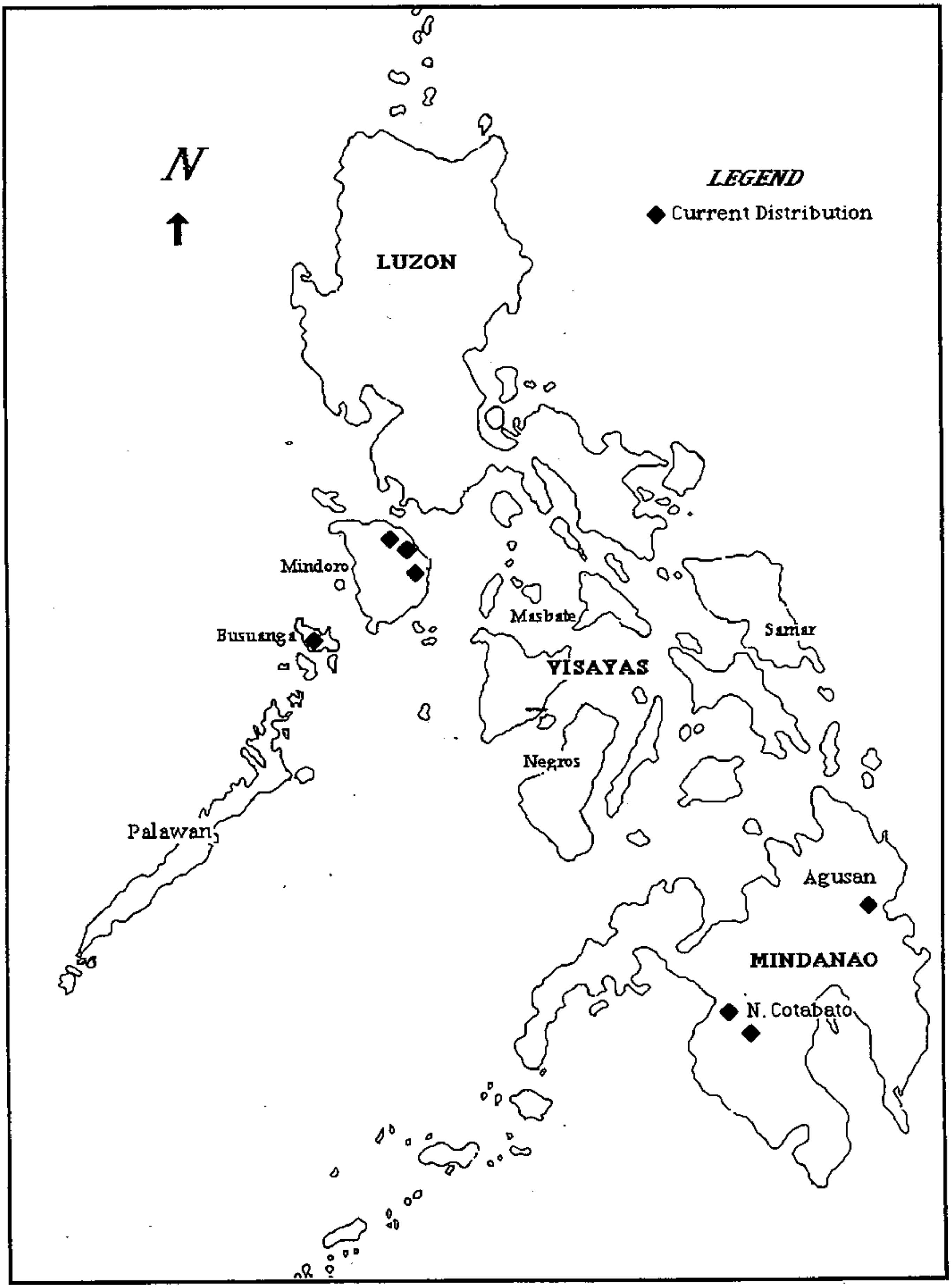

Fig. 2. Current Distribution of *C. mindorensis* in the Philippines based on CFI records

Sanctuary Identification and Establishment

Since the inception of the project in 1988, sanctuary establishment has always been a part of the over-all strategy of the Crocodile Farming Institute. Surveys of potential sanctuary sites have been undertaken. Lake Manguao, a freshwater lake in Northern Palawan, has been thoroughly studied for its potential and a final proposal has been submitted. The political leadership of the municipality of Taytay is apprehensive and the local residents are opposed to the proposal. The proposal failed because of very poor social acceptability.

In 1992, the CSG recommended that renewed efforts be made to establish an innovative crocodile sanctuary for *C. mindorensis* (perhaps on a small offshore island) and one for *C. porosus*. This may need to be done in cooperation with the Integrated Protected Areas System (IPAS) program and may need to emphasize wetlands fauna in general rather than crocodile alone. It would result in "safe" populations of these crocodiles in the wild and could in the long term, form a base for their ranching by local people. This matter is most urgent because of rapid human population growth and destruction of wetland habitats needed for crocodiles and other wetland fauna.

The Agusan Marsh which is believed to be the best among the last remaining habitats has finally been included in the IPAS program on October 31, 1996. However, the marsh is being affected by the growing community of Manobo tribal people residing in the marsh, illegal logging, downstream effects of mining, illegal fishing, wildlife poaching and trading, exotic fish seeding, and slash and burn farming. The Protected Areas Management Board of Agusan Marsh Wildlife Sanctuary and its project management has been organizing the community and educating them about conservation and sustainable utilization. With the intention of eventually designating a certain portion of the Agusan Marsh Wildlife Sanctuary as a crocodile management zone, the CFI has conducted two systematic spotlighting surveys in the Marsh (1994 and 1998). However, both surveys yielded negative results. Interviews were conducted with the community of Manobo tribesmen who are residing inside the marsh. Most of their verbal accounts did not reveal recent sightings, instead it dates back to few decades back. The most recent information however, is that in November of 1997 thirty six (36) eggs of unknown crocodile species were collected from a nest by a Manobo tribesman for food.

Liguasan Marsh in Cotabato on the other hand has always been under the control of the Moro Islamic Liberation Front (MILF), a secessionist group. Much of its original area has been converted to agricultural lands and much of this kind of development is still expected to happen. There was even a proposal to drain the marsh and convert it into an agricultural and economic zone for rebel returnees. Despite this, *C. mindorensis* and *C. porosus* are still believed to be surviving in the area.

The Crocodile Specialist Group (CSG) in its recommendation already doubted the possibility of finding even small viable populations as they contended that the only remaining crocodiles are single individuals scattered along the coast. Such is also the indication of the initial survey results and the data gathered by the CFI based on acquisition records. But despite this, CFI is determined to aggressively pursue habitat surveys and the eventual sanctuary establishment.

INTERVENTIONS

A. Captive Breeding

During the Workshop on the Prospects and Future Strategy of Crocodile Conservation of the Two Species (*Crocodylus mindorensis* and *C. porosus*) Occurring in the Philippines in 1992, the author justified the captive breeding strategy of the CFI project, to wit:

a. Crocodile population especially *C. mindorensis* is rapidly declining due to the indiscriminate and expanding use of nature brought about by the growing, scattered human population over the archipelago;

b. It is impractical to conserve crocodiles in all parts of the Philippines where there is already an existing conflict between humans and crocodiles and where there is peace and order problem. Crocodiles were collected as breeders before they face local extinction. Because at the rate it's going and if no remedy is done then extinction is inevitable;

c. Conserving them in the whole archipelago is extremely difficult and expensive;

d. People must first be informed and educated in order to reverse the prevailing attitude or at least sway their belief before they can be taught how to live harmoniously with the crocodiles; and

e. Hence, captive breeding is the most practical alternative and probably, the only option left.

In response, the CSG experts headed by Prof. Messel recommended the following:

Under normal circumstances the removal of breeding adults from depleted wild populations to stock a farm is to be discouraged, because it depresses the reproductive rate of the wild population and slow its recovery. However, it is wrong to leave the small nucleus of breeding adults in areas where they are being killed by local people and where their habitat is being converted to rice terraces. It would be foolish not to place them in a captive breeding program where its survival is guaranteed and where they can contribute to a conservation program. Abandoning *C. mindorensis* in the wild, before real protection can be accorded to them in reserves or sanctuaries, would probably have resulted in the final extinction of the species in the Philippines. To save the *C. mindorensis*, they had to be taken from the wild and placed in conditions where they can breed successfully and where the young can survive and flourish until restocking is possible (Messel et al. 1992).

Messel et al. further recommended that the acquisition of additional *C. mindorensis* be continued until such time that a safe sanctuary is established for them in the wild.

In response, recommendations were actively pursued which resulted to the acquisition of additional *C. mindorensis* stock. By 1994 CFI was able to acquire a total of two hundred and thirty five (235) crocodiles (Tab. 1). CFI since then stopped acquiring crocodiles since breeder stocks have been breeding regularly and sub-adults are already starting to breed. However, it must be noted that only 4.6% (n = 11) of the total number of foundation stocks directly came from the wild while the rest are from private collections. Also notice the classification of the age distribution of foundations stocks. Seventy four percent (n=175) are hatchlings and juveniles.

Table 1. Yearly acquisition of *C. mindorensis* (Sumiller 1998)

Class	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Total
Hatchling				7	37	29		16				89
Juvenile	9		2	6	31	30		8				86
Sub adult (F)	2		2	1	7			3				15
Sub adult (M)	5		3	2	2			3				15
Breeder (F)	1	1	2	6	3	4						17
Breeder (M)	1		1	3	7	1	—					13
Wild				5	1	5						11
Total	18	1	10	25	87	64	0	30	0	0	0	235

Using all the available mature foundation stocks, CFI was able to breed them successfully resulting to the steady increase in captive population (Table 2).

Of the original foundation stock of two hundred and thirty five, eighty four percent of this (n=198) are still alive.

To date, forty four percent (n=88) of the above mentioned stocks are already breeders.

Table 2. Population increase of *C. mindorensis* from 1988-1997 (Sumiller 1998)

	ACQUIRED				CFI BRED				TOTAL			
	No. of heads	Mortalities No.	%	Heads Live	No. of heads	Mortalities No.	%	Heads Live	No. of heads	Mortalities No.	%	Heads Live
1987	18	1	5.56	17					18	1	5.56	17
1988	1	2	10.00	16					18	2	11.11	16
1989	10			26	7	2	28.57	5	33	2	6.06	31
1990	25	1	1.92	50	14	1	5.00	18	70	2	2.86	68
1991	87	5	3.52	132	137	21	12.00	134	292	26	8.90	266
1992	64	4	2.00	192	197	26	7.05	305	527	30	5.69	497
1993		8	4.00	184	109	16	3.82	398	606	24	3.96	582
1994	30	7	3.17	207	155	33	5.63	520	767	40	5.22	727
1995		4	1.90	203	160	58	7.86	622	887	62	6.99	825
1996		3	1.46	200	253	76	7.99	799	1078	79	7.33	999
1997		3	1.48	197	248	71	6.35	976	1247	74	5.93	1173
Total	235	38		197	1280	157		976	1173	342		1173

- **The Breeding Performance**

The first successful breeding was recorded in 1989 when seven hatchlings emerged from ninety two eggs. Ever since that time eggs and hatchlings were already being produced annually with varying rates of success (see Tab. 3). F_1's produced in 1989 are now classified as breeders. It is expected that F_2 generation will be produced very soon!

Tab. 3. Annual captive breeding results 1988-1997 (Sumiller 1998)

Year	Female Paired	Female Laid Eggs	Breeding Rate	Mean Clutch Size	Hatchling Per Breeder	No. of Eggs	Fertility No.	Fertility %	Hatchling No.	Hatchling %	Yearly % Survived
1988	1	1	100.00	21	0	21	1	4.76	0	0.00	0.00
1989	7	5	71.43	18	1	92	25	26.20	7	10.32	13.33
1990	10	4	40.00	24	4	94	20	30.99	14	30.00	47.92
1991	19	12	63.16	29	11	352	241	63.82	136	50.70	73.21
1992	15	13	86.67	38	16	491	369	75.00	209	61.00	88.66
1993	23	12	52.17	28	8	331	246	68.46	98	37.72	78.99
1994	24	20	83.33	22	8	446	320	69.56	155	48.42	69.97
1995	22	16	72.73	25	10	397	320	74.04	160	46.74	64.99
1996	22	20	90.91	29	13	571	451	75.46	253	54.51	82.94
1997	26	21	80.77	27	12	573	416	70.58	248	61.06	86.72
Total/Mean	121	83	74.12	26	8	3368	2409	55.89	1280	40.05	60.67
Mean excluding 1988			71.24	27	9			61.57		44.5	67.41

The very high breeding rates and the inherently low hatching rates (mean 51%) compared to the relatively high fertility (mean 69%)should be noted. On the overall, in the CFI, the captive breeding performance of *C. mindorensis* is very much lower than that of *C. porosus* which has an average fertility rate of sixty eight percent (68%) and a mean hatching rate of seventy five percent (75%).

The matter about the low hatching rate is the biggest challenge that CFI needs to solve. Thus, there is a need to investigate the stages of embryonic death as it may point to some incubation factors or incubation techniques being employed. It could be the quality of the egg itself. Marais et al., (1994) pointed out that the quality of the eggs is affected mainly by factors associated with parental age, genetics, and nutrition.

- **Breeding Factors and Behaviours**

⇒ **Breeder Classification**

C. mindorensis breeders are classified based on the length and weight of individuals.

Table 4. Productive breeder size (Sibal et. al., 1992)

	C mindorensis
Male Length (cm)	215
Male Weight (kg)	48.4
Female Length (cm)	198.25
Female Weight	40.6

Note: The smallest recorded female to lay egg had a total length of 155 cm. and a body weight of 15.2 kg. Its male partner had a total length of 156 cm. And 15.6 kg. body weight.

⇒ **Breeding ratio**

Generally breeders are paired at a one is to one (1:1) male to female ratio. Communal breeding is not very successful due to the peculiar aggressiveness of some breeding males. These crocodiles are basically solitary or monogamous breeders. At present, young breeders, sub-adults and juveniles are maintained in communal pens to get use to this social environment.

⇒ **Pairing and compatibility**

Very critical to the success of breeding *C. mindorensis* in captivity is the careful selection of breeders to be paired. A pairing plan is prepared way ahead the onset of the breeding period. Pairing is based on origin and physical characters such as length and weight. As a rule, the male should be bigger and heavier than the female. Ages are unknown since they are stocks from the wild. Pairing is usually done on November to December except for aggressive breeders which are paired very late in February. Incompatible pairs resort to fighting especially during the entire breeding season. Fighting usually occur during courtship, nesting and post nesting. Injuries sustained are usually very serious and may result to death.

⇒ **Breeding period**

Under normal weather conditions breeding season in Palawan is between the months of February and October (Figure 3).

⇒ **Breeder Acclimatization**

Breeders acquired by the CFI did not readily breed upon pairing. This is true to both wild and captive crocodiles. It took approximately 1-2 years before they breed.

⇒ **Breeding rate** (paired females vs. nesters)

It ranges from 40-100% breeding rate or a mean breeding rate of 70%.

⇒ **Clutch size range**

18-33 eggs per clutch or a mean clutch size of 26.

⇒ **Feeding and supplementation**

Breeders are fed twice a week (Monday and Thursday) at 3% body weight. Feed type varies from fish, chicken, beef, pork and carabeef. Feed allocation is supplemented with vitamins and oyster shell.

⇒ **Nesting**

In addition to existing vegetation inside the pens, nesting materials such as bamboo grass, leaves and rice straw are introduced in January (Sibal, 1992).

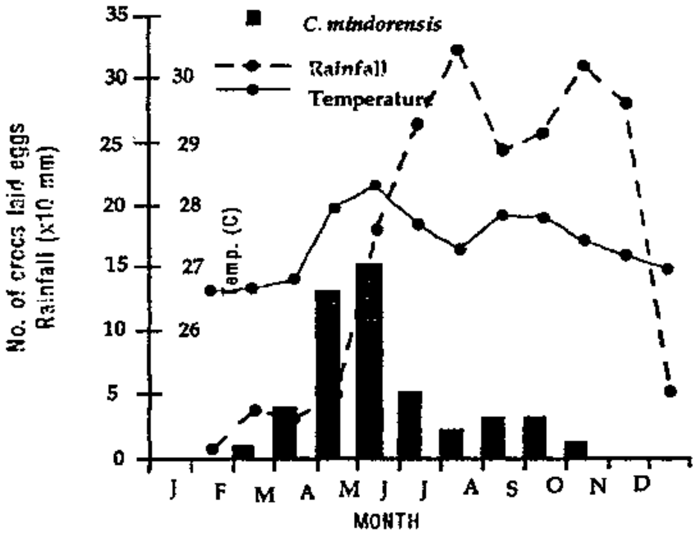

Fig. 3. **Egg Laying Season**

- **Incubation**

Proper egg incubation is very vital in captive operations. The hatching and survival rates of *Crocodylus mindorensis* eggs artificially incubated at the CFI are showing poor results compared to what has been achieved by *C. porosus.*

A retrospective study on the effect of different incubation temperatures on the hatching and survival rates was undertaken. A total of 1,470 viable or fertilized eggs were incubated in different temperature settings from 30°C to 33°C. Results shown in Table 5 reveal that the highest hatching rate was attained at 30°C while at 32°C, the survival rate of hatchlings was consistently high from the third to the twelfth month of observation (Sumiller 1998).

Table 5. Hatching and survival rates of *C. mindorensis* eggs incubated in different incubation temperatures (Sumiller, 1998)

Incubation Setting (°C)	Actual Incu. Temperature (°C)	Fertile Eggs Incubated	Eggs Hatched	Hatching Rate	Percentage of Hatchlings Survived		
					3 mos.	6 mos.	12 mos.
30	29.97 ± 0.27	335	224	78.81	81.37	79.34	72.39
31	30.95 ± 0.31	366	189	62.82	78.77	78.28	71.68
32	32.10 ± 0.31	406	214	63.57	91.90	91.32	85.98
33	32.91 ± 0.23	311	129	47.97	73.90	73.90	72.01

Other factors which can influence hatching and survival rates are:

1. Quality of eggs which is basically influenced by parental age, genetics, and nutrition (Marais et al. 1994);
2. Incubation factors (humidity, temperature and gas exchange), techniques and management;
3. Rearing technique/management especially after six months - Hutton (1987) pointed out that the growth and survival of hatchlings for the first six months of life is influenced by the incubation temperature at which they were incubated;
4. Species idiosyncrasy - inherent to the species; and
5. Purely genetic related - in the case of a group of breeders from Bacolod which had a consistently high fertility rate and a very low hatching rate.

In relation to the incubation performance of *C. mindorensis,* conservative measures are now being undertaken to improve it like supplementing vitamins and minerals to all the feed allocation of crocodiles, strict feed quality control, proper water management, improving on incubation management, heating the rearing tanks especially during cold months, and giving special attention to poor performing breeders.

To further investigate the problem, an embryonic staging study will be undertaken this year to determine the different embryonic ages of mortalities so that external factors which could have directly influenced embryonic deaths could be pin pointed and corrected.

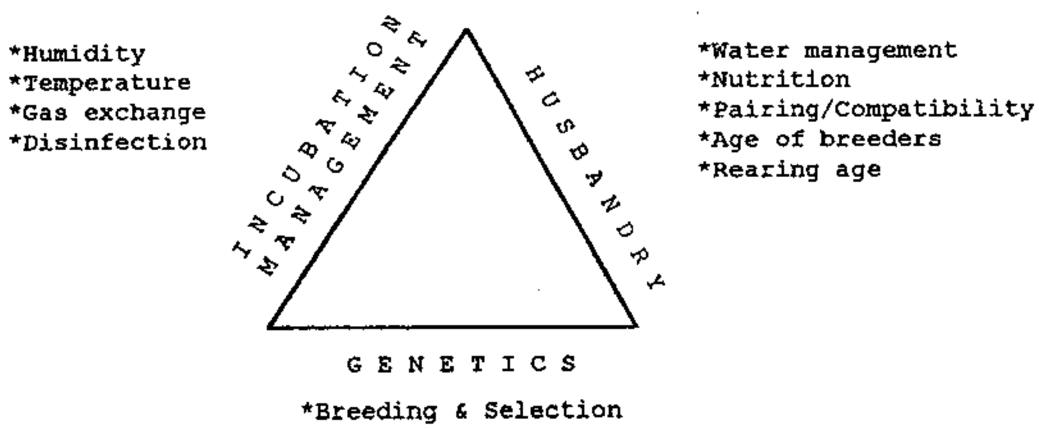

Fig. 4. Triad of factors affecting the success of breeding and incubation

- **Temperature-Dependent Sex Determination**

Eleven out of 22 known species of crocodilians showed evidence of temperature-dependent sex determination (TSD) (Lang and Andrews 1994). Cohen and Gans (1970) speculated that TSD may be universal in crocodilians, in contrast to turtles and lizards.

This fact prompted CFI researchers to subject the *C. mindorensis* to TSD analysis - in relation to the above mentioned incubation temperature study. Preliminary data gathered from 586 crocodiles which were subjected to different incubation temperature settings showed evidence of TSD. The lower the temperature the higher the number of females, and the higher the temperature the higher the number of males. However, there is a probability that the much higher temperature (34°C) could also produce females resulting to FMF (female-male-female) pattern (see Table 6) similar to related studies in *C. porosus*, *C. johnstoni*, *C. niloticus*, and Caiman crocodiles. Due to the risk of wasting fertile eggs in high temperature (34°C), incubation of eggs at this setting was discouraged. Live *C. mindorensis* hatchlings are more valuable than knowing the real effect of high temperatures.

Table 6. Effect of different incubation temperature on the sex distribution of *C. mindorensis* (Sumiller 1998)

Incubation Setting (°C)	Actual Temp Reading (°C)	Number of Crocs Sexed	Female		Male	
			No.	%	No.	%
30	29.96 ± 0.33	40	39	98	1	3
31	30.99 ± 0.37	220	202	92	18	8
32	31.99 ± 0.32	255	167	65	88	35
33	32.91 ± 0.32	69	7	10	62	90
34	34.08 ± 0.05	2	2	100	0	0

- **Rearing**

Ninety (90) *C. mindorensis* hatchlings were reared in water temperature regulated rearing tanks. The hatchlings were randomly distributed to three (3) treatments with three (3) replicates having ten (10) heads of hatchlings each.

Treatment 1: water temperature regulated at 32°C with continuous flow of hot water supply

Treatment 2: water temperature regulated at 32°C with intermittent flow of hot water supply

Treatment 3: control

Initial data gathered showed that animals reared in Treatments 1 and 2 grew faster than the control (see Table 7).

Table 7. Initial and final measurements of crocodile hatchlings reared in water temperature regulated tanks(Lagrada 1998)

	INITIAL			AFTER 3 MONTHS		
	T1	T2	T3	T1	T2	T3
Body weight (g)	64	64	61	177	241	94
Total Length (cm)	26	27	26	42	45	33
Snout vent length (cm)	12	12	12	20	22	16
Head length (cm)	4	4	4	6	6	4

- **Stocking**

A total of ninety one *C. mindorensis* hatchlings (8 months of age)ranging from 230 to 880 grams in body weight or 44 to 68 cm. In lengths - were subjected to different stocking densities. The group was divided into small-medium size class (mean BW = 300) and medium-large size class (mean BW = 530) before they were distributed to rearing tanks of different stocking densities (see Table 8).

Table 8. Mean body weights of crocodiles reared in different stocking densities(Sumiller, 1998)

MEDIUM-LARGE				SMALL-MEDIUM			
Tank No.	No. per tank	No. per m2	Ave. BW (g)	Tank No.	No. per tank	No. per m2	Ave. BW (g)
HB071	12	10	530	HB076	6	5	300
HB072	10	8	530	HB065	8	6	300
HB073	8	6	530	HB066	10	8	300
HB074	6	5	530	HB067	12	10	300
HB075	4	3	530	HB068	15	12	300
Total	40				51		

⇒ Husbandry support

The animals were fed with minced meat fortified with vitamin and minerals. They were kept in fiberglass tanks which were always cleaned the day after feeding. The lids of the pens were covered with sacks and heat bulbs were placed provided to increase the temperature of the tank.

Initial results show the following:

- Growth rates were high at lower and higher stocking densities (10 and 5 animals per sq.m.) for the medium-large group (Table 9).
- For those reared in low stocking density (3 crocodiles per sq.m.), the environment provided the space for one hatchling to display territorial instinct and dominant behaviour resulting to the killing of all its pen mates.
- Growth rates were high at higher stocking densities (10 and 12 animals per sq.m.).

Table 9. Average growth rates of crocodiles reared at different stocking densities (Sumiller 1998)

MEDIUM-LARGE						SMALL-MEDIUM					
Animals per tank	Animals per m2	Ave. BW (g)	Percent Increased	Ave. TL (cm)	Percent Increased	Animals per tank	Animals per m2	Ave. BW (g)	Percent Increased	Ave. TL (cm)	Percent Increased
4	3	740	0	67.3	7	6	5	410	39	56	14
6	5	810	54	67	15	8	6	400	34	55	17
8	6	770	47	67	15	10	8	400	35	54	11
10	8	620	12	62	6	12	10	490	68	58	18
12	10	860	62	67	18	15	12	550	83	59	18

- **Nutrition**

Studies were undertaken to investigate the feed and nutritional requirements of *Crocodylus mindorensis*. Among the studies were:

1. The growth performance of *C. mindorensis* hatchlings utilizing mixed feed rations

Hatchlings were assigned to four dietary treatments such as combined pork and chicken heads, carabeef and chicken meat, pork and chicken meat, and pork and carabeef. Results indicated that combined chicken meat and carabeef likewise pork and carabeef significantly yielded better results considering the total length of the *C. mindorensis* hatchlings. However, no significant differences in weight gain of *C. mindorensis* hatchlings fed with different feed combination were found. Therefore, *C. mindorensis* hatchlings can utilize feeds efficiently given different feed combinations (Zabala 1998).

2. Protein requirement of *C. mindorensis* hatchlings

C. mindorensis hatchlings averaging 71.5-180.9 grams body weight were used and fed diet containing 50.97% crude protein. Feeding period and fecal collection lasted for seven days. Results revealed an average of 95.94% protein digestibility of *C. mindorensis* hatchlings. The digestible protein requirement for *C. mindorensis* hatchlings was 48.90%. Therefore, formulating feed for *C. mindorensis* hatchlings should contain at least the required value to satisfy the protein requirement of *C. mindorensis* hatchlings (Zabala 1998).

3. Determination of the presence of amino acid in *C. mindorensis* meat using paper chromatography

Results showed that *C. mindorensis* meat sample has only eight kinds of amino acids. These are the: phenylalanine, norleucine, leucine, isoleucine, methionine, norvaline, valine, and alanine. Ethanol and water as one solvent was used and butanol, acetic acid and water as the other solvent. Further study is recommended with emphasis on procedures to be adapted (Zabala 1998).

4. Determination of the minimum vitamin requirement of *C. mindorensis* hatchlings

Sixty (60) *C. mindorensis* hatchlings were used and fed with pork for ten months. Results revealed that those hatchlings given a diet with vitamin supplement of 0.5% feed weight had higher body weight gain compared to those fed diets without vitamins, and with vitamins at the rate of 1% and 2% feed weight throughout the feeding period. Hatchlings fed diets of 0.5% feed weight had consistently higher total length compared to other treatments. The differences between treatments with regards to body weight and length were significant.

Based on the body weight gain, *C. mindorensis* hatchlings should be given vitamins early in life. The minimum amount of vitamin that can be given is 0.5% (which contains 1,575 I.U. Vit. A; 450 I.U. Vit. D_3; 0.525 I.U. Vit. E and Vit. B-complex with higher amount of Vit. B_2) of feed weight when given the VL strength as the brand of vitamins (Zabala 1998).

6. Confirmation of the presence of pepsin and trypsin in the C. mindorensis was done. Samples of stomach contents and feces were examined and found to have pepsin and trypsin in the body of *C. mindorensis* (Zabala 1998).

7. Observations on feeding behaviour as displayed by *C. mindorensis* hatchlings and juveniles

Observation was limited to 128 hatchlings and 72 juvenile *C. mindorensis*. Crocodiles were given feed allocation of 3% of their body weights and fed three times a week. Manifestations such as aggressiveness in feeding, running and hiding when the caretaker is approaching, and while waiting for food to be placed in feeding troughs were observed. Mostly the animals will rush to get to the feed and immediately return to the water where they will finally eat the food. Some are shy feeders that tend to move slowly towards the food location where others are taking in their feed. Juveniles hustle toward the food. Mostly the aggressive ones are the bigger animals. The weaker ones will just wait until there is anything left. Some late moving animals were observed to grab the food protruding from the mouth of those who have already taken their food. A well-documented account of the feeding behaviour of *C. mindorensis* can be of great importance as far as the conservation and management of the animal is concerned. Knowledge on feeding behaviour would complement the analysis of data in studying the various aspects of the animal (Zabala 1998).

8. Feed Conversion Rate by Class

The feed conversion rate of *C. mindorensis* bathclings, juveniles, sub-adults and breeders were studied in 1992. It was observed that hatchlings had the highest average FCR, feeding rate, and intake rate as compared to the older crocodiles. As the animal ages, its feed intake decreases thus the lower FCR. Physiologically, the bigger the animals, the slower the basic metabolic rate (BMR) that is why they feed less in terms of amount and frequency.

- **Diseases and Clinical Cases**

<u>Clinical cases involving the freshwater species of crocodiles from 1987-1997</u>

A total of 96 clinical cases involving the *C. mindorensis* were noted from 1987 to 1997. Of the total, 40 cases were traumatic in nature, 5 metabolic (runt syndrome), 1 nutritional (calcium deficiency), 10 congenital, and 16 dermatologic. The overall mortality rate in clinical cases had been placed at 14.58% (14 out of 96). Most mortalities in patients involved those with congenital lesions (n=7) and malnutrition (n=3).

Trauma cases usually involved lacerations due to fighting with only one case exhibiting skull fracture. Lacerations were sutured close when possible. In some cases of dermal laceration/abrasion which present problems in their closure, the wounds were left to granulate. Skin closure was previously done with unabsorbable suture. Since 1995, however, cyanoacrylate adhesive had been utilized with relative success.

The runt hatchlings were previously treated individually with parenteral administration of multivitamins. As of 1997, however, identified runts were now routinely segregated and placed in tanks provided intermittently with warm water. This therapeutic regimen appeared to have produced good results as of writing. Other clinical problems observed in hatchlings were that of the golf ball yolk syndrome. Still others included congenital anomalies, e.g., incomplete closure of body cavities, cleft palate.

It was interesting to note that dermatologic cases have not been encountered in recent past even without any distinct change in management. It was quite possible that these dermatologic cases had been due to poor conditions observed in their previous locations and which have been improved in their present location.

Majority of *C. mindorensis* mortalities belonged to the hatchling class as illustrated in Figure 5. Deaths in this class were often caused by thermal stress and steatitis among others. In relation to this, the runt syndrome in hatchlings had been speculated to be a form of chronic thermal stress. Juvenile mortalities had also been tentatively diagnosed as steatitis and thermal stress. On the other hand, breeder and sub adult mortalities were most often due to trauma incurred during fights.

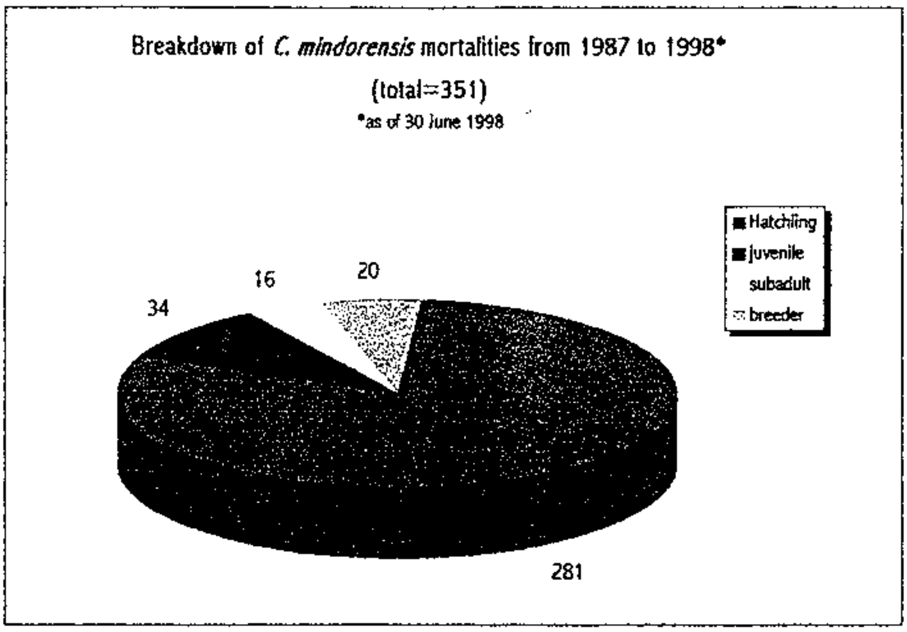

Fig. 5. Graph showing the mortalities of C. mindorensis from 1987-1998 (Aquino, 1998)

It was noteworthy that necropsy of runt mortalities in the recent past revealed no intestinal parasites. An also notable finding was that other anatomical anomalies often ran concurrent with cleft palate cases. In fact, necropsy of two cleft palate mortalities have revealed unpaired kidneys.

Treatment Studies

a. Use of cyanoacrylate adhesive for skin closure *in Crocodylus mindorensis* and *C. porosus*

The use of cyanoacrylate adhesive (Mighty Bond®[3]) in skin closure in three (3) *Crocodylus mindorensis* and two (2) *C. porosus* of varying age was relatively successful. Keloid formation, handling time and stress due to handling was reduced. No adverse effects were noted. However, since efficacy could only be evaluated through ocular inspection, the degree of success could only be approximated (Aquino 1998).

b. Surgical removal as treatment for unabsorbed yolks in hatchlings produced at the CFI

Thirteen (13) hatchlings (7 *C. mindorensis*; 6 *C. porosus*) presented to the Crocodile Clinics Unit from July 1995 to December 1996 were tentatively diagnosed with golf ball yolk syndrome. Their yolks were surgically removed and examination of the yolk sac contents revealed blood clots, congealed or petrified yolk either in combination or alone. Out of these cases, eight (8) patients (3 *C.*

mindorensis; 5 *C. porosus*) successfully recovered from the surgical procedure. The syndrome was thus speculated to be caused by physical obstruction. Other possible factors such as infection and trauma were also considered (Aquino 1998).

SPECIES IDIOSYNCRASY

During the course of captive breeding of Philippine crocodiles, peculiar behaviour and reproductive characteristics were observed. Some of these are:

1. Incompatibility

Although this also happens in saltwater crocodiles, *Crocodylus mindorensis* have exceptionally high incidence of fighting resulting to traumatic physical injuries and deaths (Table 10). There is a marked increase during the pairing and start of the breeding season when breeders are starting to adjust to each other.

Table 10. Number of cases of aggression among breeders which result to wounding and death (Sumiller 1998)

Year	No. of Paired Breeders	No. of Cases Traumatic Wounds	No. of Cases Death	Percentage (%)
1993	23	8	0	34.78
1994	24	10	0	41.67
1995	22	14	2	63.64
1996	22	14	3	63.64
1997	26	16	2	61.54

The occurrence of such behavior had no specific period of time. It may happen during courtship, during nesting, and post nesting. Females are usually the victims although there were isolated cases of male victims.

Husbandry practices being done to deal with the problem are the following:

a. Females are first introduced to the pen at few weeks before the introduction of the male to allow to establish her own territory.
b. Teeth are sometimes cut by filing.
c. Fighting/Incompatible pairs are immediately separated before serious injuries occur.
d. Victims are treated and allowed to recuperate before they are again paired.
e. Late pairing
f. Separation of breeders after the breeding season

2. **Multiple nesting or "double clutch"**

Peculiar to this species also is the case of multiple nesting behaviour observed in some pairs. Clutch sizes do not vary very much. However, fertility and hatching rates varied wherein it was observed that the first clutches of eggs have higher rates of hatching over the second clutches.

Table 11. Cases of multiple nesting (Sumiller 1998)

Year	No. of Paired Breeders	No. of Cases		Nester	Clutch Size		Days	Fertility Rate		Hatching Rate	
		No.	%	S.I.	1st	2nd	Interval	1st	2nd	1st	2nd
1991	19	1	5.26	134	29	10	79	96.55	80.00	78.57	50.00
1992	15	1	6.67	131	24	23	151	87.5	60.87	23.81	78.57
1993	23										
1994	24	1	4.17	135	23	24	192	100	79.17	95.65	42.11
1995	22										
1996	22	1	4.55	135	24	28	135	95.83	89.29	91.30	72.00

The second clutch is normally laid five to six months after the first clutch.

3. **Hole nesting and decoy mound nesting**

Another form of idiosyncrasy of this species is hole nesting and decoy mound nesting behaviour displayed by at least four (4) active female breeders. Three females were observed first forming their mound nests before laying their eggs in a hole dug-out of the loose soil in their pens. This diversionary tactic is believed to be their natural defense mechanism to protect their eggs.

Table 12. *C. mindorensis* females which displayed hole nesting behavior (Sumiller 1998)

Female SI No.	Year	No. of Eggs	Fertility No.	%	Hatchability		Survival Rate	
					No.	%		%
132	1995	18	12	66.67	11	91.67	11	100.0
27	1995	16	13	81.25	9	69.23	9	100.0
134	1995	21	21	100	1	4.76	0	0.0
395	1998	25	22	88				
Total		80	68		21		20	
Mean				83.98		55.22		66.67

4. **Congenital anomaly**

A peculiar congenital anomaly was particularly observed in the progenies of breeders from Bacolod City and Negros Occidental. Hatchlings were noticed dying few days after hatching. Necropsy results reveal incomplete closure of the hard palates technically known as "cleft palate". Fertile eggs from the same clutch which failed to hatch also reveal the same fatal abnormality. These particular group of breeders are being subjected to vitamin supplementation study.

INFORMATION, EDUCATION AND COMMUNICATION STRATEGIES

Many Filipinos view crocodiles negatively. In promoting their conservation and sustainable use, it seems that negativity rules. But the good thing is that CFI capitalizes on all these negatives. The challenge lies in turning them into something positive.

Along these lines, CFI's IEC program have made important headways in educating the public about the real characteristics of crocodiles and their ecological and economic importance as well as disseminating appropriate information about the activities and objectives of the project.

Since 1988, the Institute has produced and distributed at least 225,000 printed information materials such as brochures, posters, calendars, cards, profiles, and periodic reports. The quarterly official publication CFI News was distributed to research and government institutions in the Philippines and abroad. Starting 1998, CFI News and Research Bulletin (a biannual publication) will be circulated every July and January in place of CFI News.

Video documentaries in English and Filipino for adults and children, slide presentations in English and Filipino not to mention radio plugs were also produced. Two plugs were produced in coordination with the Philippine Broadcasting System. They are still being aired free of charge in 25 radio stations all over the country.

Press releases about CFI's activities and accomplishments are also written regularly for the media. CFI enjoyed extensive coverage in the local, national and international print and broadcast media these past years. Popular TV shows and influential TV networks have also featured the project in their programs.

In Palawan, the Philippine crocodiles conservation project site, IEC campaigns are being extensively done. Numerous information campaigns have been conducted in crocodile-inhabited areas and schools all over Palawan thereby educating tens of thousands of Palaweños about crocodile conservation and the CFI project. Almost all of the southern and the northern municipalities accessible by land have been covered. Only a handful of island municipalities remains unreached.

And if the partial result of the survey on the impact of the information campaign is any indication, the impact has been positive. Based on tabulated 1,348 questionnaires of students and teachers all over Palawan, 95.70%of the respondents agreed that crocodiles should be conserved, 83.53% answered that they support CFI's conservation efforts, 82.49% replied that there has been a positive change in the way they perceive crocodiles, and 91.25% said that they liked the information campaign.

IEC campaigns were conducted in other parts of the country as well. They consisted of video/slide presentations, lectures on crocodilian myths, facts and figures, and open fora. Places with community television were given CFI documentary films for public viewing. Filipinos in other parts of Luzon and the Visayas and the Mindanao areas got informed and educated through the tri-media-- radio, television and print.

Based on CFI experience, wary human beings can be converted into believers of and partners in conservation given scientifically-backed, economically-sound reasons why and how man and crocodiles mutually benefit from coexistence.

Also part of the IEC program is participation in trade and tourism fairs as well as other exhibits. CFI has been participating in the annual Philippine Travelmart of the Department of Tourism as part of the Palawan delegation since 1991. A CFI booth was also one of the attractions during the past annual Agro-Industrial Trade Fair of the City Government of Puerto Princesa marking its city fiesta and foundation anniversary celebrations.

Moreover, since 1995 March 6-11 is declared Crocodile Conservation Week in Puerto Princesa City. This annual seven-day celebration is made possible by Resolution 946-95 passed by the City Government of Puerto Princesa in support of crocodile conservation efforts. Essay writing and painting contests, conservation quiz shows, open house, and demonstrations of crocodile handling and restraining techniques are some of the activities during the week-long festival.

The misinformed and the uninformed usually think crocodiles are ferocious and dangerous because of their relatively ugly and fearsome visage. So how do you make a crocodile "appealing?" Use a mascot. A crocodile mascot can take the edge (or at least some part of it) off the usual preconceived negative notions about crocodiles because it is touchable, huggable and funny. The use of mascot coupled with extensive and intensive IEC campaigns is proving effective to the project. CFI experiences showed that contrary to the common notion that mascots are child stuff, adults also very well identified with Crokee probably not only through the excitement and enjoyment of their children but by looking at Crokee through the eyes of the child in them. It appears a cuddlesome albeit quite big (202 cm tall) fellow is hard to resist.

Crokee is being given maximum public exposure. The mascot was introduced to the school children of Puerto Princesa during the promotional activity "Crokee Goes to Schools". CFI has also identified festivals, holiday celebrations, town fiestas, and other

Crokee is being given maximum public exposure. The mascot was introduced to the school children of Puerto Princesa during the promotional activity "Crokee Goes to Schools". CFI has also identified festivals, holiday celebrations, town fiestas, and other conservation-related activities where Crokee can play a part. These appearances are expected to endear Crokee, the mascot, and ultimately the real crocodiles to the public.

Free lecture-guided tours around the Institute for tourists, students, academicians, technocrats, government employees and top brass, media persons, politicos, diplomats, other VIPs and celebrities are also conducted year round. CFI is open to the public from Monday to Saturday.

Before a tour commences, visitors are briefed about crocodile conservation and sustainable utilization and the CFI project to make their experience substantive. Exhibition and lecture rooms were put-up and video documentaries are shown to visitors before the actual tour.

Promotional materials like streamers and billboards are also prominently displayed on strategic locations. CFI believes it is not enough for domestic and foreign tourist to "just see" crocodiles. In many battles to combat extinction, an informed public is indeed the strongest weapon.

Taking advantage of teachable moments and opportunities is preached and practiced by CFI. One excellent example is CFI's "toilet humor" information campaign. Crocodilian facts related to excretory and reproductive organ functions are presented, tastefully and humurously.

The increasing number of guests who visit CFI annually have made it a must-see. For the past five years now, CFI is probably the No. 1 tourist destination in Palawan, the Philippines' Last Ecological Frontier, averaging more than 40,000 visitors annually.

ANNUAL NUMBER OF CFI VISITORS

Year	Number
1987	634
1988	5,219
1989	6,993
1990	24,564
1991	13,219
1992	21,139
1993	25,604
1994	31,567
1995	37,725
1996	42,611
1997	63,596
TOTAL	272,871

But more important than the numbers is the fact that all CFI visitors are educated about crocodiles and the CFI project. The result of all these activities is a significant rise in the level of public awareness and appreciation of these much maligned and misunderstood species.

POPULATION PROJECTION

The future of this conservation endeavor is greatly dependent on the number of crocodiles as a foundation stock that can be secured and produced in captivity. It would thus be helpful to visualize the future and explore it by forecast.

A forecast is hereby attempted to project the *Crocodylus mindorensis* population to see if there is a good future. This forecast will be based mainly on three major assumptions: the current trends of captive breeding, hypothetical standards, and the projected schedule of maturity of potential female breeders.

In addition to the existing population of female breeders, new potential female breeders were identified and their year of sexual maturity and reproductivity were projected. These female breeders and potential breeders were utilized as the basis of computation for projecting crocodile production as they produce eggs which in turn will be used as production indicator (see Table 13).

Table 13. Projected female breeder population (existing + potential breeders)

Year	No. of Females
1995	26
1996	41
1997	49
1998	105
1999	141
2000	157
2001	173
2002	189
2003	205
2004	221
2005	237

Two breeding standards were used: the present standard or "CFI Trend" and the hypothetical standard or "Target Standard". Obviously the "CFI Trend" will be based entirely on records of CFI experience, while the hypothetical standard or "Target Standard" is the ideal which CFI is aiming to attain (Table 14).

Table 14. Breeding standards

Parameters	Mean CFI Trend	Target Standard
Breeding Rate	71.24	70
Clutch Size	27.00	30
Fertility Rate	61.56	80
Hatchability Rate	44.50	80
Survival Rate	67.41	90

Breeding factor (B_f) for both standards were derived using the following formula:

$$B_f = B_r \times C_s \times F_r \times H_r \times S_r$$

This simply means the hatchling index per female breeder. Therefore, CFI Trend would be 3.56 and 12.00 for Target Standard. Using this breeding factor (B_f) as a multiplier, population was projected annually based on the projected female breeder population (Table 12).

Ex. Annual crocodile production = B_f x number of breeders

Therefore, for the period of eleven years (1995-2005) if all available breeders will be utilized productively, it is projected that CFI will be able to attain a total *C. mindorensis* population of 5,570 using the Trend and 18,768 using the Target.

Table 15. *Crocodylus mindorensis* population projection from 1995 to 2005

Year	No. of Breeders	Breeding Factor		Projected Production	
		Trend	Target	Trend	Target
1995	26	3.56	12.096	93	312
1996	41	3.56	12.096	146	492
1997	69	3.56	12.096	246	828
1998	105	3.56	12.096	374	1260
1999	141	3.56	12.096	502	1692
2000	157	3.56	12.096	559	1884
2001	173	3.56	12.096	616	2076
2002	189	3.56	12.096	673	2268
2003	205	3.56	12.096	730	2460
2004	221	3.56	12.096	787	2652
2005	237	3.56	12.096	844	2844
Total				5,570	18,768

Population projection based on Trend which is actually based on the poor breeding performance of *C. mindorensis* is very conservative. Because of this, there is a strong tendency to surpass the Trend because of improving husbandry practices as can be proven by the production results of 1995-1997 (Table 16).

Table 16. *Crocodylus mindorensis* comparative production performance (Actual vs. Trend and Target)

Year	No. of Breeders	Trend	Target	Actual
1995	26	93	312	160
1996	41	146	492	253
1997	69	246	828	248

This result of the forecast is highly encouraging. It promises a new hope. Given the proper support and cooperation by the Philippine Government and its people, the Philippine crocodile may once again bounce back and thrive in some of their former habitats.

FUTURE PLANS

- **Comprehensive Research and Management Plan**

Objective:

To organize a concerted effort towards the conservation and management of *Crocodylus mindorensis* both in captivity (farms, private collections, zoos, and research institutions) and in the wild.

Scope of Work/Activities:

1. Register/Inventory all crocodiles in captivity i.e. farms, private collections, and zoos at national and international level;
2. Establish a national working committee which will tackle matters and concerns about its farming, conservation management, and research and development;
3. Establish a criteria, rules and regulations about acquiring crocodiles for various purposes i.e. scientific research, collection, exhibition, and others in relation to related laws, ordinances, and administration orders and policies; and
4. To serve as an advisory body to the Protected Areas and Wildlife Bureau of the Department of Environment and Natural Resources on matters and concerns related to crocodile management.

- **Establishment of Crocodile Sanctuary**

Objective:

To conserve crocodiles in their natural habitat preferably in declared protected areas.

Scope of Activities:

1. Conduct population surveys;
2. Conduct sanctuary suitability assessment;
3. Conduct information and education campaign to promote the social acceptability of crocodile sanctuary establishment;
4. Conduct community organization and public relation works;
5. Secure the approval of the project from the Protected Area Management Board of a particular protected area; and
6. Re-stock and monitor and manage the crocodile population in the sanctuary.

- **Verification Survey and Actual Habitat Surveys**

Objective:

To verify/confirm the presence of remnant crocodiles in their habitats based on the historical and current sites.

Scope of Activities:

1. To once again verify the presence of crocodile sightings in their known habitats;
2. To confirm current verbal reports about the presence of crocodiles in some lesser known habitats in the country;
3. To come up with a scientific system of reporting actual sightings;
4. To survey and assess the viability of habitat areas with confirmed crocodile population; and
5. To propose an action and management plan in viable habitats.

- **Registration of *Crocodylus mindorensis* as a Commercial Species**

Objective:

To register with CITES as a commercial captive breeding operation for *Crocodylus mindorensis* upon the production of F_2 generation in captivity.

Justifications:

1. CFI as a research and captive breeding facility has been producing the species since 1989;
2. That pure F_2 generation will soon be produced using F_1 breeders;
3. That sustainable utilization of *C. mindorensis* as a commercial species will help ensure species conservation in the country as it will encourage people to participate and support projects with environmental and economic importance;
4. That projected population will only be attained if *C. mindorensis* are farmed out; and
5. That a certain fraction of captive bred will be used to restock sanctuary/ies to restore wild population.

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CROCODILE CONSERVATION AND DEVELOPMENT IN VIETNAM

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Introduction

Sustainable economic development is a political imperative of the Vietnamese Government and an ever-present reality that characterizes the Vietnam of the 1990s. Indeed, one of the principal motives, that stimulated the Government of Vietnam to accede to CITES in 1994, was the desire to trade legally in captive-bred specimens of Appendix I-listed crocodiles. This paper describes the present status of crocodiles in the wild, crocodile breeding facilities and measures for the protection and development of these resources in Vietnam.

The Crocodile Resource

Two species of crocodiles - the saltwater crocodile (*Crocodylus porosus*) and Siamese crocodile (*Crocodylus siamensis*) occur naturally in Viet Nam. In the past the saltwater crocodile occurred mainly in coastal estuarine habitats from Vung Tau to Kien Giang Provinces in southern Viet Nam, and in Con §ao, Phu Quoc Islands. This species is greatly feared by people who fish in the rivers and swamps. Overhunting and habitat loss have resulted in a serious decline in the numbers of *C. porosus*. According to hunters and local people the numbers of this species in the wild are less than 100 animals. Crocodylus porosus can exceed 4 metres in length. Females deposit 25-50 eggs in a nest constructed of dried and rotten grass and leaves. The saltwater crocodile is regarded as endangered in Viet Nam with only a small number of solitary individuals remaining in remote forested areas of Uminh swamp.

The Siamese Crocodile (*Crocodylus siamensis*) is distributed in suitable inland freshwater bodies in southern and central Vietnam. This species is common and distributed in rivers and deep streams that persist through the dry season. The species concentrates in deep lakes and ponds such as Lac Lake, upper Krong Pach Lake (§aclak Province), crocodile pool (Khanh Hoa Province), Crocodile Swamp (§ongnai Province). This species is abundant in Vietnam. It has been estimated that approximately 200 animals still occur in Tayson Lake and about 2000 in Lac Lake. Although is seems as though *Crocodylus siamensis* continues to exist in the wild, the pressures of an expanding human population and the associated loss of habitat have seriously affected the distribution and population densities of this species.

Both species are believed to persist in areas of suitable habitat within protected areas in southern and central Viet Nam (Figure 1), however the extent to which these areas receive adequate protection and the level and manner of management that is being applied the by the Forest Protection Department is unclear. Populations of both species of crocodiles in Viet Nam are under considerable and increasing pressure, especially given the transitional economy of the country as it develops into a free market economy. Populations in the wild continue to decline due to hunting for meat and export of skin. Suitable riverine habitat is contracting as a result of logging, urbanisation and vegetation clearance for plantation forestry and agriculture. The conservation of wild populations of *C. siamensis and C. porosus* and effective management of crocodile breeding farms has become a problem for Viet Nam that requires the development and application of policies and strategies for effective implementation of CITES that are tailored to suite the social and economic conditions that characterise Viet Nam.

In 1985 a group of 100 Cuba Crocodiles (*Crocodylus rhombifer*) were imported into Viet Nam as a gift from the Cuban Government. Because of the absence of any single facility capable of housing these animals, the Government of Viet Nam distributed the animals to different farms for breeding (Hanoi Zoo, Saigon Zoo, Da Nang, Ca Mau and Nha Trang). The housing facilities of most recipients are poor and are not suitable for breeding this species and the surviving specimens originally imported remain as solitary animals. Nevertheless, several establishments (*eg* Dong Tam Reptile Breeding Farm and Saigon Zoo and Botanical Gardens) have managed to breed this species with the native *C. siamensis* to produce hybrid progeny. Although Saigon Zoo has retained all hybrid progeny which are presently on public display, the reported presence of hybrid animals on some crocodile farms (Gorzula, 1997) is evidence that some hybrid specimens have been distributed among the network of developing farms.

The view expressed by Gorzula (1997), that there is little likelihood of these hybrid crocodiles escaping and becoming established in the wild and representing a threat to the conservation of existing populations of *C. siamensis*, is supported. In the unlikely event of escapes from crocodile farms, it is extremely unlikely that the escapee animals would survive being captured or killed by local people. Furthermore, the majority of crocodile farms are located within ready commuting distance from Ho Chi Minh City. None appears to be located in close proximity to areas where *C. siamensis* is known to persist.

It is not clear whether any specimens of *siamensis/rhombifer* hybrids have reached reproductive maturity or whether these hybrids are mature but sterile and thus incapable of producing second generation progeny. However, it is very important to document the present distribution of hybrid animals on existing crocodile farms particularly from the standpoint of managing the future development of crocodile farming in Vietnam, particularly if the Government introduces a re-stocking program to augment wild populations of *C. siamensis*. The responsible authorities should undertaken a survey to identify and document the presence of hybrids and isolating them at pure *C. siamensis*.

The Crocodile Farming Industry.
Commercial crocodile farming in Vietnam is restricted to the warmer and more humid climate of southern and central Vietnam (Table 1).

Table 1. Crocodile Holding Facilities in Vietnam

Facility	Location	Quantity
Ca mau town	Ca mau	40
Thot not	Can tho	44
Can tho town	Can Tho	100
Tay ninh	Tay Ninh	244
La nga	§ong Nai	344
Bui Van Do	An Giang	31
§ong Tam	Tien Giang	30
Vinafor	§ong Nai	10
Thu Duc	§ong Nai	332***
Suoi Tien	HCM City	400***
Sai gon Zoo	HCM City	30***
Binh Quoi	HCM City	20
§am Sen	HCM City	68
Can gio	HCM City	25 (C. porosus)
Thanh Thuan Farm	HCM City	70***
Truong son	Buon Ma Thuot	30

*** Breeding farms

Captive breeding of crocodiles in Vietnam is a relatively recent phenomenon and undoubtedly reflects the transition of Viet Nam towards a free market economy. Crocodile farming, as currently practised in Viet Nam is broadly similar to the farming model that has evolved and applied universally by all countries that breed crocodilians in captivity. The development of and dependence on family operated "satellite farms" as ancillary rearing and/or breeding operations is an adaptation that provides immediate revenue. This management strategy has the added advantage of precluding the large amounts of food species that are required for commercially efficient growth of farmed livestock. There is a thriving trade between farms in live hatchling *Crocodylus siamensis*. Specimens command as much as USD100 each. Breeding farms regularly dispose of hatchling crocodiles to these continuously-establishing "satellite farms". The development of this farming system in Viet Nam and neighbouring Cambodia appears to have been heavily influenced by the system that operates in Thailand.

The future development of the reptile (*ie Crocodylus siamensis* and *Python molurus bivittatus*) breeding industry, particularly if the structure that is evolving is retained, has the potential to produce large numbers of specimens - well in excess of the quantities able to be consumed by the international market. The commercial viability of reptile farming relies of maintaining a high unit value for the product that is being marketed. Over - production will undoubtedly result in a reduction in the unit value of the marketed products. In keeping with the political priority of the Vietnamese Government to achieve sustainable economic development, the industry, in collaboration with the Forest Protection Department, must address this issue through long-term strategic planning either to limit overall production of commodities or develop new export markets for a broader range of products.

In January 1998, at the request on industry representatives, the Ho Chi Minh City office of the FPD convened a meeting of interested reptile breeders for the purpose of assessing the feasibility of forming an industry association. At this meeting, the decision was taken to establish the Association of Wildlife Breeders of Vietnam in April 1998. This decision represents a positive move by the industry and one which, if developed and constituted correctly, will play an important role in promoting a responsible approach by its members to the commercial use of wildlife resources. This will, in turn, advance the long term commercial sustainability of the reptile breeding industry. The association plans to develop a strategic plan for breeding industry for marketing products in accords with the principles of sustainable economic development.

Conservation of crocodile in Vietnam

The crocodile population in Vietnam is under considerable pressure The number of animals in the wild declines yearly due to hunting for meat and export and habitat loss by logging for plantation and agriculture. The conservation of crocodiles in the wild and management of crocodile farming management in Viet Nam presents a problem concerning policy and strategy of nature protection in Viet Nam. Nevertheless, the Vietnamese Government is committed to protect and conserve natural resources in general and crocodiles in particular.

Legislation and Administration.

The conservation and management and management of wildlife in Vietnam is the responsibility of the Forest Protection Department (FPD) within the Ministry of Agriculture and Rural Development (MARD). Viet Nam acceded to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) on 20 January 1994. When acceding to CITES the Government of Viet Nam nominated the Forest Protection Department as the CITES Management Authority and two Hanoi-based research institutes as the CITES Scientific Authorities of Vietnam - the Institute of Ecology and Biological Resources (IEBR) and the Centre for Natural Resources and Environmental Studies (CRES) of the Vietnam National University.

There are several separate legal instruments by which the Government of Vietnam regulates the use of native wild plants and animals.

- Government Decree No.77 of 29 November 1966 on Forest Management and Protection and Management of Forest Products
- Law of 12 August 1991 on Forest Protection and Management
- Council of Ministers Decree No.18 of 17 January 1992 on the Management and Protection of the List of Precious Plants and Animals.
- MARD Circular No.13 of 12 October 1992 on Guidelines for Implementation of Ministers Decree No.18.
- Government Decree No.62 of 5 January 1995 on conditions for Trade and Non - Trade in Precious Plants and Animals, Their Parts and Derivatives (Commodities)
- MARD Circular of 5 February 1996 on Guidelines for Implementation of Government Decree No 62

- Prime Ministerial Instruction No 359 of 29 May 1996 for the Protection and Development of Wild Plants and Animals.
- FPD Official Notification No. 280 of 25 October 1996 on Capture and Use of Group I and Group II Plants and Animals.

The present legislation available to the CITES Management Authority is considered adequate to regulate the crocodile farming industry. Both species of crocodile native to Viet Nam are classified as Group I precious species under the Council of Ministers Decree No.18 of 17 January 1992. Article III of Decree No.18 prohibits hunting of Group I species. Section III of FPD Circular of 5 February 1996, (which implements Government Decree No.52 of 5 January 1995), prohibits the export of Group I species. This export prohibition is reinforced by Section IV of the FPD Official Notification No.280 of 25 October 1996 which prescribes the conditions under which Group I and II animals may be farmed. It provides for the FPD to permit the use of these species for development. All other uses require the permission of the Minister for Agriculture and Rural Development. The FPD appears to possess the authority to inspect facilities (Article IV of MARD Circular No.34 of 12 October 1992 refers). The FPD is required to register wildlife breeding farms, issue each establishment with a stock record book and conduct inspections of registered facilities. However, the FPD needs to implement a standardised system of record keeping and enforce compliance among wildlife breeding farms in Vietnam.

The breeding farms are required to accurately record inventories of new stock (eggs and births, acquisitions and disposals). The responsible authorities should control and monitor relevant documents, stock records and livestock. The CITES Management Authority of Viet Nam (FPD) and the CITES Scientific Authorities (IEBR and CRES) are responsible for monitoring and controlling all crocodile farming activities. These organisations also cooperate in applying measures to protect the resource in the wild.

Domestication of crocodile.

Crocodile farming has the potential to make a significant contribution to the Vietnamese economy and "domestication" of crocodiles commenced during the French colonial period for the production of crocodile leather. The fisherman catch crocodiles from the wild and raise them in cages and pools. Crocodiles were kept as "backyard" animals. Private holding farms became popular in South Vietnam, especially in Mekong Delta area and crocodile stocks reached more than 2000 animals. Consequently many of the present-day farmers have acquired some experience oil production, hatchling, nursing, feeding, leather production and marketing. These activities will form the basis for a future commercial industry. In this respect, it will be important to harmonise exploitation and conservation.

The Government of Vietnam places high priority on the conservation of nature in general and crocodiles in particular. The Government has promulgated regulations and decrees for habitat protection, prohibition of hunting and trade in animals from the wild. As mentioned above the Government of Vietnam conducted a meeting of crocodile farmers and interested reptile breeders. The meeting provided a forum for the exchange of information on captive management and production of reptiles, as well as establishing close cooperation between scientists and farmers.

Vietnam has established a system of protected areas which has developed from 87 sites in 1986 to more than 100 in 1997. Eight of these sites provide important wetland habitat and protection for crocodile populations (*eg* Yok Don NP, Cattien NP, Krong Pach NR, Sa Thay NR, Tay Son NR, Lak Lake NR, Ca Mau NR, Can Gio Culture Park).

Natural resources are viewed by the Government of Viet Nam as playing an important role in the sustainable economic development of the country. Accordingly, the Government of Viet Nam has adopted a policy of harmonising exploitation and protection of crocodile resources. The crocodile raising in South Viet Nam is developing and increasing income for local people. Viet Nam acceded to CITES in 1994 and desires to trade legally in captive-bred specimens of *C. siamensis* according to the provisions of CITES. For this purpose Viet Nam must enforce relevant legislative requirements for breeding farms to maintain detailed records of farmed crocodiles. The breeding operations must comply fully with the direction to supply information on the operation and livestock and satisfy all the requirements of CITES. Viet Nam should ensure that a strong positive relationship between crocodile farming and conservation of wild population is established and maintained. For instance, the crocodile farming industry needs to be strictly managed to ensure that production systems are restricted to pure *C. siamensis* such that farmed stock can be used as a source of animals that is able to be used in any restocking program.

Remarks and recommendations.

Crocodylus porosus and *Crocodylus siamensis* are known to persist in Viet Nam in areas of suitable habitat. However both species are currently listed in the endangered category with a high priority for conservation action.

Crocodile farming in Viet Nam is still largely in developmental phase and many operations have not yet achieved captive production of crocodiles. However crocodile farming facilities in Viet Nam are generally good. In the near future Viet Nam will prepare a document to register selected captive breeding operations with the CITES Secretariat in accordance with Resolution Conference 8.15.

- Viet Nam should develop, for consideration by the CITES administration, a proposal to undertake population surveys to assess the status of both species of crocodiles in areas of suitable habitat in South and Central Viet Nam.

- When registered with the CITES Secretariat, the CITES Management Authority of Viet Nam should ensure that all registered operation comply with CITES requirements and that a system of regular inspections is implemented.

- Viet Nam should collaborate with international institutions and organisations in obtaining information, technology and funds for develop the potential viability of crocodile economy in Vietnam.

Current Status of Crocodile in Cambodia in Captivity and in the Wild[1]

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Abstract

The Kingdom of Cambodia is home to two endemic crocodile species, the Freshwater crocodile (*Crocodylus siamensis)* and the Saltwater crocodile (*Crodylus porosus).* The former is still present in the wild in 14 provinces all over the country and is widely bred in captivity in 8 provinces along the rivers and especially in and around the Tonle Sap Great Lake. Whereas, the latter inhabits the estuarine areas far from human settlement. It is thought to be nearly to extinct with few specimens being sighted in the coastal areas.

Wild crocodile conservation is hampered by the lack of awareness among local communities and other stakeholders because of the long run civil war that caused overall poverty in the country. While Freshwater crocodile farming the majority of which are small scale develop rapidly because of its economic viability in the early 1990s.

Since after the general election in 1993, Cambodia has acceded to several international conventions, especially recently last year to CITES. At the mean time, the local market is saturated which may affect future development of the country as well as the national economy.

This country paper presents the status of crocodile conservation in Cambodia and highlights the marketing problem of farmed crocodile skins and derivatives that cannot be exported arising from the country's late accession to CITES. It also requests the on-going assistance of the CITES Secretariat and cooperation of interested Parties to enable the Government of Cambodia to develop the necessary understanding, technical and administrative capacity to discharge its obligation as a Party to the Convention.

1. Introduction

Cambodia is a low-lying country located almost entirely in the catchment area of the lower Mekong basin. During the monsoon, the Mekong feeds into the Tonle Sap Great Lake causing the flow of the Tonle Sap to reverse. The Mekong-Great Lake system creates a vast inland water bodies comprising numerous rivers, lakes and permanent potholes extended into flooded forests, grassland, ricefields and swamps (Ahmed et al., 1996).

[1] Contribution to the 14th Working Meeting of the Crocodile Specialist Group in Singapore, 14-17 July, 1998.

The inland water bodies of Cambodia especially the Tonle Sap Great Lake are famous in fish production in Southeast Asia (Bardach, 1959) which constitutes a good source of feed for crocodilian species to inhabit permanent lake and flooded forest around the Tonle Sap Great Lake and along the Mekong River as well as in the up-land water bodies in the mountainous regions bordering the central plain.

Two species of crocodile are endemic to Cambodia: the Siamese or freshwater crocodile *(Crocodylus siamensis)* and the Saltwater crocodile *(Crocodylus porosus)*. The former is still largely distributed in the wild around the Tonle Sap Great Lake region and along the Mekong River. They are also being largely bred in captivity in many provinces around the Great Lake. While the latter is reportedly to inhabit the coastal and estuarine areas far from human settlement in Koh Kong province. Chu Ta Kuan, a Chinese observer to Cambodia in the 13th century appreciated the natural resource rich of this country including crocodiles (Siam Society, 1992).

Cambodia began domesticating crocodiles since the 10th century, a little bit before the Angkor time. The Western Mebon ruin of crocodile pen in the Baray reservoir in Siem Reap province is a legacy. But commercial crocodile farmings were operated in around 1945 during the French colonial time. However, this business could not develop very much because the government had not issued any specific strategy or plan for development.

As a result of poor management, crocodile population has been exploited to the brink of its sustainability and became endangered until nowadays. To conserve crocodile from being over-exploited and being extinct, and to control crocodile farming, the government has issued the Code of Fisheries and regulations during the 1940s bringing crocodile under conservation.

After the collapse of the Khmer Rouge regime, the Fiat-Law no. 33 of 9 March 1987, confines the management and conservation of crocodile under the responsibility of the Fisheries Department of the Ministry of Agriculture, Forestry and Fisheries.

2. Crocodile Conservation Efforts

In the past crocodiles inhabit nearly every important water body of the country. Many places and water bodies were named related to crocodile existence and its activities. In the Great Lake and along the Tonle Sap river, one has to be cautious when fishing or navigating.

As human settlement developed, habitat encroachment and hunting put more pressure on crocodiles and put them to the brink of their home range. As the skin business increased, crocodiles were hunted heavily and became endangered resulting from poor management that has been paid to this keystone species.

To deal with the decline in crocodile population and to protect them from being over-exploited and extinct, the government has issued the Code of Fisheries during the 1940s to strictly prohibit indiscriminate crocodile exploitation.

During the genocidal regime of the Khmer Rouge, all fisheries management activities were abolished. There was a totally open access nature for all resources without limit. The then Khmer Rouge government appointed many groups of fishers with the only appointed duty to fish to supply the then farmers'cooperatives. It is worthwhile to note that, during that time, no one could get access to fishing unless they faced death penalty.

The Fisheries Fiat-Law enacted in 1987 is one step back to crocodile conservation in which it is strictly prohibited all activities related to catching crocodile. Article 19 defines clearly the need for permit to establish crocodile farm and article 18 strictly prohibits catching, selling, transporting of crocodile and 3 more endangered fish species unless special permission from the Department of Fisheries is provided.

Also with the concept of crocodile and other wildlife conservation, Cambodia attended the Earth Summit in Rio de Janeiro in June 1992 and ratified the Convention on Biological Diversity on 29 February 1995. Accession to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) on 2 October 1997, represents a further expression of the Cambodian Government's commitment to conserve its natural biological diversity and manage its components for sustainable use. For conservation reason, on the 1st day of November 1993, King Norodom Sihanouk promulgated a Royal Decree designating protected and multi-purpose use areas encompassing many of the crocodile distribution area. However, this Royal Decree left many crocodile habitats outside the protected zones.

In addition to the effort undertaken by the Government side, crocodile farmers, with the leading activity of the author in 1995, have united and formed the "Crocodile Farming Development Association of Cambodia". Furthermore, they have committed to contribute a reasonable amount of money to undertake surveys and regular monitoring activities. In addition, they are willing to keep 3 to 5% of their production to release back to the natural habitats to contribute to the conservation of the species in the wild.

3. Present Status of Crocodile Population in Cambodia

Although the Department of Fisheries, as the government authority responsible for the management of crocodile in Cambodia, employs qualified biologists, no scientifically-based, quantitative surveys have been undertaken to determine the size and distribution of either species of crocodile in Cambodia. The absence of scientific data on *Crocodylus siamensis* in Cambodia has been due principally to the more than two decades of war and internal conflict that has characterized Cambodia since the early 1970s. Many regions of Cambodia where *Crocodylus siamensis* and *Crocodylus porosus* are believed to persist have been unable to be surveyed by government officials because of the Khmer Rouge. Even in more recent years, when the territory held by the Khmer Rouge guerrillas in Cambodia became contracted to the northwest of the country near the Thai border, it remained unsafe to visit many areas because of the danger of detonated unexploded ordinance. The political imperative of the Cambodian Government to manage and use its fishery resources for the benefit of the Cambodian people and economic development of the country has dictated that available resources within the Department of Fisheries be allocated to developing and managing commercial fisheries. These financial resources have not been adequate to undertake research and other management-related activities on crocodile in the absence of any legal export trade.

3. 1 Distribution of *Crocodylus siamensis* in the wild

Historically, *Crocodylus siamensis* occurred in areas of suitable freshwater habitat throughout Cambodia, neighboring Thailand, Lao PDR and Vietnam. In recent years, specimens resembling the species have been found to occur in the Indonesian province of East Kalimantan on the island of Borneo (Jenkins, 1998). The identity of animals identified as *Crocodylus siamensis* reported in the literature as occurring in the Indonesian archipelago requires further study and clarification.

Although there are no scientific data on number of crocodiles in the wild, there are many places of suitable wetland habitat remain and it is widely known among rural fishing communities and regional fisheries officers that *Crocodylus siamensis* is present in many of these locations. Many sightings of juvenile animals are reported to provincial fisheries officers annually by fishermen. Based on advice information obtained from numerous sources, Thuok and Tana (1994) concluded that the species persists in remote areas in about fourteen (14) provinces (see table 1 and figure 1). Many of these areas coincide with the extensive network of protected areas (see figure 2) that have been established in Cambodia in accordance with the Royal Decree no. 126 of 1 November 1993 on Creation and Designation of Protected Areas. The present size and trends of the population is not known. Nevertheless, *Crocodylus siamensis* is regarded as an endangered species in Cambodia which must be studied to ensure that this resource is managed properly and conserved. The proposed registration of selected crocodile farms and the development of a legal export trade in skins and other products derived from farmed *Crocodylus siamensis,* within the framework of CITES, will provide the necessary economic and political incentives for the Government of Cambodia to invest in field studies and monitoring for the species conservation.

The Department of Fisheries has obtained the commitment of the Crocodile Farming Development Association of Cambodia to allocate funds for undertaking a survey programme of a wild populations as a first step to establishing an on-going monitoring programme. Revenue obtained from the legal export of farmed crocodile skins will provide the necessary financial incentive for the industry contribution.

Table 1 Distribution and Estimated Number of *Crocodylus siamensis* in Cambodia

No.	Province	Estimated numbers	Habitat types
1	Stung Treng	3,000-4,000	Sekong and Sesan regions
2	Battambang	1,500-2,000	Flooded forest in lots no.1-2-3-4
3	Siem Reap	1,000-1,500	Flooded forest in lots no. 1-2-3-4-6-7.
4	Kompong Chnang	200-300	Flooded forest in lots no. 1-2-3
5	Kompong Thom	150-200	Seine Stream Region
6	Kompong Speu	150-200	Triangle region of 3 provinces Pursat, Koh Kong and Kompong Speu
7	Pursat	200-300	Flooded forest in lots no. 1-2-3-4-5-6.
8	Kompong Cham	80-100	Fishing lot no. 2
9	Kampot	50-100	Anlongvil, Prek Krieng, and Stung Kach
10	Koh Kong	300-500,	Mondol Seyma district, Kbal Chhay
11	Svay Rieng	4-20	Kompong Trach river
12	Kandal	10-20	Prek Phnouv
13	Kratie	80-100	Chhlong
14	Preah Vihea	2,000-3,000	Swampy areas near Thbeng Mean Chey

According to the information given by people from Koh Kong province, some Salt water crocodiles *(Crocodylus porosus)* are still inhabiting the coastal and estuarine areas of Koh Kong province. Apart from the wild population, 4 head of *Crocodylus porosus* were brought to Siem Reap Crocodile Farm for research as well as tourist attraction and education purposes.

3. 2 Status of *Crocodylus siamensis* in captivity

3. 2. 1 Background

Cambodia has begun domesticating crocodiles since the 10th century as it is proved by the West Mebon ruin (crocodile pen) in Western Baray. That was probably the rearing of a small number of crocodiles for leisure by the then King's daughter.

Before 1970, crocodiles was farmed by a number of fishers in and around the Tonle Sap Great Lake, especially in Siem Reap, Battambang and Kompong Thom provinces. But at that time, this kind of industry has been latent because of the authority's neglect. So far, there is no adequate information about crocodile raising nor are there specific raising strategies and policies for crocodile raising development and management (Thuok, 1993).

From 1975 to 1979, when the Khmer Rouge took off the power, all private businesses were then prohibited. All crocodiles were then gathered to put into 2 collective farms, the largest one in Siem Reap province and the other in Kompong Chhnang.

After the enactment of the Fisheries Fiat-Law in 1987 and the free market economy of the country was settled down in around 1988, the privatization of the production sector was promoted with considerable haste and private sector involved in all scales of crocodile farming began to expand rapidly. In 1989 and 1990, the increased market demands for crocodile resulted in extremely high value of new-born crocodiles - a one month old baby crocodile commanded a value of USD2-300. Because of its feasibility and profitability, farming of crocodile became very popular in many communities especially the communities surrounding the Tonle Sap Great Lake area.

The total number of crocodile farms in Cambodia in 1997 is 429, the majority of which are small scale. The total number of breeding stock is 3,179 head consisting of 2,128 adult females (about half the number of females are still very young) and 1,051 adult males (table 2) with a yearly production of 13,165 offsprings in 1997. The number of hatchlings produced per year is expected to increase considerably as long as the actual rearing stocks (6,940 sub-adults) reach reproductive maturity.

Ratanakorn (1992) classified the crocodile farming in Cambodia into 3 classes, according to number of crocodiles kept, the size of the farm and management.

Class 1: Small scale, small number of crocodiles kept in earthen or concrete ponds or wooden cages. This class is the majority and maybe called " family farming" because of the small size and small number of crocodiles. There are around 386 small scale farms in Cambodia scattered along rivers and around (even in) the Tonle Sap Great Lake. Many Cambodian villagers living along rivers keep 1-2 pairs of breeders in an area at the back of their houses. Family scraps and fish from the river and lake provide a good source of food. Fish are either caught or purchased at a low price. Some fishermen who live on floating houses or boats prefer to keep crocodiles in wooden cages that float beside their houses or boats. In January, during the dry season, adult crocodiles are transferred into wooden enclosures on dry ground for mating, nesting and egg-laying. They are returned to the floating cages with the onset of wet season rains when the water level of the lake rises and inundates the surrounding low-lying land.

Class 2: Medium scale, 20-70 animals kept in collective concrete ponds. These farms are often located close to rivers or streams. This class of farms applies more sophisticated farming methods often using enclosures which feature a concrete pond and concrete or wooden fences. Crocodiles are housed together in social pond with 1:2 to 1:3 male-female ratio. Nesting materials of sod brought from the natural habitat are provided for nesting. There are 25 farms of this class.

Class 3: Large scale farms typically comprising a large area and number of crocodiles of more than 100 animals. The breeding stock is kept in concrete enclosures with concrete ponds. Nesting pens are provided with sod and decomposing vegetation brought from the natural habitat. These farms hatch crocodile eggs in artificial nests that imitate natural conditions. During the nesting season, eggs are collected early the day after laying and re-buried in the artificial nests. There are only 18 farms of this class.

3. 2. 2 Breeding Performance in Captivity

Adults crocodiles are kept in social groups for breeding. The male to female ratio is generally 1 : 3, although some farmers keep animals as separate pairs in concrete or wooden enclosures. The water depth of each pond varies from 0.5 to 1.5 metres. Courtship commences in early January and may extend to late March-early April.

In captivity, *Crocodylus siamensis* reaches reproductive maturity in 6-7 years. Upon attaining reproductive maturity, initial clutch sizes contain few fertile eggs. The number of eggs and percentage of fertile eggs increase with the age of female until a mean clutch size of 30 is reached. Under favorable condition, reproductively mature females are capable of producing up to 50 eggs annually.

Eggs are incubated as separate clutches under conditions that imitate natural conditions. Usually, in the early morning, after eggs are laid, females crocodiles are transferred to another pen and the eggs are collected and removed to the egg incubator, being careful to retain their original orientation in the nest. Eggs are placed into 2-3 layers into a cavity, approximately 20-30 cm wide and 30 cm deep, that is excavated in the incubating soil. Before placing the eggs into the cavity, a handful of dry leaves and grass are placed at the bottom of the hole. Additional dry leaves and grass are placed on top of the batch of eggs before they are covered with a compacted mound of soil approximately 15-20 cm high. Each artificial nest is separated by approximately 0.5 metre.

Incubation occurs in artificial hatcheries which are basically large wooden pens containing humus soil and decomposed vegetation. This soil is approximately 1 metre higher than the surrounding ground. Eggs are placed into cavities that are approximately 0.5 m deep and packed with soil into small mounds. Incubators are often fenced with barbed wire to a height of 1.6 metres. A canal approximately 0.5 metre wide and 0.3 metre deep is dug around the hatchery to retain water during the dry season.

Incubators are left open to natural sunlight from morning to noon. When it becomes too hot, coconut palm fronts are placed over the incubator to form a roof to shade the nest from direct sunlight and reduce the temperature. Incubators are exposed to rainfall during the incubation period. During the dry season, (especially in April) if there is no rain, water is sprinkled over the nest and in the canal that surrounds the incubator/hatchery. Sprinkling with water increases the moisture content of the rotting vegetation and assists decomposition. Soil temperatures are monitored daily (every two hours in Siem Reap Crocodile Farm) by reading the thermometer that is permanently inserted in the ground at the same depth as the egg clutches. The temperature varies between 28.5 °C during the first month of incubation (March) to 33 °C in April and May.

3. 2. 3 Hatching

Hatching typically occurs after 68-75 days of incubation. When ready to hatch, the hatchling crocodiles are quite audible when the nest is approached. At this time, eggs are excavated and offspring emerge, using their egg tooth to slice the shell membrane and then puncture the hard shell from the inside. If a hatchling is not able to puncture the shell and emerge by itself, assistance is given by manually cracking the egg-shell.

3. 2. 4 Neonate husbandry and management

After hatching, neonates are washed and transferred, as a small group of approximately 30 individuals, into separate (30 x 60 cm) wooden nursery cages. Deformed neonates and those that have not completely absorbed yolks are kept separately and exposed to adequate sunlight, at about 31 °C, until the remaining yolk is fully absorbed.

During the first year, especially the first two months, baby crocodiles of about 28 cm are very difficult to husband. They suffer stress or shock when exposed to loud noise, bright light, temperature variation or changes in their diet. Under these circumstances, baby crocodiles tend not to eat any food for many days - a condition which leads to stunting in some cases. During the period of cool weather (December-February), hatchling crocodiles tend to eat little because of lower body temperature that results at this time of the year. To overcome this, many farms keep hatchlings in a warm environment by heading them with charcoal fire stoves or where available, electric lamps.

Since becoming operational in the early 1990s, many Cambodian crocodile farms, in the absence of a legal export trade in skins, have depended on the sale of live animals internally within Cambodia as a source of revenue. In 1989-1990 there was a high demand within Cambodia for live hatchlings and a single animal was valued at USD250. Since that time, with increasing number of hatchling being produced each year, the market for live animals has become saturated. In 1997, the unit value of a hatchling had declined considerably to USD20-25. This year again, with very limited demand, the unit price still goes down to USD15-18. Depending on market demand, hatchlings are sold within 6 months of hatching. Farmers used to sell the majority of hatchlings produced each year - keeping only a small number of "healthy" animals for raising through to breeders. Therefore, the mortality was low, ranging from 0-7.5% during the first year. Some farmers have kept 50-100 head of hatchlings for fattening without experiencing any mortality. Among 200 hatchlings kept in Siem Reap Crocodile Farm, fifteen animals died during the first year - corresponding to 7.5 percent mortality.

3. 2. 5 Feeding

Hatchlings that are fed with freshly-caught small whole fish (sometime live) mixed with shrimps, exhibited increased growth during the first 2-3 months after hatching. The size of fish is increased gradually, as crocodiles increase in size. During the second and third year, crocodiles are fed daily with as many fish as they are able to consume. By practicing this feeding technique, many farms have recorded considerably faster growth rates. Under these conditions, young crocodiles are able to reach 1.2 m during the first year - some even reach 1.5 m by the end of the second year. At the end of the third year, the mean size of the animals is 1.6-1.8 m. Some specimens exceed 2 m in length.

When the Government managed the two farms in Siem Reap and Kompong Chhnang, growth rates were considerably slower with animals only reaching 1.5 m long after four years. This growth rate was caused through poor husbandry techniques which resulted in large number of animals being maintained in over-crowded condition in small enclosures.

4. Problems Encountered

Regarding the conservation of crocodiles as was stated in the fishery law and the Royal Decree on creation and designation of national parks and reserves, the government faces a lot of difficulties in enforcing the conservation law because of the lack of awareness among local communities and other stakeholders. In this respect, the government does need the participation of local communities to protect and conserve this valuable resource. The communities also need some economic incentives from their participation.

One problem arising from crocodile farming development is the lack of reliable export markets because Cambodia had just become a Party to CITES for about 9 months and does not have export relation and experiences with any Parties yet. This problem may hamper crocodile farming development in Cambodia in the future and may affect the people's livelihood as well as the national economy if skins and derivatives could not be exported soon.

The lack of qualified professionals to conduct scientific researches and surveys on crocodile in the wild as well as in captivity to properly manage this resource is a second constraint to crocodile management.

5. Conclusion

Cambodia has experienced more than two decades of war and internal unrest which destroyed tremendously all super and infrastructure of the country. Since the war has ended, the national economy of this country relies mainly on foreign aids and international and bilateral or multi-lateral assistances. In addition to this, exports of agricultural products is another source of hard currency earning in which export of crocodile skins and derivatives may contribute an important percentage in the fishery sector.

Since after the 1993 UN sponsored general election, this country has been adhering with the international community and has participated in many international treaties and conventions such as the Earth Summit, the Convention on Biological Diversity (1995) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1997. Cambodia has been a Party to CITES for only about 9 months and as such has very little understanding of and no practical experience in implementing the provision of the Convention.

The CITES Management Authority of Cambodia requests the on-going assistance of the CITES Secretariat and cooperation of interested Parties to enable the Government of Cambodia to develop the necessary understanding, technical and administrative capacity to discharge its obligations as a Party to the Convention.

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Table 2 Locations, Number of Crocodile Farms, Breeding and Rearing Stocks in Cambodia (1997)

Provinces	No Farms	Adults	Females	Males	Sub-adults	Females	Males	Hatchlings	Total
Siem Reap	319	2,182	1,455	727	4,165	2,877	1,288	5,626	11,973
Battambang	55	449	309	140	1,292	943	349	4,404	6,145
Kompong Thom	20	130	95	35	165	110	55	500	795
Kompong Chhnang	22	140	101	39	962	701	261	1,630	2,732
Phnom Penh	3	150	100	50	120	90	30	780	1,050
Banteay Meanchey	3	30	12	18	20	15	5	84	134
Pursat	5	54	24	30	196	130	66	90	340
Kandal	2	44	32	12	20	12	8	51	115
Total	429	3,179	2,128	1,051	6,940	4,878	2,062	13,165	23,284

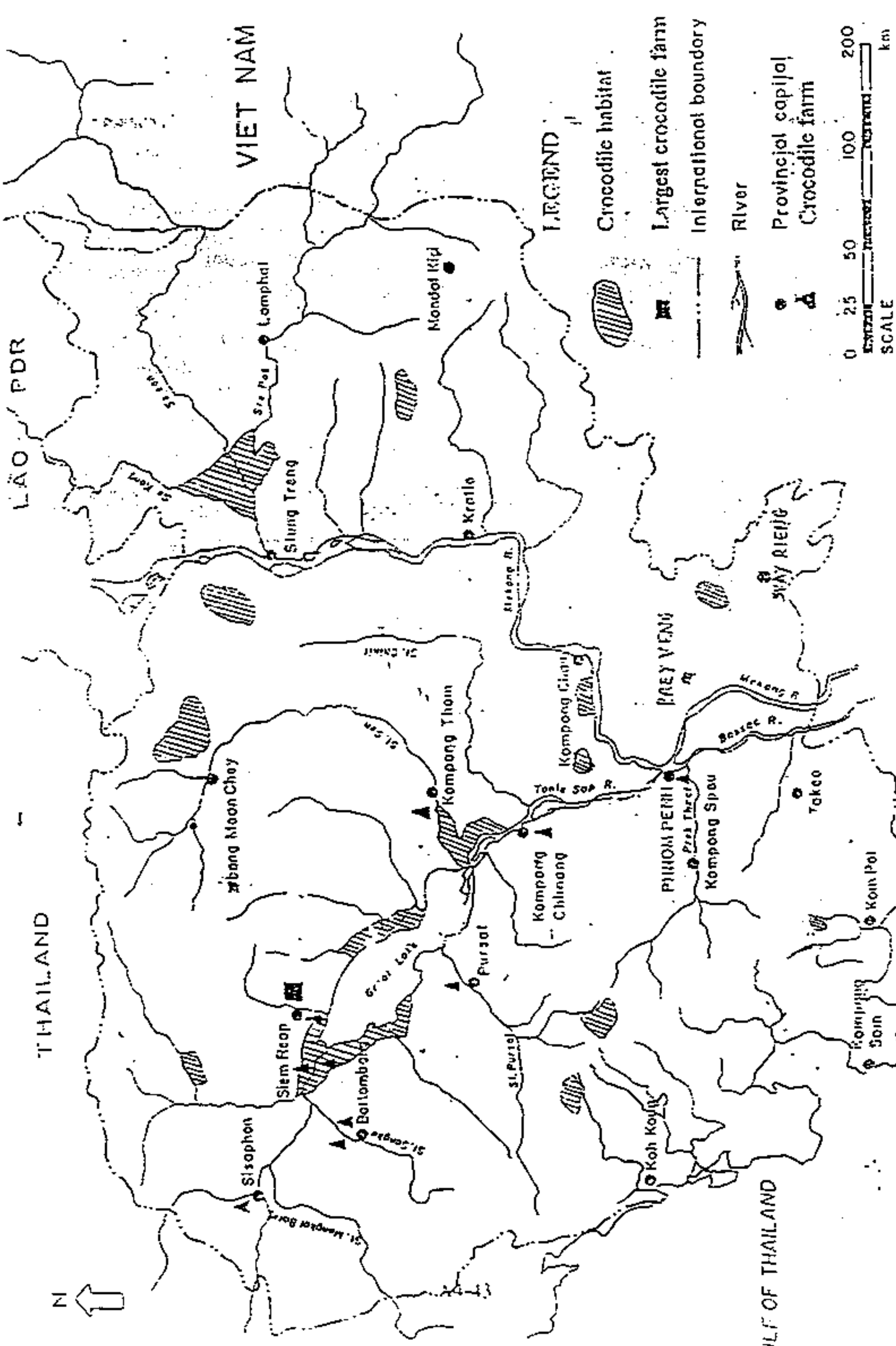

Fig. 1 Map of Cambodia indicating the distribution of wild crocodile and crocodile farms

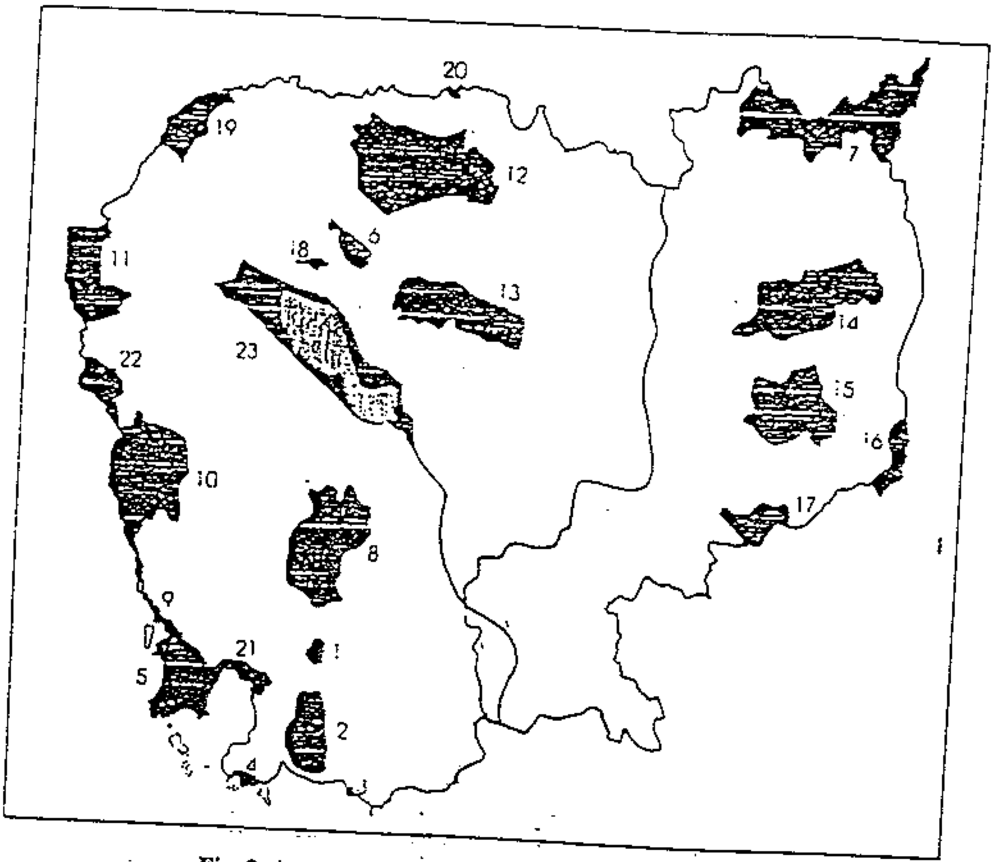

Fig. 2 Areas Designated as Protected Areas

NATIONAL PARKS
1. Kirirom
2. Phnom Bokor
3. Kep
4. Ream
5. Botum - Sakor
6. Phnom Kulen
7. Virachey

WILDLIFE SANCTUARIES
8. Aural
9. Peam Krasop
10. Phnom Samkos
11. Roniem Daun Sam
12. Kulen - Promtep
13. Beng Per
14. Lomphat
15. Phnom Prich
16. Phnom Nam Lyr
17. Snoul

PROTECTED LANDSCAPES
18. Angkor
19. Banteay Chmar
20. Preah Vihear

MULTIPLE-USE AREAS
21. Dong Peng
22. Samlaut
23. Tonle Sap

Environmental Contaminants as Concerns for the Conservation Biology of Crocodilians

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ABSTRACT: Historically, concerns for the fate and effects of environmental contaminants have not been a high priority for those concerned with the conservation biology of crocodilians. However studies of other groups of vertebrates suggest that this is probably a mistake. With advancing understanding of factors impacting crocodilian populations, it is becoming increasingly obvious that contaminants can have significant impacts upon a number of these species. There are three classes of environmental contaminants: radionuclides, heavy metals and organics, including the estrogen inhibitors. Radionuclides are generally the least important in terms of their overall impact upon global crocodilian populations. They are of concern only in certain localized areas such as those surrounding nuclear industrial facilities. Heavy metal contamination however occurs worldwide, and is of concern to many tropical populations of caimans and crocodiles inhabiting wetlands contaminated with mining effluents, particularly those associated with the extraction of gold and copper. Mercury contamination of alligator populations in the southeastern United States is widespread and may, under some conditions, limit the advisable consumption of alligator meat by humans in this area. Concern for the global impacts of anthropogenic estrogen inhibitors is of great interest in environmental toxicology today, and studies of the impacts of these contaminants upon the reproduction of American alligators (*Alligator mississippiensis*) were among the first to document the harm caused by these chemicals upon free-living wildlife.

This paper summarizes studies concerning the fate and effects of environmental contaminants upon crocodilians. This survey indicates a general lack of information regarding the importance of observed levels of contaminants in both individual animals and populations. Such information is essential for predicting how contaminants may be limiting population reproduction or viability, particularly in concert with habitat destruction, over-harvest and other limiting factors. This survey also reveals the importance of having a thorough understanding of the basic ecology, behavior and natural history of the animals involved, with this being particularly important for predicting the role that meat from some crocodilians could play as a potential vector of environmental contamination to the human food chain.

INTRODUCTION

Worldwide efforts to promote the conservation and recovery of crocodilian populations have historically focused on the issues of habitat loss and over-exploitation. Only recently, now that some of these species such as the American alligator have recovered stable numbers and demographics, has it been possible to evaluate the possible impacts, that environmental contaminants may also be having upon these populations. This situation is in sharp contrast to conservation concerns for other vertebrate predators such as birds of prey. The tendency of many environmental contaminants to biomagnify made studies in this area a primary focus of early efforts to halt population declines of these and other avian species. Indeed concerns about the global impacts of anthropogenic chemicals, particularly organic pesticides such as DDT, were at the forefront of much of today's environmental movement (Carson 1962). Subsequent management efforts based on the banning or reduction in the use of DDT and other pesticides resulted in dramatic recoveries of many avian predators. It thus became clear that these contaminants sometimes served as important limiting factors for such populations – a lesson that has obvious implications for the conservation of crocodilians today.

As our understanding of crocodilian ecology expands, it has become clear that few if any populations of these animals are immune from contaminant exposure. Even in the most remote habitats, crocodilians may be exposed to globally distributed atmospheric contamination including radionuclide fallout, pesticides, PCBs or heavy metals such as mercury. Additionally, crocodilians living near point-sources of contaminant release such as nuclear facilities, mining operations or areas of high agricultural chemical use are likely to show elevated body burdens of chemical contamination. What is notably lacking however, is an understanding of the impacts of these contaminants upon the individual animals and their populations. The unique physiology of crocodilians, which are largely poikilotherms but possess many unique attributes of homeotherms, makes it particularly difficult to predict the impacts which contaminants may have, by simply extrapolating from toxicological studies of common laboratory species.

It is the purpose of this paper to describe the major forms of environmental contaminants that may be of concern to crocodilians and their conservation. We summarize the scarce scientific literature in this field (Table 1) and attempt to develop some basic principles for understanding the impacts of environmental contaminants upon crocodilians and how these impacts may be minimized. Finally, we suggest directions for future research and indicate the need to integrate the results of such research with other studies of crocodilian biology, conservation and management.

As indicated in Table 1, the published information concerning environmental contaminants and their effects upon crocodilians is strongly biased towards the American alligator (*Alligator mississippiensis*). Of the publications located on this subject, 23/38 (61%) concern this one species alone, and 14/23 (61%) of the world's crocodilian species have no published information at all in this regard. Plainly considerable additional research still remains to be done in this area, particularly for those species found in the Old World tropics.

CLASSES AND CHARACTERISTICS OF ENVIRONMENTAL CONTAMINANTS

Environmental contaminants of importance to crocodilians may be grouped into three categories (1) organic chemicals including the so-called endocrine disruptors, (2) heavy metals, and (3) radionuclides. As will be shown below, substances in all of these categories may share certain characteristics in the ways in which they may be transported in ecological systems by both biotic and abiotic (physical) mechanisms – thereby becoming concentrated to some degree in the bodies of top carnivores such as the crocodilians. However, these categories also differ from one another in some important ways and thus will be discussed separately.

Organic chemical contaminants are organic carbon compounds. They are more similar to the body's biological molecules than are either heavy metals or radionuclides. They therefore have a greater tendency to become incorporated, often in inappropriate or harmful ways, into natural body processes. For example, organic contaminants that act as endocrine disruptors may mimic the actions of hormones and other regulators of the rates and sequences of internal physiological processes. These disruptive actions are often most notable when they occur during embryonic or other developmental stages where effects may linger long after the compounds have been eliminated from body.

Organochlorine chemicals such as DDT and its metabolites, particularly affecting top carnivores such as birds of prey, were among the first substances to be identified as environmental contaminants impacting the natural world as a result of human activities. This in turn produced a profound change in the general level of societal awareness and concern for environmental issues (Carson 1962). Later, the American alligator became one of the first free-living wildlife species for which field and laboratory studies documented the effects of organic chemicals acting as endocrine disruptors upon the embryonic development and hormonal control of the reproductive system (Guillette and Crain 1998). As indicated by the cases of the birds of prey and alligators cited above, some organic chemicals are highly resistant to environmental degredation. They thus may persist for long periods of time during which they or their metabolites tend to become biomagnified at higher levels of the food chain.

The use of some of the most notorious organic contaminants such as DDT and polychlorinated biphenyls (PCB's) has been banned in many countries including the United States. Although these chemicals were produced and released into the environment in significant quantities prior to the 1970s, the harmful residues and metabolites of these substances still persist in even the most remote parts of the biosphere today. Moreover some of these substances are still being used widely in some countries. Thus despite an early focus of both scientific research and public concern about these contaminants and their effects, crocodilian populations in many parts of the world are still vulnerable to their impacts. For example, Delany et al., (1988) found that detectable levels of DDT, DDD, DDE, dieldrin, heptachlor epoxide, lindane and PCB's persisted in the tail muscle of Florida alligators in 1985, over a decade after the use of some of those substances was banned in that state. Heinz et al. (1991) also found organochlorine pesticides and PCB's in the eggs of alligators from several Florida lakes in 1984 and 1985. DDT metabolites and heptachlor epoxide were also found in the eggs of Morelet's crocodiles (*Crocodylus moreletii*) in all three habitats surveyed by Rainwater et al. (1997) in Belize. In this latter study all eggs were collected from lagoons associated with areas of agricultural development – suggesting that use of pesticides or herbicides may have been a factor in the release and subsequent accumulation of these contaminants in the crocodile populations of the area.

Heavy metal contaminants are globally distributed as a result of releases from a variety of sources. These include mining and smelting operations, industrial effluents, paper production, trash incineration, agricultural drainwater and electric power generation using fossil fuels (Wolfe et al. 1998). Of particular importance to crocodilians in tropical riverine systems are point sources of heavy metals from areas of mining and extraction. Brazaitis et al. (1996) discuss the potential for the exposure of caiman populations to metals contamination associated with gold mining in the New World tropics. Bakowa (1996) and Figa (1996) describe research associated with concerns for the potential of copper mining effluents entering the Fly River system of Papua New Guinea to elevate the heavy metal contaminant exposure of aquatic biota inhabiting this watershed. Montague (1983) and Kula and Solmu (1996) indicate that this river system includes some of the most important habitat for crocodile populations in this part of the world.

The heavy metal of greatest concern to crocodilians is mercury. Mercury enters aquatic food chains as methylmercury which is produced by microorganisms acting upon inorganic mercury accumulated in sediments and soils (Jackson 1988; Wolfe et al. 1998). For reasons that are often not clear, methylmercury is particularly elevated in certain geographic areas such as the Everglades region of southern Florida (Ogden et al. 1974; Facemire et al. 1995). In this region, studies of mercury in alligators have produced one of the most extensive data bases for any single form of environmental contaminant in a crocodilian (Delany et al. 1988; Hord et al. 1990; Heinz et al. 1991; Heaton-Jones et al. 1997; Yanochko et al. 1997; Jagoe et al. 1998).

Some heavy metal contaminants, particularly mercury, are known to biomagnify, and the highest tissue concentrations are found in the highest trophic levels of food chains (Eisler 1987; Wolfe et al. 1998). As a consequence of its pattern of continuing bioaccumulation over the lifetime of even the longest-lived organisms, the highest levels of mercury contamination of crocodilians are invariably found in the oldest and largest individuals in the population (Yanochko et al. 1997; Jagoe et al. 1998). A combination of long life span and high trophic position thus combine to make crocodilian species one of the most sensitive "worst possible case" indicators of heavy metal contamination in aquatic systems throughout the world. Brazaitis et al. (1996) describe the contamination of two species of South American caiman populations and their riverine habitats downstream from gold-mining operations in Brazil (Table 1). The release of mercury into these habitats is the result of amalgam extraction of gold-bearing ores, with contaminated waste discarded back into the watershed. Mercury contamination has been reported by Malm et al. (1990) as much as 200 km downstream from the nearest such gold-mining operation.

Radioactive contaminants are a subset of metal contaminants. They are generally not encountered in crocodilian populations at levels that would make them a cause for concern. To be sure, global radioactive fallout from earlier atmospheric testing of nuclear weapons and accidents such as Chornobyl in the former Soviet Union have produced trace signatures of these contaminants that still persist in biota throughout the world today (Brisbin 1991; 1993). However the chief importance of these contaminants for crocodilian populations has been to serve as in situ tracers of ecological structure and function in the systems in which they are found. For example, the long-lived gamma-emitting radioisotope cesium-137 has been used to show that American alligators have one of the slowest rates of contaminant accumulation and turnover ever documented for any living organism (Brisbin et al. 1996). Studies with this same isotope have also shown that in an equilibrium state in a contaminated reservoir, free-living alligator populations incorporate within their biomass only a minute amount (less than 0.002 %) of the total inventory of this contaminant. In contrast, over 99 % of this contaminant is found in the sediments and water column, with only 0.4 % in all of the reservoir's animal species combined (Brisbin 1989). These same studies also showed that the alligators did not biomagnify cesium-137 above those levels found in their prey, in contrast to some other metals such as mercury. They also did not show a tendency to accumulate higher levels of cesium-137 contamination with increasing age and size. In this sense their cesium-137 contamination pattern was similar to that shown by yellow bullhead catfish (*Ameiurus natalis*) inhabiting this same reservoir.

Radioactive contaminants are generally an environmental concern only where their levels have been increased by nuclear weapons tests, nuclear industrial accidents or spills. Most all such sites are in the temperate zone of the northern hemisphere and the only one known to involve a crocodilian has been the United States Department of Energy's Savannah River Site (SRS) in South Carolina, USA. The American alligators resident on the SRS have been studied extensively for over 25 years (Murphy 1981; Brandt 1989; Brisbin et al. 1992; 1996). Long-term studies of the basic ecology, population biology, movement and behavior and of these alligators have served as the basis for the analysis and interpretation of the fate and effects of radioactive contaminants in these same animals (Brisbin 1989; Whicker et al. 1990; Brisbin et al. 1992; 1996). These studies have generally confirmed that the elevated levels of cesium-137 found in these alligators have had no detectable negative effects upon their health or population vigor. However, as will be discussed later, under certain conditions, some individual alligators can accumulate muscle tissue levels of cesium-137 that would make human consumption of their meat an issue of potential concern.

CROCODILIANS AS INDICATORS OF ENVIRONMENTAL CONTAMINATION

Contaminants such as organic chemicals or some heavy metals which biomagnify through the food chain show their highest levels in the tissues of the top predators. In such cases these animals may be used as sensitive indicators of these contaminants' occurrence in other parts of the environment. This principle resulted in the eggshell thinning of birds of prey becoming one of the important early warning signs of environmental contamination with DDT and other pesticides (Carson 1962; Anderson and Hickey 1972). Long-lived predators may be especially important in this regard since their contaminant burdens can represent integrated assessments of the environmental availability of contaminants such as pesticides or heavy metals over extended periods of time. As long-lived top carnivores in all of the habitats in which they occur, adult crocodilians are also likely to show any effects of such contaminants. Indeed data for American alligators (*Alligator mississippiensis)* living in Lake Apopka, Florida were among the first to demonstrate the impacts of estrogen inhibitors upon the reproduction of a free-living wildlife population (Gross et al. 1994; Guillette and Crain 1996; Guillette et al. 1996; Guillette et al. 1997). In this case abnormally low alligator clutch viability (Woodward et al. 1993) was the first early warning sign of contaminant impact and resulted in the alligator serving as an important "sentinel species" in this regard.

Despite the above considerations suggesting the appropriateness of adult crocodilians as indicators of levels of environmental contamination, a degree of caution must be incorporated into any effort to use these animals in this way. Some of the basic considerations involved in selecting any individual species or group of species as an indicator of environmental contamination levels have been summarized elsewhere (Brisbin 1993). As indicated in that study, one of the most important of these considerations is to determine whether contamination levels in the proposed species or species group actually correlates with contaminant levels in other components of the ecosystem which it inhabits. Although this has been done for some species of vegetation, invertebrates and fish (e.g. Anderson et al. 1973) such information has never been collected for any species of crocodilian and can only be assumed.

Finally, the value of any species as an indicator of environmental contamination depends in large measure on the amount of basic biological information and natural history, which is available for it. Nowhere is this truer for example than in the case of information on migration, movements and home range behavior, as pointed-out for example by Brisbin (1993) in the selection and interpretation of data from birds as indicators of environmental contamination. While not as mobile as birds, adult crocodilians such as American alligators can and do frequently move over extended distances (e.g. Brisbin et al. 1996). However under other conditions in other habitats adult alligators may also occupy relatively small "activity ranges" (Goodwin and Marion 1979), and in fact Delany et al. (1988) cite this characteristic as one of the features which they feel make alligators appropriate "indicators of local environmental pollution". Guillette and Crain (1996) provide evidence of the value of alligators as indicators of localized contaminant uptake and effects. They showed that the impacts of endocrine-disruptor chemicals upon the external genetalia of alligators found in the immediate vicinity of the site of a toxic waste spill were more pronounced than in other regions of the same Florida lake. Plainly, movement data, such as that which may be collected through the use of radiotelemetry equipment, must be considered before the full meaning of any given contaminant level can be properly interpreted in any given situation, when dealing with animals as potentially mobile as adult alligators.

EFFECTS OF ENVIRONMENTAL CONTAMINANTS ON CROCODILIANS

From the point of view of conservation concerns, the importance of understanding the uptake and concentration of environmental contaminants by crocodilians relates to the effects that these substances may have on the individuals in which they may accumulate. Although such effects are usually considered to be directly proportional to the level of the contaminant observed in the individual's body, such an interpretation is not always straightforward. Consideration must also be given for example to the amount of time that the individual has been exposed to the observed level of contamination. An older adult crocodile whose liver has been exposed to a mercury burden of 0.5 ppm mercury for the past 15 years for example, may have suffered more ill effects from this contaminant than a younger animal which had only recently arrived in a more contaminated habitat and accumulated a burden of 0.9 ppm mercury over a period of only several weeks. Here again, a thorough knowledge of the basic ecology, behavior and natural history of the animals in question is essential.

With the above in mind, the published world literature offers scant evidence that environmental contaminants have ever exerted a significant impact upon any crocodilian populations in terms of causing direct mortality. As will be discussed in more detail below, what unequivocal evidence there is for contaminant effects upon these reptiles under field conditions all involves reproductive impairment, and that mainly being the result of exposure to endocrine-disruptive organic chemicals. Moreover, beyond the level of impacts upon individual organisms, there is virtually no information concerning population-level effects of environmental contaminants upon crocodilians.

The three major classes of environmental contaminants vary widely in the degree to which they have been implicated as causative agents producing effects upon crocodilians. There is for example, no evidence of any effects whatsoever as the result of radionuclide contaminants accumulated by American alligators – the only species which has been studied in this regard (Brisbin 1989; Brisbin et al. 1992; Brisbin et al. 1996). Heavy metals however, particularly mercury, have been implicated as having possibly negative impacts upon crocodilians in several parts of the world. In light of the above caveats concerning the need for care in inferring contaminant effects without thorough information on the animals' basic ecology and natural history however, some of these implications of contaminant effects must be viewed with caution. News media for example, being aware of the elevated levels of mercury found in alligators from the Everglades region of south Florida, have described the poor body condition of these animals as being a condition in which, "Mercury pollution may also be involved." (Barr 1997).

Brazaitis et al. (1996) similarly suggest that mercury and lead contamination resulting from gold mining activities in Brazil may be negatively impacting caiman populations living downstream from these operations. These authors admit that, "The precise source of lead contamination in caiman in Brazilian gold-mining regions is as yet unknown . . ." and that "The short- and long-term effects of mercury and lead contamination and toxicosis on crocodilian populations is yet unknown." However they then go-on to suggest that, "it is reasonable to assume that a serious threat exists to those species' well-being and to the continued viability of populations, . . ." While this may well be the case, no mercury contamination levels were even determined for these caiman, being only available for their prey and the sediments of their riverine habitats. Under such conditions the conclusion that these contaminants do indeed pose a "serious threat" would be difficult to substantiate.

Subsequently, Brazaitis et al. (1998) refer to this same situation and describe caiman as being found "dying of pollution . . ." in these areas. This study again confirms that mercury contamination levels are known only for the habitats and not for the animals themselves and that above all, "the effect of mercury and lead on caimans is not known". They also suggest that "one can only presume that the metals are as detrimental to these creatures as to humans". That this is a poor presumption is shown by Wolfe et al. (1998). This review of the scant literature available for the effects of mercury on reptiles reported no effects of toxicity in snakes fed diets containing up to two orders of magnitude higher levels of mercury contamination than those which cause behavioral and/or reproductive impairment in birds and mammals. Controlled toxicological studies are thus needed before the levels of mercury and other metals which cause harm to crocodilians, can be determined with certainty. Until such information is available however caution must be used in attributing death or debilitation observed in given individuals.

In January 1996 a very large (total length 3.92 m) adult male alligator was found dead of unknown causes in the Par Pond reservoir of the Savannah River Site. Subsequent analyses of tissues from this alligator revealed wet-mass mercury levels of 3.48 ppm muscle, 33.55 ppm kidney, and 158.85 ppm liver. These extraordinarily high levels of mercury contamination, particularly that in the liver, are the highest ever reported in the literature for any form of free-living wildlife. They even exceed those levels known to be associated with lethality in controlled laboratory studies of mercury dosage of a wide variety of bird, mammal, reptile and amphibian species (Hall 1980; Wolfe et al. 1998). Under these conditions it would not be unreasonable to suggest the involvement of mercury contamination in the death of this alligator. This conclusion is further supported by this alligator's generally emaciated condition at the time of death, suggesting a general weakening of the animal during what must have been a long-term chronic exposure to this pollutant. In fact, this same alligator had been captured and marked over 20 years earlier in the same reservoir in which it subsequently died. For at least two of those years it carried a radiotransmitter confirming its continued residence in the reservoir which is known to show elevated levels of mercury contamination in both sediments and various forms of alligator prey (Brisbin et al. 1996; Yanochko et al. 1997). These facts further strengthen the possibility that the death of this particular alligator may be the first documented case of mortality of any individual crocodilian likely to be the result of environmental contaminant exposure. It is difficult to understand however, why many other alligators have inhabited this same reservoir for their entire lives without showing any apparent ill effects from contaminant exposure (Brisbin et al. 1992; 1996). Neither have any other alligators studied in this reservoir showed such extremely elevated levels of tissue mercury contamination, although most of the ones which have been studied have not been as large and thus presumably were not as old as the alligator which died (Yanochko et al. 1997; Jagoe et al. 1998).

The clearest case yet documented for the effects of environmental contaminants on free-living crocodilians has been the impacts of organic contaminants on the reproduction of alligators in Lake Apopka, Florida, USA. Field and laboratory studies of the reproductive impairment of the alligators of Lake Apopka will be described further in other papers in this volume. Briefly however it is important to point-out that the pollutants involved, which were largely pesticides from surrounding agricultural operations, effluents from a nearby municipal sewage treatment facility and contaminants from a major industrial pesticide spill (Gross et al. 1994), were largely endocrine disruptors which exert their greatest influence during embryonic development after having been incorporated into the egg (Crain et al. 1998). Heinz et al. (1991) studied this situation and concluded that, "it did not appear that any of the pesticides we measured [organochlorines] were responsible for the reduced hatching success of Lake Apopka eggs." Nevertheless, current thinking based on a number of years of both field and laboratory research have still concluded that endocrine-disruptor chemicals, possibly involving synergisms between pesticides and other contaminants such as PCB's, have been responsible for the observed impacts on alligator reproduction (Gross et al. 1994; Guillette and Crain 1996).

The expressions of these impacts upon lake Apopka alligators have been documented in a variety of forms. They include alteration of gonadal morphology and plasma sex steroid and hormone levels (Guillette et al. 1994; and Guillette et al. 1997, respectively), alteration of gonadal steroidogenesis (Guillette et al. 1995), and alteration in the size and degree of development of male external genetalia (Guillette et al. 1996). Effects of such reproductive impairment of individuals has also been expressed at the population level as declines in alligator population densities and shifts in population age structure (Woodward et al. 1993). Subsequent to their documentation in the lake Apopka alligators, similar effects of endocrine-disruptor chemicals have been found in other reptiles such as turtles (Guillette and Crain 1996), and concern has grown globally for the possibility of similar impacts occurring in a variety of vertebrate species including man.

Crocodilians as Potential Vectors of Contaminants To the Human Food Chain

Although there is a clear need for better information on the effects of various contaminants on crocodilians and other reptiles, there is sufficient data now to predict risks to humans that consume crocodilian meat from contaminated environments. Mercury, particularly in the methylated form that accumulates in fish and wildlife, is toxic to humans, with pregnant women and young children being at particular risk because of potential developmental effects. We estimated the amount of alligator meat that a regular consumer could safely eat per week (Table 2), based on published mercury concentrations in alligator muscle and reference doses (RfD's) for ingestion of methylmercury, as published by the World Health Organization of the U.N. and the U.S. Environmental Protection Agency (WHO 1990; EPA 1997). The WHO advises that 0.47 μg Hg per kg of body mass per day could be safely consumed over a lifetime. The U.S. EPA has adopted a more strict standard of 0.1 μg Hg per kg body mass per day. There is still debate over the relative merits of these standards (Egeland and Middaugh 1997), so we calculated consumption limits based on both standards for comparison. The calculations for maximum amounts that could be consumed per week assume (1) an adult body mass of 70 kg, (2) that all mercury in the alligator meat is methylmercury, (3) that 100% of the ingested methylmercury is absorbed (WHO 1990), and (4) that there are no additional sources of methylmercury in the diet. If the latter assumption is not true, then only lower amounts of alligator meat could be safely consumed. Likewise, if the body mass of an individual were less than 70 kg, a proportionally lower amount of meat would be considered safe.

While many of the above calculations are based on average values, it is important to recognize that individual animals in some locations can sometimes have much higher mercury concentrations, and thus it would be safe to eat far less meat from such individuals. For example, a large alligator found dead in Par Pond on the SRS in 1996 had about 3.5 mg Hg/kg wet mass in its muscle; by the WHO standard, it would be safe to consume only 54 g per week of this meat, while the more conservative EPA standard would allow consumption of only 14 g per week of meat at this concentration. Also, while the organs of alligators are seldom consumed, they usually contain far higher mercury concentrations than muscle (Heaton Jones et al. 1997; Yanochko et al. 1997; Jagoe et al. 1998). The liver of the alligator found dead in Par Pond in 1996 contained 159 mg Hg/kg wet mass; it would be safe to consume a mere 1.3 g per week of liver at this concentration using the WHO RfD value, and less than 1 g by the EPA standard.

Radiocesium in the diet of humans leads to increased risk of cancer. This contaminant may be of potential concern to humans consuming crocodilians from areas with histories of radioactive contamination, such as the SRS in South Carolina, USA. Although the SRS is closed to public access and there is no alligator hunting, larger alligators have been shown to be capable of leaving the site's boundaries and moving onto pulblic lands where they could be harvested as nuisance animals and their meat marketed for human consumption (Brisbin et al. 1992; 1996). To estimate the risk associated with consuming alligators from the SRS, we converted radiocesium concentrations in muscle as reported by Brisbin (1989) and Brisbin et al. (1996) to committed dose equivalents, using a value of 1.35×10^{-4} μSv/Bq of ingested radiocesium, as recently published by Sun et al. (1997). The International Commission on Radiological Protection recommends that the total dose from ingested radionuclides to the general public should not exceed 1 mSv per year (ICRP 1990). Assuming no additional sources of radionuclides to the diet, we calculated the amount of alligator meat that could be consumed from various SRS locations (Table 3). This table also includes data for an alligator removed from a highly-contaminated seepage basin at the SRS in late spring 1998. By ICRP standards, it would be safe to consume less than 4 kg of meat with this radiocesium concentration over the course of a year. In contrast, radiocesium levels in most alligators sampled at the SRS were much lower, and proportionally higher amounts of meat could be safely consumed.

Finally, it is important to realize that the individuals most likely to consume larger amounts of meat from crocodilians such as the alligators described above, would include subsistence hunters and fishermen who would be likely to also take-in elevated levels of the same contaminants from other portions of their diet as well (Jenkins and Fendley 1968). Estimations of the overall contaminant risks to humans consuming meat from crocodilians thus need to consider sociological and demographic factors for the target consumer population(s) as well as the levels of contamination in the animals being harvested for consumption.

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Table 1. Survey of the world literature describing the fate and /or effects of environmental contaminants in crocodilians.

Species	Location	Contaminant	Reference
Alligator mississippiensis	Florida (USA)	Mercury	Heaton-Jones et al. (1994) Heaton-Jones et al. (1997) Hord et al. (1990) Peters (1983)
	Florida (USA)	Metals & Organics	Delany et al. (1988) Heinz et al. (1991)
	Florida (USA)	Organics	Crain et al. (1998) Gross et al. (1994) Guillette & Crain (1996) Guillette et al (1994) Guillette et al (1995) Guillette et al (1996) Guillette et al (1997) Woodward et al. (1993)
	Georgia (USA)	Mercury	Ruckel (1993)
	South Carolina (USA)	Mercury	Bowles (1996) Rhodes (1997) Brisbin et al. (1996)
	South Carolina	Radiocesium	Brisbin (1989) Brisbin et al. (1996)
	South Carolina & Florida (USA)	Mercury	Yanochko et al. (1997)
	South Carolina, Florida, & Georgia (USA)	Mercury	Jagoe et al. (1998)
	Lousiana (USA)	Zinc	Lance et al. (1995)
Alligator sinensis	China	Organics	Zi-ming et al. (in press)
Caiman crocodilus	Brazil	Mercury & Lead	Brazaitis et al (1996) Brazaitis et al (1998)
	Surinam	Metals & Organics	Vermeer et al. (1974)
Caiman yacare	Brazil	Mercury & Lead	Brazaitis et al (1996) Brazaitis et al (1998)
Crocodylus acutus	Florida (USA)	Organics	Hall et al. (1979) Ogden et al. (1973)
	Florida (USA)	Metals	Stoneburner & Kushlan (1984)
Crocodylus moreletii	Belize	Mercury & Organics	Rainwater et al (1997)
Crocodylus niloticus	Zimbabwe	Metals & Organics	Phelps et al. (1986)
	Zimbabwe	Organics	Billing and Phelps (1972) Wessels et al. (1980)
Crocodylus rhombifer	Zoo	Lead	Cook et al. (1983)
Tomistoma schleglii	Zoo	Lead	Cook et al. (1983)

Table 2. Mercury concentrations in alligator meat in the southeastern United States, and calculated weekly consumption limits based on World Health Organization (WHO) and U.S. Environmental Protection Agency (EPA) reference doses for mercury in food.

	Total Mercury (mg/kg wet mass)		Amount that could be safely consumed per week on a regular basis (grams)	
Sampling Location	**Mean**	**Range**	**WHO standard**	**EPA standard**
Everglades, Florida[a]	1.30		150	38
Central Florida[a]	0.43		465	114
Okefenokee, Georgia[a]	0.19		1053	258
SRS, South Carolina[a]	1.08		185	45
Florida[b]	0.61		327	80
Florida[c]	-	0.39 - 2.92	68 - 512	17 - 125
Georgia[d]	-	0.1 - 1.4	142 - 2000	35 - 490
Everglades, Florida[e]	2.8		71	18

[a] data from Jagoe et al. (1998)
[b] data from Delany et al. (1988)
[c] data from Hord et al. (1990)
[d] data from Ruckel (1993)
[e] data from Heaton-Jones et al. (1997)

Table 3. Muscle radiocesium in alligators from the Savannah River Site, South Carolina, USA, with calculated dose equivalents to potential human consumers, and maximum amounts that could be consumed according to guidelines from the International Commission on Radiological Protection. All values expressed on a wet mass basis.[a]

Sampling Location on the Savannah River Site	Muscle radiocesium ($Bq\ g^{-1}$)	Committed dose equivalent if ingested ($mSv\ kg^{-1}$)	Maximum consumption per year (kg)	Maximum consumption per week (g)
F Area Seepage Basin	20.2[b]	0.27	3.7	71
Par Pond mean, pre-drawdown	0.48	0.0065	153.8	2958
Par Pond mean, post-drawdown	0.37	0.0050	200.0	3896
Highest value recorded, Par Pond	0.63	0.0085	17.6	2261
Lowest value recorded, Par Pond	0.28	0.0038	263.2	5061
Pond B (whole body count)	0.49	0.0066	151.5	2913

[a] data from Brisbin (1989); Brisbin et al. (1996).
[b] P. Fledderman, pers. comm.

CONSEQUENCES OF HORMONE DISRUPTION OF SEXUAL DEVELOPMENT FOR CROCODILIAN CONSERVATION

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ABSTRACT
All crocodilians exhibit temperature-dependent sex determination, in which the incubation temperature of the egg during the middle third of development, not sex-specific chromosomes at fertilization, determines the individual's gender. Research suggests that steroid hormones have the same effect as incubation temperature, directing sex determination in these species. Today's environment contains a number of synthetic compounds that mimic or block the actions of steroid hormones, known generically as endocrine disruptors. These compounds are found in pesticides, herbicides, fertilizers and plastic stabilizers. They persist in the environment and as they pass up the food-chain, they are magnified and concentrated in lipids in animals. In crocodilians they accumulate in the yolk and disrupt normal sexual development in the embryo, resulting in abnormal gonads and morphology in the resulting hatchling. These compounds can also have adverse effects on other aspects of the phenotype including growth and behavior. The utility of these compounds in industry is such that they will continue to be used. Thus, a basic knowledge of how steroid hormones are normally involved in the process of sex determination and differentiation is necessary if we are to understand how these endocrine disrupting chemicals exert their actions and enable us to develop methods to protect the embryo.

INTRODUCTION

The suggestion that certain chemicals can mimic the action of estrogen, profoundly affecting the course of sexual development, emerged from studies of alligators, birds, fish, and turtles in nature. These chemicals include herbicides, insecticides, fungicides, styrenes, polychlorinated biphenyls, and penta- to nonylphenols and have been shown to disrupt normal endocrine functions. This leads to aberrant development of female and male reproductive tissues and results in decreased fertility or sterility. These effects are consistent with alterations one might anticipate if the steroid hormone dependent processes that regulate these systems were impaired (Table 1).

Table 1. Characteristics of endocrine disrupting chemicals

*	UBIQUITOUS AND PERSIST IN THE ENVIRONMENT
*	STRUCTURALLY DISSIMILAR TO THE STEROID HORMONE MOLECULE BUT BIND TO STEROID HORMONE RECEPTORS
*	ACT BY SIMULATING THE ACTION OF NATURALLY-OCCURRING STEROID HORMONES OR BLOCKING NORMAL STEROID HORMONE-MEDIATED DEVELOPMENTAL EVENTS
*	ACCUMULATE IN YOLK
*	ACT DURING EARLY DEVELOPMENT
*	DELAYED OUTCOME INFLUENCING MORPHOLOGY (2° SEX CHARACTERS AND GROWTH), PHYSIOLOGY (STEROIDOGENIC ENZYME ACTIVITY AND CONSEQUENT STEROID HORMONE LEVELS), AND PROBABLY BEHAVIOR
*	EFFECTIVE AT (LOW) DOSAGES TYPICALLY FOUND IN NATURE
*	NON-LINEAR DOSE-RESPONSE CURVE
◊	PRESENT IN MIXTURES AND MAY SYNERGIZE, PRODUCING GREATER THAN ADDITIVE EFFECTS
◊	EXPERIMENTS WITH ESTRADIOL INDICATE THERE MAY NOT BE A THRESHOLD DOSE

* demonstrated in American alligator
◊ demonstrated in red-eared slider turtle

In this paper we will review briefly the present state of our knowledge of sex determination in vertebrates in general and in crocodilians and other reptiles with TSD specifically. We will point out that the hormones present early in development influence not only the type of gonad that will form, but also the differentiation of secondary sex structures as well as the growth and behavior of the juvenile and adult. We will end by considering some recent discoveries of how endocrine disruptors may influence these processes and consider some issues that are of particular concern to crocodilian husbandry.

SEX DETERMINATION IN VERTEBRATES

The current model of sex determination and sexual differentiation in amniote vertebrates was first articulated in 1947 by Alfred Jost. In mammals, birds, and some reptiles, the gonadal sex of the embryo is fixed at fertilization by the presence of specific chromosomes (Figure 1). In the last decade remarkable progress has been made at identifying the cascade of genetic events that lead to gonad determination in mammals. Development of a testis is determined by the presence of the Y chromosome or, more specifically, the gene for testis-determining factor known as *SRY*, for sex-determining region Y (see Capel, 1996 and Gustafson and Donahoe, 1994 for reviews). In the absence of *SRY*, the so-called "default" pathway is the development of an ovary. In mammalian sex determination, *SRY* as well as other genes related to *SRY*, such as *SOX*, or *SRY*-related HMG genes, and *Dax1*, may also be involved in the male cascade (daSilva *et al.*, 1996; Zazopoulos *et al.*, 1997; Swain *et al.*, 1998). Other genes important in the development of the male and female phenotype are *SF-1*, or steroidogenic factor 1, which plays a key role in the gene regulation of several steroidogenic enzymes and protein hormones (Lala *et al.*, 1992; Lynch *et al.*, 1993; Shen *et al.*, 1994), the P450 steroidogenic enzyme aromatase (P450arom), and the protein hormone Müllerian Inhibiting Substance (*MIS*), a growth factor-like hormone produced by the Sertoli cells that causes the morphological cell death of the Müllerian duct; in its absence, the Müllerian ducts form oviducts, uterus, and the upper vagina and the Wolffian ducts regress (Cate *et al.*, 1990). Analysis indicates that *SF-1* is required for steroidogenesis in mammals and is expressed at the earliest stages of urogenital ridge development; disruption of the gene encoding *SF-1* results in newborns that lack adrenal glands and gonads (Ikeda *et al.*, 1994; Luo *et al.*, 1994a; Shen *et al.*, 1994). Both male and female embryos express *SF-1*, with *SRY* promoting upregulation of *SF-1* transcripts in males, while the absence of *SRY* results in a decrease of *SF-1* in females; shortly after differentiation of the Sertoli cells and formation of testicular cords, *SF-1* expression persists in males but ceases in females (Luo *et al.*, 1994b). It is important to note that *SF-1* is expressed in brain and is essential for the formation of brain nuclei known to be important in reproduction (Ikeda *et al.*, 1995).

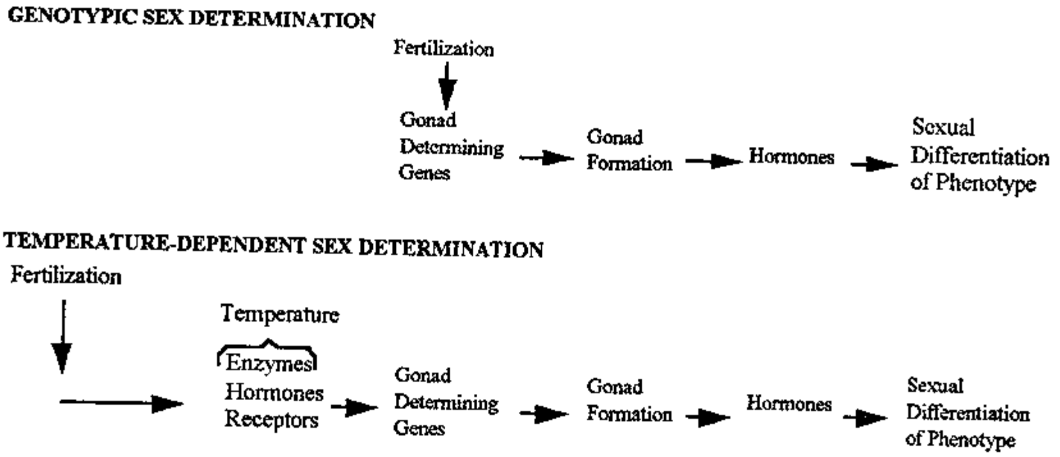


Figure 1. Schematic representation of our model of major events in genotypic sex determination (top) and temperature-dependent sex determination (bottom). This model could include PCBs, which have been shown to mimic hormones.

In temperature-dependent sex determination (TSD) gonadal sex is not set by the genetic composition inherited at fertilization, but rather depends on the incubation temperature activating a genetically programmed sequence of developmental events during a specific period of embryonic development (Figure 1). Although the determinants of one sex or another are still being identified, some major factors in sex determination in TSD vertebrates may also include the same or homologous genes as those identified in mammalian sex determination and gonadal differentiation. In the slider turtle, estrogen receptor mRNA is in higher abundance in the genital ridge at the beginning of the temperature-sensitive period in embryos at a male-producing temperature compared to embryos at a female-producing temperature, but this pattern is reversed during the temperature-sensitive period (Bergeron *et al.*, 1998). Similarly, there are developmental and temperature differences in the distribution and abundance of androgen receptor mRNA (T. Osborne and D. Crews, unpublished). In the alligator and the red-eared slider turtle, there is an increase in *SOX9* mRNA two-thirds of the way through the temperature-sensitive period in embryos incubating at a male-producing temperature and not in embryos incubating at a female-producing temperature at any stage (Western *et al.*, 1998; Spotila *et al.*, 1998). This suggests that *SOX9* is not directly regulated by temperature but rather has a temperature-sensitive regulator controlling it either directly or indirectly. In the slider turtle, *SF-1* has been identified (Wibbels *et al.*, 1998) and its mRNA found to be more abundant at the beginning and during the temperature-sensitive in urogenital tissues of embryos incubating at a male-producing temperature (A. Fleming and D. Crews, unpublished data). There appears to be differential expression of P450arom mRNA levels in the developing brain of the red-eared slider during embryogenesis according to incubation temperature (E. Willingham and D. Crews, unpublished data); interestingly, there is no evidence of gonadal expression or P450arom whereas it is evident in the POAH during the temperature-sensitive period. Further, *SF-1* mRNA is present at the beginning of the temperature-sensitive window in the POAH (A. Fleming and D. Crews, unpublished data). A hypothetical sequence of the action of temperature is depicted in Figure 2.

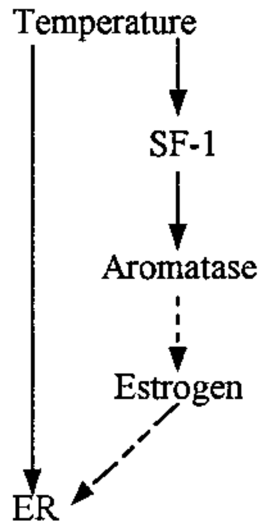


Figure 2. Hypothesized sequence of actions of incubation temperature. Incubation temperature influences the expression of steroidogenic factor 1 (SF-1) which in turn upregulates the expression of the gene coding for aromatase, the enzyme critical in the synthesis of estrogen. This estrogen in turn binds to the estrogen receptor (ER). Incubation temperature also has a directly modulates the expression of the estrogen receptor.

STEROID SYNTHESIS DURING EMBRYONIC DEVELOPMENT

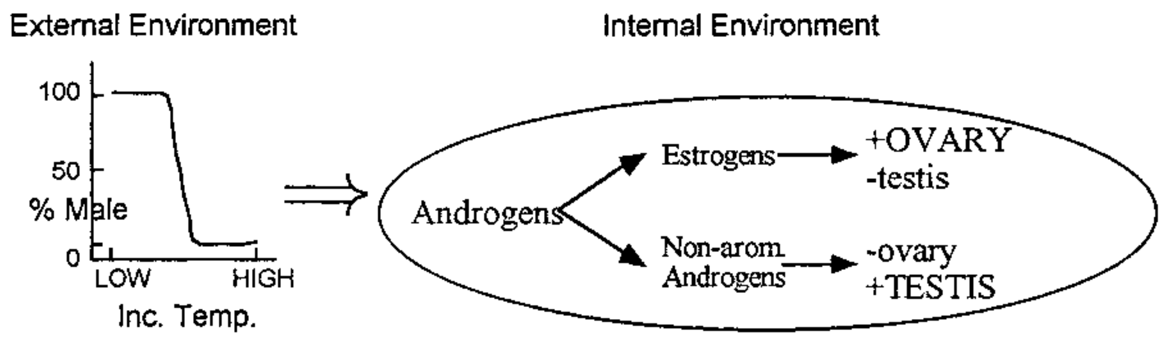
Steroids are not gene products, so if steroids are important in TSD, the mechanism might involve differential responses to temperature of steroid-converting enzymes (which are gene products). The biosynthesis of androgens and estrogens from cholesterol involves the action of several enzymes, including hydroxysteroid dehydrogenases (HSD), reductase, and aromatase enzymes. Until recently it was believed that in mammals the fetal gonad was quiescent steroidogenically until it differentiated into a testis or ovary. In this scenario the hormones produced by the distinct testes or ovaries then acted to sculpt the many differences between males and females. It is known that the testes develop before the ovaries differentiate, and begin to secrete testosterone

(T) coincidentally with the differentiation of the Leydig cells and preceding masculinization of the urogenital tract (Gondos, 1980; George and Wilson, 1994). Thus, it was believed that until gonadal differentiation, enzymatic activity and steroid biosynthesis was similar between the sexes (Milewich *et al.*, 1977; George *et al.*, 1979). There is now evidence that gene expression and steroidogenesis begins prior to gonadal differentiation.

Using reverse transcriptase-polymerase chain reaction (RT-PCR) to study the ontogeny of expression of the genes encoding for four of the steroidogenic enzymes necessary for androgen and estrogen production (P_{450} cholesterol side-chain cleavage, 3β-HSD, P_{450} 17α-hydroxylase/C_{17-20} lyase, and P_{450} aromatase), Greco and Payne (1994) report increased mRNAs for these steroidogenic enzymes prior to gonadal differentiation in the rat, but only 3β-HSD mRNA was present in some of the ovaries examined, and the detection of transcript for the other enzymes rare, when compared to males. This suggests the characteristic low ovarian steroid hormone production results from the lack of expression of enzymes necessary for androgen and estrogen biosynthesis. Interestingly, both male and female rat fetuses express transcripts encoding 5a-reductase (Berman *et al.*, 1995). In chickens, there is no sex difference in the abundance of transcripts of the gene coding for 17α-hydroxylase prior to gonadal differentiation, but aromatase mRNA is more abundant in putative ovaries compared to putative testes (Abinawanto *et al.*, 1996; Yoshida *et al.*, 1996).

In egg-laying vertebrates, including crocodilians, the egg yolk is a rich repository of hormones and their precursors (Bern, 1990; Brown and Nunez, 1994; Conley *et al.*, 1996). Further, all of the steroidogenic enzymes necessary to produce sex steroid hormones are present in the urogenital system of embryos of TSD species (Merchant-Larios and Villalpando, 1990; Pieau *et al.*, 1994a,b; Smith and Joss, 1994; Thomas *et al.*, 1992), suggesting steroid biosynthesis. Standard histochemical methods have assessed the activity of 3β- and 17β-HSD enzymes at the beginning, during, and after sex determination at both male- and female-producing incubation temperatures in the red-eared slider (Thomas *et al.*, 1992). Male- and female-producing incubation temperatures result in different patterns of HSD activity in the adrenal and mesonephros during development. Significantly, reaction product is not observed in the genital ridge at the beginning of the temperature-sensitive period at either incubation temperature, nor is it apparent in the differentiating gonads in embryos during temperature-sensitive period; the only activity detected in the gonad is observed after the temperature-sensitive period. This pattern is also seen in the Olive Ridley sea turtle (Merchant-Larios and Villalpando, 1990) and saltwater crocodile (Smith and Joss, 1994), but not in the European pond turtle (Pieau *et al.*, 1994a,b). This suggests that in the red-eared slider turtle, tissues proximate to the gonad or elsewhere, such as the brain, may produce steroid hormones at the beginning and during the sex-determining period.

A large body of evidence from all major lineages of non-mammalian vertebrates indicate that steroids play a pivotal role in the sex determination process. In particular, exogenous steroids can override genetic and temperature influences and cause complete and functional sex reversal in many fish, amphibians, and reptiles (Burns, 1961; Lam, 1982; Witschi, 1959; Crews *et al.*, 1988). Extensive research in turtles and crocodilians indicate that steroid hormones are the physiological equivalent of incubation temperature, directing sex determination in these species.



Female determination:

1) Estrogen and aromatizable androgens produce females at a male incubation temperature.
2) Aromatase inhibitors block female development and induce male development at a female-producing temperature. Administration of testosterone plus aromatase inhibitor at female-producing incubation temperature blocks aromatizable androgen-induced feminization.
3) Critical period for estrogen effect overlaps with temperature-sensitive window.
4) Estrogenic ligands feminize via an estrogen-specific receptor.
5) Estrogen effect is dose-dependent.

Male determination:

1) Nonaromatizable androgens produce males at a threshold incubation temperature.
2) Reductase inhibitors block male development and induce female development at both threshold and male-biased incubation temperatures. Administration of testosterone plus reductase inhibitor at male-producing temperature results in female hatchlings.
3) Critical period for DHT effect overlaps with temperature-sensitive window.
4) Androgenic ligands masculinize via an androgen receptor.
5) DHT effect is dose-dependent.

Figure 3. The physical stimulus of temperature is transduced into different concentrations of steroid hormones which in turn direct the sexual development of the embryo. The evidence depicted in the figure was conducted on the red-eared slider turtle.

Even before we settled on the red-eared slider as an experimental model in 1987, Jim Bull and David Crews developed the hypothesis that the physical stimulus of temperature is transduced into an endocrine precursors signal that directs the sex determination process: specifically, estrogens and their aromatizable stimulate the female-determining cascade and inhibit the male-determining cascade, whereas nonaromatizable androgens stimulate the male-determining cascade and inhibit the female-determining cascade (Crews, 1996; Crews *et al.*, 1994). The primary support of this hypothesis is summarized in Figure 3. Five different approaches have yielded data that strongly suggest steroid involvement in TSD in the red-eared slider turtle, and probably in crocodilians as well. First, by using various metabolites, it has been possible to identify the enzymes and preferred biosynthetic pathways for steroid production. These data indicate that the 17β-HSD detected at the beginning and during the temperature-sensitive window is an operational biosynthetic pathway. Second, preliminary results with Jean Wilson indicate that T is present in the adrenal-kidney (mesonephros)-gonad (AKG) complex at the beginning and during the temperature-sensitive window, but not afterwards, in embryos from a male-producing incubation temperature, and is not detectable in embryos from a female-producing temperature at these same embryonic Stages. Third, use of specific enzyme inhibitors indicates that both aromatase and reductase are active during the temperature-sensitive window. Fourth, enzyme kinetic studies indicate that both aromatase and reductase are present during the temperature-sensitive window and that reductase activity is higher than aromatase throughout this period in embryos at a male-producing temperature. Fifth, simultaneous administration of DHT and estradiol causes the development of ovotestes, indicating that male and female sex-determining cascades are separate.

Although ovarian sex determination in the red-eared slider turtle normally involves estrogen, exogenous estrogens can be viewed as a toxicant if they are present in supranormal levels during the period of embryogenesis that normally would lead to male development. The red-eared slider turtle embryo is extremely sensitive to exogenous estradiol. For example, experiments exposing turtle embryos to estrogens at incubation temperatures that produce only male hatchlings, result in significant sex-reversal. At 26° C, a dose of 0.5 μg (equivalent to 0.04 ppm) of estradiol, or 0.05 μg of E3 (equivalent to 0.004 ppm) produces a significant sex-reversal effect in eggs and at 28.6° C the effective dosage of estradiol reduces to 0.4 ng (less than 0.0004 ppm or 0.04 ppbillion). Thus, the red-eared slider turtle model system has proven to be a sensitive *in vivo* indicator of estrogens and their mimics in the environment.

SITE AND MECHANISM OF STEROID ACTION

Without specialized receptors to detect their presence, sex steroid hormones or their mimics will have no effect on the animal. Sex steroid hormone receptors are located in the cell nucleus and comprise a family of transcriptional factors that bind to the DNA. There are multiple forms of receptors for each steroid hormone, for example the α and β form of the estrogen receptor (ER). Typically these receptors are localized in specific organs such as the liver or the oviduct, as well as in bone and skin and the limbic nuclei of the brain.

The affinity of numerous environmental estrogens for binding ER is weaker than the natural sex hormone estradiol (Korach *et al.*, 1988; White *et al.*, 1994; Klotz *et al.*, 1996). However, the biological responses produced by some of these estrogenic chemicals are equivalent to estradiol, albeit at higher concentrations. For example, the sex-reversal of turtle embryos incubating at a male-determining temperature with high concentrations of the hydroxylated PCBs was equivalent to the effects of exogenous estradiol (Bergeron *et al.*, 1994). Furthermore, the induction of vitellogenin in male fish can be induced to the same extent with estradiol or 1,000-fold greater concentration of octylphenol or nonylphenol (Jobling and Sumpter, 1993). This has also been observed for o,pí-DDT and coumestrol (Pelissero *et al.*, 1993). These observations suggest that even though many synthetic or natural chemicals with estrogenic activity have weak ER binding affinity, they are capable of producing activity *in vivo* that is similar to estradiol.

BRAIN AS TEMPERATURE SENSOR AND COMMUNICATION LINK TO THE GONAD

How does the embryo sense temperature and how does this information get translated into signals that activate one genetic sex-determining cascade while inhibiting the other? In all vertebrates, including mammals and reptiles, there are temperature-sensitive neurons within preoptic area-anterior hypothalamus (POAH) (Cabanac *et al.* 1967; Rodbard *et al.* 1950; Heath *et al.* 1968). In addition to being a master controller of thermoregulation (Satinoff, 1995), this same area contains neurons containing sex steroid hormone receptors. Research with a variety of TSD species indicate that when temperature exerts its effect on sex determination, the temperature-sensitive period, and gonadal differentiation are not entirely coincident. In turtles the diencephalon differentiates at the same time as the temperature-sensitive period of gonadal development (Senn, 1979), and Merchant-Larios (1998) has suggested that the signal for sex determination is extragonadal and that the histological differentiation of the gonad is a secondary effect. In support this hypothesis, they report that at the beginning of the temperature-sensitive period the hypothalamus of embryos from a presumptive female-producing temperature has higher levels of estradiol in comparison to embryos from a presumptive male-producing temperature. Interestingly, and consistent with research on other TSD species, estradiol levels were not different in the gonads or serum between embryos of the male- and female-producing temperatures during the temperature-sensitive period. Similarly, in the diamondback terrapin, aromatase mRNA expression begins prior to the sex-determining period of development in presumptive females; these levels decline until, at the end of the temperature-sensitive period, aromatase levels are higher in the brain at male temperatures than they are at female temperatures; administration of exogenous estradiol appears to depress aromatase expression in the brain at male incubation temperatures (Jeyasuria and Place, 1998).

In vertebrates there are direct neural connections between the gonad and the hypothalamus (Crews, 1993), and consistent with the hypothesis that the brain communicates temperature information to the gonad via this link (Merchant-Larios, 1998) is the observation of neural innervation of the embryonic gonad in turtles (Merchant-Larios *et al.*, 1989).

TRADITIONAL TOXICOLOGICAL VS. ENDOCRINE DISRUPTOR PARADIGMS

Risk assessment paradigms are changing as we learn more about hormone-like chemicals (Figure 4). Lake Apopka in Florida has been a classic example of how environmental contamination can affect reproductive development in alligators.

Traditional approach	Endocrine disruptors approach
• carcinogenic model	developmental model
• mortality/acute toxicity	delayed dysfunction
• threshold	no threshold
• additive effects	synergistic effects

Figure 4. Differences in the indices that mark the traditional toxicological approach to risk assessment and the newly emerging approach for endocrine disrupting chemicals.

The resemblance of gonadal and penile abnormalities of the American alligator in Lake Apopka, Florida (Guillette *et al.*, 1996) to those described in mice treated with the potent, synthetic estrogen diethylstilbestrol (McLachlan *et al.*, 1980), led to detailed studies documenting that chronic pollution by agricultural runoff exacerbated by a chemical spill of dicofol was the most likely cause of the reproductive anomalies observed in the alligators of Lake Apopka (Guillette *et al.*, 1994). Dicofol and its components, have been shown to bind the ER from the American alligator (Vonier *et al.*, 1997), and therefore, may function as an estrogen in the alligator. In addition to DDE/DDT contamination, a variety of other pesticides have been detected in alligator eggs, including dieldrin, toxaphene, cis/trans nonachlor, arachlor, chlordane and pp'DDD (Heinz *et al.*, 1991). Exposure of alligator (Guillette, unpublished data) and red-eared slider turtle (Willingham and Crews, 1998) embryos to concentrations of these compounds typically found in nature result in anomalous reproductive development (Figure 5).

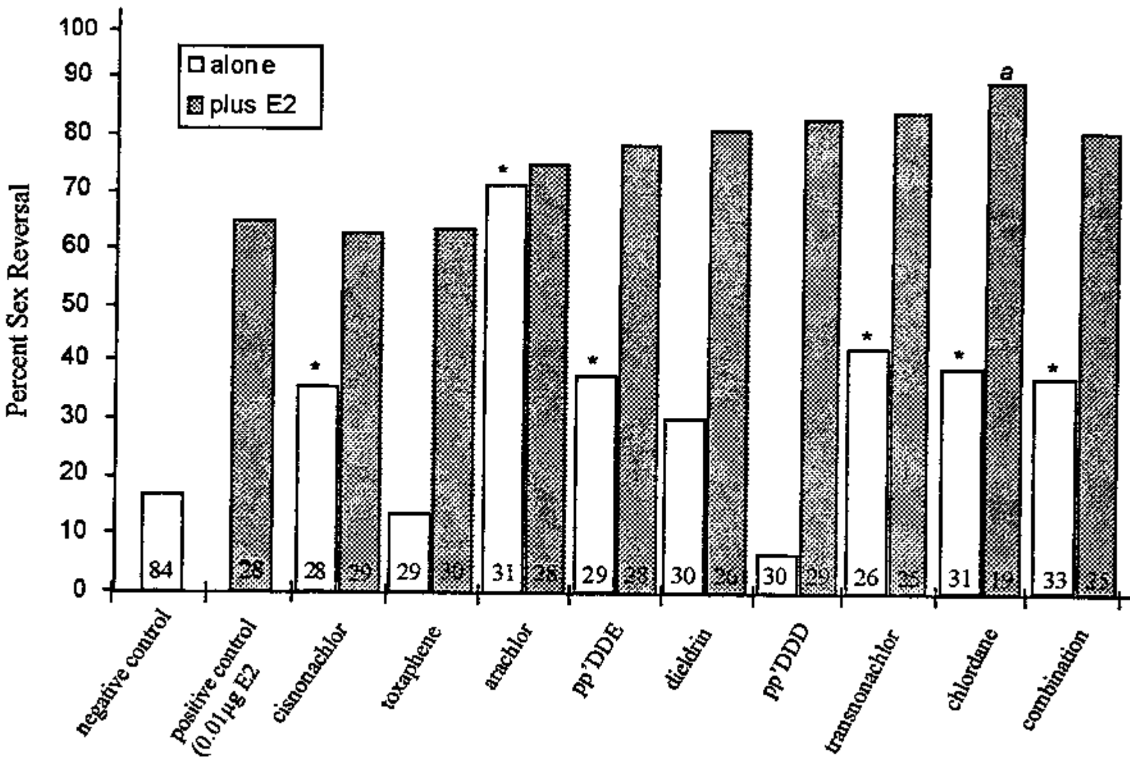


Figure 5. Effect of exogenous ligands on sex determination in the red-eared slider turtle, *Trachemys scripta elegans*, showing percent reversal from each treatment. All eggs incubated at 28.6□ C. Compounds were assayed alone and in combination with 0.01µg estradiol. Percent reversal for negative (solvent only) control and E2 control also shown. Numbers in bars indicate sample size. * indicates significant reversal versus negative control for compounds applied singly. a indicates significant reversal versus positive control for compounds applied in combination with estradiol. (from Willingham and Crews, 1998).

The difficulties in demonstrating a clear cause-and-effect relationship between endocrine disrupting chemicals and reproductive anomalies arises from the fact that the wrong yardstick has been used. Environmental toxicological paradigms typically focus on high pharmacological dosage exposure to adult individuals resulting in mutagenesis, cancer and death as unequivocal indications of contaminant effects. Endocrine disrupting chemicals, however, are characterized by a delayed response, often measured in years. between exposure to low physiologically-relevant dosages during sensitive periods of organ development in the embryo. Thus while traditional toxicological paradigms require a clear causal relationship traceable from exposure to the development of a cancer and death, what we are confronted with is functional sterility resulting from the bioaccumulation of chemicals that persist in the environment at relatively low levels. Two other notable features of endocrine-disrupting chemicals is the (i) synergistic actions of natural estrogens and their synthetic mimics resulting in reproductive dysfunction (Bergeron *et al.*, 1994, 1998; Arnold *et al.*, 1997), and (ii) recent evidence that the concept of a threshold dosage does not apply for endocrine disruptors (Sheehan *et al.*, 1998).

Synergistic actions of hydroxylated PCBs. Synergism occurs when the effect of two factors together is greater than the sum of their effects when given separately (i.e., greater-than-additive effects). Current controversy concerning environmental estrogens is whether they exhibit synergistic activity. A number of synthetic compounds mimic estrogens, although with a lower potency than natural steroidal estrogens (Soto *et al.*, 1994; McLachlan, 1993; Korach *et al.*, 1988). When considered individually, these chemicals may exist in the environment in concentrations too low to be of concern. In combination, however, low dosages of these same compounds may act synergistically to produce a strong estrogenic response. This low-dose synergy was first shown with polychlorinated biphenyls (PCBs) using an *in vivo* sex-reversal assay in the red-eared slider turtle (Bergeron *et al.*, 1994). As metabolites of other PCBs, hydroxylated PCBs may exist in steady-state concentrations in aquatic environments, potentially exposing wildlife to their effects via direct contact or through the food chain (McKinney *et al.*, 1990). The application of some PCBs can act as estrogens and override a male-producing temperature and reverse sex presumably through their action on gonad determining genes. Using the all-or-nothing nature of the response of red-eared slider turtle embryos to exogenous estrogen, we assayed 11 common PCB's (Bergeron *et al.*, 1994) Only two of the compounds tested, 2',4',6'-trichloro-4-biphenylol (3-PCB) and 2',3',4',5'-tetrachloro-4-biphenylol (4-PCB), were found to have estrogenic activity as indicated by the production of female hatchlings from eggs incubated at a male-producing temperature. In these instances only the high dosage produced females complete with fully developed oviducts. The former compound showed 100% sex reversal at 100 μg or just below 9 ppm. In tests using mouse tissue, these same two compounds show an appreciable affinity for ER, due in part to their conformational properties as hydroxybiphenyls (Korach *et al.*, 1988; McKinney *et al.*, 1990). Because purified PCB compounds are rarely found in the environment, we decided in the second series of experiments to look at combinations of the same PCBs. All eggs were incubated at 27.8 °C and received a low (10 μg), medium (100 μg), or high (145 - 190 μg) dosage of compounds. Some eggs received a cocktail of all PCBs except the two which caused sex reversal (3- and 4-PCB). Others were exposed to combined hydroxybiphenyls, again excluding 3- and 4-PCB. Lastly, some eggs were treated with combined non-hydroxylated PCBs with no evidence of sex reversal. Since we knew 3- and 4-PCB showed estrogenic activity at the slightly higher temperature, we decided to try these two compounds at a temperature that produces 100% males (26 °C). Both compounds showed significant sex reversal at this temperature. When combined, 3- and 4-PCB synergized, resulting in a significant increase in ovarian development at a dose of 10 μg or less than 1 ppm, whereas 3-PCB alone and 4-PCB alone required at least a tenfold higher dose to show sex reversal. Exogenous estradiol produces similar results at a dose of 0.5 μg, or .04 ppm (Wibbels *et al.*, 1991).

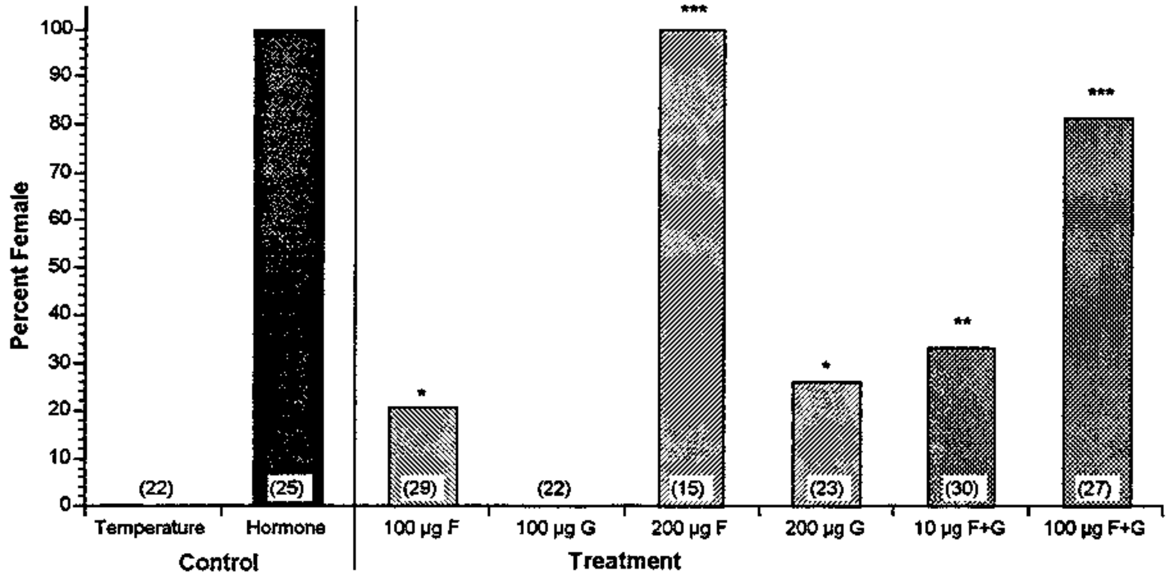


Figure 6. Percent of female hatchlings at a temperature which normally produces 100% males (26 °C) following treatment with two estrogenic PCB compounds in ethanol. Controls: temperature-ethanol alone; hormone- 10 µg estradiol-17β. PCB compounds: F = 2',4',6'-trichloro-4-biphenylol; G = 2',3',4',5'-tetrachloro-4-biphenylol. Significant sex reversal is indicated by * p□ 0.03; ** p= 0.003; *** p= 0.0001. Redrawn from Bergeron *et al.*, 1994.

The concept of a threshold dosage does not apply for endocrine disruptors. Traditionally, risk assessments are founded on a carcinogenic model characterized by indices of acute toxicity/mortality, the presumption of additivity of chemicals, and the existence for every chemical of a threshold dose below which no adverse effects occur. Gaylor *et al.* (1988) suggested that this assumption does not apply when an endogenous chemical, such as a hormone, reaches a sufficient concentration to cause an effect. In such cases, the threshold for the endogenous chemical is already exceeded and, therefore, no threshold dose exists for a mimic. We tested this hypothesis with the red-eared slider and demonstrated a biologically based dose-response model for developmental toxicity. First, analysis of our published data on the effects of varying doses of estradiol at different incubation temperatures revealed dose-response curves that fit a Michaelis-Menten equation. A power-analysis approach was then used to conduct a large (2400 egg) dose-response study designed to test whether the threshold hypothesis applies to estradiol in this animal model system, and to determine whether the Michaelis-Menten equation can predict organismal response. This equation provided an ED_{50} of 5.0 with a 95% confidence limit of ±2.0 ng (endogenous dose = 1.7 ± 1.3 ng; exogenous dose = 3.3 ± 1.7 ng) and an r^2 = 0.90 for fit of the modified Michaelis-Menten equation.. The lowest dose, 0.4 ng/10 g egg, significantly increased the female fraction by 11.4%. An important feature is that the curve becomes increasingly more linear as dose decreases relative to ED_{50}, reinforcing the failure to find a threshold dose by an empirical fit. A replication of the study was conducted the following year with similar results. The results indicated that both past and current studies of slider sex reversal at an organismal level (i) can be fit to a Michaelis-Menten model of a single protein-molecule interaction driving a reversible process, and (ii) reveal no threshold dose for chemicals acting through the same mechanism. Thus it may be that even low environmental concentrations of endocrine-disrupting, receptor-dependent chemicals will carry risk.

CONCLUSION

As the complexities of interaction between genes, hormones and hormone receptors during sex determination become better understood, the disruptive influence of man made compounds on normal sexual development has emerged as a serious concern for conservationists, wildlife managers and crocodile farmers. Compounds capable of interfering with normal development have become ubiquitous in natural environments and become concentrated by bioaccumulation in natural food chains. Long-lived organisms feeding at the top of the food chain, such as crocodilians, are particularly vulnerable to accumulating heavy burdens of contaminants. The studies reported and reviewed here indicate that while these compounds may not affect the adult organism, they can be passed to the egg yolk where they are potent at extremely low doses in disrupting normal sexual development.

Recently it has become evident that assumptions about additivity and thresholds may not apply to chemicals that mimic the action of ligands important to sexual development. For example, there is an increasing body of evidence indicating that minute amounts of xenobiotics present during early development may not result in cancer and death, but rather alter sexual development such that the adult cannot reproduce. Such sterile individuals occupy space and use resources but cannot contribute to population growth. Similarly, recent studies have demonstrated that certain combinations of steroidal and nonsteroidal estrogens and their mimics are synergistic rather than additive in their effects. Finally, current risk assessments for virtually all chemicals except genotoxic carcinogens assume that there is a dose below which no adverse effects occur (the threshold dose). In practice, the highest dose without toxicity is used as a surrogate for the threshold dose. Assessing risk becomes more complicated, however, when a chemical mimics the action of an endogenous substance important in development. It has been suggested that this threshold dose hypothesis cannot apply to non-carcinogenic chemicals that mimic the action of endogenous substances important in normal development since, upon exposure, the threshold for the endogenous substance is already exceeded and, therefore, no threshold dose exists for the mimic.

The consequences of these effects to crocodilian conservation may be profound. In the best studied example on Lake Apopka, Florida, low egg viability resulted in the reduction of juvenile cohorts and the distortion of size class distributions extending for many years after the presumed causal event (Woodward *et al.* 1993). Even as the wild alligator population begins to recover from this setback (Rice, 1997), research indicates that many of the surviving juveniles demonstrate impaired gonad function, abnormal hormone levels and ambiguous sexual morphology (Guillette *et al.*, 1994). Whether these individuals will eventually mature and recruit to the breeding population remains to be seen, but appears unlikely.

Crocodilian conservation programs worldwide have been established on sustainable use and harvest programs (Ross 1996, 1997 a.). These programs in turn are based upon demographic models and assumptions about reproductive effectiveness which determine harvest levels and provide the basis for the resiliency of crocodilian populations to modest levels of harvest. If subtle effects of biogenic compounds cause abnormal sexual development and impaired reproductive capacity, the foundation of these programs will be challenged. Crocodilian populations which demonstrate more or less normal densities to superficial field survey, may in fact not be reproducing.

The consequences to crocodilian ranching and farming efforts are also obvious. If the subtle effects of contaminants in the environment reduce either the quantity or quality of eggs collected from the wild ranching programs or obtained from captive breeders then the economic efficiency of these programs will be compromised (Ross 1997 b.). As the continuation of management and conservation activities is often dependent upon economic incentives from commercial harvests, both commercial and conservation interests could suffer.

Crocodilian habitats around the world are associated with drainages and watersheds subject to intense human settlement and agricultural use, often with poorly regulated contaminant controls. While hormone disruption in crocodilians is only reported from a small number of localities in Florida USA, it seem highly likely that this problem may be widespread. As it is unlikely that the use of endocrine disrupting compounds can be prevented, and as they are in any case highly persistent in the environment, any response to this new challenge needs to be based upon an understanding of the complex biochemistry and physiology concerned.

At the field level, we suggest that the viability of crocodilian eggs may serve as a simple and readily obtained index of potential endocrine disruption. While other factors may cause occasional drops in normal egg viability, persistent drops, associated with changes in the gonadal and penile morphology of hatchlings may serve as an adequate monitoring mechanism. Such parameters can quite readily be monitored in wild populations, ranch egg collections and captive breeding farms. For the future, as our understanding of mechanisms improves it may be possible to develop biochemical interventions which protect the developing embryo from hormone disruptive effects. We speculate that it should be theoretically possible to treat ovigerous females with compounds which bind and sequester hormone disruptors and protect the developing embryo. A partnership between field conservationists, commercial producers and researchers in reproductive physiology will be productive to meet this challenge.

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Population Dynamics of Lake Apopka's Alligators

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Abstract: Beginning in 1981, a major decline was observed in the juvenile alligator population on Lake Apopka, a large fresh water lake located in central Florida. Evidence exists that environmental contamination is partially responsible for this decline. We examined clutch characteristics, viability, and population growth on the lake from 1981-1995 and observed partial recovery of the system. The total population of alligators decreased until 1989 then increased through 1995 ($P < 0.01$). Over the same period, juveniles decreased by 95% through 1989 then increased by 480% ($P < 0.01$). Clutch viability decreased by approximately 80% through 1988 and then increased over 400% (0.12 to 0.53) through 1995. However, viability remained depressed when compared to a reference area, Lake Woodruff National Wildlife Refuge (Lake Woodruff; $P < 0.001$). Lake Apopka alligators produced more eggs ($P = 0.006$) per clutch than Lake Woodruff, but clutch weights did not differ ($P > 0.05$). Lake Woodruff produced more hatchlings ($P < 0.001$) per clutch than Lake Apopka. While many parameters associated with the alligator population on Lake Apopka remain depressed when compared to relatively natural areas, signs of population recovery from reproductive failure are now evident.

INTRODUCTION

In the late 1970's there was considerable interest from the Florida Game and Fresh Water Fish Commission (GFC) and the alligator industry to commercially harvest both adult and early age class alligators in Florida. The GFC had instituted a nuisance alligator program and had embarked on research to investigate the feasibility of sustainable adult harvest on public waters (Hines and Woodward 1980). Florida's alligator farmers were interested in harvesting eggs and hatchlings for captive rearing (ranching) to supplement closed-system farming. Alligator farmers and the GFC developed a cooperative venture in 1979 to monitor alligator populations by night light survey on 3 lakes (lakes Apopka, Griffin, and Jesup) from which hatchlings were being harvested. These lakes were considered as demographically similar lakes in the St.

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John's River drainage having dense populations of both adult and early age class animals. Night-light surveys commenced in September 1979 and hatchling harvests began in 1981.

In 1981, the Florida Cooperative Fish and Wildlife Research Unit (FCFWRU; University of Florida, GFC, and USGS Biological Resources Division cooperators; the U.S. Fish and Wildlife Service was a cooperator in 1981) entered into the research funded by the Florida Alligator Farmers Association (FAFA) in cooperation with the GFC. A population crash on Apopka was observed between 1981-1984 in <182 cm animals (Woodward et al. 1993). Relatively small pod (group of hatchlings) size and an unusual number of unhatched eggs on Apopka were noted during 1982. A low clutch viability rate (number hatch/total eggs in a clutch) of alligator eggs on Lake Apopka was observed in 1983 after studies began examining the feasibility of collecting eggs rather than hatchlings for ranching purposes. Although Apopka was less important as a harvest site because of the alligator population decrease, the lake continued to be a focus of attention because of extreme differences in hatch rates from other lakes. With the support of GFC, FAFA, and the American Alligator Farmers Association (AAFA), subsequent investigations expanded research to include variability in clutch viability on a number of lakes, including Lake Apopka.

Through 1987, long-term trends still indicated a decline in juvenile alligators on Lake Apopka. Meanwhile, other lakes in the St. Johns River drainage showed numerically stable or increasing alligator populations (Jennings et al. 1988; Rice 1996; Woodward et al. 1993). Controlled incubation of alligator eggs indicated that Lake Apopka had the lowest clutch viability rates of any population examined (Percival et al. 1992; Masson 1995). In 1988, the Lake Apopka viability rate fell to a low of 0.04. These data, derived from laboratory incubation, appear to correlate closely with events occurring in the wild. Investigations of neonatal wild pods demonstrated that Lake Apopka had the lowest density of pods and the smallest pod size of all study areas in Florida (Percival et al. 1992).

In 1988, the FCFWRU began to investigate causes of Apopka's low clutch viability and population declines. Coupled with a study investigating the reproductive physiology of adult female alligators, the possibility of environmental contaminant effects was examined. Lake Apopka had substantial contaminant inputs from agricultural run-off, sewage effluent, and a major chemical spill (U.S. EPA 1994). An analysis of alligator eggs collected in 1985 from 3 Florida lakes showed that eggs from Lake Apopka had significantly elevated levels of DDD, DDT, and DDE (Heinz et al. 1991). Other studies have documented increased estrogenic activity (a possible effect of exposure to environmental contaminants) in juvenile alligators from Lake Apopka. Other endocrine effects and gonadal abnormalities also were found (see Rice and Percival 1996).

This study examined long-term trends in both alligator clutch viability and population indices on Lake Apopka. In particular, the hypothesis of the recovery of a population following catastrophic reproductive failure is tested. Further, the dynamics of the Lake Apopka alligator population are compared with those of a reference population from Lake Woodruff National Wildlife Refuge.

This study was fortunate to receive substantial funding from many institutions including the American Alligator Farmer's Association, the Florida Alligator Farmer's Association, the Florida Wildlife Federation, the Florida Game and Fresh Water Fish Commission (GFC), the St. Johns River Water Management District, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, and the Florida Cooperative Fish and Wildlife Research Unit. The project has had the luxury of incorporating the expertise of many individuals from multiple agencies over the years. At the risk of eliminating many important names, these people always had pride in referring to themselves as members of a loosely organized group, the Florida Alligator Research Team. Requiring special reference are the following: J. Anderson, A. Brunell, D. Carbonneau, J. Connors, R. Conrow, D. David, G. Davidson, L. Folmar, M. Fuller, T. Gross, C. Hope, L. Hord, M. Jennings, W. Johnson, L. Rhodes, T. Schoeb, S. Shrestha, R. Spratt, H. Suzuki, C. Tucker, J. White, J. Wiebe, and C. Wieser.

METHODS

Egg Collections

Alligator clutches were collected from nests on Lakes Apopka and Woodruff during the summers of 1994 and 1995. Prior collections from 1983 to 1993 also were included for long term trend analysis. Alligator nests were located via aerial surveys and ground searches. For each collected clutch, nest height, diameter, ambient temperature (thermometers were calibrated to a standardized thermometer), clutch cavity temperature, clutch depth, approximate percentage of daily shade, flooding status, female presence and behavior, and nesting habitat were recorded. Each nest was completely dismantled and searched completely because multiple nesting (two or more females ovipositing in a single nest) had been observed (Percival unpubl. data). Disturbed or depredated clutches were not collected. All eggs present in the nest, including damaged and non-viable ones, were collected.

Eggs were placed into plastic bus pans (61 cm X 36 cm X 13 cm) on 5 cm of natural nest material with additional nest material cushioning layers of eggs when required. Eggs along the bus pan perimeter were cushioned with 2-3 cm of nesting material. An identifying plastic plant tag was affixed with copper wire to a hole in the corner of the bus pan rim. The order (approximately uppermost to lowermost) in which eggs had been removed from the nest was maintained. To ensure that data sheets could be matched later with clutches, nest number, date, time, and collectors' names were recorded on the tag, as well as on the data sheets. Parts of eggs or eggs which were found crushed were sealed in a labeled plastic bag.

Transportation of eggs followed recommendations by Woodward et al. (1989). During transportation of clutches, care was taken to avoid excessive vibration or shock, which could kill embryos by detaching their membranes from the shell (Ferguson 1985). Clutches were protected by inflatable cushions and foam rubber within transport boats, which were carefully maneuvered within sheltered waters to avoid additional vibration and shock. Eggs were transported to an incubator facility in Gainesville, FL within 24 hrs of collection in the covered bed of a pickup truck, which was cushioned like the transport boat (Woodward et al. 1989).

Clutch and Egg Characteristics

At the incubation facility, care was taken to avoid vibration and rotation of viable eggs. Bus pans were weighed with and without eggs to calculate a clutch weight. All intact (unbroken) eggs were transilluminated to check for viability and egg band development (Woodward et al. 1989). Anomalous eggs (those containing two yolks, yolkless, or with aberrant calcified regions) were recorded and, when possible, were measured. Non-viable eggs were identified by the absence of an opaque embryo attachment spot or band. Unbanded eggs were opened, and a visual status determination was made. If band development was visibly retarded, or if vascular color was not similar to that of other, apparently healthy, eggs in a clutch, the egg in question was opened and the developmental age and embryonic status (good, weak or dead and presence of deformities) of the embryo was determined. One healthy representative egg was removed from each clutch and sacrificed for determination of clutch age and expected hatch date. Crushed eggs and empty eggshells were examined to determine whether an embryo was present and its developmental age. Whenever possible, embryo age was determined using a combination of back-dating (date of collection minus embryo age), an embryological developmental chart (Masson 1995), and egg band progression (Ferguson 1985). Eggs were transilluminated at approximately 14-21 day intervals thereafter to identify and age dead embryos. Eggs remaining unhatched at the end of the incubation period also were opened and embryo age determined. The disposition of each egg within a clutch was recorded.

Incubation

All eggs were incubated in a modified 7.3 m x 3.7 m portable building (Lark Industries, FL). The building was layered for insulation with 2.54 cm blown-in foam insulation, 7.6 cm fiberglass batting, a visqueen vapor barrier, and 2.54 cm styrofoam sheeting. The humidity and temperature were controlled by a Hawkhead International heat/cool humidifier unit providing controlled high humidity warm air. This unit used mercury switches for temperature and wet-bulb humidity monitoring. Thermostatically controlled electric fans and louvers, as well as ceiling fans circulated air throughout the building. The relative wet bulb humidity in the building was 94-96% and mean temperature within the nests and in the building was 30.6 C ! 0.5. However, nesting material had to be moistened every 7-10 days to maintain the appropriate moisture level.

Clutch integrity and within-clutch collection order were maintained. All clutches were incubated in damp sphagnum moss (a minimum of 2.5 cm on top, bottom, and all sides) in bus pans placed on shelves within the incubator. Each bus pan was covered with 50% shade screening cloth to allow air circulation and to contain hatchlings. To minimize premature hatching of alligators by audible cuing from adjacent clutches, clutches with similar hatch dates were grouped together.

Hatchling Care

Hatchlings were maintained in the aforementioned insulated incubation building for approximately 14 days before release at their original nest site. The building contained 6 galvanized aluminum tanks separated into 24 individual 0.6 m x 0.7 m compartments. Compartments were divided with a galvanized aluminum wall sealed with latex caulking. Each compartment was on a 3.8 cm slope to provide both dry and wet surfaces. To increase the dry surface area and minimize stress from overcrowding, an elevated mesh platform was added to each compartment (2.5 cm square mesh constructed from molded plastic-coated heavy gauge wire). Tanks were cleaned following each feeding and refilled with fresh water. A maximum of 30 hatchlings was placed in each compartment. Whenever possible clutch integrity was maintained (hatchlings produced from a given clutch were maintained within a single compartment). Each person working with hatchlings was required to wash his/her hands and equipment with a Betadine surgical scrub and/or a 3% bleach solution prior to beginning and between compartments to eliminate cross contamination.

Hatchlings were retained until they were actively feeding and the entire compartment appeared healthy. After yolk absorption, hatchlings were web-tagged in their right hind foot with sequentially numbered #1 Monel tags (National Band and Tag Co., KY). Throughout this period, data on physical abnormalities, weakness, and mortality were recorded. In 2 week increments, those animals prepared for release (hatchlings that appeared healthy and were eating, etc.) were transported to their original lake in buspans. If 1 or more animals in a pod were not ready for release (i.e., weak), the entire pod was held at the incubation facility until all could be transported together. Hatchlings were transferred to a transport boat and released at their original nest site or the nearest feasible and appropriate location.

Viability and Clutch Size

Clutch size (CS) was the total of all shelled and unshelled eggs found in a clutch cavity. Clutch viability (V) rates were defined as the number of hatchlings surviving >1 day divided by CS. Since the inherent viability of eggs was of interest, clutches from flooded or disturbed nests (by predators, turtles, humans, or other alligators) were excluded from viability analyses. Only clutches from disturbed nests were excluded from analyses of CS. A single clutch was the sample unit in analyses of V and CS.

Survey Procedures

Night-light surveys were conducted in late May or early June on lakes Apopka and Woodruff in 1994 and 1995. Surveys from 1980 to 1993 from Lake Apopka and 1981-1993 for Lake Woodruff also were included for long term trend analysis. Night-light surveys (2/year in most years) were conducted in late May or early June. Survey routes generally followed the open water-shoreline interface (Murphy 1977; Woodward and Marion 1978). Dense marsh, wooded swamp, and other inaccessible alligator habitat were not surveyed. The entire circumference of Lake Apopka was surveyed. On Woodruff, only selected canals and creeks were surveyed. However, in each case, surveys were standardized across years.

Searches for alligator eye reflections were conducted with an airboat at a planing speed of 20-25 km/hr, depending on water conditions. When dense groups of alligators were encountered, the airboat was sufficiently slowed to allow a thorough count. A 200,000 c.p. spotlight was used and size of detected alligators was judged as approaching them at normal survey speed.

To estimate alligator size, both the snout length:total length (TL) index described by Chabreck (1966) and a general impression of size, periodically calibrated by catching and measuring size-judged alligators, were used. Alligators were classified in 30cm (1-ft) size classes when possible or placed into broader TL categories (0-60 cm, 61-121 cm, 122-182 cm, <122 cm, and <183 cm; Woodward and Moore 1990) when specific size class could not be determined but other indications of size were evident (e.g., habitat, eye reflection, bubble trails, size of splash or wake). Size was classified as "unknown" when no indication of size was apparent.

Water levels were recorded from U.S. Geological Survey water level gauge stations in permanent locations on the main water bodies. The "water level" analyzed for each survey date was departure from mean water levels (DMWL) for all surveys (see Woodward and Moore 1990).

Survey Analysis

For trend analysis, the size distribution of unknown-size alligators was assumed consistent with the distribution of known-size alligators (assumed equal detectability among size classes). Unknown-sized animals were apportioned accordingly in 4 TL classes [30-121 cm ("juvenile"), 122-182 cm ("subadult"), <30 cm ("total population"), and <183 cm ("adult")] (see Woodward and Moore 1990). During the May-June surveys, hatchlings from the previous year (approx. 9 months old) were considered to be sufficiently dispersed to render their sighting probabilities as independent and were included in the analyses.

For Lake Woodruff, tests for trends in count densities were conducted by regressing log-transformed counts of alligators in each general size class on elapsed time and DMWL. DMWL was previously found to explain a significant proportion of variation in night-light surveys (Woodward and Moore 1990). For Lake Apopka, both a model similar to that utilized for the Lake Woodruff data and a non-linear model were fitted to log-transformed counts regressed on elapsed time and DMWL. The non-linear segmented model incorporated both a quadratic and a linear response to test for possible increasing trends during recent years. In all cases, the quadratic portion of the model was specified first due to the relative amount of data (years of survey) before and after the lowest count (the quadratic segment required the estimation of an additional parameter). We allowed the model estimation program (Proc NLIN, SAS Institute, Inc. 1988) to choose the point where the two segments met by imposing a continuity restriction on the model. We specified that the quadratic and linear segments must meet exactly. In addition to estimates of possible trends in the populations and model goodness-of-fit statistics, adjusted R^2 (Rawlings 1988) values and the analog for non-linear models (proportion of variance explained: model SS / total SS adjusted for number of parameters) which allow valid goodness-of-fit comparisons among regression models having different numbers of parameters were reported.

Clutch Viability Analysis

For Lake Apopka data, the fit of a non-linear model to arcsine-squareroot transformed viability rates regressed on elapsed time was tested. This non-linear segmented model incorporated both a quadratic and a linear response to test for possible increasing trends during recent years. The quadratic portion of the model was specified first due to the relative amount of data (years of survey) before and after the lowest measured viability rate (the quadratic segment required the estimation of an additional parameter). We allowed the model estimation program (Proc NLIN, SAS Institute, Inc. 1988) to choose the point where the two segments met by imposing a continuity restriction on the model. We specified that the quadratic and linear segments must meet exactly. Additionally, we tested the fit of an identical model for the proportion of clutches on Lake Apopka which produced no hatchlings.

RESULTS

Clutch Viability and Clutch Characteristics

During the summers of 1994 and 1995, 109 alligator nests from lakes Apopka and Woodruff were collected for incubation and other studies and transported to the central incubation facility in Gainesville (Table 1). Clutch viability differed between lakes ($P < 0.0001$; df = 103), but not between years ($P = 0.19$; df = 103; Table 1). In addition, a difference was found in the number of hatchlings produced per nest between lakes Apopka and Woodruff ($P < 0.001$; df = 103; Table 1).

In past years, it was noted that a significant portion of hatchlings produced from Lake Apopka's nests emerged from only a few clutches with many clutches producing no hatchlings (Woodward et al. 1993; Masson 1995). However, during 1994 and 1995, less than 20% of Apopka clutches produced no hatchlings. In addition, Percival et al. (1992) observed that a large proportion of Lake Apopka's hatchlings did not survive the first week post-hatch. Very little (<1%) post-hatch mortality occurred in 1994 and 1995. In general, egg mortality followed that observed by Masson (1995). Most mortality occurred pre-egg deposition or in early incubation with the next largest proportion of mortality occurring very late in incubation.

Clutch size was significantly higher on Lake Apopka ($P = 0.006$; df = 103; Table 1), but no difference was found between years ($P = 0.22$; df = 103; Table 1). However, there was no difference between the two lakes in clutch weight ($P = 0.37$; df = 103; Table 1), indicating that mean egg weight on Lake Apopka was less than Lake Woodruff. Mean clutch weight was not different between the 2 years, 1994 and 1995 ($P = 0.90$; df = 103).

Population Trends

Count densities of subadults, juveniles, and the total population of animals increased ($P < 0.01$) with decreasing water levels on both Lake Apopka and Lake Woodruff. Therefore, water level was included as an adjustment covariate in both models (Woodward and Moore 1990). Trends on Lake Apopka were investigated from 1980-1995 and 1981-1995 on Lake Woodruff. On Lake Apopka, for juveniles and the total population, the nonlinear segmented model was chosen over the linear regression model due to goodness of fit (for linear model: $R^2_{adj} < 0.18$; $P > 0.24$; for nonlinear model: $\sim R^2_{adj} > 0.78$, $P < 0.01$). The total population decreased approximately 84% from 1980 to 1989 then increased approximately 160% through 1995 ($P < 0.01$; $\sim R^2_{adj} = 0.87$; Table 2). Juveniles decreased by almost 95% through 1989 then increased by 480% over the next 6 years ($P < 0.01$; $\sim R^2_{adj} = 0.78$; Table 2; Fig. 1). No trend in either subadult or adult animals was found over the study period ($P > 0.70$; $R^2_{adj} < 0.01$; Table 2).

On Lake Woodruff, an increasing trend of 8.1% per year was detected over the study period for animals <30 cm ($P = 0.001$; $R^2_{adj} = 0.61$; Table 2). Juveniles (30-121 cm) increased by 10.8% per year ($P = 0.001$; $R^2_{adj} = 0.72$; Table 2; Fig. 2). Similarly, subadult animals (122-182 cm) increased by 8.6% per year through the present ($P = 0.001$; $R^2_{adj} = 0.68$; Table 2). A trend of 3.3% per year was detected in the adult population over the study period ($P = 0.003$; $R^2_{adj} = 0.35$; Table 2).

Clutch viability trends on Lake Apopka were similar to those results for the smaller size classes detected utilizing night-light surveys. A decrease in clutch viability of approximately 80% from 1983 to 1988 and an increase of over 400% through 1995 was detected ($P = 0.05$; $\sim R^2_{adj} = 0.82$; Fig. 3).

A decreasing trend in the proportion of nests from Lake Apopka which produced no hatchlings also was detected ($P = 0.06$; $\sim R^2_{adj} = 0.78$; Fig. 4). The proportion of nests which produced no hatchlings increased by about 200% through the 1988 nesting season then decreased by 73% through the present (Fig. 4).

DISCUSSION

Lake Apopka's alligator population has increased since 1989 after declining from 1980-1989. This coincides with a similar decline and rise in clutch viability rates. Will this rise translate into a real long-term recovery of alligator populations on the lake? One can assume that the adult animals present today will eventually stop production through senescence or mortality. Some of the juveniles present on the lake today will be recruited into the adult population. If those juveniles survive at a sufficiently high rate, enter the adult breeding population, and produce offspring, the population may be able to recover toward the limits of its modern-day habitat. However, if observed abnormal endocrine function and hormonal concentrations have altered the reproductive capabilities of those juveniles (as suggested in Rice and Percival 1996), another reduction in the population could occur. Obviously, only through further monitoring of the Lake Apopka population can this hypothesis of recovery be fully evaluated.

At this point there is certainly ample evidence of some recovery on Lake Apopka. Juvenile populations have increased dramatically in the last few years. However, certain questions arise with data generated through night-light surveys such as independence of replicate counts, numerous sources of count variation, and independence of sighting probabilities among the young animals (which may remain in pods). When coupled with the equally dramatic rise in clutch viability rates, an increase in the juvenile population has certainly occurred. Further, the increase in juveniles detected during night-light surveys began in the sampling period immediately following the observed increase in clutch viability.

An increase in subadult animals has not yet occurred. Presumably, in the next few years, the increased numbers of juvenile alligators should begin to grow into this segment of the population if survival and growth rates are sufficient. These cohorts should be monitored both through the subadult size-classes and into the adult class to monitor either a recovery of the total population to pre-1980 levels or a secondary crash due to reproductive failure. There exists a rare opportunity to observe a dynamically changing wild population.

Clutch viability rates on Lake Apopka are still well below those found on Lake Woodruff. Lake Apopka also produces fewer hatchlings per nest than Lake Woodruff even though Lake Apopka's alligators lay more eggs. However, Lake Apopka's clutch viability rates for the last two years are comparable to those found in other areas of the state (Masson 1995). It is unclear whether the differences in clutch viability between lakes Woodruff and Apopka is due in part to nutritional, environmental, or contaminant level differences among areas. Lake Woodruff is less eutrophic and has less agricultural effluents than other areas. Lake Apopka had a myriad of contaminant inputs including muck farms on the northern shore which require backpumping water into the lake, citrus orchards on the western shore (now largely defunct), and treated municipal wastes from the south. Further, Lake Apopka suffered the run-off from a large chemical spill in the early 1980's and remains an EPA SuperFund Site.

Alligator clutch sizes were larger and mean egg size smaller on Lake Apopka than on Lake Woodruff. Smaller eggs are known to produce smaller hatchlings (Webb et al. 1987; Deeming and Ferguson 1989; Deeming and Ferguson 1990), and hatchling size may affect survival probabilities. At this point, there is no evidence that the increase of juveniles on Lake Apopka is being hampered by low survival of young. However, if survival is in fact decreased, the probability that an increase will occur in the subadult and adult populations will be lessened. Again, this is further cause for continued monitoring of the Lake Apopka population.

Another cause for optimism in the case of the Lake Apopka alligator is the decrease in the proportion of clutches that fail completely. Until recently, most hatchlings that emerged from Lake Apopka alligator eggs did so from a very few nests (Woodward et al. 1993). A large proportion of nests (as high as 75%) produced no hatchlings. This total reproductive failure of many nesting adult females whether due to environmental contaminants directly or through some indirect (hormonal), demographic, or environmental cause certainly contributed to the crash in juvenile populations on the lake. In this study, a substantial decrease in total reproductive failure was found. Most nests (>80%) produce hatchlings.

Many hypotheses have been offered for the crash in alligator populations and continued depressed clutch viability on Lake Apopka. The most publicity (and research effort) has been given to environmental contaminant effects (see Rice and Percival 1996). However, it is certain that other demographic and environmental (habitat changes and nutrition) are at least partially responsible.

Lake Apopka's wildlife populations have been continually influenced by exploitation of other lake system resources through the influx of environmental contaminants, nutrients, and the loss of habitat. However, evidence now exists that the effects of this exploitation may not persist indefinitely. Recovery of the Lake Apopka alligator population is not a certainty at this juncture, but the future does hold promise.

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