CROCODILES

Proceedings of the
17th Working Meeting of the Crocodile Specialist Group
of the Species Survival Commission of
IUCN - The World Conservation Union
convened at
Darwin, Northern Territory of Australia, 24-29 May 2004

(Unreviewed)

IUCN - The World Conservation Union
Rue Mauverney 28, CH-1196, Gland, Switzerland

2004
Literature citations should read as follows:

For individual articles:


For the volume:


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ISBN: 1 876248 94 7
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The Crocodile Specialist Group

The Crocodile Specialist Group (CSG) is a worldwide network of biologists, wildlife managers, Government officials, independent researchers, non-government 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 (SSC) 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 of international trade and identifying products. Working meetings of the group are held every two years.

Foreword

For the people who work on crocodilians around the world, the biennial meetings of the CSG have long been recognised as something special. They provide an opportunity for like-minded people to get together, to share information and experiences, and to discuss how the field crocodilian conservation and management has evolved since their last meeting. Regardless of advances in communication, it seems that nothing beats face-to-face contact with colleagues, and the ability to establish and re-establish personal relationships.

Despite the successes we have achieved with crocodilian conservation in many countries, there remains some serious problems with crocodilian conservation. Some species exist as minor remnants of their former abundance, still fighting for survival in countries where human survival is the national priority. Reviewing these critical conservation problems and formulate actions to help overcome them, is the core business of the CSG Working Meetings.

The 17th CSG meeting, held in Darwin, Northern Territory of Australia, continued a fine tradition of "good" CSG meetings. The Steering Committee meeting, which is open to all members, addressed a daunting array of different problems. One of the outcomes was that I would replace Professor Harry Messel as CSG Chairman, when he stands down in November. The meeting itself reviewed the linkages between the CSG and various international organizations and instruments, provided case history reports on conservation in many nations, and provided an opportunity for members to be updated on current research initiatives.

For the Tomistoma Task Force, formed at the 16th CSG meeting in Gainesville, USA (2002), it provided the first opportunity for TTF members to meet, discuss progress, and raise more funds for Tomistoma surveys in Kalimantan later in 2004. Other working groups met to discuss the conservation and management of Siamese Crocodiles in Cambodia, the Philippine Crocodile, the Chinese Alligator, human-crocodile conflicts, veterinary aspects, trade, etc. We had a lively evening social program to complement each day's deliberations, which finished with a field trip to the McKinlay River, where an Australian Freshwater Crocodile population has been studied for over 25 years.

The CSG could not operate without the shared commitment of its members to improving crocodilian conservation. Their willingness to donate time, effort and funds to help achieve the IUCN's goals with crocodilians, is the glue that binds members together. Continuing this commitment and activity is the challenge to be faced as the new Chairman, and I am looking forward to it.

Grahame J.W. Webb
Chairman-elect
Summary of the Meeting

Between 24 and 29 May 2004, 232 members and supporters of the Crocodile Specialist Group, from 34 countries, convened in Darwin, Northern Territory, Australia for a very successful 17th Working Meeting. Wildlife Management International Pty. Limited hosted the meeting, which was held at the MGM Grand Hotel, in Darwin.

The organising committee [Grahame Webb, Charlie Manolis, Tom Dacey Nancy Pedersen, Larry Bannister and Mike Letnic] were ably assisted by WMI staff and a band of volunteers. A large number of donors and sponsors made the meeting possible, and we are particularly grateful to the Northern Territory Government, the Rural Industries Research and Development Corporation and the Key Centre for Tropical Wildlife Management (Charles Darwin University) for their financial support. Internationaler Reptilhelderverband e.V. and Reptilartenschutz e.V. (Offenbach, Germany) provided financial assistance for some participants to get to the meeting.

The first day of the meeting was devoted to the CSG Steering Committee, which handled a daunting schedule of international crocodile issues. A highlight was the election of Professor Grahame Webb as CSG Chairman-elect, to take over the leadership when Professor Harry Messel steps down in November 2004.

The working meeting was opened by Professor Harry Messel and the Chairman of the Species Survival Commission, Dr. David Brackett. The official opening and welcome to the Northern Territory was carried out by Dr. Chris Burns, Minister for Infrastructure, Planning and Environment, at Parliament House. This occasion was also used by the SSC Chairman to present Professor Messel the IUCN’s highest award for conservation - the Sir Peter Scott Medal.

Major workshops were held concurrently with the meeting, and dealt with skin quality, human crocodile conflicts, sustainability of trade, CSG core business, and conservation of Tomistoma, Siamese Crocodiles and Philippine Crocodiles.

A session on the “Conservation, Management and Sustainable Use of Crocodiles in Australia” reviewed each of the State and Territory programs and discussed the unique role of Aboriginal people in management. Two sessions dealt with the foundations of crocodilian conservation, and provided reviews of many issues intimately linked to crocodilian conservation today (IUCN, CITES, Compliance with CITES, Article IV of CITES, Precautionary Principle, IUCN Red List, wildlife management practices and principles; and, adaptive management in Louisiana, bio-economic modelling, harvesting adults and parallels between the management of crocodiles and kangaroos in Australia).

A session was devoted to actions being taken with some of the most endangered species: Chinese Alligators, Siamese Crocodiles, Tomistoma and Muggers in Iran. This was followed by a series of sessions on management case histories from Cambodia, Sri Lanka, the Philippines, Sarawak, Congo/Gabon, Bolivia, Sabah, Venezuela, Argentina, Bangladesh and South America generally. A session on local people in crocodilian conservation examined the challenges of education generally, particularly on the internet, and examined case histories from Cambodia, Bolivia and the Philippines. A session on trade issues included some advances in crocodile farming technology.

More than 40 posters were presented, and in a break from tradition, most of the poster authors were given the opportunity to address the plenary for 5 minutes about their work. This was very successful in terms of linking the audience to particular issues and subjects before they got to the posters. The subjects addressed in the posters were highly diverse, ranging from strictly pure to applied science.

The final day was devoted to miscellaneous papers and reports which again covered a diverse range of subjects: effects of heavy metals and other pollutants; diving behaviour, crocodilian red blood cell physiology, the case for an anatomical treatise on crocodilians, genetics, radio-tracking, satellite tracking, survey biases, biomechanics, integumentary sense organs, Caiman yacare life history, American Crocodiles in Florida, reproduction of Gharials, artificial foods, population modelling, immune responses, etc.

“Nocturnal” activities included an “ice breaker” hosted by the National Aquarium in Baltimore, and a BBQ at the Darwin Trailer Boat Club. Even an atypical thunderstorm as participants made their way to the boat club could not dampen people’s spirits. A high point of the social agenda was the closing banquet, served outdoors at Crocodylus Park. Participants revelled in the ‘down-under’ hospitality, meal and drinks, together with Latin music.

The Castillo prize for crocodilian conservation, a hand-made Mexican silver pitcher, was presented to Jenny Daltry in recognition of the exciting research she has been undertaking in Cambodia and southeast Asia. A raffle was
organised for crocodile skin wallets and opals, and together with additional items sold at the meeting, resulted in around $US3000 being raised for the Tomistoma Task Force.

The field trip began early the next morning, with participants departing by bus and 4-wheel drive to the McKinlay River, about 120 km east of Darwin. The McKinlay River population of Australian Freshwater Crocodiles has been under study for over 25 years. Most people were able to go out in the boats and help catch freshies, and assist with processing and measurement. Of the 17 crocodiles caught, most were marked, some as long ago as 1980. Cane toads have just arrived in the McKinlay River, and significant increases in mortality rates are expected over the next few years.

The meeting could not have been as great a success without the contribution of many people and organisations: crocodile farms (Janamba, Koorana, Lagoon, QDPI) provided crocodile meat; Lenah Game and Gourmet provided kangaroo fillets; local industry (Newfishing Australia, Taroona, Marine Harvest) provided seafood; Parks and Wildlife Service Rangers assisted in the field trip; Kerry Sharpe (media liaison) organised the media; and, volunteers manned the registration desk and assisted in so many ways (Lesley Sullivan, Peter Sullivan, Peta Jones, Harvey Ottway, Erin O’Brien, Pushpa Palianappan). Akira Matsuda set up a secure server for registrations. Adam Britton ensured that presentations were loaded and ready to go as scheduled.

A special thank-you must go to the chief organiser, Tom Dacey, for his considerable efforts in the months leading up to, and at the meeting.

The CSG Working Meetings, held each two years, are the primary international meeting dedicated to crocodilian conservation. They have become the major forum for discussion of conservation problems, new findings and new directions. Each meeting has its special highlights, and participants at the 17th CSG Meeting seemed unanimous in their view that it had been one of the “best” meetings.
Hosts, Sponsors and Donors

Host Organisation

• Wildlife Management International

17th CSG Meeting Organising Committee

• Tom Dacey, Clifton Beach, Queensland
• Graeme Webb, Wildlife Management International
• Charlie Manolis, Wildlife Management International
• Larry Bannister, Department of the Chief Minister
• Nancy Pedersen, Department of Business, Industry and Resource Development
• Mike Letnic, Parks and Wildlife Service of the Northern Territory

Major Sponsors

Key funding was kindly provided by the following organisations:

• Northern Territory Department of Business, Industry and Resource Development
• Northern Territory Department of Infrastructure, Planning and Environment
• Rural Industries Research and Development Corporation
• Key Centre for Tropical Wildlife Management, Charles Darwin University

Additional Sponsors and Donors

The following people and/or organisations provided additional financial or in-kind support for the meeting:

• IUCN-SSC Crocodile Specialist Group
• Internationaler Reptilenederverband e.V., Offenbach, Germany
• Reptilartenschutz e.V., Offenbach, Germany
• National Aquarium in Baltimore, USA
• John and Lillian Lever, Koorana Crocodile Farm, Rockhampton, Queensland
• John Hannon, Lagoon Crocodile Farm, Darwin, Northern Territory
• Stuart Barker, Janamba Croc Farm, Middle Point, Northern Territory
• Queensland Department of Primary Industry, Townsville, Queensland
• John Kelly, Lenah Game and Gourmet, Hobart, Tasmania
• John McKenna, Newfishing Australia, Darwin, Northern Territory
• Normie Heddich, Tarooma Pty. Ltd., Darwin, Northern Territory
• Akira Matsuda, AIBAS, Okinawa, Japan
• Marine Harvest, Darwin, Northern Territory
• Crocodylus World Practice Firm, Charles Darwin University, Darwin, Northern Territory
• Parks and Wildlife Service of the Northern Territory, Palmerston, Northern Territory
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Chairman-elect Prof. Grahame Webb with Chairman Prof. Harry Messel (Photo: Charlie Manolis).

Craig Franklin, Boyd Simpson, Adam Britton and Akira Matsuda at the BBQ night (Photo: Charlie Manolis).
Alvaro Velasco with his first McKinlay River freshie. Included in the background are Chris Hagen, Jayantha Jayewardene, Mick Pitman, Hildegarde Huchzermeyer and Ashgar Mobaraki (Photo: Alvaro Velasco).

Colin Stevenson (right) and Michael Comerford (left) help Adam Britton process a freshie. (Photo: John Breuggen).
‘Croc’ women and Allan Woodward at work catching a McKinlay River freshie (from left, Allan Woodward, Libby Bernadin, Heather Thompson and Susan Woodward) (Photo: Phil Wilkinson).

The McKinlay River population of freshwater crocodiles has been studied by WMI for over 26 years. The field trip gave participants an opportunity to see the study-site and participate in the capture of a number of freshies. The impact of cane toads on this population is currently under investigation (Photo: Grahame Webb).
The History of Crocodile Conservation in Australia

Goff Letts

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For millions of years Australian crocodiles (now represented by *Crocodylus porosus* and *C. johnstoni*) managed their own affairs quite successfully as predators and reproducers at the top of our aquatic food chain. The arrival of Aboriginal people, up to 40,000 years ago, made an impact, though it was not critical. Eggs and meat became part of the diet of coastal people. At the same time these majestic reptiles were embraced into Aboriginal culture in story, ceremony and art.

Early European explorers encountered crocodiles. In 1818, Phillip Parker King misnamed the Alligator Rivers during his maritime survey of the northern coastline. In 1855, A.C. Gregory, the first to cross Australia from west to east, lost horses to crocodile attacks near the mouth of the Fitzmaurice River, an event vividly recorded by the party’s artist, Baines. In 1894 Knut Dahl, accompanying Aborigines on the lower Daly River, gave us a sketch of numbers, size and distribution of crocodiles there, and of their cultural significance.

For the next half-century, crocodiles continued to do their own thing within their natural range. The north coast was sparsely populated by settlers who embarked on sporadic hunting forays to counter livestock predation or to harvest a few skins. Webb *et al.* (1984) estimated the Australian population of *C. porosus* in 1945 to be in the order of 200,000.

This peaceful existence was interrupted dramatically from 1945 onwards when world demand for skins attracted professional and amateur shooters to the hunt. Webb *et al.* (1984) estimated that in the order of 300,000 *C. porosus* were harvested from the wild between 1945 and 1972. There was minimal industry regulation. Licences were issued, skins were given a cursory inspection and exports were cleared through customs.

*Crocodylus johnstoni* entered the market later in about 1958. In readily accessible habitat, they were easy targets. Their over-exploitation gave rise to concern among northern wildlife management authorities.

They were given legal protection in Western Australia in 1962 and in the Northern Territory in 1964, following passage of the Northern Territory’s first Wildlife Conservation and Control legislation. Some poaching and leakage through Queensland continued.

As the wild harvest of *C. porosus* went on apace, numbers and size dropped. Concern rose within the Commonwealth and States Conservation Ministers’ Council (CONCOM) leading to protection action at State level, first in Western Australia (1969), then in the Northern Territory (1971). The Commonwealth Government, exercising its constitutional powers, embargoed exports in 1972, and Queensland adopted protection in 1974.

The next 15 years were critical in the story of crocodile conservation and management in Australia. In 1971 Professor Messel and Sydney University had initiated the North Australia research program. His landmark surveys of *C. porosus* populations in northern estuaries and rivers continued to 1984. Research into the biology of both species stepped up in the Northern Territory, Queensland and NSW. It became the basis for management plans in force today.

In 1975 the Australian National Parks and Wildlife Service commissioned Grahame Webb to prepare a report on the status, conservation and management of world crocodilians. His recommendations in the Australian section were to prove prophetic.

At the same time, international decisions were impacting on the Australian scene. IUCN identified the endangerment of all crocodilians throughout their range. The advent of CITES in 1973 saw our *C. porosus* first listed on Appendix II, then transferred to Appendix I in 1979. (The contiguous Papua New Guinea population remained on Appendix II).

That coincided with a rise in interest in farming crocodiles in Australia, to take advantage of leather and tourism markets and as part of conservation programs. Edwards River Aboriginal project, based on captive breeding, got under way. But for others, the Appendix-I listing would prove difficult. Tensions between interested parties, at home and abroad, followed.
“Problem” crocodiles, increasing in numbers and size, were appearing in Darwin Harbour. Between 1979 and 1981, six attacks (4 fatal) were recorded in Territory coastal areas. Between 1980 and 1982, 179 crocodiles were taken from Darwin Harbour. Public apprehension was growing and crocodiles were becoming politically difficult at the local level.

Based on his surveys Harry Messel was unhappy about future prospects for “salties”. He pointed to losses caused by fishing nets and other limiting factors. His advice to the CITES Secretariat - no change!

Grahame Webb’s research team was painting a more optimistic picture. CONCOM agreed that C. porosus' conservation interests would be best served by an appendix change. CITES ranching resolution opened the door; internationally the role of sustainable utilisation in conservation was being realized.

It was a bumpy road. Supporting the change at CSG meetings at Victoria Falls and St. Lucia in 1982, I found myself in splendid isolation. A follow-up application by Australia at CITES (Gabarone, 1983) was withdrawn in the face of general opposition (with some evidence of self-interest). I learnt about international conservation politics.

1984 saw the breakthrough. A comprehensive proposal for an CITES appendix change for the NT population of C. porosus, drafted by Webb et al. (1984), was endorsed in a meeting of minds at the CSG meeting in Caracas, Venezuela and subsequently by IUCN. The CITES meeting in Buenos Aires in 1985 approved Australia’s application for an Appendix-II downlisting (ranching).

By that time 5 farms were operating in Australia - 3 in the NT, 2 in Queensland. About 4500 C. porosus and 7000 C. johnstoni were being held on these establishments under approved plans of management. In January 1985 a very successful international crocodile conference was held in Darwin. Substantial progress was made in public education (“Living With Crocodiles”), feral buffalo elimination, net fishing reduction, expansion of protected areas, and Aboriginal consultation (60% of C. porosus habitat is on Aboriginal-owned land). By 1986, Professor Messel acknowledged that “recovery is under way” (Messel et al. 1986).

Since then there have been regular refinement to management plans, Australian crocodiles continue to survive and grow in the wild, the industry has come through ups and downs, and research continues to break new ground. The CSG maintains a watching brief. Most of the tensions have eased.

To see the above events in context, it is necessary to understand something of the intricacies of Australia’s federal system. Under our Constitution, land, rivers, coastal fringes and wildlife management are largely the responsibility of State and Territory Governments. The Commonwealth Government is directly responsible for matters of common national interest. For example, through Customs it regulates export activities. It also plays a role in co-ordinating common State interests.

Under the Constitution, the Commonwealth is responsible for “external affairs”. The High Court has interpreted this to give the Commonwealth jurisdiction over matters which are the subject of international treaties like CITES and the RAMSAR wetlands Conventions. In exercising this power the Commonwealth enacted the Wildlife Protection (Regulation of Exports and Imports) Act, 1982 (since amended to the Environment Protection and Biodiversity Conservation Act, 1999), becoming the Scientific and Management Authority for Australia. The Act embraces the CITES Appendices.

The States have day-to-day responsibility for wildlife management and research. Policies and programs are co-ordinated through a ministerial council that includes representation from New Zealand and Papua New Guinea, backed by regular meetings of departmental heads and technical working groups.

Today the management of crocodiles in Australia is the product of sound biological research, robust debate, private enterprise and government support, leavened by goodwill and co-operation, in all of which the CSG has plated a significant role.
Literature


Crocodile Management in the Northern Territory of Australia

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Abstract

Two species of crocodile, the estuarine crocodile (Crocodylus porosus) and the Australian freshwater crocodile (C. johnstoni) occur in the Northern Territory. Since crocodiles were declared a protected species in 1971 their populations have increased dramatically. In 1972 the C. porosus population was estimated to be 3000 individuals. Today there are more than 70,000 non-hatching estuarine crocodiles in the Northern Territory.

Crocodiles are iconic species that attract considerable publicity and a wide range of community views regarding their abundance and cultural and economic importance. Crocodile management in the Northern Territory is directed towards the conservation of crocodiles, their sustainable use and ensuring that crocodiles do not threaten human safety and enjoyment of the environment. In this paper I discuss the conservation and management of crocodiles in the Northern Territory.

Introduction

Two species of crocodile, the estuarine crocodile (Crocodylus porosus) and the Australian freshwater crocodile (C. johnstoni) occur in the Northern Territory. Since crocodiles were declared a protected species in 1971 their populations have increased dramatically. In 1972, the C. porosus population was estimated to be 3000 individuals. Today there are more than 70,000 non-hatching estuarine crocodiles in the Northern Territory. There are no reliable estimates of the population size of C. johnstoni, however they are regarded as being abundant.

In the Northern Territory crocodiles are iconic species that attract considerable publicity and a wide range of community views and opinions regarding their abundance, distribution and cultural and economic importance. Community views towards crocodiles range from them being regarded as totems of spiritual significance by some Aboriginal communities to being regarded as objects of revile and as dangerous pests among some other sectors of the community. Crocodiles are also an important natural resource for many community sectors including Aboriginal communities, the tourist industry and the wildlife harvesting industry.

The opportunities for development provided by an abundant crocodile population in the Northern Territory are considerable. Crocodiles are a major attraction for tourists visiting the Top End of the Northern Territory and many tourists have an expectation that they will see a large crocodile during their visit to the Northern Territory. The abundant crocodile population also supports the crocodile farming industry and provides people living in remote and rural communities with the opportunity to harvest wild crocodiles and their eggs. Wild harvesting of crocodiles and their eggs offers rural and remote communities, particularly indigenous communities, with opportunities for economic development without substantial capital investment.

Because of crocodiles’ economic significance, danger to people and property and the potential for conflict between different user groups, crocodile management in the Northern Territory is a complex task. In this paper I provide an overview of crocodile management in the Northern Territory. The paper will concentrate mainly with the management of C. porosus because this is the main species of management concern.

Distribution of Crocodiles within the Northern Territory

Crocodylus porosus occurs in tidal and freshwaters in northern Australia ranging from Gladstone to Port Hedland (Fig. 1). In the Northern Territory, C. porosus occur in high densities in the tidal portions of some mangrove-lined rivers. They are also common in freshwater floodplain habitats and may occur in any freshwater habitat within their range. Detailed descriptions of C. porosus habitats within the Northern Territory are available in Messel et al. (1979-1987), Magnusson (1980), Magnusson et al. (1978), Magnusson and Taylor (1980) and Webb et al. (1977, 1983).
*Crocodylus johnstoni* are found only in northern Australia; in Western Australia, the Northern Territory and Queensland (Fig. 2). *Crocodylus johnstoni* occur primarily in freshwater habitats although they may also occur in the saline, upper tidal reaches of river systems.

**The Conservation Status of Saltwater Crocodiles in the Northern Territory**

The Northern Territory population of *C. porosus* is the largest in Australia. Trends in total population size have been monitored by spotlight counts in a number of tidal rivers since the 1970s (Messel and Vorlickeck 1986; Stirrat et al. 2001). In 1994 the *C. porosus* population was estimated to be between 70,000 and 75,000 non-hatchling individuals (non-hatchlings are greater than 60 cm total length) (Webb et al. 1994). Of this number between 20-40% are likely to occur in fresh water (Webb et al. 1984).

There are few known threats to the conservation status of crocodiles in the Northern Territory. The habitats of crocodiles are, in general, not threatened by development and crocodiles appear to be little affected by the invasion of freshwater wetlands by introduced plants such as *Mimosa* (*Mimosa pigra*). Since the 1970s the disturbance of floodplain habitats by feral buffalo and cattle has been reduced greatly following eradication campaigns. Cane toads are potentially a threatening process to freshwater crocodiles but are not considered to be a threat to saltwater crocodiles (van Dam et al. 2002).

Entanglement in fishing nets is known to be a cause of mortality for crocodiles in the Northern Territory. Losses of *C. porosus* due to accidental capture and drowning in barramundi fishing nets was assessed in the early 1980s (Webb et al. 1984). Firm data on the level of mortality and the effect of that mortality on crocodile populations are not available for the Northern Territory (Webb et al. 1987). Commercial fishing has been banned within a number of river systems that are important habitats for *C. porosus*, such as the Mary, Adelaide, Roper and Alligator Rivers. Fishermen are not permitted to utilise wild crocodiles that drown in their nets.

**Population Dynamics**

Since they were declared a protected species in 1971, *C. porosus* populations throughout the Northern Territory have undergone a dramatic recovery. The population increased at a rate of around 4-5% per year during the 1980s and early 1990s (Webb et al. 1998). Recent surveys suggest that in most areas the rate of increase of the crocodile population is slowing or approaching an asymptote.

The population of *C. porosus* on the Blyth River near Maningrida has been the most intensively studied crocodile population in the Northern Territory and its population density and dynamics are typical of those seen in rivers throughout the Territory. The population on the Blyth River increased dramatically following protection in 1971 and has been relatively stable since the late 1980s (Fig. 3). An examination of the age structure of the population indicates that since protection, the proportion of individuals, greater than 2.1 m in length, has increased and continues to increase with time (Fig. 4). Similar trends in crocodile populations have been observed throughout areas subject to both the harvesting of crocodile eggs and adult crocodiles. The results of crocodile surveys conducted throughout the Northern Territory since the harvesting of eggs began in 1983, provides no evidence for changes in the size or structure of crocodile populations that can be attributed to egg harvesting or the harvesting of adult crocodiles.
Figure 3. Long-term monitoring data for *Crocodylus porosus* in the Blyth River showing the density of non-hatchling crocodiles from the time of protection in 1971 until 2003.

Figure 4. Long-term monitoring data for *Crocodylus porosus* in the Blyth River showing the size structure of the population expressed as a percentage of the population in 4 size classes.
Studies of survivorship indicate that there is a high mortality rate of crocodiles from egg to maturity. Webb and Manolis (1993) predicted rates of survival for several size classes of C. porosus in the wild: at least 25% of eggs usually hatch; 54% of hatchlings survive to one year; 30% of one-year-old crocodiles survive to two years; 60% of two-year-olds survive to three years of age; 56% of three-year-olds survive to four years of age; 56% of four-year-olds survive to five years of age. It follows that about 18 crocodiles would survive to five years from 1000 eggs laid. The actual rates of survival between age five and maturity have never been estimated; however, Webb and Manolis (1993) estimate that less than 1% of these individuals survive to breed. The survival rate of mature animals is unknown.

The gradual decrease in rate of population increase over time, changes in the age structure of populations and studies of the mortality of crocodiles at each stage of their life cycle suggest that the survival of hatchling, juvenile and adult crocodiles is most dependent upon the density of larger crocodiles. It is likely that larger crocodiles prey upon and/or competitively exclude smaller crocodiles (Webb and Manolis 1993). Although most crocodile populations in the Northern Territory appear to display classic density-dependent population dynamics similar to that observed on the Blyth River, some like the Mary River show very different dynamics.

Figure 5 shows the population dynamics of C. porosus in the tidal part of the Mary River. This population, like those elsewhere, underwent a dramatic increase in numbers following protection in 1971. However, the Mary River population is exceptionally dense when compared to other populations that have been surveyed in tidal rivers and also has an atypical population structure. Population structure data for the Mary River indicate that, unlike most other rivers, the population is dominated by individuals greater than 2.5 m in length (Fig. 6). There is no immediately apparent reason to explain why the Mary River population is so different to those in other tidal rivers. It may be that the Mary River is located on a particularly rich floodplain area that can support a large number of crocodiles without invoking intra-specific competition between individuals.

![Graph](image)

Figure 5. Long-term monitoring data for Crocodylus porosus in the Mary River showing the density of non-hatchling crocodiles from the time of protection in 1971 until 2003.

There is a general consensus that the population and range of C. porosus in freshwater habitats is increasing, however, little is known of the population size or population structure of C. porosus in freshwater habitats. There has been a considerable body of literature describing the breeding habits of C. porosus in freshwater areas (see Webb et al. 1977; Magnusson 1980). The paucity of information on the ecology of C. porosus in freshwater areas is due largely to the difficulties associated with conducting studies in these habitats. These include poor visibility owing to emergent and overhanging vegetation and limited access to freshwater habitats.
Figure 6. Long-term monitoring data for *Crocodylus porosus* on the tidal section of the Mary River showing the size structure of the population expressed as a percentage of the population in 4 size classes.

**Brief History of Management**

Crocodile meat and eggs are thought to have been used as a food source by Aboriginal people for as long as Australia has been settled. The importance of crocodiles in Aboriginal culture is reflected in a complex system of totems and ceremonies that is still evident in northern Australia today (Lanupuy 1987).

In the Northern Territory, commercial hunting of *C. porosus* began in 1945 and continued until 1971 when the species was declared protected due to the marked decline of the population. The decline of the *C. porosus* population between 1945 and 1971 is evident from the reduction of skins produced during this period. Between 1945 and 1971 the total number of *C. porosus* skins from the Northern Territory entering trade is estimated to have been 113,000, with 87,000 between 1945 and 1958 and only 26,000 between 1959 and 1971 (Webb et al. 1984).

After protection in 1971, the Northern Territory population of *C. porosus* increased from approximately 3000 non-hatchlings (individuals >0.6 m total length) in 1971 to between 30,000 and 40,000 individuals in 1984 (Webb et al. 1984). On 1 July 1975, *C. porosus* was listed on CITES Appendix II. On 28 June 1979, all populations of *C. porosus* except for the population in Papua New Guinea were moved to Appendix I. Following the recovery of the *C. porosus* population, the Australian and Indonesian populations were transferred from Appendix I to Appendix II in 1985. The transferring of populations to Appendix II allowed the re-establishment of an export orientated crocodile industry. In the Northern Territory, this industry began operating in 1980 as crocodile farming whereby farm-stock was derived from wild harvests of crocodile eggs and from captive breeding programs. The first crocodile farm in the Northern Territory was established in 1980.

The ranching industry has been managed closely to ensure that it does not have any detrimental effects on crocodile populations. The current egg harvest quota is 25,000 eggs. Since 1996 limited harvesting of adults and hatchlings from the wild has also occurred. The sustainability of crocodile harvesting in the Northern Territory is evidenced by the continued increase of the *C. porosus* population.

The current management program for *C. porosus* is directed at the long-term sustainable utilisation and conservation of crocodiles and their habitats throughout the Northern Territory. The rationale underlying the program is that abundant populations of crocodiles should be maintained for their ecological and economic value while at the same time ensuring that crocodiles do not threaten human safety and the enjoyment of the environment.
The Territory Parks and Wildlife Conservation Act 2000 provides for traditional harvest (otherwise than for the purpose of sale) of crocodiles and their eggs for food gathering, ceremonial and religious purposes by Aboriginal people. The extent of traditional harvests of crocodiles is difficult to quantify and varies greatly from area to area and year to year. The number of eggs and non-hatchling crocodiles harvested in the last several years is estimated to be around 2000 individuals.

Use of and Trade of Crocodile Products

The commercial harvesting of crocodile eggs started in the early 1980s. Records kept by the Parks and Wildlife Service of the Northern Territory show that the total number of eggs collected has increased from 135 in 1984 to a maximum of 29,044 in 1995/96 (Table 1). The number of eggs collected each year depends to a large extent on the timing and extent of rainfall, which can cause the flooding of nests and therefore influence egg survival.

<table>
<thead>
<tr>
<th>Season</th>
<th>Total Eggs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979/80</td>
<td>135</td>
</tr>
<tr>
<td>1980/81</td>
<td>2758</td>
</tr>
<tr>
<td>1981/82</td>
<td>327</td>
</tr>
<tr>
<td>1982/83</td>
<td>298</td>
</tr>
<tr>
<td>1983/84</td>
<td>2320</td>
</tr>
<tr>
<td>1984/85</td>
<td>3518</td>
</tr>
<tr>
<td>1985/86</td>
<td>3737</td>
</tr>
<tr>
<td>1986/87</td>
<td>4401</td>
</tr>
<tr>
<td>1987/88</td>
<td>5300</td>
</tr>
<tr>
<td>1988/89</td>
<td>6497</td>
</tr>
<tr>
<td>1989/90</td>
<td>12,010</td>
</tr>
<tr>
<td>1990/91</td>
<td>9212</td>
</tr>
<tr>
<td>1991/92</td>
<td>15,298</td>
</tr>
<tr>
<td>1992/93</td>
<td>12,379</td>
</tr>
<tr>
<td>1993/94</td>
<td>17,322</td>
</tr>
<tr>
<td>1994/95</td>
<td>19,033</td>
</tr>
<tr>
<td>1995/96</td>
<td>29,044</td>
</tr>
<tr>
<td>1996/97</td>
<td>21,979</td>
</tr>
<tr>
<td>1997/98</td>
<td>10,812</td>
</tr>
<tr>
<td>1998/99</td>
<td>13,976</td>
</tr>
<tr>
<td>1999/00</td>
<td>11,987</td>
</tr>
<tr>
<td>2000/01</td>
<td>15,478</td>
</tr>
<tr>
<td>2001/02</td>
<td>17,536</td>
</tr>
</tbody>
</table>

Adult and juvenile crocodiles have been removed from the wild over the past two decades to stock crocodile farms with breeding animals. Since 1997 adult crocodiles have been harvested from the wild under permit for direct skin and meat production. Data held by the Parks and Wildlife Service of the Northern Territory show that the numbers harvested have increased from 17 individuals in 1997 to 158 individuals in 2001 (Table 2).

There are currently six crocodile farms in the Northern Territory. Details of commercial crocodile farm production in the Northern Territory are given in Table 3.

Crocodiles and Tourism

Tourism is one of the major industries in the Top End of the Northern Territory and saltwater crocodiles are currently the Territory’s principal marketing icon. Most tourists visiting the Top End have an expectation that they will encounter a crocodile during their time there. The demand to see crocodiles is reflected by a vast array of tours and facilities
Table 2. The number of *Crocodile porosus* harvested from the wild and the number of problem crocodiles removed by PWSNT staff each year between 1996 and 2002.

<table>
<thead>
<tr>
<th>Year</th>
<th>Wild Harvest</th>
<th>Problem Crocodiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>0</td>
<td>135</td>
</tr>
<tr>
<td>1997</td>
<td>17</td>
<td>128</td>
</tr>
<tr>
<td>1998</td>
<td>10</td>
<td>112</td>
</tr>
<tr>
<td>1999</td>
<td>91</td>
<td>139</td>
</tr>
<tr>
<td>2000</td>
<td>92</td>
<td>181</td>
</tr>
<tr>
<td>2001</td>
<td>158</td>
<td>252</td>
</tr>
<tr>
<td>2002</td>
<td>138</td>
<td>150</td>
</tr>
</tbody>
</table>

Table 3. Numbers of skins produced and quantity of meat produced (kg) by Northern Territory crocodile farms since 1987.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Farms</th>
<th>Skins</th>
<th>Meat (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>4</td>
<td>251</td>
<td>2072</td>
</tr>
<tr>
<td>1988</td>
<td>4</td>
<td>962</td>
<td>3171</td>
</tr>
<tr>
<td>1989</td>
<td>4</td>
<td>1402</td>
<td>2675</td>
</tr>
<tr>
<td>1990</td>
<td>4</td>
<td>1954</td>
<td>4939</td>
</tr>
<tr>
<td>1991</td>
<td>6</td>
<td>2381</td>
<td>No data</td>
</tr>
<tr>
<td>1992</td>
<td>6</td>
<td>3277</td>
<td>4017</td>
</tr>
<tr>
<td>1993</td>
<td>6</td>
<td>4796</td>
<td>13,850</td>
</tr>
<tr>
<td>1994</td>
<td>7</td>
<td>3595</td>
<td>17,401</td>
</tr>
<tr>
<td>1995</td>
<td>8</td>
<td>6917</td>
<td>26,626</td>
</tr>
<tr>
<td>1996</td>
<td>8</td>
<td>6410</td>
<td>35,411</td>
</tr>
<tr>
<td>1997</td>
<td>8</td>
<td>8448</td>
<td>34,621</td>
</tr>
<tr>
<td>1998</td>
<td>8</td>
<td>8456</td>
<td>44,115</td>
</tr>
<tr>
<td>1999</td>
<td>8</td>
<td>8466</td>
<td>45,651</td>
</tr>
<tr>
<td>2000</td>
<td>8</td>
<td>7643</td>
<td>41,502</td>
</tr>
<tr>
<td>2001</td>
<td>6</td>
<td>6351</td>
<td>28,634</td>
</tr>
<tr>
<td>2002</td>
<td>6</td>
<td>3938</td>
<td>14,794</td>
</tr>
</tbody>
</table>

that allow people to encounter crocodiles. These range from tours of crocodile farms, to tours of waterways that allow people to see crocodiles in their natural habitats. Because of this demand, the management of crocodiles in the Northern Territory recognizes the value of crocodiles to tourism. This is evidenced in the current management program by the creation of areas where the harvesting of adult crocodiles is restricted due to their high usage by tourists. Areas where crocodile harvesting is currently restricted are parts of the Adelaide River, Mary River and Daly River catchments. By restricting harvesting it is expected that crocodiles will be more abundant and less wary than would be the case if there was harvesting.

**Human-Crocodile Conflicts**

*Crocodile porosus* is a species that is potentially dangerous to humans and unfortunately there have been numerous records of fatal attacks by crocodiles on humans in the Northern Territory. Since 1971 there have been 10 fatal attacks and at least 33 non-fatal attacks by crocodiles. In most instances where attacks have occurred the victims have been in the water at the time of the attack, though in some cases the victims were located on the waters edge. Saltwater crocodiles are also known to attack livestock and although these losses have never been quantified, they are at times said to be substantial.
To reduce the likelihood of human crocodile/conflicts the Parks and Wildlife Service operates a program to remove problem crocodiles and also issues permits to private individuals allowing them to remove problem crocodiles. *Crocodylus porosus* are not relocated because of their homing instincts (Walsh and Whitehead 1993). The majority of animals captured under the Parks and Wildlife Service’s problem crocodile program are distributed to farms and some enter trade directly as skins. These animals may be used for breeding stock or processed for skins and meat along with captive-bred and ranched animals.

In some areas such as Darwin Harbour, Gove Harbour, the Katherine River and swimming areas in National Parks, all crocodiles are considered problem crocodiles and there are permanent removal programs. Data on the Darwin Harbour problem crocodile program are presented in Table 4. In Darwin Harbour there are 19 permanent crocodile traps. These traps capture over 100 crocodiles per year. The sex ratio of the captured crocodiles is biased towards males and is dominated by individuals between 2 and 3 m in length (Fig. 6).

<table>
<thead>
<tr>
<th>Year</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>82</td>
<td>33</td>
<td>115</td>
</tr>
<tr>
<td>2002</td>
<td>89</td>
<td>41</td>
<td>130</td>
</tr>
<tr>
<td>2003</td>
<td>130</td>
<td>57</td>
<td>187</td>
</tr>
<tr>
<td>2004 (Jan-Apr)</td>
<td>73</td>
<td>14</td>
<td>87</td>
</tr>
</tbody>
</table>

Figure 6. Size distribution of *Crocodylus porosus* removed from Darwin Harbour in 2002.

In other areas, crocodiles that pose a threat to human safety or that have made repeated attacks on stock are considered to be problem crocodiles and are removed by Parks and Wildlife staff or private contractors. The Parks and Wildlife Service conducts regular public awareness campaigns aimed at reducing the occurrence of harmful interactions between people and crocodiles.

**Conclusion**

Crocodiles are a prominent and economically important component of the Northern Territory’s fauna. Managing crocodiles is a complex task that requires finding a balance between competing economic uses, conservation requirements and reducing the dangers posed by crocodiles to people. To reflect these competing uses the management of crocodiles is becoming increasingly regionalised to reflect the different social and economic pressures on crocodile populations in different parts of the Northern Territory.
Literature


Crocodiles in Queensland - An Overview

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Abstract

Crocodiles are large, semi-aquatic oviparous reptiles. Two species occur in Queensland (Cogger 1992): the estuarine crocodile (Crocodylus porosus) and the smaller freshwater crocodile (C. johnstoni). As the names imply, the preferred general habitats utilised by these two crocodiles are separate, but in ecological terms they regularly occur in sympatry. In Queensland, C. porosus can be found in marine, estuarine and freshwater habitats from Gladstone to the Queensland-Northern Territory border (Taplin 1987; Read et al. 2004), including some of the islands and reefs of the Northern Great Barrier Reef (Limpus 1980; Miller and Bell 1997). In contrast, the freshwater crocodile (C. johnstoni) can be found in many freshwater habitats west of the Great Dividing Range (Taplin 1987; Tucker 1997) and in the upper reaches of the Herbert River (QPWS, unpubl. data) and Lakefield National Park on the east coast of Queensland (Taplin 1987; Read and Miller 1998) as well as in isolated introduced populations in some rivers along the eastern coast (QPWS, unpubl. data). C. johnstoni can also be found in estuarine and brackish waters in Queensland (Read 1998).

Distribution of crocodiles and description of crocodile habitat within Queensland

The estuarine or saltwater crocodile is broadly distributed around the coastline of Queensland and is recorded over 12.5° of latitude. Estuarine crocodiles are regularly sighted in the Fitzroy River at Rockhampton (23.5°S, 150.6°E), with infrequent sightings as far south as Elliott Heads (24.9°S, 152.5°E) near Bundaberg. The most southern breeding population is located in the Fitzroy River at Rockhampton (Taplin 1987).

The freshwater crocodile is also broadly distributed over 12.5° of latitude, with animals recorded from Cape York Peninsula to the Fitzroy River in the south (Read 1999b). The main population is distributed on the western side of the Great Dividing Range, or in Lakefield National Park on the eastern coast.

Following extensive vessel-based and aerial surveillance of C. porosus populations and habitat in Queensland, Taplin (1987) defined eight crocodile biogeographic regions based largely on major drainage divides, changes in physiography, land use and human population density (Fig. 1). These biogeographic regions differ considerably in available habitat and population abundance of C. porosus, thus providing a general structure by which to describe the estuarine crocodile population in Queensland. Detailed descriptions of these crocodile biogeographical regions can be found in Taplin (1987).

The eight biogeographical regions as defined by Taplin (1987) are:

1. Southern Gulf Plains
2. Northern Gulf Plains
3. North-west Cape York Peninsula
4. North-east Cape York Peninsula
5. Princess Charlotte Bay
6. Eastern Coastal Plains, sub-divided into:
   (a) Cape Melville to Cooktown
   (b) Cooktown to Ayr
   (c) Ayr to Gladstone
7. Burdekin River Catchment
8. Fitzroy River Catchment
1. Southern Gulf Plains

The Southern Gulf Plains are comprised of extensive flat plains and large meandering rivers. The region is dominated by enormous expanses of saltpan and saline meadows of marine couch grass (*Sporobolus virginicus*) and floodplain lagoons are widespread. Winter is characterised by low rainfall, low temperatures and extensive periods of strong winds (>20 kts), with intermittent but extensive flooding in summer.

There is a considerable amount of good crocodile habitat within this region, but nesting habitat is poor overall (Magnusson *et al.* 1980; Taplin 1987) and the number of successful nests produced each year is limited (Read 1998a, 1999a; Read *et al.* 2004). Taplin (unpubl. data) located nests on the Norman and Bynoe Rivers in saltmeadows that formed a narrow fringe between mangroves and saltpan; in dense stands of pure rubber vine *Cryptostegia grandiflora*, an introduced tangling vine which infests many stranded beach ridges in the Gulf; and in bare mud under the mangrove fringe. Taplin reported these nests produced low numbers of hatchlings, but the impact of the apparently unfavourable locations on the survival of eggs or subsequent fitness of hatchlings is unknown. Creches of hatchlings have been recorded in Walkers Creek, Jenny Lind Creek, Wills Creek and the Gilbert River (Read 1998a, 1999a).

*C. johnstoni* occurs throughout the Southern Gulf Plains region and are usually encountered in the middle to upper reaches of these waterways. Individuals are occasionally captured in estuarine sections less than 5 km from the river mouth (Read 1998a, 1999a). Limited research has been done on the population of *C. johnstoni* in these areas, so there is no information on current distribution and abundance or population status for this species.

The relative densities of non-hatchling *C. porosus* in waterways in the Southern Gulf Plains is low to very low, with the majority of waterways sustaining <0.5 non-hatchlings km⁻¹. Spotlight surveys conducted in five waterways in 1999 indicated a mean relative density of 0.8 ± 0.5 (mean ± standard deviation) non-hatchlings km⁻¹ (Read 2001). Several small creeks in the middle reaches of the Norman River, Walkers Creek, Jenny Lind Creek and Wills Creek, all sustain higher numbers of non-hatchlings, with relative densities between 1.5 and 2.5 non-hatchlings km⁻¹. Netting for commercially important finfish species occurs in most waterways of the Southern Gulf Plains, with regular unofficial reports of *C. porosus* drowning in nets (Taplin 1987). Previously it was assumed that only the larger size classes of crocodile were drowned in nets, but recent data indicates that animals as small as 0.9 m TL become tangled and drown (QPWS, unpubl. data). The cumulative impact of *C. porosus* drowning in nets remains unquantified.

2. Northern Gulf Plains

The Northern Gulf Plains have a flat topography like the Southern Gulf Plains, but higher annual rainfall, hotter
summers and milder winters (Parkinson 1986). Extensive areas of the region are flood-prone. Grasses such as black speargrass (*Heteropogon contortus*) and marine couch (*Sporobolus virginicus*) grow on eroding banks or behind the mangrove fringe on low-energy banks (Taplin, unpubl. data). The dune swale swamps of the extensive beach ridge have yet to be assessed.

*C. johnstoni* occurs throughout the Northern Gulf Plains region and are usually encountered in the middle to upper reaches of these waterways. Individuals are occasionally captured in estuarine sections less than 5 km from the river mouth (Read 1998a, 1999a). Limited research has been done on the population of *C. johnstoni* in these areas, so there is no current information on distribution and abundance or population status for this species.

As with the Southern Gulf Plains, waterways in the Northern Gulf Plains do not support good crocodile nesting habitat, with low numbers of hatchlings recorded in all waterways during surveys (Read 1998a, 1999a). The relative abundance of non-hatchling *C. porosus* in waterways in the Northern Gulf Plains is usually higher than for waterways of the Southern Gulf Plains, with spotlight surveys recording <1.0 non-hatchlings km⁻¹. Spotlight surveys conducted in three waterways in 1999 indicated a mean relative density of 0.8 ± 0.3 non-hatchlings km⁻¹ (Read 2001). Netting for commercially important finfish species also occurs in most waterways of the Northern Gulf Plains, with intermittent unofficial reports of *C. porosus* drowning in nets.

3. **North-west Cape York Peninsula**

The North-west Cape York Peninsula region has a unique combination of high temperature and rainfall, extensive deep-water estuaries and permanent freshwater swamps. Small areas of freshwater swampland are scattered throughout the North-west Cape York Peninsula, from the Archer River north to the Jardine River. Heathlands and shallow, sandy estuaries occur over much of the area.

The region is dominated by two large, complex bay systems: Albatross Bay and Port Musgrave. Both systems are associated with deep-water estuaries and freshwater swamps in the middle to upper reaches of the waterways, which provide prime crocodile nesting habitat (Magnusson *et al.* 1980; Messel *et al.* 1981). The waterways of the Port Musgrave system are fringed in the middle third by areas of dense estuarine rainforest and the mangrove palm *Nypa fruticans*. Small freshwater creeks flow into the estuaries in this area (Read, pers. obs.). Along the coastline north of Port Musgrave is a series of regularly spaced rivers and creeks, interspersed with freshwater swamps and dense stands of Melaleuca (Read and Miller 1997).

*C. johnstoni* occurs throughout the North-west Cape York Peninsula region and are only encountered in the middle to upper reaches of these waterways. Limited research has been done on the population of *C. johnstoni* in these areas, so there is no information on the current distribution and abundance or population status for this species in this region.

Waterways of the North-west Cape York Peninsula region contain the highest relative density of *C. porosus* in Queensland (Messel *et al.* 1981; Miller 1994; Read *et al.* 2004). Spotlight surveys conducted in Tenpole Creek, a tributary of the Wenlock River, have recorded non-hatchling densities as high as 10.5 km⁻¹ (Read and Miller 1997) with a non-hatchling density averaged across all waterways surveyed in 2000 calculated at 2.2 ± 1.3 km⁻¹ (Read *et al.* 2004). Waterways of Port Musgrave also support successful nesting by *C. porosus*, especially the Wenlock River and Tenpole Creek (Messel *et al.* 1981; Taplin 1987; Miller 1994; Read *et al.* 2004).

The principal impact on crocodiles in this area of the North-west Cape York Peninsula region comes from the presence of the town of Weipa, the largest settlement on Cape York Peninsula (population ~2500) and site of the world’s largest bauxite mine. There is an intense seasonal tourist influx into this region, with many visitors travelling to experience the remote and relatively undisturbed habitats of this region. Netting for commercially important finfish species also occurs in many waterways of the North-west Cape York Peninsula region, with intermittent unofficial reports of *C. porosus* drowning in nets.

4. **North-eastern Cape York Peninsula**

The North-eastern Cape York Peninsula region has a rainfall and temperature regime comparable to the North-western Cape York Peninsula region. Many of the coastal streams run fresh for much of the year. However, the region is dominated by inaccessible dune lake systems of low fertility and has only a narrow coastal plain for the most part.
This region is dominated by three large estuarine systems of Newcastle Bay, Temple Bay and Lloyd Bay, and the three major waterways of the Olive River, Pascoe River and the Stewart River. Spotlight surveys conducted in ten waterways of the North-eastern Cape York Peninsula region in 2000 indicated a mean relative density of 0.6 ± 0.3 non-hatchlings km\(^{-1}\) (Read 2001).

*C. johnstoni* occurs throughout the North-east Cape York Peninsula region and are only encountered in the middle to upper reaches of these waterways. Limited research has been done on the population of *C. johnstoni* in these areas, so there is no current information on distribution and abundance or population status for this species in this region.

5. **Princess Charlotte Bay**

The Princess Charlotte Bay region has four substantial estuarine systems and large numbers of inland lakes and lagoons. It has more in common with the Northern Gulf Plains around the Nassau and Mitchell Rivers than with other parts of the eastern Cape York Peninsula. It lies at the same latitude, has a similar climate, and consists of a broad, flat, depositional plain with large, meandering rivers. It supports areas of sedges, fringing forest and broadleaf grasses.

Two of the four river systems of Princess Charlotte Bay (the North Kennedy and Bizant Rivers) are contained wholly or largely within the boundaries of Lakefield National Park. The Normanby River forms the eastern boundary of the park for some 80 km of its length. Lakefield National Park is a very popular recreational fishing area, receiving more than 7000 visitors a year. The park plays a very important role in *C. porosus* conservation on the east coast of Queensland, as it provides an area of good crocodile habitat contained within protected area estate.

During the dry season the reduction in water flow within the major river systems forms a series of linked waterholes in the middle to upper reaches of the park, which often support both species of crocodile. There is a significant difference in the relative density of *C. porosus* in non-tidal waterholes versus tidal waterways (ANOVA: \( F_{1,8} = 5.59; p<0.005 \)), with the relative density of non-hatchling *C. porosus* in the waterholes recorded at 3.5 ± 0.4 compared to 1.3 ± 0.9 in the tidal waterways (QPWS, unpubl. data).

*C. johnstoni* occurs throughout Lakefield National Park and are usually encountered in the middle to upper reaches of these waterways, with individuals occasionally captured in the tidal reaches of the estuaries. Information on the current distribution and abundance of this species in Lakefield National Park has been collected during surveys for *C. porosus* and indicate that this species can be found throughout the park (Read and Miller 1998; Miller and Coleman 1999; Miller and Beloff 1999; Read 2001).

6. **Eastern Coastal Plains**

The Eastern Coastal Plains region is divided into three sub-regions extending from Cape Melville to Cooktown (6a); Cooktown to Ayr (6b); and Ayr to Gladstone (6c). The Cape Melville to Cooktown sub-region is considered separately from the other sub-regions that constitute the populated east coast of Queensland.

*C. johnstoni* has been recorded in numerous small populations throughout the Eastern Coastal Plains, but are only considered to represent natural populations for those that occur in the upper Herbert and the upper Burdekin Rivers. The populations that occur around Townsville, Giru, and Rockhampton and further south are considered introduced. In all these areas the species occurs in low density only (QPWS, unpubl. data).

**Cape Melville to Cooktown (sub-region 6a)**

This region has much in common with North-eastern Cape York Peninsula, having a narrow coastal plain backed by a sedimentary plateau, high rainfall, many small freshwater streams, and large areas of silica sand dunes with extensive but infertile lakes and swamps. Human density in this sub-region is very low, encompassing the townships of Cooktown and Hopevale, seasonal travellers and a sand mining operation near Cape Flattery.

Ground surveys of 20 lakes in the Cape Flattery dunefields during September 1985 and 1986 revealed only very low densities of *C. porosus* (Taplin, unpubl. data). Twenty-one crocodiles were sighted, including 12 hatchlings. Local residents and observations from helicopter pilots indicate that crocodiles move in and out of the lakes from
coastal streams. There are no current data on the distribution and abundance of *C. porosus* in this sub-region.

**Cooktown to Ayr (sub-region 6b)**

This sub-region takes in a coastal fringe, typically less than 40 km wide, in which mangroves, freshwater swamps, agriculture, urban development, humans and crocodiles are concentrated. It is distinct from all other regions of Queensland and virtually all other parts of the range of *C. porosus* in Australia.

The area between the townships of Cooktown and Tully in sub-region 6b encompasses some 325 km of coastline. During the past 50 years this area has undergone tremendous urban, rural residential and agricultural development. The major waterways between Cooktown and Tully were surveyed for estuarine crocodiles between 1996 and 1998 (Kofron and Smith 2001). Three hundred and forty-six kilometres of waterway were surveyed, sighting 146 crocodiles at non-hatchling relative densities ranging from 0.11 to 1.00 km⁻¹, with a mean of 0.34 non-hatchlings km⁻¹ (Kofron and Smith 2001). Spotlight surveys conducted in twelve waterways in 2000 indicated a mean relative density of 0.6 ± 0.6 non-hatchlings km⁻¹ (Read et al. 2004).

Human activities such as urban, rural residential and agricultural development, clearing of riparian vegetation, commercial gill netting in estuaries and removal of crocodiles appear to be keeping crocodile numbers low in this area.

**Ayr to Gladstone (sub-region 6c)**

This region is similar to sub-region 6b and consists of a coastal fringe, typically less than 40 km wide, in which mangroves, freshwater swamps, agriculture, urban development, people and crocodiles are concentrated. Waterways in this sub-region support low to very low numbers of crocodiles, with the notable exception of the Proserpine River, which supports a comparatively healthy *C. porosus* population. Spotlight surveys conducted in this system have recorded relative densities as high as 3.2 non-hatchlings km⁻¹. Several successful nests are usually recorded in this system every year and the population is dominated by juvenile crocodiles (QPWS, unpubl. data).

**7 and 8. Burdekin and Fitzroy River Catchments**

Neither catchment area provides important resources for crocodiles, and populations are scarce and recruitment is minimal. Due to sub-optimal ambient temperature conditions, these regions have always represented marginal habitat for *C. porosus* (Taplin 1987).

**Burdekin River Catchment**

The Burdekin River catchment has a favourable climate in its downstream reaches but the prime wetlands are now largely developed for sugarcane, rice and small crops as part of the Burdekin Delta Irrigation Scheme. Crocodiles are reported only occasionally in the area, with the majority of reports from the Haughton River area (Read 2002). Upstream of the delta, the river runs through a series of narrow, rocky, gorges with long, shallow, sandy or rocky stretches providing limited deep-water refuges. The upstream reaches pass through an arid, rain-shadow region inland of the coastal ranges and experience cold, dry winters comparable with those on the Fitzroy River System.

A comprehensive spotlight and aerial survey was conducted in fourteen waterways of the Burdekin catchment in 2002. A total of 199 km of waterway were covered, and only 12 non-hatchling *C. porosus* were sighted for a mean relative density of 0.06 ± 0.01 non-hatchlings km⁻¹ (Read 2002).

**Fitzroy River Catchment**

The Fitzroy River catchment lies at the southernmost boundary of the breeding distribution of *C. porosus* in eastern Australia (Taplin 1987). Due to sub-optimal ambient temperature conditions, this region has always represented marginal habitat for *C. porosus* (Taplin 1987), and it is questionable whether this sub-region ever had the capacity to maintain a large crocodile population without a continuing influx of migrants from more productive coastal systems to the north, most which are now affected by agriculture.
Intensive vessel-based surveys conducted in 1998 and 1999 found there were few *C. porosus* in the Fitzroy River, with the numbers of crocodiles highest in the freshwater reaches some 60 km upstream from the mouth of the river. Fifteen *C. porosus* were sighted in 1998, and eight in 1999 (Read 1999b, 2001). Only two of these crocodiles were sighted in the tidal section of the Fitzroy River below the barrage, a concrete weir installed to control water flow and upstream tidal influx, with the remaining sighted in the non-tidal freshwater sections of the river above the barrage. The presence of seven hatchling *C. porosus* sighted in the upper reaches of the Fitzroy River in 1997 suggests that limited recruitment is occurring there (Read 1999b).

**Population size and trends over time since protection**

Information on the current distribution and abundance of *C. porosus* in Queensland comes from data collected during statewide spotlight surveys conducted between 1994 and 2000 (Read et al. 2004). A total of 6444 *C. porosus* (4303 non-hatchlings and 2141 hatchlings) were recorded during 196 vessel-based surveys of 103 waterways covering 4174.3 km.

The distribution and abundance of the *C. porosus* population in northern Queensland is spatially variable, with the highest relative density of crocodiles recorded from waterways of the North-west Cape York Peninsula region. Hatchling numbers follow this same trend, with the highest numbers of hatchlings recorded from waterways of the North-west Cape York Peninsula region, followed by Lakefield National Park and selected waterways of the East Coast Plains (Read et al. 2004). The structure of the population, as determined by spotlight surveys, was biased towards immature crocodiles with 91% of all animals sighted less than 2.0 m in total length.

The *C. porosus* population in northern Queensland appears to be undergoing a limited recovery, with marginal increases in the mean relative abundance of non-hatchlings across the state (Table 1). There were no discernible

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 Southern Gulf Plains</strong></td>
<td>Mean: 0.19</td>
<td>Mean: 0.4</td>
<td>Mean: 0.81</td>
</tr>
<tr>
<td></td>
<td>Std: 0.12</td>
<td>Std: 0.3</td>
<td>Std: 0.72</td>
</tr>
<tr>
<td></td>
<td>R: 0.09-0.33</td>
<td>R: 0.14-0.86</td>
<td>R: 0.13-2.4</td>
</tr>
<tr>
<td></td>
<td>N= 7</td>
<td>N= 9</td>
<td>N= 23</td>
</tr>
<tr>
<td><strong>2. Northern Gulf Plains</strong></td>
<td>Mean: 0.66</td>
<td>Mean: 1.0</td>
<td>Mean: 0.98</td>
</tr>
<tr>
<td></td>
<td>Std: 0.37</td>
<td>Std: 0.3</td>
<td>Std: 0.41</td>
</tr>
<tr>
<td></td>
<td>R: 0.19-1.13</td>
<td>R: 0.75-1.5</td>
<td>R: 0.5-1.5</td>
</tr>
<tr>
<td></td>
<td>N=9</td>
<td>N= 4</td>
<td>N= 8</td>
</tr>
<tr>
<td><strong>3. North-west Cape York Peninsula</strong></td>
<td>Mean: 1.6</td>
<td>Mean: 2.5</td>
<td>Mean: 2.4</td>
</tr>
<tr>
<td></td>
<td>Std: 0.881</td>
<td>Std: 3.0</td>
<td>Std: 2.7</td>
</tr>
<tr>
<td></td>
<td>R: 0.41-3.21</td>
<td>R: 0.14-10.5</td>
<td>R: 0.14-10.7</td>
</tr>
<tr>
<td></td>
<td>N=9</td>
<td>N=23</td>
<td>N=33</td>
</tr>
<tr>
<td><strong>4. North-east Cape York Peninsula</strong></td>
<td>Mean: 0.51</td>
<td>Mean: 1.2</td>
<td>Mean: 0.7</td>
</tr>
<tr>
<td></td>
<td>Std: -</td>
<td>Std: 0.6</td>
<td>Std: 0.47</td>
</tr>
<tr>
<td></td>
<td>R: -</td>
<td>R: 0.5-2.07</td>
<td>R: 0.4-1.07</td>
</tr>
<tr>
<td></td>
<td>N= 1</td>
<td>N= 5</td>
<td>N= 2</td>
</tr>
<tr>
<td><strong>5. Lakefield National Park</strong></td>
<td>Mean: 0.87</td>
<td>Mean: 0.7</td>
<td>Mean: 1.4</td>
</tr>
<tr>
<td></td>
<td>Std: 0.39</td>
<td>Std: 0.4</td>
<td>Std: 1.6</td>
</tr>
<tr>
<td></td>
<td>R: 0.47-1.11</td>
<td>R: 0.12-1.2</td>
<td>R: 0.06-7.5</td>
</tr>
<tr>
<td></td>
<td>N= 3</td>
<td>N= 5</td>
<td>N= 20</td>
</tr>
<tr>
<td><strong>6. East Coast Plains</strong></td>
<td>Mean: 0.37</td>
<td>Mean: 0.4</td>
<td>Mean: 0.51</td>
</tr>
<tr>
<td></td>
<td>Std: 0.66</td>
<td>Std: 0.4</td>
<td>Std: 0.9</td>
</tr>
<tr>
<td></td>
<td>R: 0.00-2.67</td>
<td>R: 0.00-2.0</td>
<td>R: 0.00-3.9</td>
</tr>
<tr>
<td></td>
<td>N=22</td>
<td>N= 36</td>
<td>N= 49</td>
</tr>
<tr>
<td><strong>7. Burdekin River Catchment</strong></td>
<td>Mean: 0.29</td>
<td>Mean: 0.0</td>
<td>Mean: 0.0</td>
</tr>
<tr>
<td></td>
<td>Std: -</td>
<td>Std: -</td>
<td>Std: -</td>
</tr>
<tr>
<td></td>
<td>R: -</td>
<td>R: -</td>
<td>R: -</td>
</tr>
<tr>
<td></td>
<td>N= 1</td>
<td>N= 1</td>
<td>N= 1</td>
</tr>
<tr>
<td><strong>8. Fitzroy River Catchment</strong></td>
<td>Mean: -</td>
<td>Mean: -</td>
<td>Mean: 0.1</td>
</tr>
<tr>
<td></td>
<td>Std: -</td>
<td>Std: -</td>
<td>Std: 0.02</td>
</tr>
<tr>
<td></td>
<td>R: -</td>
<td>R: -</td>
<td>R: 0.09-0.12</td>
</tr>
<tr>
<td></td>
<td>N= -</td>
<td>N= -</td>
<td>N= 2</td>
</tr>
</tbody>
</table>
trends in the data describing changes to the *C. porosus* population structure over the duration of the survey period for six of the eight biogeographic regions. There were considerable fluctuations in the proportion of the population represented by crocodiles in the 2-4 ft, 4-6 ft and >6ft+EO size class, with a significant increase through time in the number of crocodiles in the larger size classes for three of the biogeographical regions (Table 2).

<table>
<thead>
<tr>
<th>Crocodile biogeographic region</th>
<th>Size Class</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-4ft</td>
<td>4-6ft</td>
<td>&gt;6ft+EO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGP</td>
<td>F: 0.12</td>
<td>P: 0.76</td>
<td>22.6</td>
<td>0.04</td>
<td>1.19</td>
</tr>
<tr>
<td>NGP</td>
<td>F: 0.002</td>
<td>P: 0.97</td>
<td>0.85</td>
<td>0.52</td>
<td>0.06</td>
</tr>
<tr>
<td>WNCYP</td>
<td>F: 1.7</td>
<td>P: 0.25</td>
<td>1.10</td>
<td>0.34</td>
<td>26.3</td>
</tr>
<tr>
<td>NECYP</td>
<td>F: 0.02</td>
<td>P: 0.91</td>
<td>19.10</td>
<td>0.05</td>
<td>0.79</td>
</tr>
<tr>
<td>LNP</td>
<td>F: 1.46</td>
<td>P: 0.35</td>
<td>1.42</td>
<td>0.36</td>
<td>1.01</td>
</tr>
<tr>
<td>ECP</td>
<td>F: 2.22</td>
<td>P: 0.20</td>
<td>0.08</td>
<td>0.79</td>
<td>1.55</td>
</tr>
</tbody>
</table>

A chronology of crocodile research and management in Queensland

Intensive commercial utilisation of crocodiles in Queensland commenced in 1945/46 following the influx of soldiers returning from the Second World War (Taplin 1987). In Queensland, the majority of these crocodile hunters were land-based, with the first vessel-based hunting expeditions commencing in the early to mid-1950s. Over the years of hunting, thousands of skins of both species were exported from Queensland (Roff 1966), with the result that the numbers of wild *C. porosus*, and to a lesser extent, *C. johnstoni*, were reduced dramatically (Taplin 1987). Efforts to conserve wild populations of crocodiles in Queensland began indirectly in 1972 with a Commonwealth Government embargo on the export of crocodile products (Taplin 1987). Effective protection of both species began in 1974 with the declaration of the Queensland Fauna Conservation Act.

Initial research into the distribution and abundance of crocodiles in Queensland focussed on *C. johnstoni*, with the first surveys starting in the Gulf of Carpentaria in 1972. A more comprehensive survey to determine the distribution and abundance of this species covering northern Queensland was initiated in 1976, and one of the first detailed demographic studies was started the same year in the Lynd River and continued for many years (Tucker *et al.* 1994). This study site was revisited in 1992, and numerous publications on the ecology and demographics of this species were produced (see Tucker 1997).

The first research on *C. porosus* commenced in 1979 when the first broad-scale, vessel-based survey of selected waterways in the Gulf of Carpentaria and Cape York Peninsula were completed (Messel *et al.* 1981). Messel and his team collected information on the physical and habitat characteristics of these waterways, as well as determining the distribution and abundance of crocodiles. This research trip provided the initial database that identified the Wenlock River-Tentpole Creek system as an area of prime habitat for *C. porosus* in Queensland (Messel *et al.* 1981).

Laurie Taplin was appointed as a crocodile biologist in 1984 and began conducting a series of vessel-based surveys throughout the Gulf of Carpentaria and Cape York Peninsula. During his tenure with the Service, Taplin produced a series of publications and internal reports on the status of *C. porosus* and *C. johnstoni* in Queensland (Taplin 1987, 1990; Taplin *et al.* 1988; Taplin and Krieger 1989).

Taplin’s research showed that the abundance of *C. porosus* in Queensland was spatially variable, with low numbers of crocodiles in most waterways apart from those in the Port Musgrave area north of Weipa. Research indicated that one of the limiting factors controlling population growth of *C. porosus* in Queensland was the availability of suitable nesting habitat. Magnusson *et al.* (1980) conducted an aerial survey in February 1979 from the tip of Cape York Peninsula to the mouth of the Norman River at Karumba, assessing the habitat for suitability of nesting for crocodiles. They concluded that the amount of suitable nesting habitat decreased from north to south, principally because the broad alluvial plains of the Gulf of Carpentaria are often subjected to extensive flooding. They found that the best nesting habitat for crocodiles was located around the Wenlock River and Tentpole Creek area near Port Musgrave.
Through another series of aerial surveys, Taplin showed that annual low-density nesting occurred in the Lockhart River basin and the Escape River system (Taplin et al. 1988; Taplin and Krieger 1989). Taplin et al. (1988) concluded that no major nesting areas comparable to the swamplands of Port Musgrave existed in Queensland.

In an effort to alleviate public concern about the numbers of crocodiles on the east coast of Queensland and the threat of crocodile attack, the East Coast Crocodile Management Program (ECCMP) was introduced in late 1987. Under this plan, areas within the state were allocated to one of three ‘zones’, where in zone ‘A’ all crocodiles were removed, in zone ‘B’ all crocodiles which exceeded a minimum length of 1.2 m total length were removed and zone ‘C’, where crocodiles were removed only by staff from the former Queensland National Parks and Wildlife Service (QNPWS). This management program was continued until the early 1990s.

A revision of the status of C. porosus in Queensland was published in 1993 (Miller 1994). And the management of crocodiles was redefined in a management programme entitled Conservation and management of Crocodylus porosus in Queensland 1995 to 1997 (QDEH 1995) which defined a ‘problem’ crocodile, allowed for the removal of up to 50 ‘problem’ crocodiles from the wild to protect people, prevented ranching and promoted farming, following the IUCN/CITES definitions. Under this program problem crocodiles were removed on a case-by-case basis.

In May 1998, the Minister for the Environment modified the management of crocodiles on the East coast by declaring a three-year Trial Intense Management Area for Crocodiles (TIMAC). This management area extended from Wonga Beach (south of the Daintree River) to the northern point of the Trinity Inlet near Cairns, and within this zone all crocodiles were to be removed. The plan also called for the removal of all crocodiles from the areas of the Russell, Mulgrave, North Johnstone and South Johnstone rivers west of the Bruce Highway. TIMAC had three primary goals:

1. To increase protection of Cairns’ popular swimming beaches;
2. To promote safe practices in crocodile habitat; and,
3. To improve crocodile conservation and management.

These goals were achieved by:

1. Removing crocodiles from designated areas in the Cairns and Port Douglas Shires;
2. Surveys and monitoring;
3. Public education; and,
4. Relevant research.

In addition, staff responsible for servicing the TIMAC program were responsible for managing problem crocodiles outside the TIMAC zone. The number of crocodiles removed from within and outside the TIMAC zone between May 1998 and June 2001 is shown in Tables 3 and 4.

### Table 3. Crocodiles removed from the TIMAC zone, May 1998 to 30 June 2001.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number crocodiles removed</th>
<th>Sex ratio</th>
<th>Yearly total</th>
<th>Size range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estuarine</td>
<td>Freshwater</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>1998</td>
<td>12</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>1999</td>
<td>7</td>
<td>0</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>13</td>
<td>0</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>2001</td>
<td>13</td>
<td>0</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
<td>1</td>
<td>29</td>
<td>10</td>
</tr>
</tbody>
</table>

To augment the TIMAC program, the Queensland Parks and Wildlife Service (QPWS) also implemented a system to work cooperatively with local councils by signing memoranda of understanding with councils. Although not legally binding, these MOUs provided a framework for the formation of a cooperative partnership and a better working relationship. Under these agreements QPWS still had legislative responsibility to manage crocodiles, but the local councils were involved in the decision-making process and the release of joint media statements about crocodiles.

In May 2001 the TIMAC program was continued as the Intensive Management Area for Crocodiles (IMAC) program. This management program and the MOU’s with council continue to date.
Table 4. Crocodiles removed from areas outside the TIMAC zone, May 1998 to 30 June 2001.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number removed</th>
<th>Sex ratio</th>
<th>Yearly total</th>
<th>Size range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estuarine</td>
<td>Freshwater</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>1998</td>
<td>5</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>1999</td>
<td>14</td>
<td>1</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>2000</td>
<td>10</td>
<td>0</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>2001</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>2</td>
<td>21</td>
<td>11</td>
</tr>
</tbody>
</table>

Philosophies underlying management

The two primary philosophies underlying the management of *C. porosus* in Queensland are to ensure that viable populations are maintained across their natural range while providing for public safety and ecologically sustainable use.

Objectives

The specific objectives of the management program are:

1. To maintain wild populations of *C. porosus* across its range in Queensland, at least at current population levels consistent with the Queensland Government’s obligations concerning public safety;
2. To permit and control legitimate commercial enterprises that use crocodiles;
3. To increase public awareness and safety in crocodile habitat; and,
4. To educate the public to appreciate the ecological significance of crocodiles and the need for crocodile conservation.

Strategies

The strategies developed to attain these objectives are:

Objective 1

- Monitor crocodile populations and assess the impact of control measures and economic use;
- Undertake research to support the management program, including research into genetic structure, population dynamics and conservation requirements;
- Ensure that sufficient wetland habitats remain to maintain populations of *C. porosus* within and outside protected areas;
- Identify and establish key areas for crocodile conservation; and,
- Ensure that any commercial use of wild crocodiles is sustainable and provides a conservation benefit for crocodiles.

Objective 2

- Regulate the use of estuarine crocodiles by the crocodile farming industry;
- To develop and permit and monitor a trial harvest of crocodile eggs on Aboriginal lands in western Cape York Peninsula; and,
- Always provide for a conservation benefit in specified areas to ensure that conservation of the species and its habitat is not compromised by the management procedures.

Objective 3

- Develop strategies for the management of crocodiles in populated areas, particularly along the east coast between Gladstone and Cooktown;
- Provide for a crocodile removal zone in the Cairns and Port Douglas areas (IMAC - Intensive Management Area for crocodiles);
- Investigate whether crocodile removal zones, such as IMAC, are an effective and efficient strategy for preventing crocodile attack;
Monitor visitor/crocodile interactions in protected areas;
Promote the need for appropriate and responsible behaviour in crocodile habitat; and,
Increase public awareness and educate the public that crocodiles may be encountered in most coastal waterways (both saltwater and freshwater) in tropical Queensland and emphasising that “crocodile free” areas do not exist.

Objective 4

Conduct a community education program with the aim of changing community attitudes towards crocodiles, including the use of videos, television and radio broadcasts, brochures, displays, signs, and education kits for schools.

The QPWS continues to intensively manage crocodiles in the IMAC zone (between Cairns and the Daintree River) and problem crocodiles located outside that area are managed on a case-by-case basis. All crocodile sightings are investigated and crocodile are classified as a ‘problem’ crocodile based on standard protocols (www.epa.qld.gov.au). Between 15 and 25 crocodiles are removed annually, with the majority of these animals captured north of Townsville.

QPWS has a specialised unit, the Crocodile Management Unit, to investigate and manage crocodile-related incidences, but an additional 60 staff have received training in crocodile handling and assessment and share this response. QPWS has memoranda of understanding for crocodile management with eight local councils in Northern Queensland, creating a reciprocal working relationship between the two groups that is beneficial for crocodile management and responses. QPWS has also signed a MOU for crocodile management and research with Australia Zoo, whereby QPWS can call on the services and equipment of Australia Zoo to manage crocodile responses in remote or logistically challenging areas. This service has now been utilised three times.

The QPWS implemented the ‘Croc-Wise’ program in October 2001 to raise public awareness about crocodiles and to better inform people about appropriate human behaviours in crocodile country. The aim of this program was to provide better information to people to minimise the risks posed by crocodiles. The messages of the Croc-Wise campaign have been delivered at agricultural and local shows, boating and camping shows, public and community seminars and through radio, print and TV media.

Use of and trade in crocodile products

There are six functional crocodile farms in Queensland: the Edward River Crocodile Farm (Porimparaaw); Hartleys Creek Crocodile Farm (Hartleys Creek, north of Cairns); Melaleuca Crocodile Farm (Mareeba); Cairns Crocodile Farm (Cairns); Johnstone River Crocodile Farm (Innisfail) and Kooral Crocodile Farm (Rockhampton). Edward River Crocodile Farm is primarily a breeder farm and hatchery, with post-hatchlings entering the grow-out phase at Cairns Crocodile Farm. The remaining farms maintain breeding populations and grow-out and process their own stock.

Currently in Queensland, it is closed system of farming with no take from wild populations, except for the occasional crocodile designated by QPWS to be a problem crocodile and sold through a rotating purchase system.

The QPWS is also committed to investigate the sustainable utilisation of wild crocodiles. Given that *C. porosus* is listed as ‘vulnerable’ under state conservation legislation, there is a need to ensure any harvesting will not be detrimental to the wild population. QPWS is working cooperatively with external proponents to establish research programs to determine the impact of egg harvesting on wild *C. porosus* populations. No harvest of wild live crocodiles is planned.

Crocodile farming

Regulatory control of farms and zoos

Applications for licences to farm or exhibit crocodiles under provisions of the Nature Conservation Act 1992 will be considered for approved farms or zoos. Such licences are valid for a maximum period of three years.

The holder of a Wildlife Farming Licence or Commercial Wildlife Licence for Dead Protected Wildlife is required by regulation to keep records in the required format and to submit Returns of Operations (eg Wildlife Farming Licence - monthly Returns; Commercial Wildlife Licence - annual Returns). A licensee is required by regulation to enter in the Record Book details of wildlife breeding, acquisitions, disposals, deaths and escapes. Record Books and Returns remain the property of the State.

QPWS and the Department of Environment and Heritage (formerly Environment Australia) have implemented a tagging and marking system for identifying skins, skin products and other parts, products and derivatives of crocodiles. These items may be destined for overseas export, either as commercial shipments or as personal effects carried by tourists. Products derived from crocodiles include whole skins, other skin products (including taxidermied and stuffed whole skins, wallets, handbags, and belts), meat (including offal) and low unit-value items (including teeth, claws, skin remnants and skulls).

Human-crocodile conflicts

Since 1985 there have been 13 reported crocodile attacks in Queensland, with four fatalities. These attacks have all occurred in northern Queensland, with the most southern attack occurring at Babinda (17.35°S, 145.96°E) in September 1999. The spatial distribution of these attacks is shown in Figure 2.

Figure 2. Map of Queensland showing the distribution of crocodile attacks since 1985.
The statistics on these crocodile attacks are:

- 11 (85%) of the attacks occurred in the water;
- 6 (46%) of the attacks occurred while victims were swimming at night; and,
- 7 (54%) of the victims had been consuming alcohol before the attack occurred.

To minimise the potential for a negative interaction between a crocodile and a human, QPWS intensively manages crocodiles around urban areas and promotes appropriate humans behaviours as part of the ‘Croc-Wise’ campaign. QPWS is also using proactive media to target and highlight dangerous human behaviours in crocodile country, such as dumping fish frames and wastes around public facilities like boatramps. Under Queensland legislation, it is an offence to feed dangerous wildlife such as crocodiles. Significant fines can be imposed on people who break this law.

**Ongoing management research and monitoring program**

QPWS has initiated a management-orientated research and monitoring program to gain better information about crocodile populations and patterns of spatial utilisation.

To obtain better information about the status of the wild population, vessel-based surveys have been conducted in Lakefield National Park and waterways of the North-West Cape York Peninsula region, and surveys are planned for the North-east Cape York Peninsula, Southern and Northern Gulf Plains regions to determine the current distribution and abundance of *C. porosus* in Queensland and to examine in trends in the population. These surveys will also provide information on the size class distribution and help to identify threatening processes acting on the population.

Intensive research projects to determine how crocodiles use space through time have recently been designed and implemented across northern Queensland. These projects are using radio and satellite telemetry to look at the movement patterns of immature and mature *C. porosus* in tidal and non-tidal waterways. A total of six *C. porosus* have been fitted with satellite transmitters and an additional eleven animals have been fitted with radio transmitters. A further research project is planned for 2004-2005 to attach additional satellite and radio transmitters to crocodiles on Lakefield National Park and around Weipa. The aim of this research is to determine movements and habitat requirements for these crocodiles and to see how crocodiles near urban areas interact with people and man-made structures. Part of this research will also involve translocating crocodiles fitted with satellite transmitters to determine whether these animals display homing behaviour, thus determining whether translocation is an appropriate management option in Queensland.

This work has been substantially supported and resourced through a partnership agreement with Australia Zoo and a bequest by the late Charles Tanner.

**Summary**

1. **Crocodile habitat**

   Both species of crocodile are distributed over 12.5° of latitude, from the tip of Cape York Peninsula to Rockhampton, with irregular sightings of *C. porosus* as far south as Elliott Heads. Crocodile habitat is markedly different around the state, such that the area has been divided into different crocodile biogeographic zones. The distribution and abundance of estuarine crocodiles reflects these differences, with the highest numbers recorded in waterways of the North-west Cape York Peninsula region north of Weipa. Crocodile habitat along the populated east coast of Queensland has undergone extensive modification to support intensive agriculture, grazing and urban development, and the numbers of crocodiles in these waterways is low to very low.

2. **Crocodile populations**

   The population of *C. porosus* in Queensland has undergone a limited recovery, with the relative density of non-hatchlings increasing in most crocodile biogeographic zones. The population, as surveyed using standard spotlight techniques, is biased towards immature crocodiles with >90% of all animals sighted less than 2.0 m long. There were no discernible trends in the data describing changes to the *C. porosus* population structure over the duration of the survey period for six of the eight biogeographical regions.
3. Management of crocodiles

The two primary philosophies underlying the management of *C. porosus* in Queensland are to ensure that viable populations are maintained across their natural range while providing for public safety and ecologically sustainable use.

4. Managing human: crocodile interactions

There have been thirteen crocodile attacks in Queensland since 1985, with four fatalities. Analysis of these attacks indicates that a high proportion occurred while the victims were engaged in an activity that placed them directly in crocodile habitat. The QPWS aims to minimise the risks posed by crocodiles by the targeted removal of animals from urban areas and around high use public facilities like boatramps, and by raising public awareness of the dangers posed by crocodiles and promoting appropriate human behaviours in crocodile habitat. People are reminded that they are responsible for their own safety in crocodile habitat.

5. Crocodile research and monitoring

Crocodile research in Queensland is focused on determining the current distribution and abundance of *C. porosus* and to determine how adult crocodiles use space through time in remote areas and urban areas using telemetry.

Literature


Crocodile Management in Western Australia

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Abstract

In Western Australia, crocodiles were hunted extensively for skins between 1930 and 1970, with C. porosus almost hunted to extinction. Both species are at the western limits of their range in Australia and a combination of factors including lower rainfall, limited riparian vegetation and degradation remaining vegetation as a consequence of cattle grazing have had an impact on the rate of recovery of both species since legal protection was put in place. Crocodylus porosus populations have yet to reach pre-hunting levels, but are showing signs of a steady rate of increase (1-2.5%) in monitored areas. There are two licensed crocodile farms in Western Australia, with no intention by the Government to issue any further licences in the immediate future. Crocodile farming is managed under an approved management plan. Increasing tourism in northern Australia, particularly by crocodile-naive tourists appears to be resulting in an increase in conflicts, some fatal. High visitor use areas are designated as crocodile control zones and any crocodiles found in these areas that pose a threat are relocated to crocodile farms or culled. Better public education will be required to ensure that crocodiles can continue to increase to pre-hunting levels while reducing the risk of conflict with the human population.

Introduction

Two species of crocodile, the saltwater crocodile Crocodylus porosus and the freshwater or Johnstone’s crocodile C. johnstoni, occur in the Kimberley and Pilbara regions of Western Australia. The majority of the populations of both species occur in the Kimberley region. Crocodylus porosus occupy marine, estuarine and freshwater habitats below waterfalls. Crocodylus johnstoni is occasionally found in low numbers in estuarine habitat, but more common in freshwater habitats, particularly those above waterfalls where they do not have to compete with C. porosus.

Distribution

The distribution of crocodiles in Western Australia is provided in detail by Burbidge (1987), Grigg and Gans (1993), Cooper-Preston and Jenkins (1993) and Molnar (1993). C. porosus are found in most of the major river systems of the Kimberley including the Ord, Patrick, Forrest, Durack, King, Pentacost, Prince Regent, Lawley, Mitchell, Hunter, Roe and Glenelg Rivers and Parrys Creek. The largest populations occur in the rivers draining into the Cambridge Gulf, the Prince Regent and the Roe River systems of the east and northwest Kimberley. Much lower densities occur in the rivers draining into King Sound and Stokes Bay in the west Kimberley. Lone male crocodiles have also been recorded as resident in isolated rivers in the Pilbara region including the Sherlock River. Vagrant crocodiles have been recorded in marine habitat at Derby, Broome (Cable Beach and Willies Creek) and as far south as Carnarvon on the mid-west coast.

Nesting habitat for C. porosus is limited and only the Ord, King and Roe River systems support suitable vegetation for nesting to significant levels. A few nests have been recorded in other river systems such as the Drysdale and Prince Regent Rivers and Admiralty Gulf Creek. C. porosus occur in four of the ten conservation reserves >2000 ha in area in the Kimberley that have rivers running through them.

C. johnstoni occupies the same river systems as C. porosus in the Kimberley region, with most animals occurring above waterfalls that exclude the larger species. C. johnstoni is also common in the Fitzroy River system. This species has also established large populations with the creation of two dams that impound sections of the Ord River to form Lakes Kununurra and Argyle. C. johnstoni breeds in all of the river systems where it occurs. Freshwater crocodiles occur in all ten of the conservation reserves >2000 ha in area in the Kimberley that have rivers running through them.
Habitat

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

River systems in the Pilbara region further to the south, flow through less steeply dissected landscapes and include areas of flood plain. However, the significantly lower annual rainfall and the resultant differences in fringing vegetation mean that most rivers in the Pilbara cannot support viable crocodile populations.

Population Size and Trends Since Protection

*C. porosus* was extensively hunted for the skin trade in the 1950s and 1960s, and while the pre-harvest population size is unknown, the species apparently suffered a decline in numbers throughout its range in Western Australia. It is considered that the total population of *C. porosus* in Western Australia is now only in the order of a few thousand non-hatchlings. Nesting habitat is limited, with very few nests located during the surveys conducted to date. Nevertheless, from anecdotal information and limited surveys, the *C. porosus* appears to be recovering from past hunting, and still occupies its historical range.

The number of *C. porosus* killed for trade prior to the species being protected in Western Australia is unknown. However, Webb et al. (1984) estimated that a total of between 270,000 and 330,000 *C. porosus* were killed in Australia from 1945 to 1972, with the upper estimate comprising 271,500 skins exported, 13,500 (5%) assumed killed and not retrieved, and 45,000 juveniles killed for the curio trade. Webb et al. (1984) estimated that 10% of the skin harvest was from Western Australia, and it therefore seems likely that some 25,000 *C. porosus* were harvested in Western Australia from 1946 until 1970. Webb et al. (1987) considered that the earlier estimate of the number of juveniles killed for the curio trade was probably an overestimate.

There are no published estimates of the numbers of *C. johnstoni* killed in Western Australia for the skin trade prior to the species being protected (Burbidge 1987). While the intensity of legal hunting of *C. johnstoni* in Western Australia was always low, there was significant poaching in accessible habitat during the 1960s and early 1970s (Bustard 1970; Burbidge 1987).

The first documented report on the status of *C. porosus* populations in Western Australia was that of Bustard (1970), who in 1969 conducted limited boat spotlight surveys in several areas. Bustard concluded that *C. porosus* “has been hunted to the verge of extinction” and recommended that the species be protected for ten years.

The first systematic surveys of *C. porosus* populations in Western Australia were conducted in 1977 (Messel et al. 1977) and 1978 (Burbidge and Messel 1979). These boat spotlight surveys covered the estuarine portions of major river systems across most of the range of *C. porosus* in Western Australia. The combined results yielded the estimates of the non-hatching populations in the surveyed portions of each river system given in Table 1. Extrapolating from the survey results to correct for unsurveyed areas, Burbidge and Messel (1979) estimated that there were about 2000 non-hatching *C. porosus* in the whole of Western Australia at that time.

In 1986, most of the areas surveyed in 1977 and 1978 were resurveyed, as well as some additional areas (Messel et al. 1987), resulting in a Kimberley-wide population estimate of 2500 non-hatching *C. porosus*. The 1986 survey revealed a significant increase in the proportion of large crocodiles in the population, and showed that the largest populations were in the Cambridge Gulf, and the Prince Regent and Roe River systems.

Since 1986, no further large-scale population surveys covering most of the range of *C. porosus* in the Kimberley have been conducted. However, the *C. porosus* population in King Sound and Stokes Bay was surveyed for the first time in 1989, resulting in an estimated population of the order of 25 (G Webb Pty Ltd 1989a). The low density of *C. porosus* in the King Sound area reflects a generally poor environment at the extremity of the main part of the range of *C. porosus*.

Associated with the Western Australian Government’s 1988 decision to permit crocodile farming, the West Arm
Table 1. Non-hatchling C. porosus population estimates from 1977-1978 boat spotlight surveys (after Messel et al. 1977; Burbidge and Messel 1979). (a) = estimate was subsequently revised to 245-297 by Messel et al. (1987).

<table>
<thead>
<tr>
<th>River</th>
<th>Population Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ord</td>
<td>235-306 (a)</td>
</tr>
<tr>
<td>Lawley</td>
<td>44-57</td>
</tr>
<tr>
<td>Mitchell</td>
<td>60-78</td>
</tr>
<tr>
<td>Hunter</td>
<td>51-67</td>
</tr>
<tr>
<td>Roe</td>
<td>177-230</td>
</tr>
<tr>
<td>Prince Regent</td>
<td>190-246</td>
</tr>
<tr>
<td>Glenelg</td>
<td>200-259</td>
</tr>
<tr>
<td><strong>Total (all surveyed rivers)</strong></td>
<td><strong>957-1243</strong></td>
</tr>
</tbody>
</table>

river systems in Cambridge Gulf that had been surveyed in 1986 were resurveyed in 1989, 1990, and 1992-2003 inclusive (G Webb Pty Ltd 1989b, 1990, 1992; Wildlife Management International 1994b, 1995-2003). In 1992 the Ord River, which had been partly surveyed in 1978 and 1986, was fully surveyed for the first time (G Webb Pty Ltd 1992). As a result of the 1989-1993 surveys, Wildlife Management International (WMI), which has been contracted by the Department of Conservation and Land Management (CALM) to conduct the crocodile surveys, developed helicopter-monitoring zones for the East Arm (Ord River) and West Arm areas of the Cambridge Gulf. After trial development and proofing, population estimates from 1994-on have been based on the results of the helicopter surveys of monitoring areas. The Ord River has been surveyed annually during the period 1993-2003 (Wildlife Management International 1994a, 1994b, 1995-2003).

The results of crocodile population monitoring surveys (helicopter count indices and spotlight data) in the Cambridge Gulf river systems are summarised on Figure 1. The results from the 2003 survey show that the 2003 population estimate for the West Arm of Cambridge Gulf is almost 50% greater than the estimate for 1989. In the East Arm the 2003 population is slightly more than 50% above the original (1992) estimate (Fig. 2).

![Graph showing numbers of non-hatchling C. porosus sighted during helicopter surveys of the West Arm monitoring zone, 1986-2003. Lines indicate linear regression relationships (1986-1998; r² = 0.45, p = 0.03; 1998-2003, r² = 0.66, p = 0.048).](image)

Figure 1. Numbers of non-hatchling C. porosus sighted during helicopter surveys of the West Arm monitoring zone, 1986-2003. Lines indicate linear regression relationships (1986-1998; r² = 0.45, p = 0.03; 1998-2003, r² = 0.66, p = 0.048).
The Cambridge Gulf river systems have been the principal source of *C. porosus* for crocodile farms in Western Australia. The combined population estimates for the two survey areas give a total population in 2003 of 885, which is a 53% increase on the first combined estimate available (577 in 1992).

Prior to 1989, there had only been very limited surveys of the *C. johnstoni* population in Western Australia. As a consequence of the 1988 decision by the Western Australian Government to allow crocodile farming, there has been a considerable increase in knowledge about the Western Australian *C. johnstoni* population. The earlier construction of two dams on the Ord River impounded Lake Kununurra (in 1963) and the very large Lake Argyle (in 1972). In 1989, boat spotlight surveys yielded non-hatchling population estimate of 25,000 in Lake Argyle and 7500 in Lake Kununurra (G Webb Pty Ltd 1989d).
Also in 1989, boat spotlight and helicopter surveys yielded a population estimate of 13,000 non-hatchling *C. johnstoni* along 172 km of the Fitzroy River and in some of its tributaries and Seventeen Mile or Camballin Dam (G Webb Pty Ltd 1989a). Boat spotlight surveys in 1992 and 1993 yielded estimates of 2100 and 2900 *C. johnstoni* respectively in the Ord River downstream of the Diversion Dam which forms Lake Kununurra, all within 90 km of the dam (G Webb Pty Ltd 1992; Wildlife Management International 1994a). During 1994 a comparison of boat spotlight and helicopter counts was undertaken by WMI in order to provide helicopter count indices for future population monitoring. Helicopter counts were repeated in 1995-2003, giving the monitoring results displayed on Figure 3. There has not been a more recent survey of the total Western Australian *C. johnstoni* population since that conducted in 1989 (G Webb Pty Ltd 1989d), nevertheless the species is clearly common in suitable habitat and would have a total population in the order of an integer x 10⁴, if not higher.

Management of Crocodiles 1958-2004

Crocodiles were not afforded legal protection in Western Australia until it became apparent that unregulated harvesting and illegal poaching were having a severe impact on their populations. *C. johnstoni* was the first species to receive protection in June 1958, but *C. porosus* was not fully protected until April 1970.

Active management in the form of surveys of wild crocodile populations did not commence until 1969 (see above). In 1988 the Western Australian Government authorised the establishment of the first commercial crocodile farms. Since that time three farms have been established; one at Wyndham (in 1989), one at Broome (in 1991) and the other at Fremantle (in 1990). The Wyndham and Fremantle operations were owned and operated by the same company. The Fremantle operation closed in 1998 when the land was sold for development and all stock was either slaughtered for the trade or relocated to the Wyndham facility. Since 1991 there have been no further applications for crocodile farming in Western Australia.

All commercial crocodile farming in Western Australia has been managed under the provisions of approved management plans (eg Anon 1993; CALM 1993). A new 10-year management plan is currently before the Commonwealth Department of the Environment and Heritage for consideration.

Philosophies Underlying Management

Crocodile management in Western Australia is based around three goals that are applied to both species of crocodile.

Those goals are:

- maintain viable populations of *C. porosus* and *C. johnstoni* over their natural range in Western Australia in an ecologically sustainable manner;
- provide for public safety by maintaining public awareness and providing a mechanism for removing “problem” crocodiles; and,
- where possible, to manage crocodile species as a renewable natural resource providing the conservation of the species is not compromised.

Use of and Trade in Crocodile Products

Crocodile products produced by the commercial crocodile farms include skins for both the domestic and international market and meat for the domestic market. There is a minor market for byproducts such as feet, teeth, skulls and leather products manufactured from smaller pieces of the hide that are usually sold through secondary curio outlets. Currently there is very little market demand for products from *C. johnstoni* and as a consequence the current stocks of this species held by both the crocodile farms are low.

Sustainable Use and Tourism

The concept of sustainable use of crocodiles and crocodile products is supported by one of the three goals of the Western Australian crocodile management plan (see above). Achieving sustainable use of crocodiles can only be achieved by management of the commercial harvest of crocodiles through a best practice harvest quota system, effective licence and tag procedures, and monitoring and maximizing compliance with relevant legislation. It also
requires that CALM and industry members improve their understanding of the impacts that commercial harvest and unrelated industries (such as cattle grazing and irrigation horticulture) have on crocodiles, their habitat and ecosystems. Given the small current population of *C. porosus* and the poor market demand for *C. johnstoni* products at present care needs to be taken to ensure that market forces do not take precedence over conservation imperatives.

There is no regulated tourism based around crocodiles in Western Australia. There are however, a number of boat-based tourism businesses operating in waters inhabited by crocodiles. CALM has in the past received a small number of applications to allow for the capture and holding of *C. johnstoni* for short periods to facilitate close observation of crocodiles by tourists. CALM has not approved any of these applications because of the risks of injury during capture to the crocodiles, the greater risk of injury to the person catching the crocodiles and the risk of injury to tour patrons in the event of an animal escaping within the tour vessel. Repeated capture or attempts at capture is also likely to lead to avoidance behaviour by crocodiles, which could detract from non-invasive tourism opportunities.

Fishing charter boats also operate in parts of the Ord River and Lakes Kununurra and Argyle targeting a range of freshwater fish species. Several of these operators take the opportunity to draw charter patrons’ attention to the presence of crocodiles and a small number have engaged in feeding larger crocodiles to habituate the animals to the close approach of boats. While such behaviour is likely to lead to successful tourism interactions it is also likely to reduce any natural fear that crocodiles have of humans and fishers. In a worst-case scenario this is likely to lead to large crocodiles approaching small boats and threatening the safety of boat-owners and fishers. CALM has made a point of taking this issue up with individual charter operators and seeking their co-operation in ending the feeding of crocodiles. CALM has a “no feeding” policy with regard to wildlife, in particular where such activities are likely to place members of the public at risk of injury or death.

**Human-Crocodile Conflicts**

Most people consider human-crocodile conflicts to involve situations whereby people are actually bitten or killed by crocodiles. However, with ever-increasing recreational activities in habitat occupied by crocodiles and an increasing resident human population and a rapidly increasing but seasonal tourist population (see Table 2) combined with a slowly increasing crocodile population the potential for a range of conflicts will arise.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Data Collection Sites</th>
<th>Total Number of Visits (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996/97</td>
<td>137</td>
<td>6.4</td>
</tr>
<tr>
<td>1997/98</td>
<td>144</td>
<td>8.1</td>
</tr>
<tr>
<td>1998/99</td>
<td>149</td>
<td>8.7</td>
</tr>
<tr>
<td>1999/00</td>
<td>158</td>
<td>8.9</td>
</tr>
<tr>
<td>2000/01</td>
<td>158</td>
<td>9.7</td>
</tr>
<tr>
<td>2001/02</td>
<td>185</td>
<td>9.8</td>
</tr>
<tr>
<td>2002/03</td>
<td>190</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Localized surveys of visitors entering conservation estates in the east Kimberley show important trends in demographics of those visitors. Typically more than 90% originate from outside of Western Australia, with more than 75% of those coming from other parts of Australia with a bias towards those coming from the southern States of Australia. More than 70% are over 40 years of age and more than 90% of the tourists are visiting those sites for the first time. Visitor trends and demographics such as these while encouraging from the point of view of increasing the public exposure to the wonders of the State, but they also clearly indicate that the majority of people entering into areas occupied by crocodiles are unlikely to have had any prior experience in how to ensure their own safety in the presence of crocodiles. This means that the CALM has an increasing requirement to ensure adequate signage at sites inhabited by crocodiles and visited by tourists as well as an over-arching role in community education about the need to conserve crocodiles while ensuring the safety of the public.
CALM has identified Crocodile Control Zones for *C. porosus* around selected centres of human population or activity. Within these areas effective control of *C. porosus* is possible, taking into account the availability of staff and resources and the potential for reinvasion. The aim is to remove all *C. porosus* entering these areas, regardless of size. Whenever practical crocodiles removed from these zones will be caught alive and relocated to crocodile farms (because of their homing tendencies, it is generally impractical to relocate these animals in the wild). However, because of the unacceptable risk to public safety in Crocodile Control Zones, CALM officers may destroy any *C. porosus* within these zones whenever it is deemed necessary. Persons other than CALM officers may be authorised in writing to remove *C. porosus* from these zones. Within these criteria, particular emphasis will be given to problem crocodiles at Wyndham, Derby, Broome, Aboriginal settlements and popular recreational areas along the Ord and Fitzroy Rivers. It is important that the public recognize that a Crocodile Control Zone does not guarantee and area is “crocodile-free” and therefore absolutely safe.

The documented cases of attacks on humans by crocodiles in Western Australia since the Second World War are shown in Table 3. It is likely that there were more cases than this, particularly in the period pre-1980 but these were not reported or recorded in medium that readily allows them to be collated. Most of the early records listed in Table 3 come from print media articles, while all of the later ones come from direct investigations by local police and/or CALM staff.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Species</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun 1947</td>
<td>Wyndham Harbour</td>
<td><em>C. porosus</em></td>
<td>British merchant seaman - suspected taken by crocodile. Confirmed that crocodile ate him but did not necessarily kill him.</td>
</tr>
<tr>
<td>Nov 1980</td>
<td>Gulf at Wyndham</td>
<td><em>C. porosus</em></td>
<td>Paul Flanagan - killed while having a midnight swim.</td>
</tr>
<tr>
<td>28 Nov 1986</td>
<td>Parry Creek, Wyndham</td>
<td><em>C. porosus</em></td>
<td>Stephen Forrest - attacked, required stitches in arm.</td>
</tr>
<tr>
<td>1 Apr 1987</td>
<td>King Cascades, Derby</td>
<td><em>C. porosus</em></td>
<td>Ginger Meadows 24 - fatal.</td>
</tr>
<tr>
<td>26 Apr 1987</td>
<td>Geike Gorge National Park</td>
<td><em>C. johnstoni</em></td>
<td>Mark Weir - severe lacerations to feet, stitches required.</td>
</tr>
<tr>
<td>17 May 1990</td>
<td>Oombulgurri Community</td>
<td><em>C. porosus</em></td>
<td>Molly Gore - survived, caught trying to fish, deep lacerations to chest and abdomen.</td>
</tr>
<tr>
<td>10 Mar 1991</td>
<td>Chamberlin Gorge</td>
<td>Unknown</td>
<td>All survived after a crocodile tipped their canoe and they had to swim to the bank of the gorge.</td>
</tr>
<tr>
<td>12 Apr 2003</td>
<td>Ord River, Kununurra, just below the Diversion Dam</td>
<td><em>C. porosus</em></td>
<td>Drunk man swimming in known crocodile habitat. Was warned off by local police, but re-entered the water shortly after and was bitten on the right lower leg by 2.4 m crocodile</td>
</tr>
</tbody>
</table>

As recreational pursuits in and around waterbodies increase, so to does people’s desire to involve their domestic pets in these activities. Unfortunately, dogs are a very attractive food source to crocodiles (Table 4).

**Ongoing and Management and Research**

CALM is committed to the sustainable management of crocodile populations in Western Australia in accordance with the aims set out in the approved management plan. A new management plan for the period 2004-2013 has been through the public comment process and final amendments are being made prior to submission to the Commonwealth Minister for the Environment.
Table 4. Crocodile attacks on domestic dogs in Western Australia.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Species</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 February 1984</td>
<td>Boat ramp - Wyndham</td>
<td><em>C. porosus</em></td>
<td>Two dogs found dead - only one confirmed killed by crocodile</td>
</tr>
<tr>
<td>31 March 1987</td>
<td>Wyndham</td>
<td><em>C. porosus</em></td>
<td>Three dogs taken in last three months</td>
</tr>
<tr>
<td>6 April 1987</td>
<td>Crossing Falls, Lake Kununurra</td>
<td><em>C. johnstoni</em></td>
<td>Small dog attacked - survived.</td>
</tr>
<tr>
<td>15 June 1987</td>
<td>Wyndham</td>
<td><em>C. porosus</em></td>
<td>Dog found dead - presumed crocodile attack</td>
</tr>
<tr>
<td>1 July 1989</td>
<td>Boat ramp - Wyndham</td>
<td>Unknown</td>
<td>Dog found dead, crocodile attack witnessed</td>
</tr>
</tbody>
</table>

Other than the annual surveys of the populations in specific monitoring zones there has been very little research conducted on either species. In 1975 tissue samples from both species of crocodile were collected from the east Kimberley area as part of a survey to determine the bioaccumulation of DDT in the ecosystem. DDT had been used fairly widely in the irrigation area to control pests of cotton and horticulture crops. In 2003 the opportunity arose to resample both species of crocodile in Lake Kununurra, the lower Ord River and the Ord River irrigation area to determine whether the levels of DDT residues had decreased in the intervening 28 years. The samples are currently being analysed in Japan and the results should make for interesting reading given the role of crocodiles as top-order predators. It will also be interesting to learn what impact pesticide residues might have on the reproductive function in crocodiles given the known impact of by-products of DDT on crocodilian reproductive endocrinology.

A PhD student has also just completed (and submitted) his thesis on the population ecology of *C. porosus* in the Kimberley of Western Australia. Several manuscripts have been prepared as a result and some of these have been accepted for publication while others are currently under review.

**Ongoing Monitoring Programs**

Crocodile populations have been monitored annually since 1990 in Western Australia using a combination of spotlight boat surveys and helicopter surveys. Recent published studies examining crocodile survey data from the Northern Territory (eg Stirrat *et al.* 2001; Harvey and Hill 2003) indicate that there may be good reasons to modify survey techniques in the future to provide more accurate population estimates, but also to provide some economies to offset the steadily increasing costs of surveys. The applicability of some of these new techniques may be limited or will require modification given the very different nature of crocodile habitat in Western Australia.

Be that as it may, CALM is committed to continued monitoring of the crocodile populations in accordance with the undertakings set out in the new draft management plan.

**The ‘Big Picture’**

In Western Australia the commercial crocodile industry is small in terms of the number of licensed operators. Accordingly there has been a limited harvest from the wild and it is expected that as captive husbandry in the farms improves the need to source animals direct from the wild will further decrease. Recovery of both species of crocodiles has occurred, with rates of increase influenced by the availability of suitable nesting habitat and competing land uses (eg pastoralism) that can lead to degradation of scarce of nesting resources for *C. porosus*.

An increasing seasonal tourist population visiting areas inhabited by crocodiles places increasing responsibilities on CALM to ensure adequate levels of public education and awareness of the risks of living with crocodiles. This requirement must also take into account the fact that most visitors are crocodile naive and a significant proportion come from overseas and for whom English may not be their first language. The continued development and diversification of the tourism industry and the types of products they wish to offer customers along with new industries based around greater water use (eg aquaculture, intensive irrigation) will also have the potential to impact on crocodile conservation and management. CALM will need to be actively involved in providing comment on any such proposals to ensure that their impacts are minimal and that public safety is not jeopardized. As with most conservation agencies around the world the capacity of the Department to continue to achieve these goals will be influenced by resources.
Literature


Crocodile Management in Australia - The Federal Government’s Involvement

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Abstract

The State and Territory Governments of Australia have primary responsibility for wildlife conservation and management. The Federal Government regulates the import and export of wildlife including administering the provisions of CITES, and manages wildlife on Federal land. The Department of the Environment and Heritage (DEH) is the Australian Government Department responsible for regulating the import and export of wildlife. Kakadu National Park is jointly managed by DEH and the traditional landowners. This paper summarises the Australian Government’s involvement in crocodile management in Australia, explains how DEH fulfils its role as the CITES Management and Scientific Authorities, gives details of the legislative requirements that allow exports and discusses how crocodiles are managed in Kakadu.

Background

Australia has a federal system of government. Under the Australian Constitution, the States and Territories have primary responsibility for wildlife conservation and management. The Australian (or Federal) Government has responsibility for regulating exports and imports, managing wildlife on Federal land and negotiating and abiding by international treaty obligations.

Australian crocodiles were listed on Appendix II of CITES in 1975. At the second Conference of the Parties (COP2; San José, 1979), the world population of *C. porosus* was transferred from Appendix II to Appendix I with the exception of the population of *C. porosus* within Papua New Guinea, which was retained on Appendix II.

At COP5 (Buenos Aires, 1985), the Australian population of *C. porosus* was transferred from Appendix I to a restricted Appendix II listing. The restriction limited the wild harvest to ranched specimens. At COP9 (Fort Lauderdale, 1994) the Appendix II listing was changed to a non-restricted listing.

Federal Regulation of Trade

The Australian Department of the Environment and Heritage is responsible for regulating trade in native and CITES listed species. CITES became enforceable under Australian law on 27 October 1976. Initially, CITES was enforced under the Customs (Endangered Species) Regulations. From 1984, the Wildlife Protection (Regulation of Exports and Imports) Act 1982 governed wildlife trade. Under amendments effective from 11 January 2002, Australia’s responsibilities under CITES is now provided by Part 13A of the Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act).

CITES requires that countries divide the responsibility of administering CITES provisions into separate Management and Scientific Authorities.

CITES Scientific Authority

The role of the CITES Scientific Authority is undertaken by the Sustainable Wildlife Industries Section (SWI) in DEH. This section is responsible for making non-detrimen findings, and does so by assessing the sustainability of the management arrangements of the State or Territory from which the crocodiles are sourced.

Western Australia and the Northern Territory prepare management plans which are submitted to SWI for approval under the EPBC Act as Approved Wildlife Trade Management Plans. SWI works with the States and Territories to ensure that the plans meet the requirements of the EPBC Act and CITES. The Australian Minister for the Environment and Heritage (or delegate in DEH) is responsible for approving the plans. (A more detailed description of the EPBC
Act’s requirements for an approved wildlife trade management plan is included in Legislative Framework below).

A management plan is approved for a maximum period of five years. Crocodile management plans require the State agencies to provide annual reports to SWL. An approval can be revoked or conditions added to ensure that the harvest remains sustainable. In approving a plan, the Minister may add conditions to that approval.

Queensland does not allow the wild harvest of crocodiles, except those removed for public safety. Crocodiles held in Queensland crocodile farms are either captive-bred or sourced from the Northern Territory or Western Australia. The Queensland licensing regime has been assessed and approved as a captive breeding program to permit export of crocodiles that have been captive-bred in Queensland.

**CITES Management Authority**

The role of the CITES Management Authority is undertaken by the International Wildlife Trade Section in DEH. This section provides tags to the States/Territories, issues permits and reports to the CITES Secretariat.

**Animal Welfare**

The Australian Government is committed to animal welfare and, as the Australian crocodile industry continues to grow, the Government is working towards the development and implementation of a nationally consistent set of minimum standards for the humane treatment of wild taken and farmed crocodiles. The key focus of the draft Code of Practice for the Humane Treatment of Wild and Captive Australian Crocodiles is to ensure the humane treatment of a protected native species which is harvested on a sustainable basis. The scope of the Code is limited to the taking of crocodiles from the wild and the farming of crocodiles. It does not cover the public display of crocodiles in zoos and animal parks, which have different requirements. The minimum standards recommended in the draft Code draws on current knowledge of crocodile welfare issues and best practice in humane handling techniques.

The draft Code was published on the DEH website in January 2004 for a further round of public consultation. DEH is currently considering all comments received and is keen to finalise the Code.

Crocodile trade management plans will be approved subject to adherence to the draft Code. State and Territory Governments are responsible for the enforcement of the Code as a normal component of their wildlife management, compliance and enforcement functions.

**Legislative Framework**

International movement of wildlife and wildlife products is regulated under Part 13A of the EPBC Act. Specifically, the Act regulates the:

- export and import of CITES specimens;
- export of Australian native species other than those identified as exempt; and,
- import of live plants and animals that, if established in Australia, could adversely affect native species or their habitats.

Objects of the wildlife trade provisions of the EPBC Act are to:

- comply with CITES and the Biodiversity Convention obligations;
- protect wildlife that may be adversely affected by trade;
- promote the conservation of biodiversity in Australia and other countries;
- ensure that commercial utilisation of native wildlife is managed in an ecologically sustainable way;
- promote the humane treatment of wildlife;
- ensure the ethical conduct during research associated with the utilisation of wildlife; and,
- ensure the precautionary principle is taken into account.

**Permits**

The EPBC Act sets out the criteria that must be met before an export permit may be issued. Criteria for commercial export include that the specimens come from a program or plan that is approved under the EPBC Act. In the case of
C. porosus and C. johnstoni, this is either an Approved Captive Breeding Program or an Approved Wildlife Trade Management Plan.

The commercial export of live C. porosus and C. johnstoni is prohibited. The EPBC Act prohibits the live export of native birds, reptiles, mammals and amphibians except for specific non-commercial purposes that are outlined in the EPBC Act. These include research, education (enrolled students) and exhibition (zoos).

Captive Breeding Program

A captive breeding program can be approved if the Minister (or delegate) is satisfied that:

- if an animal reproduces sexually, its parents transferred gametes in a controlled environment;
- if an animal reproduces asexually, its parents were in a controlled environment when it began to be developed;
- breeding stock must be:
  - established in a way that is not detrimental to survival of the species in the wild;
  - maintained without introduction from wild except to ensure ongoing genetic viability and to dispose of animals confiscated, seized, rescued or removed from the wild for public health and safety; and,
- the animal has produced offspring to at least the second generation, or is managed in a way that has been demonstrated to be capable of reproducing second generation offspring.

Approved Wildlife Trade Management Plan

The Minister (or delegate) must not approve a plan unless satisfied that:

- the plan is consistent with the objects of the EPBC Act;
- there has been an assessment of the environmental impact of the activities of the plan;
- the plan includes management controls to ensure that the impacts of the activities are ecologically sustainable;
- activities undertaken under the plan will not be detrimental to survival or conservation status of the taxon or any relevant ecosystem; and,
- in the case of plans that cover mammals, reptiles, birds or amphibians that animal welfare requirements are met.

In approving a management plan the Minister (or delegate) must have regard to whether the legislation relating to the taxon is in force in the relevant State or Territory and whether it applies throughout the State or Territory and is effective.

Prior to approving a wildlife trade management plan, a notice setting out the proposal (plus a copy of the relevant State or Territory management plan) is placed on the Internet for a minimum period of 20 business days and inviting written comment. The Minister must consider any comments received when making a decision. In addition, the Minister must consult the relevant agency of each State or Territory affected by the declaration of a wildlife trade management plan.

Miscellaneous

The EPBC Act provides additional protection for specific species that are listed on lists maintained under the EPBC Act (that is, threatened, marine and migratory species). Crocodylus porosus and C. johnstoni are not listed as threatened, but C. porosus is a listed migratory species and both are listed as marine species. These listings require additional protection in or on a Federal area.
Crocodile Management - Kakadu National Park

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Abstract

Kakadu National Park is jointly managed by DEH and the traditional landowners. This paper discusses how crocodiles are managed in Kakadu.

Preface

The term ‘crocodile’ is used herein to refer to the species Crocodylus porosus, the salt-water or estuarine crocodile. The species Crocodylus johnstoni will be referred to in full as “freshwater crocodile”.

Background

Crocodiles are of high conservation, cultural and tourism significance. As with other areas in Australia’s Top End both species of crocodile were commercially hunted to a situation of serious decline, with their populations critically endangered, in the late 1960s and early 1970s. Since protection crocodiles have made a remarkable population recovery to levels not seen since pre-hunting times. Parks Australia, the Commonwealth (Australian Government) management agency responsible for managing Kakadu (in a joint management partnership with Kakadu’s Aboriginal traditional owners, has a responsibility to manage this natural heritage population whilst minimizing the obvious risks they pose, particularly saltwater crocodiles, to humans (Kakadu residents and visitors). The main management issue predominantly lies not with crocodiles but with managing and educating people about the risks whether living in or visiting Kakadu, where large and healthy populations of crocodiles exist in varying densities throughout Kakadu’s waterways. This paper provides information about current crocodile management practice in a world heritage listed (natural and cultural heritage) landscape.

Introduction

Kakadu is about 19,804 square kilometres in area. About 50% of Kakadu is Aboriginal land leased back to the Commonwealth to be managed as a national park. Today, about 1600 people live in Kakadu. About 1164 (214 indigenous) live in the township of Jabiru, which is situated roughly in the centre of Kakadu. 207 indigenous and 188 non-indigenous residents reside outside Jabiru in Kakadu, at Aboriginal community outstations and park ranger stations. About 170,00 to 180,000 people visit the park each year.

Many residents and visitors carry out activities near or in water bodies in which crocodiles occur. Aboriginal people continue their traditional hunting and gathering of food in these areas. Other residents and visitors carry out activities including camping, fishing, boating and, in some locations, swimming. Estuarine crocodiles present a risk to people carrying out these activities. The level of risk varies depending on physical features of the area, the time of year, the size and behavior of crocodiles in the area, the type of people that use the area and the activities they carry out.

Some activities dangerously attract the interest of crocodiles. Such activities include: cleaning fish; leaving offal or food scraps near the water’s edge; camping close to the water’s edge; fishing while standing in the water; getting captured fish by hand from the water; holding fish in the water for some time before releasing them; going very close to crocodiles in boats; feeding crocodiles; annoying crocodiles; boating in unsafe or small craft; adults or children wading and splashing at the water’s edge; and, swimming in areas where crocodiles may be.

There have been numerous adverse interactions between crocodiles and people since the park was declared, ranging from crocodiles entering campgrounds to scavenge food waste, to fatal attacks on people. Over the years, Parks Australia developed and adopted a range of strategies to reduce the risk of crocodile attacks on people in Kakadu, and to respond to any attacks.
Legal and management framework for managing crocodiles in Kakadu

Kakadu National Park is a Commonwealth reserve under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

Approximately half of Kakadu is Aboriginal land under the Aboriginal Land Rights (Northern Territory) Act 1976 (Land Rights Act) and is owned by Aboriginal Land Trusts on behalf of the traditional Aboriginal owners. The Land Trusts have leased the land to the Director of National Parks. Most of the remaining land in Kakadu is under claim under the Land Rights Act.

The Director of National Parks and the Kakadu Board of Management manage the park, in accordance with the EPBC Act and the management plan for the Park. Day to day management is carried out by Parks Australia (staff within the Department of the Environment and Heritage).

Section 354(1) of the EPBC Act prohibits killing, injuring, taking, trading, keeping or moving a member of a native species except in accordance with a management plan. Each management plan for Kakadu since 1986 has specified that park staff may capture and relocate or destroy problem crocodiles.

The EPBC Act, the Land Rights Act and the lease agreements protect the rights of indigenous people to continue their traditional use of areas and resources in the park for hunting, food gathering, ceremonial and religious purposes. This means that indigenous people have rights under contemporary legislation as well as under traditional Aboriginal law to continue to take crocodiles and their eggs in Kakadu for food and other traditional purposes.

Kakadu has been listed on the World Heritage List for both its natural and cultural values. Australia has obligations under the World Heritage Convention, codified in the EPBC Act, to protect, conserve and present the attributes of the park that are of World Heritage significance. The World Heritage values include animal species of conservation significance, including crocodiles.

Crocodiles are listed as endangered on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This listing placed restrictions on international trade in crocodiles and crocodile products. Consequently, Part 13A of the EPBC Act regulates imports and exports of crocodiles and crocodile products to and from Australia. Within Australia, crocodiles they are protected and managed under Commonwealth, State and Territory legislation. In Commonwealth areas, including Kakadu, crocodiles have strong legislative protection through being listed as migratory and marine species under Part 13 of the EPBC Act. This strictly limits the circumstances under which crocodiles or their eggs may be taken. In the rest of the Northern Territory, the Territory Parks and Wildlife Conservation Act 2000 provides for the protection of crocodiles and regulates the harvesting of crocodiles and eggs.

Historical background

Archeological evidence suggests man has occupied Kakadu continuously for up to 60,000 years or more while the climatic history of the Top End indicates Kakadu may have been unavailable to saltwater crocodiles periodically and in fact may have been solely the domain of freshwater crocodiles for much of these 60,000 years.

In more recent times the Top End rivers were visited by early explorers and occupied by following settlers. They noted the region was “infested” with crocodiles with these impressions recorded permanently in local place names: the Alligator Creeks, Alligator Head, Alligator Billabong and Crocodile Island, etc.

Since contact times (pre-1945) crocodiles have been exposed to commercial harvesting for their hides. Other reasons for killing crocodiles (by poison baiting, hooking and nest destruction) involved cattlemen reducing stock predation. Despite this type of hunting pressure crocodile numbers remained high until after World War II. Then, the adoption of spotlight shooting for commercial hunting of crocodiles, coupled with a good return for hides and a surplus of adventurous hunters, brought a rapid decline in crocodile numbers (D. Lindner, pers. com). Due to the decimation of crocodile populations both species were given protection in the late 1960s and early 1970s. Since then there has been a rapid increase in the observable population of crocodiles (Palmer 1992). This is particularly evident on the tidal and inland waterways (eg Alligator and Wildman Rivers, Yellow waters - late dry season) of Kakadu.

Kakadu’s crocodile population grew rapidly in the 1980s then leveled out in the 1990s, however the number of
estuarine crocodiles found in upstream areas is still increasing each year. Parks Australia staff estimate that, as at 2004, there are about 5000 to 6000 (very approximate estimation only) estuarine crocodiles in Kakadu, which roughly represents 10% of the Top End’s crocodile population.

Managing and maintaining Kakadu’s resident crocodile population in or near to its natural state

Both species of Australian crocodile, the estuarine crocodile (Crocodylus porosus) and the freshwater crocodile (Crocodylus johnstoni) live in Kakadu National Park.

Aboriginal people in the Kakadu region refer to the saltwater crocodile as Ginga and the freshwater crocodile as Gumugen. The estuarine crocodile is most common in tidal wetlands and freshwater bodies associated with sub-coastal plains. Both species occur in the upper freshwater regions of tidal rivers, creeks and billabongs. Estuarine crocodiles are dangerous to humans. Freshwater crocodiles, although generally harmless to humans, can be dangerous, particularly if they are annoyed or interfered with.

Before non-Aboriginal people arrived in this area, Aboriginal people and crocodiles preyed on each other. People understood the risks. For Aboriginal people, swimming or deep wading in waters down stream from the waterfalls of the escarpment crocodiles attacks presented a degree of risk, which to an experienced person varied from negligible to extremely high. At the high risk end of the scale even camps were made well away from waters edge to avoid crocodile attacks. For crocodiles, Aboriginal people were nest robbers, and a cunning predator using decoys, with the victim crocodile ambushed by gangs of people armed with spears.

Man could hunt crocodiles occupying small water holes or floodplain wallows and burrows with relative impunity and this effectively confined crocodiles in their wetland distribution. Neither man nor adult crocodiles had other predators to consider (other than their own species) unless they entered a deep-water environment.

This relationship may offer an explanation why crocodiles often appear wary of humans by instinct, in contrast to their behaviour to other large animals (eg dingoes, pig, buffalo and horses) where they don’t appear to sense threat and are often attracted to these animals, particularly dogs on Aboriginal outstations situated near billabongs.

Today, Aboriginal people still live in Kakadu and still eat crocodile meat and eggs, but they take far fewer crocodiles and eggs than they did before non-Aboriginal people arrived. There are fewer Aboriginal people living in Kakadu than there were in the past, they live in fewer locations and, in most situations, are not living immediately in or adjacent to the wetland and estuarine areas that historically provided most of these peoples rich food resources. Aboriginal people are no longer solely reliant on these areas and resources for hunting and gathering for food.

“Boss crocodiles”

Very large crocodiles (5 m long and larger) exist throughout the tidal and inland waterways of the park. Some of these individual identity animals have co-existed with Aboriginal residents prior to declaration of Kakadu in 1979; as a result Aboriginal people afford them protection. The smaller peer crocodiles (up to 2.5 m) in a large crocodile’s territorial home range were commonly hunted and are still intermittently hunted today.

As an example one large crocodile, known locally as Roughnut, is about 5 m long. Roughnut resides at a very well used floodplain and billabong area known as Gindjela. Aboriginal people have seen Roughnut in this area since 1975. At Gindjela Aboriginal people utilize the resources such as magpie geese, file snakes, feral pig, water pythons, saratoga, barramundi, catfish, freshwater turtles, and aquatic plants. Roughnut and Aboriginal people in this area have experienced a dramatic change where crocodiles numbers in this waterhole were very low. In recent times the numbers of smaller peer group crocodiles has become very high, particularly at the end of the dry season where receding water has forced about 100 crocodiles to live in the 3 km stretch of billabong (2003).

Roughnut’s territory includes a couple of 4 m plus crocodiles. This is followed by number of crocodiles about the 3 m size class. The most abundant size range in this group of 100 crocodiles is the 1 to 2.5 m size class. Typically, as with other ‘boss crocodile’ situations the majority of these crocodiles (about 60% of the population) occupy about 25% of the space available, at one end of the billabong system. Roughnut and the remaining 40% of the population occupy the other 75% percent of the billabong. The crocodiles “accommodated” by Roughnut are usually animals up to 2.7 m in length and are fairly evenly dispersed throughout the billabong. The remaining 60% of Roughnut’s peer group exist in the shallow end, which is about 2 m deep in the middle sections. These crocodiles co-exist, albeit the
smaller ones with a nervous disposition to the larger size classes, in fairly high densities in about 750 m of waterway that is about 150 to 200 m in width at its widest point.

The status of Roughnut as a peer boss crocodile is demonstrated in his Goose Camp Billabong environment. Roughnut’s wives use his presence when feeding, other crocodiles in the 3 m plus size class leave when Roughnut approaches, his harem of females remain in his presence when feeding albeit at a close distance. Roughnut’s presence affects peer crocodiles when he approaches. These smaller crocodiles are engaged in predatory observation and stalking of magpie goose flocks; their attention is immediately diverted to when Roughnut approaches the area. What is not understood is how crocodiles sense each other, particularly when Roughnut is approaching from 500 m to a kilometre away. The smaller crocodiles sense his approach and seem to divert their behaviour from predatory observation to wariness and avoidance of the approaching boss crocodile. These observations of boss crocodile behaviour are made by crocodile “wise” people but it is not understood- needs research to fully understand what is occurring. This may also be a guardianship situation to aboriginals fishing from the bank in parts of the billabong in Roughnut’s main territorial zone. Other crocodiles are kept away, if a “non-tolerated” smaller male is present its attention is diverted to monitoring Roughnut’s presence and it situates itself accordingly while remaining constantly vigilant on the surface, it is clearly visible to other crocodiles and people in the area.

One particular Aboriginal family hunted this group of crocodiles on a fairly regular basis until very recent times. One method used to hunt these animals comprised one family member tying a dead magpie goose to a rope and throwing it out into the billabong. This attracted the attention of a crocodile usually about 1.5 to 2 m long. The dead goose was pulled through the water back towards the bank and as the crocodile approached very close to the goose it was then shot by another family member who was waiting concealed behind a large paper bark tree. The dead crocodile was then retrieved in the shallow water.

Park management approaches to crocodile management

For park management, crocodiles now present an on-going area of active risk and wildlife management. The significance of any incidents (even if irregular in occurrence) and the need for active management means that crocodile management is a regular and routine work responsibility. This responsibility prescribes the need for park-specific assessment and action undertaken under set guidelines that aim to fulfill the Park’s Plan of Management objectives;

To monitor potential human/crocodile situations that may occur in relation to:
- personnel working in Kakadu,
- visitor use areas,
- fishing activities,
- Aboriginal outstations and hunting areas; and,
- other likely interaction activities.

In broad summary Kakadu management has responsibility for maintaining a large predator species population, in as near as possible, to its natural wild state while protecting a visiting, and resident, prey species (people) from predation.

Educating people and warning people about the risks of crocodile attack

While crocodile observation is a major attraction to most Kakadu visitors the prey size range of crocodiles extends to animals much larger than humans (eg horses, buffalo, cattle) and territorial aggression in the species results in brawls between crocodiles weighing well over 500 kg, that is, of small boat or typical canoe dimensions.

While observing crocodiles Kakadu visitors are often in the proximity of both a potential man-eating predator and an occasional “boat bashing”, strongly territorial, species. Crocodiles may be attracted to distressed fish fighting on fishing lines, geese or other wounded game trying to escape a hunter, or they may get accustomed to food from fisherman discarding unwanted catfish or offal from cleaning fish in their territory. High dog populations (domestic pets) make Aboriginal communities a virtual game farm for local crocodiles.

An important part of the park’s approach to managing crocodile risks is to raise awareness among visitors and residents about crocodiles in this ‘crocodile environment’. To do this Parks Australia provides information that educates and warns visitors, residents and tour operators about crocodiles and encourage people not to place themselves at risk of attack by crocodiles, using all available cost-effective methods.
The methods used to educate and advise people about crocodiles include development and promoting key messages about crocodiles and safe behaviour in Kakadu, through:

- Signs and displays
- Information in the park Visitor Guide and other park publications, including pre-visit information
- Face-to-face communication with visitors and residents by park staff
- Education of tour guides through a range of methods including the Kakadu Tour Operators’ Manual and Tourism Industry Seminars
- Videos shown within Kakadu
- Information provided to the media

Some of the key messages that encourage people to respect crocodiles in Kakadu and not to place themselves at risk of attack by crocodiles are that:

- Most of Kakadu is prime crocodile habitat.
- There is some risk of crocodile attack if you enter the water anywhere in Kakadu.
- In most of Kakadu there is a very high risk of crocodile attack if people enter the water.
- In a few places in Kakadu, Parks Australia takes steps to reduce the risk of attack on people swimming, but even in these places, Parks Australia cannot guarantee people’s total safety from all crocodiles. People enter the water at their own risk.
- There are several ways for people to reduce the risk of crocodile attack if they are fishing, boating or near water in Kakadu.

Parks Australia regularly reviews these messages and develops and promotes other messages (as required) to encourage people not to place themselves at risk of attack by crocodiles.

**Signs**

Parks Australia maintains crocodile warning signs near the entrances to the park, at boat ramps, at camping areas and day use areas near water, and places warning and information signs at other strategic locations.

Crocodile warning signs range in size from small, pictogram-only signs to large signs with detailed information. Several types of signs are used, including:

- warning signs used at locations where estuarine crocodiles are known to live;
- warning signs used at locations where estuarine crocodiles are not known to live but may move in undetected (eg escarpment pools, waterfall plunge pools and adjacent waterways);
- general information signs at park entrances and other strategic locations; and,
- temporary warning signs if there is a higher risk than usual but a closure is not used while the risk is being addressed (eg if there is an inquisitive crocodile near a boat ramp).

All crocodile warning signs include symbols and most sizes of signs that include English text. Some signs also use other languages, including German, Japanese, French and Italian. Parks Australia also works with other agencies to maintain consistency across jurisdictions (Northern Territory, Western Australia, Queensland) in design and wording of crocodile warning signs.

**Crocodile surveys**

Data has been collected from surveys conducted on tidal areas and inland waters of the Park since 1977. Parks Australia staff have been surveying crocodiles in Kakadu since declaration of the park in 1979, when stage one of the park was declared. In 1979 crocodile numbers were much lower than today, as crocodile hunting had been allowed until 1971 and populations had just started to recover.

In summary the crocodile population had a rapid increase from 1971 to 1988. The rapid increase was consistent with population increase for the rest of the Top End.

Between 1988 and 1998 the population increase declined and steadied and there was an increase in >6 foot (2 m) size class, and the crocodile population was steady. It may still have been a population of young animals but Kakadu may
have achieved a full-grown population. Kakadu might have reached a total recovery in its crocodile numbers during this period. The most recent assessment between 1998 and 2003 has reinforced the view that Kakadu’s estuarine crocodile population is reaching or has reached plateaux. The survey results are consistent with crocodile population results for the rest of Top End. The population is dominated by crocodiles in the four foot (1.2 m) size class.

Kakadu survey results suggest that Kakadu’s crocodile population is now peaking or is at its peak. Staff and resident field observations support this, with crocodiles dying from:

- territorial disputes;
- predation from other crocodiles;
- heat desiccation, floodplain fires;
- movement into extra-limital range (plunge pools); and,
- peer aggression.

The number of estuarine crocodiles found in freshwater upstream areas is still increasing each year. These upstream habitats are not optimal for estuarine crocodiles and in the 1980s and 1990s crocodiles were seldom found here, but by the 2000s large estuarine crocodiles are common found, albeit in low numbers, but none the less are found regularly in these upstream plunge pool regions of Kakadu.

Continued monitoring of crocodile numbers, size and behaviour is necessary to provide accurate information as a basis for assessing and managing the risks of adverse interactions between crocodiles and people.

Parks Australia will continue the long-term crocodile survey program in Kakadu in order to:

- Monitor changes in crocodile population numbers, age structures and distribution throughout the Park;
- Endeavour to detect and count the crocodiles in water bodies that people visit, boat on or live near;
- Estimate the size class of each crocodile detected in those water bodies; and,
- Monitor the behaviour of crocodiles in those water bodies, as a basis for risk assessment.

Table 1. Trends in mean crocodile density in Wildman River, Kakadu National Park, 1977-2003. Information is specific to time and date of each survey conducted. Very high-count results were achieved when surveys were conducted in cooler months between July and August. Crocodiles are in warmer water when air temperature was very cool and lower than water temperature. * = actual distance not available, mean provided. NH= non-hatchlings.

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<th>Total Count</th>
<th>NH &gt;2 feet</th>
<th>NH &lt;2 feet</th>
<th>NH Density (per km)</th>
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Future research options

Further survey data is required to try and monitor any changes to that may be occurring. Some research may be required to determine:

- Size structure of future populations - a mature population may be made up of larger individual animals - leaner and more competitive dominant males?
- Are floodplains still after removal of large numbers of feral water buffalo and what are the implications for crocodile habitat, especially nesting? It appears wetlands recovery from buffalo modification is still far from complete (eg *Phragmites karka* is still rare on the South Alligator system and floodplain swamps, and paleo-channel rafts of this species are still absent). This would have significance to crocodile numbers and distribution.
- Is crocodile age and biomass increasing with this plateau?
- What kinds of interaction between freshwater and estuarine/saltwater crocodiles occurs in plunge pool and gorge areas? How do short-term and long-term estuarine/saltwater incursions into these areas impact on resident freshwater crocodile populations? What impacts are individual outcast vagrant saltwater crocodiles having on freshwater crocodile populations, with no continuous Aboriginal hunting factor?

Removal of Estuarine Crocodiles from specific plunge pools visited by tourists

When the park was first declared the estuarine crocodile population was still very low after many years of hunting and people swam in many locations in the park. The estuarine crocodile population has increased steadily since they were protected from hunting, and now there are very few places in the park where visitors can swim without significant risk of crocodile attack.

Parks Australia uses signs and other methods to advise visitors that estuarine crocodiles inhabit the water and instruct people not to enter the water or to swim in most locations in Kakadu.

In wet seasons since 1991, estuarine crocodiles have moved all the way upstream in major creeks and are now regularly found in some water pools at the base of the Arnhem Land escarpment. Park staff have surveyed and removed any saltwater crocodiles remaining in or near plunge pools that the public visit, before these areas were opened to the public for the season.

Typically, the saltwater crocodiles that move into these areas are males who are vagrant outcast individuals from downstream populations. These saltwater crocodiles can become dangerous due to low prey biomass in the marginal habitats of plunge pool areas. In some cases they may be recovering from injuries that reduce their success at catching their normal prey species. Consequently they can be very dangerous to humans in and near the water.

In terms of the effect on the saltwater crocodile population size and structure, the removal of a small number of saltwater crocodiles a year from these areas of marginal habitat is believed to have the same, effect as previous traditional Aboriginal hunting of crocodiles for food in these areas.

Twin Falls as a case study

Until 2002, visitors swam in Twin Falls gorge, but by 2003 the number of saltwater crocodiles moving into the area each wet season had increased to the extent that park staff could no longer be reasonably certain that all crocodiles had been removed. Concern about the continuing risk of a large crocodile in Twin Falls gorge meant that the area remained closed for all of the 2003 dry season to prevent people swimming where estuarine crocodiles could be present.

Twin Falls is an area with about 4 separate pools of varying sizes. Accessing the plunge pool further upstream requires traversing about 150 to 200 m of water. Historically visitors have swum the section to access the next walking stage that eventually leads to the spectacular falls and plunge pools area. In 2003 a large 3.5 m saltwater crocodile was seen but never captured despite every attempt to do so. In normal circumstances, prior to 2003, the area would probably have been opened to the public once other tasks had been addressed (seasonal opening chores) aside from removing the crocodile problem.

Below is a summary of problem crocodiles, including freshwater crocodiles (where stated) removed from two of the main plunge areas visited during the dry season.
Twin Falls

- 1988: 1.8 m male freshwater crocodile
- 1990: 2 m male freshwater crocodile
- 1991: 2 m male saltwater crocodile
- 1995 6 June: 2.445 m male saltwater crocodile
- 1996 23 May: 2.89 m male saltwater crocodile
- 1996 7 June: 2.6 m male saltwater crocodile
- 2003 8 May: 2.2 m male saltwater crocodile
- 2004 5 April: 2.67 m female saltwater crocodile
- 2004 12 May: 2.2 m saltwater crocodile

This year (2004) a situation occurred that continued to justify the closure of Twin Falls to swimming pending alternate visitor access options (boat ferry and walkway). After the two estuarine crocodiles (2.67 m and 2.2 m - both female) were removed on 5 April and 12 May the area was surveyed a number of times and no further signs of estuarine crocodiles was detected. No bites were detected on the crocodile detection floats, and the free baits remained untouched. Two weeks after the removal of the 2.2 m animal a very large estuarine crocodile about 3.5 m had moved in between 21 May and 27 May the day went it was sighted near the baited trap. The floats had no bite marks prior to 21 May. The animal had bitten all the crocodile detection floats placed in the gorge. It was a recent arrival, presumably from a downstream location. This animal was overtly displaying itself and was actively feeding in full view of rangers on free baits set. The animal represented the most dangerous scenario if swimming had been allowed. The animal at times was puffing itself on the water surface in the area visitors previously entered to swim up the gorge. The crocodile was displaying all the aspects of a large dominant predatory crocodile with no sign of fear toward humans who were observing from the bank. At the time of writing park staff were in the process of attempting to remove this large crocodile.

At the present time (2004), the only natural water bodies in Kakadu where visitors can swim, that is, where there was minimal risk of saltwater crocodiles moving in undetected, are the creeks above the Arnhem Land escarpment; a few pools immediately below the escarpment: namely Jim Jim Falls, Maguk, Gunlom and Koolpin; the Gubara pools below the Mt Brockman outlier, and some small, spring-fed pools in the southern section of the park. At these locations (other than those above the escarpment), signs and other methods are used to warn people that crocodiles may move into the area undetected, and that people swim there at their own risk.

There is increasing concern among traditional Aboriginal owners and experienced park staff that some of these areas may become places where large crocodiles are increasingly present, increasing risks to swimmers.

Groups of Aboriginal people sometimes wade or swim in the shallows of water bodies where estuarine crocodiles occur, while gathering food or for recreation. Adult Aboriginal people who have lived in Kakadu for a long time generally have a very good understanding of crocodile behaviour, and take numerous precautions to reduce the risk of attack. Additional warning signs may be placed at aboriginal residential areas and high use hunting areas to minimise risk of crocodile attacks.

Managing Swimming

In most areas of the park, swimming is strongly discouraged and may be prohibited, due to the presence of estuarine crocodiles. In specific locations, swimming may be allowed, subject to assessments of the risks of crocodiles moving into those areas and the costs of risk management measures.

In most water bodies of Kakadu, either estuarine crocodiles live there permanently or there is a moderate or high likelihood of estuarine crocodiles moving in from time to time. Consequently, in most of Kakadu, Parks Australia aims to strongly discourage swimming, using signs and other methods to instruct people not to enter the water or swim.

As part of the park’s risk management approach Parks Australia and the Kakadu Board of Management may review at any time whether crocodiles should be removed or whether the area should be closed to swimming or to public access, either temporarily or long-term.
Procedures

To remove estuarine crocodiles from these areas, park staff take the following steps:

1. Surveys to detect the presence of crocodiles (including use of free baits)
2. Informing and consulting relevant officers and traditional owners if a crocodile is detected
3. Setting traps
4. Harpooning if the crocodile cannot be caught by trap
5. Killing the crocodile by shooting; or
6. Live removal and relocation of the crocodile
7. Keeping baited traps, crocodile detection buoys and nets in place during the dry season
8. Utilising other capture methods if trapping and harpooning fails

Managing freshwater crocodiles

- At times, a freshwater crocodile may start to behave aggressively towards humans intruding into its territory.
- In this case, a line of marker buoys may be set up to keep people out of the crocodile’s territory. Signs will be erected to inform the public of the purpose of the buoys and to warn people to stay away from the crocodile.
- If this course of action is insufficient, Parks Australia and traditional owners will consider whether the area will be closed to swimming or whether the freshwater crocodile will be removed and either relocated or destroyed.
- If the crocodile is to be removed, park staff will follow the same procedures used for removing estuarine crocodiles.

Seasonal or temporary closures of some areas to the public due to crocodile attack risks

Seasonal and temporary closures

Each wet season, Parks Australia closes areas of Kakadu that become flooded, due to the risk of crocodile attack and other risks associated with floods. At any time of the year, Parks Australia may also close an area to the public temporarily while dealing with a crocodile that presents a high risk to people. Boat ramps, camping areas near billabongs, plunge pools or any other area may be temporarily closed while action is being taken to deal with a crocodile that presents a high risk to people. These areas are closed by use of signs and temporary barriers.

Managing individual crocodiles that may pose a threat to human safety

Crocodiles now present an on-going issue of concern to park management. Management actions are guided by guidelines to assist in meeting management objectives outlined in the Kakadu Plan of Management. These guidelines are set out in the Kakadu crocodile management strategy.

Most estuarine crocodiles generally avoid or, at most, tolerate people, unless people are swimming or are stationary close to water. A crocodile is considered more likely to attack people if it has:

- Behaved very inquisitively towards people, boats, fishing lines and other objects that people use;
- Stayed close to a boat ramp while people are there;
- Scavenged around camping areas;
- Nested in high visitor use areas;
- Snatched fish from lines close to boats or the water’s edge;
- Nudged or bashed boats;
- Taken dogs or other prey from the water’s edge close to visitor or residential areas; and,
- Stalked people.

Procedures

The procedures used to manage crocodiles assessed as more likely to attack people are to:

1. Obtain an accurate report of the inquisitive or aggressive behaviour;
2. Inform and consult relevant officers and traditional owners, and decide on the management action to be taken; and,
3. Use temporary signs, barriers, closures or other methods to reduce the risk to people while the management action is being taken; and,
4. Monitor the crocodile; and/or,
5. Capture, measure, mark and release the crocodile; or,
6. Capture and destroy the crocodile; or,
7. Capture and relocate the crocodile.
8. Record information about the incident and the measures taken.

In some situations where crocodiles pose an immediate threat to people the animal may be captured and removed immediately to reduce danger to the public and staff.

**Responding to crocodile attacks**

Despite the risk management measures that Parks Australia implements, crocodile attacks have occurred in the past, and may in the future. It is essential to be prepared and ready to respond swiftly when attacks occur.

Two human fatalities have resulted from crocodile attacks in Kakadu:

- 1987: during the day a fisherman walking in waist deep water was attacked and killed by a 4.5 to 5 m saltwater crocodile after being washed off by Cahill’s Crossing on the East Alligator River;
- 2002: About 11 pm at night a German visitor was taken and killed by a 4.6 m crocodile while swimming in four metres of water about 10 m from the bank at Sandy Billabong (Nourlangie Creek-South Alligator River catchment).

Parks Australia will respond to crocodile attacks promptly and effectively in a manner that minimises risks and distress to the victim, staff, other people and to crocodiles. The response actions taken to address a crocodile attack follow procedures outlined in the Kakadu crocodile management strategy.

**Training staff - crocodile management**

Crocodile management activities have significant inherent risks to people carrying out those activities. Most field staff in Kakadu have participated in surveys and many have coordinated surveys, but only a small number of staff are fully trained and experienced in crocodile capture and handling.

Crocodile capture operations are carried out only under the supervision of a trained, experienced park officer. The operations are conducted in a manner designed to minimise risks to staff while carrying out the operations and to the public once the area is open, and as far as possible to minimise distress to the animal when caught.

Before carrying out crocodile management actions in the field, park staff with experience and expertise in crocodile management assess the risks to park staff and any other people involved in taking the action, and take steps to minimise the risks.

Parks Australia ensures that all Kakadu staff involved in crocodile management are sufficiently trained and experienced to carry out crocodile management activities in a manner that minimises risk to themselves and other people, and minimises distress to animals.

**Procedures**

Park staff that are experienced in crocodile survey and capture techniques provide training and supervised practice to other field staff. This training and practice is carried out in the field in a number of ‘stages’, outlined in the Kakadu crocodile management strategy.

**Liaison**

Kakadu staff regularly liaise with external crocodile managers and with other wildlife managers to maintain up to date knowledge of crocodile management techniques and issues.
Joint Exercises

Parks Australia supports park staff with experience and skills in crocodile surveys, captures and handling to further develop their skills by participating in crocodile management exercises with the Parks and Wildlife Commission of the NT.

Summary - crocodile realities for Kakadu

Kakadu crocodiles are a ‘natural heritage’ population, of which there are large individual” boss crocs” 4 to 5.6+ m (13 to 18+ foot) crocodiles These large crocodiles, along with their peers, are just as important as when they were critically endangered in 1970.

Kakadu aims to maintain natural populations of native wildlife and the continuing existence of large crocodile populations are justified and appropriate. Crocodiles are only removed when there is a need to address visitor/ resident safety issues arising from human - crocodile interaction. This falls in line with Aboriginal approaches to crocodile management that included removal of estuarine crocodiles at places where Aboriginal people swam. The increasing presence of large crocodiles in waterfall plunge pools, where people like to swim has become a park management issue. These crocodiles are extra-limital individual animals (outcasts, mostly males) from downstream populations and some of these vagrant outcasts may have experienced (and be recovering from) serious injury.

In most of Kakadu breeding populations of resident crocodiles are dominated by large males (eg Roughnut at Gindjela) with vagrant crocodiles in upstream areas (near or at escarpment bases) and small back swamps. These large dominant male boss crocodiles play a role in controlling behaviour of the smaller animals in the peer group. The benefits to Aboriginals and other user groups of this dominance is unknown, but in areas like Gindjela (Goose Camp Billabong) the dominant boss crocodile “Roughnut” keeps 60% of the population at the east end in 25% of the waterway. Aboriginal people enjoy fishing from the banks in the remaining 75% of waterway! They are vigilant for crocodiles but only have to keep an eye on 40% of population, widely dispersed over 2.25 km, as opposed to fishing in 750 m of waterway where about 60 crocodiles are condensed and range in size from 50 cm to 4.5 m. A large proportion of this group are in the 2 to 3 m size class.

Kakadu is a crocodile environment. A large, healthy population of estuarine crocodiles is one of the key World Heritage values of Kakadu National Park. Kakadu management has a responsibility to protect visitors and residents (prey) from predation from crocodiles while at the same time maintaining Kakadu’s crocodile population in or near to its natural state.

Literature


.
Australian Aboriginal Aspirations and Crocodile Management in Arnhem Land, Northern Territory

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Abstract

Arnhem Land is a large area (94,000 km²) in the Top End of the Northern Territory held by Aboriginal people under inalienable freehold title. The region maintains high levels of ecological integrity, including large areas of highly favourable crocodile habitat. Aboriginal attitudes to crocodile management are no less diverse than in other segments of the north Australian population. Some seek substantial reductions in crocodile densities because they interfere with fishing and hunting. Others require the removal of particular nuisance animals. A few treat large animals with special deference and strongly promote their protection. Most regard crocodiles as a potentially useful source of food. Others accept special obligations to conduct ceremony and take other related actions intended to maintain the health of populations and their relationships with humans. There are no particular Aboriginal objections to commercial use, provided proper consideration is given to the interests of traditional owners of lands from which crocodiles are taken, as well as the obligations of those with special customary responsibilities. A number of communities harvest eggs, hatch them and sell the hatchlings or take a direct harvest of sub-adults or small adults. Expansion of the range of harvest options has been sought by a number of communities. This paper deals with some of those options. In particular, they and the Northern Land Council have pressed for Federal Government approval of additions to the NT management plan to allow fee-paying “safari” hunters to take 25 large animals per annum. In his preliminary approval of the Northern Territory plan, the Minister explicitly rejected the safari hunting component. Whilst the decision is not final, lobbying by animal rights interests appears to have been effective in blocking this initiative, despite support by both the Northern Territory Government and Opposition. This experience illustrates a wider issue of constraints on Aboriginal aspirations when key elements among the few options for improved livelihoods are arbitrarily blocked by inappropriate regulation that has nothing to do with sustainability.

Introduction

Arnhem Land is one of few areas in Australia that have been comparatively little changed since European settlement in the late 18th Century. Landscape structure is all but unmodified. Clearing of native woody vegetation is limited mostly to the minimum needed to insert sparse infrastructure associated with a few small towns and tiny settlements (outstations), and mostly unsealed roads and tracks linking them. There are no dams or other significant impoundments of rivers and streams. Topography is mostly subdued near the coast, with major rivers often meandering through extensive floodplains that are deeply inundated in the monsoonal wet season, and retain water in often large seasonal and perennial wetlands (see Whitehead and Chatto 1996). Wildlife remains diverse and sometimes spectacular. The human population is small (about 20,000 people) and mostly indigenous. The whole of the area of 94,000 km² (about half the area of Great Britain) is held under inalienable communal freehold title issued under the Aboriginal Land Rights Act 1976.

The Arnhem Land economy

Private mainstream economic activity is dominated by mining, mostly concentrated around the township of Nhulunbuy. On-site tourism is presently a relatively minor source of economic activity, although artworks produced in Arnhem Land and sold to visitors through a number of retailing arrangements generate substantial incomes (Altman 2003a). Government at various levels employs some residents, but most Government income support reaches local Aboriginal people through welfare payments to individuals and families. Only about 16% of the Aboriginal population of the Northern Territory is employed within the mainstream economy, and Aboriginal incomes are low compared with other sectors of the Northern Territory population (Taylor 2003). Although no separate analysis has been done for Arnhem Land, it is probable that employment rates are similar or lower than the Territory average. The Community Development Employment Program - a “work for the dole” system - operates variously as minimum income support,
a training scheme, or a source of financial support for other community-based activity (see Altman and Johnson 2000), and is a key source of income for households throughout the region. In addition, the customary (subsistence) economy continues to be important, contributing in excess of 30% of household cash and non-cash income in some locations (Altman 1987, 2003b).

Many indigenous communities suffer high rates of adult and juvenile mortality and morbidity, and social problems like disproportionately high imprisonment rates, poor educational attainment, and domestic violence. Influences on these problems are numerous and complex. Governments, communities and individuals, including Indigenous leaders, are increasingly emphasising the negatives of ongoing dependence on welfare (eg Pearson 1999), and as a consequence, calling for increased efforts from Aboriginal people to enter the mainstream economy. But what economic options are available to Aboriginal residents of Arnhem Land?

Economic options in Arnhem Land

The reasons for many aspects of post-settlement development largely bypassing Aboriginal lands are many, but often derive from the landscape being seen to be inhospitable and unproductive. Those lands were available for return to Aboriginal people only because the early settlers and government administrators did not see them as warranting the investments that would otherwise have led to their alienation and consequent unavailability for claim under land rights legislation. For example, central and western Arnhem Land is dominated by a huge sedimentary (sandstone) platform, the Arnhem Land Plateau, laid down by fluviatile processes about 1700 million years ago (see Russell-Smith 1995). These ancient sediments and surrounding parts of the landscape have been tectonically stable, and extensive erosion and weathering over these extraordinarily long periods has produced large areas of exposed rock and often skeletal, low nutrient soils. Consequently, the landscape is mostly unsuitable for intensive agriculture or sometimes even for extensive pastoralism (Holmes 2002). To now call for their rapid development by a small number of Indigenous residents with limited access to capital and expertise is, at best, disingenuous.

Even when ventures are supported by substantial public capital and operational funds, experience has shown that the origin has been increased by the origin of developments outside communities and consequent weak matches to local interests, aspirations and capabilities, often contribute to failure.

Important elements of contemporary Indigenous interests and aspirations include a determination to avoid gross changes in landscapes and their biological features that often accompany orthodox development. For example, the objectives of the Bawinanga Aboriginal Corporation, operating from the township of Maningrida in central Arnhem Land are to “promote the development of communities…, promote the welfare of residents, and foster the preservation and development of traditional and other cultural… activities”. Principal utilitarian roles are to provide basic housing and access to potable water. But as reflected in formal Corporation objectives, Traditional Owners also regard maintenance of the environment and its capacity to support customary activity as a high priority. These activities include fire management, hunting and gathering and related ceremony (see BAC 2001 and other annual reports for details).

Against this background, the interest expressed by many Aboriginal communities in developing small-scale enterprise based on the application of traditional skills and knowledge to the commercial use of native plants and animals - using what is already present rather than substituting other species - warrants particular attention (Whitehead 2003; Whitehead et al. in press).

It is in this context, of community interest in establishing small-scale enterprise based on native species, that I set out what I understand to be the attitudes of some Aboriginal people and their organisations regarding the management of estuarine crocodiles Crocodylus porosus in Arnhem Land. I do not suggest that this account is based on a systematic or comprehensive analysis, but is informed by personal experiences in Government and outside it, as member of Boards of national parks jointly managed with Aboriginal people, by formal and informal consultations regarding resource management issues on Aboriginal lands, and in receiving and responding to individual requests for support to design systems for sustainable use. I summarise examples of constraints placed on crocodile management and other use of native species by the Federal (Commonwealth) Government, to illustrate problems created for good land management practice in remote Australia by ill-informed and poorly considered conservation policy.

Attitudes to crocodiles and their use

Aboriginal attitudes to crocodile management are no less diverse than in other segments of the north Australian
population. Some seek substantial reductions in densities of estuarine crocodiles because their presence interferes with fishing, hunting and foraging. Others require the removal of particular nuisance animals. Most regard crocodiles as a potentially useful source of food. A few treat large animals with special deference and strongly promote their protection. Others accept special obligations to conduct ceremony and take other related actions intended to maintain the health of populations and their relationships with humans (see Lanhupuy 1987).

**Customary use of crocodiles**

The extent to which crocodiles are presently used for food varies regionally, but total usage appears relatively minor. For example, during studies of customary use of wild resources extending over 269 days in 1979/1980, in areas of central Arnhem Land that included favourable estuarine crocodile habitat, Altman (1987) recorded one estuarine crocodile and 60 eggs being taken by Aboriginal hunters. More recent studies (J. Altman and A.J. Griffiths, unpublished data), recorded harvest of a sub-adult estuarine crocodile only once over 80 days and 172 hunts. Clearly customary use of crocodiles in Arnhem Land, despite some limited availability of firearms, is likely to have little impact on the dynamics of crocodile populations. It is noteworthy that rapid recovery following prohibition of commercial hunting for skins (see Webb et al. 1984; Stirrat et al. 2002), occurred with no change in the law (and hence no restrictions) regarding Indigenous use for food or other customary purposes.

**Commercial use of crocodiles**

The capacity and willingness of Aboriginal people to meet their customary responsibilities while still making commercial use of crocodiles is well illustrated by the practice adopted by the Gumatj people of eastern Arnhem Land. Whilst the estuarine crocodile is an important totem for Gumatj, and crocodiles cannot be killed or eaten by clan members, they do not object to others with different affiliations using the species for customary or commercial purposes, provided there is consultation and opportunity to discuss implications for customary law and practice (Lanhupuy 1987). Indeed, one of the Northern Territory’s crocodile farms is owned and operated by Aboriginal people.

Many Aboriginal groups are presently using crocodiles commercially under the Northern Territory’s crocodile management programs. These plans are drafted to comply with both Territory law and the requirements of the Commonwealth’s Environmental Protection and Biodiversity Conservation Act 1999, through which Australia meets its obligations under the Convention for International Trade in Endangered Species of Wild Flora and Fauna (CITES). The existing program provides for ranching (collection of eggs from the wild for artificial incubation), as well as a much smaller direct harvest of sub-adult (500) and adult (600) animals from the wild for their skins (Parks and Wildlife Commission of the Northern Territory 2000).

During the period 1995 to 2004, records of the Parks and Wildlife Service indicate a total of 31,819 eggs and 232 adults was harvested from Aboriginal land (Arnhem Land as well as other lands in the western Top End and Gulf of Carpentaria). These harvests represented 60% and 72% respectively of the total for the Northern Territory. However, it is important to note that 41% of these eggs were collected by non-Aboriginal, non-residents of the Aboriginal lands harvested. Whilst royalties of about $5 per egg are paid by crocodile farms, clearly such incomes are relatively minor and do not contribute to the creation of local employment opportunities. At a few sites (eg Maningrida), a substantial proportion of the eggs collected by Aboriginal harvesters are incubated by Aboriginal people and the products sold as hatchlings, which provides a much better return to the community.

**Adding options for crocodile use**

Following review of its crocodile management program during 2003, the Northern Territory Government proposed that a small number of larger animals should be available to be taken by recreational (“safari”) hunters. A total annual quota of 25 animals over 4.0 m in length was proposed (Parks and Wildlife Service of the Northern Territory 2004), many of which would be taken from Aboriginal land. It should be noted that this quota involves no addition to the existing levels of harvest, but is rather a “sub-quota” within the 600 adults available for harvest under the existing plan. A “safari” harvest of this scale is likely to have little effect on the size of the Northern Territory’s large and growing crocodile populations, which have been estimated to exceed 60,000 animals. Crocodiles would be required to be taken in accordance with a Draft Code of Practice for the Humane Killing and Treatment of Wild and Captive Australian Crocodiles. The methods used to take such animals will not differ significantly from those already approved for use in other segments of the harvest and in crocodile management more generally.
It is anticipated that the harvest of these animals will involve payment of substantial trophy fees - in the order of several thousand dollars for each crocodile taken - to landowners and employment of local residents in conducting hunts. Clearly the hunting skills and local knowledge of Aboriginal people would be particularly useful in such operations. The Northern Land Council, as administrative agent for traditional landowners in the Top End [Section 23 of the Aboriginal Land Rights (Northern Territory) Act 1976], has supported the proposal, arguing that such use of wildlife constitutes an important opportunity to build local enterprise. In addition there is virtually unanimous political support among both Government and Opposition members of the Northern Territory Parliament and local members of the Federal Parliament.

However, this change to the Territory’s management arrangements requires the endorsement of the Federal Minister for Environment and Heritage, if the plan is to retain its status as a Commonwealth “Approved Wildlife Trade Management Plan”. Without this endorsement, Northern Territory crocodile producers and processors are denied access to overseas markets.

The (then) Minister, in a draft declaration, approved the Northern Territory plan, with the exception that he did not permit “recreational harvest of crocodiles … for profit” (see http://www.deh.gov.au/biodiversity/trade-use/sources/management-plans/draft/croc/nt-croc-min.html). No reasons were given for the exclusion of safari hunting. However, in the absence of conservation arguments to support the exclusion, it is difficult to avoid the implication that the decision involved exercise of a philosophical or aesthetic position relating to animal rights or similar concerns, with little or no grounding in the objects of the legislation under which the draft declaration was made. Following a change of Minister in a reshuffle of portfolios in August 2004, the decision has yet to be confirmed. However, previous experience of application of the legislation and the particular stance that Australia has taken in international debates about wildlife use, suggests that the opportunity to develop commercial options that promote conservation outcomes may be arbitrarily dismissed. Should this interpretation prove to be correct, then the implications for conservation in northern Australia are profound.

Anti-use philosophies and conservation in northern Australia

The Senate Rural and Regional Affairs and Transport Reference Committee (1998) recognised that commercial use of wildlife represented one of the few enterprise options available to Aboriginal people in remote Australia. The Commonwealth Government endorsed the committee’s recommendations, including an apparent acceptance of the argument (Senate Hansard, 9 December 1999) that loss or degradation of habitat was the principal cause of wildlife decline and that commercial use could provide an incentive to better manage habitat to protect its suitability for wildlife. However, there is no evidence in the EPBC Act, as enacted or subsequently amended to incorporate wildlife trade provisions, that this recognition significantly influenced the legislation’s emphasis or the detail of its contents. It is relevant to note that constraints imposed on opportunities of Aboriginal people to develop local enterprise extend beyond options that could conceivably evoke concerns about animal rights, to include plants. Cycads for landscaping have been identified as one of the few plant products of higher unit value (like crocodiles) that might conceivably offer favourable enterprise opportunities to Aboriginal people in northern Australia. There is a demonstrable demand that, given large cycad populations in favourable well-managed habitat, could be filled without significant ecological risk. Estimates of potential returns suggest that under reasonable regulatory and other conditions, harvest could provide adequate returns to communities and hence some incentive to actively manage sites to protect their natural values, including the cycad populations themselves (Whitehead et al. in press).

However, essentially arbitrary international and national assignment of these plants to categories of special concern militates against successful enterprise. Monitoring requirements designed to reflect this formal status are so onerous that meeting them consumes much of the potential return. Those requirements appear at least in part to be designed to require harvesters to fund work that is of no immediate relevance to the impacts of their activity. Rather it provides basic information on cycad demography that is of wider application and interest and therefore might more reasonably be regarded as the province of Government, rather than the responsibility of a few of Australia’s most economically marginalised people.

Imposition of such an over-prescribed monitoring scheme is an example of all-too-common regulatory disincentive for good conservation practice. Attempts to earn a modest return from demonstrably sustainable use of a native plant are saddled with severe financial constraints. Such costs would not be levied if, for example, landowners chose to destroy large parts of the cycad population to foster a cattle grazing enterprise (Whitehead 2000). Thousands of cycads could be bulldozed and burned without penalty under prevailing land clearance guidelines on pastoral leasehold or freehold land. Under these circumstances, sales of salvaged cycad stems actually create incentives for habitat
destruction through land clearing (Liddle 2004).

The anomalous treatment of such options occurs despite some potentially important provisions about the role of Indigenous people in sustainable use and conservation in the EPBC Act. Three of the seven principal objects of the Act refer to obligations to:

- “. . . promote a co-operative approach to the protection and management of the environment involving governments, the community, land-holders and indigenous peoples; and,
- “. . . recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia’s biodiversity; and,
- “. . . promote the use of Indigenous peoples’ knowledge of biodiversity with the involvement of, and in co-operation with, the owners of the knowledge”.

These formal statements are potentially important, because it is clear that without the engagement of Aboriginal people and their active support in choice of management regimes for their lands, Australia will be unable to achieve its stated goals for conservation of biological diversity. Aboriginal people own and manage some of the most biodiverse lands in the nation (Yibarbuk et al. 2001), so their land use decisions will have a major impact on biodiversity conservation at a national scale. However, we are aware of no coherent steps to achieve that engagement in northern Australia. There is certainly no evidence of a comprehensive Commonwealth plan.

This inaction is probably a reflection of the dominant public view of appropriate conservation activity. Unfortunately, many Australians take a very narrow view of good resource management practice and the ways in which it is legitimately achieved. For conservation, they focus on uninhabited parks and reserves as the apex of conservation practice and the set asides they represent as the best way of protecting exploited resources. The difficult reality is that many of the most severe conservation problems in northern Australia result from the absence of humans from large parts of the landscape (Whitehead 1999). Trust in a few sparsely-staffed reserves is unwise.

In the absence of opportunities to use native species commercially, Indigenous landowners will be left with few options but to leave their lands or to turn them over to more intensive forms of land use. History shows that both responses will create conservation problems. In regard to moves away from traditional lands, management of tropical savannas demands active intervention to impose fire regimes that favour wildlife habitat quality (Yibarbuk et al. 2001). Regular movement through country by residents provides supplementary benefits in early detection and control of weed and feral animal problems. Uninhabited country is unhealthy country (Whitehead 1999; Whitehead et al. 2000).

In regard to intensification of land use, environmental problems often originate in attempts to force unsuitable forms of production from systems that are incapable of sustaining them at the intensity required for profitability (Holmes 1990). Many attempts to transplant orthodox agriculture and forestry to north Australia have failed due to harsh conditions (Lacey 1979; Woinarski and Dawson 2002). Moreover, the adverse change in wildlife values already seen in relatively intact landscapes suggests that the additional impacts on wildlife from forms of development involving significant fragmentation of habitats may be particularly severe (Rankmore and Price 2003).

**Building capacity in resource management for remote Australia**

It is important to recognise that the regulatory barriers we have identified do much more than damage opportunities for modest incomes from wildlife use and contributions to conservation management of lands. They also have much wider social implications. They arbitrarily deny opportunities for Aboriginal people to pursue the sorts of engagements with the market that they have repeatedly identified as most practical and likely to succeed. The most plausible paths towards improved capacity to interact productively with the mainstream economy are blocked (Whitehead et al. in press). To urge people to seek ways to escape dependence and then to erect arbitrary barriers on the routes they seek to follow is worse than perversive. Ultimately, regulatory regimes must be reshaped to exploit opportunities for enhancing both social and conservation outcomes in northern Australia.

However, because there is considerable discretion in much relevant law, in the short to medium term much can be done to develop and test ideas for wildlife-based enterprise with shifts in policy emphasis and administrative process rather than a revolution in legal frameworks. A collaborative approach supported by Government could provide the information needed to shift public perceptions of the risks of wildlife harvest compared to the alternative orthodox uses of land and foster an evolution in resource use policy and regulation. Whitehead (2000, 2002, 2003) proposed
large scale "experiments" that would explore the conservation, socio-economic and legal issues associated with a local economy based on a range of consumptive and non-consumptive uses of wildlife. Engagement of regulators at both Commonwealth and Territory levels will be an essential component of such experiments.

Conclusions

The EPBC Act follows an old-fashioned, expensive and ultimately ineffectual dichotomisation of resource and conservation management activity into sets of the intensively used and the untouchable, with provisions for bouts of heroic rescue when the effects of heavy use spill over to affect the untouchables. This may make good politics, but historical failures and contemporary trends show that it makes for awful conservation performance.

The present approach also places great demands on public funds, because it disables application of local capacity and interest in managing lands for sustainability over the longer term. In contrast to many other resource users, Aboriginal people holding traditional land under inalienable communal title are directly answerable to their local communities and do not have the option of cashing in and moving on.

There is a critical need to seek additional creative ways of meeting the incontestable obligation to improve the socio-economic position of Aboriginal people, in ways that are compatible with social and cultural norms and contemporary educational and institutional capacity. There is an associated obligation to use these engagements to build capacity to expand the range of options over the longer-term.

Conservationists have long recognised that in situ conservation of viable wild populations in their natural places is greatly to be preferred over artificial maintenance in specially protected places. It is past time to recognise the potential contribution of systems of "in situ production" of native species to conservation, and attitudes to wild harvests to be reconsidered.

Aboriginal people are willing to collaborate in novel ways to contribute to the nation’s conservation goals. But that willingness should not be abused by either completely denying opportunities for economic advancement based on native species or, more cynically and destructively, saddling Aboriginal enterprise with ongoing compliance costs of a sort not met by promoters of "ex situ production" of exotic species that require the immediate or longer-term destruction of entire natural systems.

Despite its modest scale, the proposal to allow hunting of a few large crocodiles is an important test of the willingness and capacity of our conservation institutions to forge genuine conservation partnerships with the Aboriginal people of northern Australia.

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Harvest of Saltwater Crocodiles by an Arnhem Land Aboriginal Community

Ray Hall

The Djelk Rangers are the Land Management Agency for the Bawinanga Aboriginal Corporation (BAC). BAC represents around 1000 members who are the landowners of an area of almost 10,000 square kilometres of north-central Arnhem Land. The region is drained by two major rivers, the Blyth and the Liverpool, whose catchments are quality natural ecosystems with almost no economic activity in them. It is the desire of the landowners to maintain the natural ecosystem for cultural, social and subsistence reasons but the need to gain economic outcomes is great and growing as the population expands. The path of choice for economic development has been through the sustainable use of natural resources because it is compatible with the other uses and the desires of the landowners. The economic development activities therefore are also a responsibility of the Djelk Rangers. Crocodiles were the first wildlife used for commercial purposes in the region for several reasons but mostly because it is an established industry. Djelk Rangers harvest and incubate crocodile eggs to sell the hatchlings to crocodile farms and also harvest wild crocodiles for skins.
The Development of the Australian Crocodile Industry

Vicki Simlesa

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Pre-Crocodile Industry

- Unregulated hunting of *Crocodylus porosus* occurred between 1945 and 1974 in Australia. Wild populations of *C. porosus* were protected in Western Australia (1969), the Northern Territory (1971) and Queensland (1974).
- Australian Freshwater Crocodiles were hunted from 1959 onwards, and wild populations of *C. johnstoni* were protected in Western Australia (1962), Northern Territory (1964) and Queensland (1974).
- Skins exported prior to 1972 were estimated at: Saltwater Crocodiles 330,000 and Freshwater Crocodiles 200,000-300,000.

Crocodile Farming Outcomes

- Production
- Conservation
- Education, tourism
- Employment

Northern Territory

- Currently 6 farms in operation (5 in the Darwin region, one on the Victoria River) (previously 8; see later).
- Based on production, tourism, education and hatchery.
- Captive breeding and ranching of wild eggs.
- Direct harvest of Saltwater and Freshwater Crocodiles.
- Export market for skins.
- Domestic market for live animals, skins and by-products (eg flesh).

Western Australia

- Currently 2 farms in operation (Broome, Wyndham).
- Based on production, tourism, education, research and development programs.
- Captive breeding and ranching of wild eggs.
- Direct harvest of Saltwater and Freshwater Crocodiles.
- Export market for skins and by-products (eg flesh).
- Domestic market for live animals, skins and by-products (eg flesh).

Queensland

- Currently 6 farms in operation [Mareeba, Cairns (2), Innisfail, Rockhampton, Edward River].
- Based on production, tourism, education and hatchery.
- Captive breeding only (no ranching of wild eggs).
- Export market for skins.
- Domestic market for live animals, skins and by-products (eg flesh).

Western Australia and Northern Territory Management Plans

- The crocodile industries in the Northern Territory and Western Australia operate under management programs that aim to:
  - Maintain viable wild populations of crocodiles and protect habitat upon which they depend.
  - Enhance public safety by maintaining public education and mechanism for removing problem crocodiles.
  - Management of the sustainable utilisation of crocodiles as a renewable resource, providing the conservation of the species is not comprised.
• NT: A management program for *Crocodylus porosus* and *Crocodylus johnstoni* in the Northern Territory of Australia.

• WA: Saltwater Crocodile (*Crocodylus porosus*) and Freshwater Crocodile (*Crocodylus johnstoni*) Management Plan for Western Australia.

**Queensland Code of Practice**

• The Queensland crocodile industry follows a code of practice that aims to have:
  - Management practices ensuring the welfare, health and nutritional requirements, are met for farmed crocodiles.
  - Promote public understanding of the value of crocodiles in the wild.
  - Compliance with any legislative requirements relating to crocodile farming.


**Northern Territory Crocodile Industry**

**Crocodile Farms NT**

Established in 1981 with wild-caught crocodiles. It is located 38 km south of Darwin, on the Stuart Highway. The farm operates as a commercial venture with production and tourism. It has a large captivity breeding program and a kiosk with crocodile products available.

**Lagoon Crocodile Farm**

Established in 1987 by the Hannon Group, the farm initially started with purchased hatchlings. The farm is located in Berrimah, about 20 minutes from Darwin City. The farm is a commercial venture exporting to domestic and international markets.

**Janamba Croc Farm**

Established in 1981, the farm is located 30 km east of Humpty Doo, off the Arnhem Highway, and 50 minutes from Darwin. The farm is a commercial operation, selling raw products to international and domestic markets and has a well established captivity breeding program.

**Coolibah Crocodile Farm**

Established in 1991, the farm located near the Victoria River, 2 hours from Katherine. Operates as a commercial farm with some tourism. Largely dependent on wild ranching of eggs, mainly from aboriginal land for hatchlings and sells live to the domestic market.

**Crocodylus Park**

Located at Berrimah and established in 1994 by Grahame Webb as part of Wildlife Management International. Offers production, research, education and tourism. Has a museum, crocodile products available and a range of other wildlife on display.

**Elizabeth Valley Crocodile Farm**

A small commercial hatchery established in 1995 near Noonamah. Mostly ranching of wild eggs, mainly from aboriginal owned land, and sells to the domestic market.

**Garrangali Crocodile Farm**

Established in Gove by the Gumatj Aboriginal community. Operated as a hatchery and collected eggs from the Gumatj land. Currently closed, only receiving problem crocodiles.
Letaba Crocodile Ranch
Established in 1981 on Labelle Station, approximately two hours from Darwin. Operated as a commercial venture. Closed when Labelle Station was sold.

Western Australian Crocodile Industry

Wyndham Crocodile Park
Established in 1989, the farm was later sold and merged with the Fremantle Crocodile Park (which had been established after the America’s Cup Yacht Race in 1987). It offers commercial production, tourism plus research and development programs. It keeps both species of Australian crocodile and exports both flesh and skins.

Broome Crocodile Park
Established in 1978 on 2.5 ha by Malcolm Douglas. In 1983, wild caught sub-adults were introduced for farm production. The park has the two Australian crocodilian species as well as New Guinea Freshwater Crocodiles, Caimans and American Alligators. Located on Cable Beach Road in Broome, the park is both educational and entertaining.

Queensland Crocodile Industry

Koorana Crocodile Farm
Established and operated by John and Lillian Lever since 1981, it is located 38 km east of Rockhampton. Offers tourism, production and education. Crocodile products available for purchase.

Hartley’s Creek
Established since 1933, it has the longest running crocodile shows. Purchased in 1986 by the Freeman family, it is located 40 km north of Cairns. Offers adventure tourism, production, education and range of other Australian wildlife on display.

Edward River
Established in 1969 by the Applied Ecology group as a means to provide employment to indigenous people in the Pormpuraaw Aboriginal Community in the Gulf of Carpentaria. A commercial business operating since the 1980s as a hatchery, producing eggs and raising hatchlings for Cairns Crocodile Farm. Shifted grow-out facilities to Cairns Crocodile Farm (previously Redbank Crocodile Farm) in 1991.

Cairns Crocodile Farm
Established in 1992, it is the largest farm in Queensland and is 45 minutes southeast of Cairns. Originally called Redbank Crocodile Farm, started as off shoot to Edward River Farm. Now a commercial business offering tourism and production.

Johnstone River Crocodile Farm
Established in 1986 in Innisfail, south of Cairns. The farm offers educational guided tours, tourism and production. The farm also has other native wildlife on display.

Melaleuca Crocodile Farm
Established in 1984 by the Fisher family. Located 60 km west of Cairns on 26 ha near Mareeba. Offers Saltwater Crocodile production for the international and domestic markets. The farm is currently expanding which will increase production numbers. The farm is unlike the traditional design, it has sound environmental practices and new concepts for crocodile handling in safety.
Current Markets

- Skins sold overseas (Japan, France, Singapore, Hong Kong)
- Flesh sold overseas (Great Britain, Japan, Korea, Denmark, New Zealand, China)

General Production Figures

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Acknowledgements

- QDPI and WA, NT, QLD Crocodile Industry for input.

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- Other species - crocodiles. ABARE report 03.8
Population Genetics of Australia’s Crocodiles: A Comparison Between

_Crocodylus johnstoni_ and _C. porosus_

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James Cook University, Townsville, QLD 4811, Australia

Effective management of Australia’s crocodile species requires a better understanding of crocodilian population
boundaries, migration patterns and the historic relationship among populations. To investigate these features of
crocodilian biology, we have taken a comparative approach by looking at both species and using two types of genetic
markers; mtDNA and microsatellite loci. Extensive sampling throughout the range of both species has included more
than 460 freshwater crocodiles and 570 estuarine crocodiles that were analysed for variation at ten microsatellite
loci. More than 150 individuals of each species were sequenced to determine the patterns of mtDNA variation. Our
results from the nuclear microsatellites indicate significant genetic heterogeneity among river systems in both species;
with gene flow being more limited among populations of the freshwater species relative to the estuarine crocodile.
These data indicate a significant correlation between the extent of gene flow and geographic distance observed in
each species. Contrasting results were seen at the two genetic markers in terms of genetic diversity, with the nuclear
genes showing greater diversity in the estuarine crocodile, whereas the mtDNA revealed greater genetic diversity
within freshwater crocodiles. Common mtDNA variants were found in nearly all populations of each species, but
there were also unique variants found only in certain regions, indicating moderate genetic structure. These results
will be discussed in relation to crocodile biology and management.
Crocodilians and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

Dietrich Jelden

Federal Agency for Nature Conservation, Bonn, Germany

1. Effects of CITES on the World Trade in Crocodilian Skins

   • 1960s: 6-8 million skins in world trade
   • Today: 1.5-1.8 million skins in world trade

2. Evolution of the Convention

   • 1960: First discussion of problems of illegal wildlife trade at 7th General Assembly (GA) of IUCN.
   • 1963: 8th GA of IUCN passed resolution on illegal wildlife trade -> call for an International Convention.
   • 1964: First draft by IUCN for a Convention.
   • 1969: 10th GA of IUCN discussed list of species to be controlled.
   • March 1973: 21 countries signed CITES (Plenipot. Conf. which IUCN had recommended in 1963).
   • 1 July 1975: CITES entered into force after 10 Ratifications.

3. Core Contents of the Convention

   • CITES protects 7000 animals and 25,000 plants through listing in 3 Appendices (I, II and III).
   • CITES regulates international trade through a system of permits required before specimens enter or leave a country -> ANNUAL REPORTS provide trade data.
   • National implementation of CITES important (ie designation of authorities, legal protection of CITES species, sanctions).
   • Over 95% of CITES protected species are legally classified as not being endangered -> sustainable commercial trade is permitted.

   Many exemptions (Article VII) under the Convention (captive-bred, personal effects, pre-Convention, etc.)


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5. Major Crocodilian Conservation Relevant Decisions Adopted at CITES Conferences

5.1. CITES - 1st Conference of the Parties (1977)

- Criteria for the **addition** of species and other taxa to CITES Appendix I and II (biological and trade criteria) - Resolution Conf. 1.1 (now Resolution Conf. 9.24)
- Criteria for **deletion** of a taxon from Appendix I or **transfer** to Appendix II - Resolution Conf. 1.2 (now Resolution Conf. 9.24)

5.2. CITES - 2nd Conference of the Parties (1979)

- Transfer of the American Alligator to Appendix II
- Trade in hunting trophies - Resolution Conf. 2.11:
  - Only for non-commercial activities;
  - Acknowledgment that killing of App. I animals could enhance the survival of a species
- Specimens bred in captivity or artificially bred - Resolution Conf. 2.12:
  - Aims to avoid that wild taken specimens are considered as captive-bred (ie ranched specimen);
  - Defines term ‘captive bred’ for Appendix-I species (biologically and legally)
  - Marking requirements

5.3. CITES - 3rd Conference of the Parties (1981)

- Transfer of the Saltwater and the American Crocodile (C. porosus and C. acutus) to Appendix I
- Trade in ranched specimens - Resolution Conf. 3.15 (now 11.16):
  - New system for transfer of populations from Appendix I -> Appendix II
  - Initiative originated from adoption of CITES captive breeding Resolution (Resolution Conf. 2.12)
  - Focus on crocodilians
  - Rearing wild specimens in controlled environment must be beneficial to wild population
  - Monitoring, reporting and marking requirements

5.4. CITES - 4th Conference of the Parties (1983)

- Transfer of Zimbabwe Nile Crocodile population to Appendix II persuant to CITES Resolution on “Ranching”
- Control of captive breeding operations of Appendix I species (Resolution Conf. 4.15 now 12.10):
  - Establishment of a register of operations based on Parties information;
  - No trade with operations which are not registered

5.5. CITES - 5th Conference of the Parties (1985)

- Transfer of several crocodile populations to Appendix II under temporary system based on annual export quotas (Kenya, Somalia, Malawi, Sudan, Zambia, Indonesia, etc.)
- Legal basis: CITES Resolution Conf. 5.21 (Special criteria for transfer of taxa from Appendix I to Appendix II)
  - Transfer under **quota system** only for species (in reality mostly crocodiles) sufficiently safe in the wild (studies);
  - No application of Berne Criteria (Resolution Conf. 1.2) necessary if species were included in CITES Appendix I before listing criteria existed;
  - Temporary approach only (review at COP7 and COP9).

5.6. CITES - 7th Conference of the Parties (1989)

- CITES Resolution Conf. 7.14 (Special criteria for the transfer of taxa from Appendix I to Appendix II):
  - Extension of mandate of quota resolution adopted at COP5 until COP9;
  - After COP9 either maintainance of populations in Appendix II under normal downlisting criteria or ranching criteria;
  - Evaluation: in many, but not all cases quota system was useful (Madagascar, Somalia, Sudan).
5.7. CITES - 8th Conference of the Parties (1992)

- CITES Resolution Conf. 8.3 (Recognition of the benefits of trade in wildlife)
- CITES Resolution Conf. 8.14 (Universal tagging system for the identification of crocodilian skins)
- CITES Resolution Conf. 8.22 (Additional criteria for the establishment of captive breeding operations and for the assessment of ranching proposals for crocodilians):
  - Acknowledges ranching as valuable conservation tool;
  - Being more beneficial for conservation ranching should be given priority over farming;
  - No wild-caught animals should form the breeding stock unless justified by national management plan.

5.8. CITES - 10th Conference of the Parties (1997)

- CITES Resolution Conf. 10.17 (Animal hybrids)
  - COP decided that trade in hybrids should be controlled in order to support controls on trade in the species included in Appendix I and II;
  - Determination of legal status of hybrids through the respective CITES protected animal (Appendix I or II) in the recent lineage (= 4 generations).

5.9. CITES - 12th Conference of the Parties (2002)

- CITES Resolution Conf. 12.9 (Personal and household effects):
  - definition of term personal and household effects (legality, personal owned and possessed);
  - no CITES documents for up to 4 specimens per person made of crocodilian leather from Appendix II species;
  - Parties should provide in general information on CITES for tourists and more specific at places of international departure, etc.

6. CITES Generates Trade Data

**Estimated Trade in Crocodilian Skin by Method of Production (including caiman production), 1983-2002**

![Graph showing estimated trade in crocodilian skin by method of production from 1983 to 2002](image-url)
Compliance with CITES

Tomme Rosanne Young
Senior Legal Officer, IUCN Environmental Law Centre (Distillation)

Context (Current Proposals)

This October, the 13th Conference of the Parties (COP) to the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) will consider adopting a new document entitled “Guidelines on Compliance with the Convention” (still as of this writing, available as SC 50, Doc. 27 in the documents of the 50th Meeting of the CITES Standing Committee2). Although this document speaks of a primary objective of “preventing non-compliance,” it focuses on enforcement at the international level - specifically, the creation of a detailed quasi-judicial process that will apply where the Standing Committee and COP believe that a Party is not complying with its obligations under the Convention.

Based on the CSG’s valuable involvement in the CITES processes, as well as the experiences of other Conventions and international institutions3, this paper notes that a broader view of compliance is essential. A greater focus on remedying situations of non-compliance and on re-evaluating administrative/systemic requirements of on-the-ground implementation must receive predominant attention in all discussions of compliance with CITES.

In general

At all levels (including intergovernmental objectives, domestic governance, and private-sector industry initiatives), CITES approach to compliance must be “outcome oriented.” In other words, rather than perceiving the issue as one of “enforcing the Convention” (making sure that all requirements are met “to the letter”), it should seek to promote the ultimate outcomes. Those outcomes can be expressed in two ways:

- maximizing compliance with the overall CITES system (optimizing the operations of that system), or
- promoting the conservation of species through their sustainable use.

To this end, CITES’s compliance strategy should focus on improvement of capacity and development of mechanisms to improve the efficiency and usability of the CITES system. This necessarily means that even questions of the intergovernmental compliance should primarily focus on the on-the-ground system, how it works, and how governments, individually and collectively, can improve its functioning.

“Enforcement” only or all aspects “Compliance”?

In many instances, CITES has tended to address compliance questions entirely in the context of “enforcement” - a process that consists of: (i) identifying instances of non-compliance; (ii) calling on the non-complying party to come into compliance; and, (iii) if necessary, imposing sanctions. Often its attention to enforcement focuses entirely in the context of national commitments under the Convention (the national obligations to identify management and scientific authorities, to adopt relevant legislation, to apply permit and certificate requirements, enforce border controls, to authorise the imposition of sufficient penalties, etc.).

However, an outcome-focused approach requires that these issues be considered in tandem with several other key elements of compliance:
- assisting the Parties to bring their activities into compliance,
- improving capacity of relevant agencies and others,
- addressing systemic problems that inhibit compliance at the national level,

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1 A longer discussion of CITES compliance issues and their relationship to the objectives of the Convention and sustainable trade in crocodilians can be found at www.iucn.org/themes/law under the heading “Developments ________.” This paper is the source of this distillation and of the presentation made to the CSG’s 15th Working Meeting.
2 CITES documents, including the documents of the 50th Standing Committee and the documents tabled for COP13, are available on the internet at www.cites.org.
3 Detailed in the paper cited at footnote 1.
identifying and promoting factors that would provide an incentive for compliance by the regulated community (harvesters, ranchers, breeders, traders, etc.),
- relationships with the private sector and markets that can both be benefited by and provide incentives for the existence of an effective functional system.

One can easily see, after the briefest examination of the relevant issues and opportunities, that these latter elements of compliance often have a far greater impact on achievement of the above-described outcomes than the enforcement of national obligations.

**Limitations on Enforcement of National Obligations under CITES**

The ability of the international community (the other Parties to CITES, the Secretariat, etc.) to directly and formally compel a country to implement CITES is relatively limited. No person or government may assume rights of any sovereign government, unless that government agrees. This means that unless the Government has adopted and implemented/enforced CITES legislation, no other government or group may force the people within the country to comply with CITES. Similarly, in normal circumstances, no formal legal process (including hearings in international tribunals) may be brought against a country that is not complying with its international obligations, unless that country agrees to participate in the tribunal and to accept its judgement.

For this reason, there are two mechanisms for directly enforcing a country’s obligations. So-called “citizen’s suits” - persons or companies under the jurisdiction of the country are sometimes empowered to sue the government when it is not meeting its obligations. In a few countries, this power includes compelling government to implement its obligations under national convention. CITES existing process under which other Parties are adjured to voluntarily refrain from permitting import of goods from a country that has failed to comply with the Convention. In general, enforcement of national obligations does not include examination of matters of judgement or planning. This means it is rarely possible to bring action against a country for actions that may be seriously harmful to the objectives of the CITES system, including:

- Failure to issue permits or certificates;
- Refusal of an application;
- Failure to comply with domestic quotas or management plans; and,
- Failure to cooperate with other agencies, including especially habitat-protection authorities.

**Broader Approach to Compliance - Promoting Key Outcomes**

More important than the fact that enforcement is not always a strong option, is the fact that it is not an effective strategy for achieving key outcomes. It is not possible to guard every specimen, to directly oversee every user, or to inspect every packet, suitcase or container passing national boundaries. The success of a compliance programme is not measured by enforcement activities, but by the extent of compliance by to which governments and affected individuals or groups without direct compulsion or enforcement.

**Effective, Functional System:** Applying an outcome focus, compliance questions should begin with analysis of the on-the-ground issues:

CITES clearly identifies the actions to be regulated (transboundary movement of species by humans) and the reasons why (to ensure that trade does not harm the conservation status of species, and the role it plays in the ecosystem);

Since CITES adoption, the Parties to CITES have collectively recognised that in many cases, the promotion of sustainable international (and domestic) trade in species can actually be a positive tool for conservation, suggesting a further obligation to promote controlled and sustainable trade.

Thus, it is essential to examine both the current limitations on government’s ability to take action (set quotas, adopt plans and policies, issue or deny permits) in a commercially reasonable time, other “bottlenecks” and systemic components that can be made more efficient without sacrificing conservation and sustainability objectives. Addressing these matters is a key element of compliance, in that it will make it easier for the regulated community to comply without governmental compulsion. Some examples of how this approach has been used come from the Crocodile Specialist Group, which has successfully promoted numerous improvements in the CITES permit system with regard to crocodile trade, including the universal crocodilian-skin tagging system, clarification of the “personal effects
exemption from CITES (simplifying and clarifying the rights of retail purchasers, thereby giving them more confidence to purchase crocodilian items, while at the same time, ensuring that the exemption does not become a cover for smuggling by non-CITES (unsustainable) producers and traders).

Other improvements, including a simplified process for permits for the cross-border movement of trade fair sample of crocodilian skins, are being developed, and will be submitted to the Conference of Parties in October. This approach, helping to reshape the specific elements of compliance by management authorities and by the regulated individuals and industries, appears to be a key element to achievement of the primary objectives of compliance. A number of other factors may be relevant as well, including collaboration among various key agencies and authorities.

Enabling and Enhancing the Capacity of Agencies: National compliance is most effective where the Parties are clearly aware of two sides of their obligation - the obligations directly assumed under the Convention (designation of MA/SA, national legislation, sufficient penalties, etc.), and the institutional and practical needs that will make the CITES permit system more functional and effective on the ground.

At this point, the most effective components of compliance are usually those that are not involved with compulsion (ie assistance in bringing their activities into compliance, capacity-building, and identification and confrontation of systemic problems that inhibit compliance at the national level). (While the underlying power of enforcement through the recommendation of voluntary moratoriums is undoubtedly an incentive underlying compliance, it is generally true, as noted above, that the situations in which CITES has to resort to enforcement represent failures of the Convention. Rather, it is the larger number of cases in which non-enforcement activities result in positive compliance that provide the best evidence of its success.)

One of the best examples of this approach is the CITES Secretariat’s work on the “legislation project”. Under this project, the Secretariat and other organisations analyse each country’s CITES implementation legislation to determine if it meets the requirements of the Convention. Countries are graded as category 1 (fully in compliance), category 2 (partly in compliance) and category 3 (generally not in compliance). Parties in categories 2 and 3 are given assistance in amending or developing legislation that is fully compliant. Only where it appears that Parties have not made or attempted to make progress after a significant time would enforcement action be considered.

Involvement and Initiatives of the Affected Industry: Often direct relationship with traders and other commercial and industrial actors, can have a major impact on CITES compliance. Trade in crocodilian skins and their products provides a useful example of this, where many members of the crocodile products industry recognise that they benefit by the existence of a controlled and functional sustainable trade system. Programmes that promote demand for CITES-permitted skins have been a major contributor to the current comparative successes of the crocodilian trade under CITES.

Recommendations

Future development in CITES compliance should focus on the positive aspects of compliance, giving attention to enforcement as a final back-up tool. Accordingly, it is important for work on consistency to focus on;

- Improvement of the on-the-ground system, by considering the nature of current problems and limitations that inhibit the functioning of that system;
- Identification of the reasons underlying those problems, and development and authorisation of practical solutions to those problems, while ensuring that streamlining of the system does not have negative conservation impacts or create opportunities for circumventing the law;
- Enabling and enhancing governmental compliance and more efficient application of the CITES system, through direct assistance with the creation, empowerment and implementation of relevant institutions and processes, and;
- Programmes for enhancing national capacity to implement the Convention, including planning, management, evaluation and system development;
- Addressing key deficiencies in the existing international-level enforcement system, by clarifying a consistent process for identifying possible situations of non-compliance for further deliberation, clear investigatory authorities and procedures (including the rights of the Party being investigated); and,
- clarifying the role of enforcement as a final option in cases in which other types of compliance have not been successful.
Article IV of CITES and the Concept of "Non-detrimen"'

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CITES - A Brief Overview

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was agreed in 1973, and the treaty came into force in 1975. CITES has now been acceded to by 165 Parties (by 2004). The core business of CITES is to ensure that international demand for wild plants and animals does not cause the wild populations of these species within Range States, to become extinct or be threatened with extinction (Article II). Demand, international trade and threats to survival are all linked to each other, sometimes in simple and obvious ways, but often in ways masked by the complexities of trade and processing routes (Fig. 1).

![Diagram of international trade](image)

Figure 1. A hypothetical chain of events linking supply and demand for a wildlife product in international trade (Webb et al. 2004).

Through CITES, the contracting Parties agree to some "broad-brush" cooperative approaches to controlling international wildlife trade. One of the first priorities is to identify species threatened by trade and allocate them to the Appendices of CITES in accordance with the degree of threat.

In extreme cases, where international trade is known to be causing extinction, the primary mechanism of CITES intervention is to list the affected species on Appendix I (Article II). This action effectively bans international trade between Parties to CITES and breaks the chain linking supply and demand (Fig. 2). [An exception is made for Appendix-I specimens bred in captivity for commercial purposes (see below)]. Appendix-I listing is the ultimate coercive action within the trade-based mandate and agreed boundaries of CITES.

Where a threat exists, but it is not extreme enough to merit a trade ban, species are usually listed on Appendix II. Specific directions about Appendix II listing are:

1. If a species is considered vulnerable to becoming threatened with extinction through international trade, and thus become a candidate for Appendix I [Article II.2(a)]; or,

2. If a species is so similar in appearance to a vulnerable species listed in Appendix II, that for the practical purposes of controlling trade, the "look-a-like" species also needs to be listed [Article II.2(b)], even though its status in the wild may not be in question.
Figure 2. Appendix I bans international trade and breaks the chain of events through which international trade is providing commercial incentives for excessive harvesting of threatened species (Webb et al. 2004).

Figure 3. Appendix II-listed species can be traded if the conditions of Article IV are met ("Regulation of Trade in Specimens of Species included in Appendix II"). This represents a significant challenge, cost and responsibility to producing (exporting) nations.
International trade in Appendix II listed species is allowed if certain conditions are met. These conditions are contained in Article IV - "Regulation of Trade in Specimens of Species included in Appendix II". The central aim of this paper is to look more closely at the interpretation of Article IV, which underpins most crocodilian trade and represents a significant technical expense and responsibility for exporting Parties (Fig. 3).

Individual nations can list any species in international trade on Appendix III if they consider they need increased cooperation from other Parties to help them control trade. All crocodilians were listed on Appendix I or Appendix II in 1975, because they were experiencing genuine declines due to international trade, and/or the species were difficult to distinguish from each other in trade.

**Article IV**

**General**

Trade in CITES-listed species is fundamentally restricted to Appendix II species, and Article IV must be satisfied before export permits can be issued and trade can take place. There are no exemptions in Article IV, so regardless of whether a species were listed on Appendix II because they were threatened with extinction [Article II.2(a)] or because they looked like a threatened species [Article II.2(b)], compliance with Article IV is mandatory.

It is not always clear how all the provisions of Article IV should be implemented or complied with. Nowhere is this confusion more entrenched than with the biological safeguards. Article IV.2(a) requires assurance that each export will not be detrimental to the survival of that species and Article IV.3 requires assurance that the species' role in the ecosystem is being maintained. Both are serious technical challenges.

**Not detrimental (Article IV.2(a))**

Rosser and Haywood (2002) attempted to provide guidance on "non-detriment". Their basic assumption was that exports were less likely to be detrimental if they came from a sophisticated (versus simple) management program.

The degree complexity or sophistication of a large sample of management programs may be correlated with the degree of detriment caused by management, but assuming cause and effect would be fraught with peril. For example, some of the most sophisticated management programs (eg Atlantic Cod) have resulted in grossly unsustainable patterns of use, causing real threats to the survival of species. Against this, some of the simplest of management protocols (eg Aboriginal harvesting of many species in northern Australia), with no formal scientific monitoring, have resulted in harvests being sustained for tens of thousands of years. The approach proposed by Rosser and Haywood (2002) sheds insights into management practices but provides no real guidance on how Article IV.2(a) should be assessed.

In provide guidance on Article IV.2(a) it is important to recognise that it refers specifically to detriment in terms of the survival of that species. In other words, actions that truly threaten the survival of the species are deemed detrimental, whereas actions that do not threaten survival of the species per se (despite numerous other potential adverse impacts) are not detrimental.

Given that significant population reductions can occur without a wild population's ability to survive and recover being truly compromised, the detriment in Article IV.2(a) is not a particularly sensitive trigger for action. It is more about ensuring no obvious and gross negative impact of harvesting is being allowed to continue operating while a species is being exported.

But even in this context it is a fine line between detriment and non-detriment. Survival of the species has rarely been tested for any species, and gross errors may exist between theory and practice. For example, the recovery rates of depleted crocodile and sea turtle populations may be many times greater than rates predicted from theory alone (Webb et al. 2004). Satisfying Article IV.2(a) will always be difficult.

**Role in the Ecosystem (Article IV.3)**

The implicit assumption in Article IV.3 is that role in the ecosystem for each Appendix II species in trade can and will be monitored, and if the role is compromised anywhere in a species' range, the cessation of trade would be a first step response, regardless of whether trade was involved in compromising the role or not. Article IV.3 clearly extends the
Article IV

“Regulation of Trade in Specimens of Species Included in Appendix II”

1. All trade in specimens of species included in Appendix II shall be in accordance with the provisions of this Article.

2. The export of any specimen of a species included in Appendix II shall require the prior grant and presentation of an export permit. An export permit shall only be granted when the following conditions have been met:

   (a) a Scientific Authority of the State of export has advised that such export will not be detrimental to the survival of that species;

   (b) a Management Authority of the State of export is satisfied that the specimen was not obtained in contravention of the laws of that State for the protection of fauna and flora; and

   (c) a Management Authority of the State of export is satisfied that any living specimen will be so prepared and shipped as to minimize the risk of injury, damage to health or cruel treatment.

3. A Scientific Authority in each Party shall monitor both the export permits granted by that State for specimens of species included in Appendix II and the actual exports of such specimens. Whenever a Scientific Authority determines that the export of specimens of any such species should be limited in order to maintain that species throughout its range at a level consistent with its role in the ecosystems in which it occurs and well above the level at which that species might become eligible for inclusion in Appendix I, the Scientific Authority shall advise the appropriate Management Authority of suitable measures to be taken to limit the grant of export permits for specimens of that species.

4. The import of any specimen of a species included in Appendix II shall require the prior presentation of either an export permit or a re-export certificate.

5. The re-export of any specimen of a species included in Appendix II shall require the prior grant and presentation of a re-export certificate. A re-export certificate shall only be granted when the following conditions have been met:

   (a) a Management Authority of the State of re-export is satisfied that the specimen was imported into that State in accordance with the provisions of the present Convention; and

   (b) a Management Authority of the State of re-export is satisfied that any living specimen will be so prepared and shipped as to minimize the risk of injury, damage to health or cruel treatment.

6. The introduction from the sea of any specimen of a species included in Appendix II shall require the prior grant of a certificate from a Management Authority of the State of introduction. A certificate shall only be granted when the following conditions have been met:

   (a) a Scientific Authority of the State of introduction advises that the introduction will not be detrimental to the survival of the species involved; and

   (b) a Management Authority of the State of introduction is satisfied that any living specimen will be so handled as to minimize the risk of injury, damage to health or cruel treatment.

7. Certificates referred to in paragraph 6 of this Article may be granted on the advice of a Scientific Authority, in consultation with other national scientific authorities or, when appropriate, international scientific authorities, in respect of periods not exceeding one year for total numbers of specimens to be introduced in such periods.

The notion of "detriment" well beyond survival of the species per se, to virtually any aspect of the species existence within its ecosystem.

Although the spirit of Article IV.3 is obvious, in terms of laying down a safeguard that restricts trade to reasonably healthy wild populations, no Party has yet been expected to comply with Article IV.3 in any way other than generalities. The technical challenges would be truly enormous for any species.
Sustainable Use

Regardless of how sustainable use of wildlife is defined, the concept involves three main components: i) use, both consumptive and non-consumptive; ii) sustainability, a process, simple or complex, to keep uses going indefinitely; and, iii) impacts, the ability to specify limits on potential unwanted effects of use. Sustainable use of wildlife can thus be defined as: use of wildlife associated with a process aimed at ensuring the use can continue indefinitely and that its impacts are maintained within prescribed limits. In practical terms this usually means use associated with a management program that aims to sustain a harvest program indefinitely and ensure adverse impacts are avoided or minimized.

The text of CITES does not specifically mention sustainable use, yet sustainable use is now recognised as being fundamental to wildlife conservation and managed use, and its application to Article IV is clearly recognised in the CITES Strategic Plan. Perhaps most important, the evidence usually presented to satisfy the biological safeguards of Article IV typically relates directly to sustainable use. For example:

i. if sustainable use can be demonstrated, the probability of detriment to survival [Article IV.2(a)] can be rejected.
ii. if uses are demonstrated as being unsustainable, the probability of detriment to survival [Article IV.2(a)] cannot be rejected and further study would be required to determine whether survival itself is compromised.
iii. by prescribing and monitoring the impacts of use, a mechanism is provided for defining and monitoring elements of role in the ecosystem over time [Article IV.3].

When crocodilian programs are assessed from a sustainable use perspective, information germane to two basic questions are needed: i) is the wild population sustaining the harvest? ii) are the impacts of the harvest being controlled within the context-specific levels prescribed? These approaches provide the only practical approach for complying with Article IV.2(a) and Article IV.3.

Appendix-I Animals Bred in Captivity for Commercial Purposes

The Convention (Article VII.4) establishes that the progeny of Appendix-I species bred in captivity for commercial purposes should be deemed, for the purposes of international trade, to be specimens in Appendix II.

In terms of regulating trade in such captive-bred Appendix-I specimens, Article VII.5 establishes that a certificate issued by the Management Authority shall be accepted in lieu of any of the permits or certificates required under the provisions of Article III, IV or V. However, there is no blanket exemption from Articles III, IV or V as explicitly exists with personal or household effects (Article VII.3).

This raises the issue of whether Article IV.2(a) and Article IV.3 (biological safeguards) do have some role to play in the regulation of trade in captive bred Appendix I specimens. Bearing in mind that captive breeding for commercial purposes can directly compete against sustainable use programs, and thus undermine conservation of wild populations, this issue should not be dismissed lightly.

When the Parties agreed to Resolution Conf. 12.10 (Guidelines for a procedure to register and monitor operations that breed Appendix-I animal species for commercial purposes), at COP12 in Santiago, Chile (2002), it was clear that where trade in Appendix-I captive-bred specimens was concerned, the Parties did expect compliance with Article IV:

(Resolves e) Parties shall strictly implement the provisions of Article IV of the Convention with respect to specimens of species included in Appendix I originating from operations that breed such specimens in captivity for commercial purposes.

Conclusions

At the time CITES was enacted, banning trade in species whose survival was directly threatened by trade was the major priority. Through listing on Appendix I, such bans were achieved reasonably easily and effectively, and they did help reduce the pressure on wild populations. As wild populations of crocodilians began to recover in Range States, transfers from Appendix I back to Appendix II became commonplace, with controlled use and trade replacing the uncontrolled and excessive uses of the past.
The major obligations of exporting countries were clearly to comply with Article IV, and particularly, to be able to demonstrate "non-detriment". In addition, special "Ranching" provisions were agreed for transferring from Appendix I to Appendix I. In addition to complying with Article IV (non-detriment), proponents of ranching programs also needed to demonstrate a "conservation advantage" from their program (Resolution Conf. 11.16).

As experience has been gained with crocodilian management there is now a lot more confidence that wild populations can be used sustainably, with no serious threat to the survival of species. That is, that the intent of Article IV can be satisfied with confidence. The ability to demonstrate sustainable use is perhaps now far more relevant than considerations of survival and extinction for all but a handful of species.

**Literature**


Precautionary Principle

Rosie Cooney and Jon Hutton

The precautionary principle has become, over recent years, an ever-more prominent principle in environmental policy, decision-making and advocacy. But what does it mean? How should it be applied? This paper describes a series of issues raised by the precautionary principle in biodiversity conservation and natural resource management (NRM), with special reference to crocodilians, and introduces a collaborative project aimed at developing guidance on the meaning and implementation of precaution.

Risk and uncertainty

Uncertainty is ever-present and fundamental in conservation and management of living natural resources. The dynamics, behaviour, and responses to disturbance, disease, habitat destruction and hunting, extraction or fishing even of single species are usually poorly understood. Ecosystems, particularly the most biodiverse, are composed of myriad interacting species engaged in complex interactions with each other and with abiotic factors such a nutrient, temperature, and hydrological regimes. Uncertainty is magnified at the ecosystem level: these are complex systems, composed of myriad interacting components, characterised by chaotic dynamics, threshold effects, and inherent stochasticity. Experimentation involving any but the simplest variables is not generally possible. The history of natural resource management is characterised by “surprise”, and ecology is unlikely ever to become a predictive science. Tackling this uncertainty poses major challenges to governance and management systems.

Environmental law and policy have evolved two principles which are relevant here, which is it important to distinguish: the principle of prevention and the principle of precaution. Risk involves negative outcomes that may or may not occur. Sometimes, usually from quantitative assessment of past occurrences, it is possible to reliably identify possible outcomes and assign to each a likelihood of occurrence. This is “classic” risk: the system, the possible outcomes and their likelihoods are well understood. Action to protect the environment from such outcomes is prevention. This can be contrasted with the situation where there is uncertainty surrounding possible outcomes and their likelihood of occurrence. There is no clear rational basis for assigning probabilities to identified outcomes. This is where the precautionary principle is relevant.

The precautionary principle: what is it?

The precautionary principle is various described as the fundamental principle underlying all environmental policy, or as a pointless distraction from the real issues. It is seen as anti-scientific, subject to abuse, inherently Northern, anti-innovation, and anti-sustainable use. It is seen as safeguarding future generations, a fundamental element of sustainable development, and countering a tendency to overlook scientific uncertainties in an unscientific manner. It raises issues which are central to many current international debates around environment, poverty, sustainable development and biodiversity, including protectionist approaches vs sustainable use; indigenous and local people’s involvement in conservation and protected area management; biodiversity conservation for its own sake vs for the people that rely on it; around regulatory vs incentive-based approaches. It has generated an enormous literature over the last decade or so from the standpoint of lawyers, environmentalists, economists and ethicists.

While it is used in different ways by different people, the core of the precautionary principle is about anticipating, foreseeing and acting to avert possible, uncertain harm, rather than waiting until there is clear scientific evidence of harm before taking action to avoid it. It emerged into environmental law in the context of marine pollution, where the prevailing approach had been to allow emissions until the point where there was evidence of harm. Precaution can be viewed as related to and evolving from two other well-established principles of environmental law: the polluter-pays principle, and the principle of prevention. All these principles have as their aim environmental protection, and they can be seen as reflecting a progression in the law in the time at which it addresses environmental harm: from reactive law, responding to damage after it has occurred (polluter-pays); addressing known risks before harm occurs (prevention); and anticipating and guarding against unknown risks (precaution). It is now very widely adopted in environmental agreements. Formulations of the principle differ, but the most widely cited is that of the Rio Declaration Principle 15 (1992):

“In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.”
Most would agree that this central core of the principle is extremely sensible in conservation and NRM: waiting until there is absolutely clear scientific evidence of impending harm will successfully delay any efforts to avert it indefinitely. However, in the context of management and use of wildlife and natural resources, there are some major questions surrounding the way precaution is interpreted and applied.

The precautionary principle and crocodilians: why is it relevant?

The principle is reflected in many international and national environment instruments. The Convention on Biological Diversity contains a formulation of the principle in its Preamble, and operational guidelines for Principle 5 of the Addis Ababa Principles on Sustainable Use, on minimising ecosystem impacts, include applying a precautionary approach in management decisions. Within CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the precautionary principle is incorporated into criteria on listing species in the CITES Appendices. When Parties are deciding which species should be placed in the Appendices, in the case of scientific uncertainty it is provided that Parties should act “in the best interests of the species”, and further specific “Precautionary measures” restrict the circumstances under which species can be transferred from Appendix I to Appendix II. At national level the precautionary principle is increasingly being incorporated into national environmental, biodiversity, or natural resources legislation and policy, for instance in Australia, South Africa, and Ecuador. Even where not specifically set out in law or policy, the precautionary principle is often a very important principle used in advocacy or management.

Issues for management and policy

Can protectionist interpretations of precaution conflict with sustainable use or incentive-driven conservation?

Applying the precautionary principle in NRM and biodiversity conservation is often equated with restriction or prohibition of utilisation or trade of species and natural resources. In particular, precaution is frequently used to argue against extractive use, in which individuals (or parts thereof) are permanently removed from wild populations. For instance, the precautionary principle is commonly used in advocacy and debate within CITES as an argument specifically in favour of increased trade regulation and of trade bans/restrictions (see Dickson 1999). This equation of precaution and protection is perhaps particularly evident where larger, more “charismatic” animals are concerned.

Extractive utilisation may pose a wide range of threats both to target species and to other components of the ecosystem, including not just overexploitation, but spread of disease (through e.g. release from captivity in ranching programmes); change to selective pressures on populations and consequent genetic change; and social or ecological disruption or disturbance to the target species or more broadly. Consideration of such threats may promptly lead decision-makers to view restriction of utilisation as the appropriate precautionary response. However, assessing only the risks of exploitation may lead to inappropriate and ineffective application of the precautionary principle. Under some circumstances it is clear that utilisation and trade of wild species may assist conservation of target species and broader ecosystems. Consumptive use may provide economic incentives for communities, private interests or states to conserve and maintain wild lands, outweighing benefits of conversion to intensive revenue-producing uses such as agriculture and plantations, or it may provide incentives for management of wild species rather than allowing uncontrolled hunting or grazing. Benefits to non-target species can flow from maintenance of lands as wild, control of hunting, and reduction of grazing pressure. Conversion and degradation of wild habitat remains the primary threat to biodiversity worldwide, so the importance of these incentives, where they exist, should not be understated. Less direct benefits may also exist. Revenue from wildlife utilisation and trade, including from direct sales of specimens or of permits and licences, is sometimes responsible for a substantial proportion of budgets of wildlife departments.

Restrictions on utilisation and trade may undermine these conservation benefits, and have a range of further negative impacts. Trade restrictions, particularly when applied in the absence of a clear scientific rationale, can provoke antagonism among disenfranchised resource users toward conservation instruments or conservation organisations. Prohibition of use or trade in specific species may lead simply to deflection of demand to other species. Finally, consumptive use will sometimes be simpler to implement than alternative conservation strategies, and avoid other environmental risks associated with them. Ecotourism, for instance, frequently put forward as a precautionary conservation strategy, requires substantial institutional capacity and infrastructure development, is vulnerable to a fickle tourist market, and carries attendant environmental risks such as habitat degradation and pollution.

This complex set of conservation risks and benefits of utilisation and trade, even leaving aside considerations of socio-economic impact and practical feasibility, illustrates the difficulty in interpreting “precautionary” as necessarily
“protectionist”. This raises the broader issue of what guidance is provided by the precautionary principle when a decision-maker is confronted by multiple risks. The typical conceptual paradigm of precautionary decision-making involves an activity (such as releasing a pollutant, clear-cutting a forest, harvesting a fish stock) that poses clear potential environmental risks as compared to absence of the action. Decisions are between “risk” and “caution”. However in practice, natural resource decision-makers are often confronted with a choice of strategies which each carry attendant environmental risks - the choice is between risk and risk. If a species does not yield some commercial income, the land will be put to more “productive” uses. If harvest of crocodilians for trade in meat or hides is prohibited, people may resent such restrictions and oppose further conservation efforts. Management of an ecosystem for the benefit of commercially valuable species may yield economic benefits that ensure the habitat is not converted to agriculture, but may lead to alterations detrimental to other species. What does applying the precautionary principle mean in these situations? Risks may arise from different sources and over different time-scales - should the precautionary principle be understood as requiring consideration, and some sort of balancing, of all of them?

*Should biological information be the sole basis for “precautionary” policy?*

This equation of precautionary strategies with protectionist strategies often stems from a narrow definition of what information is seen as relevant in assessing conservation risk. Specifically, the “conservation risks” facing species or populations are often defined purely in terms of biological status. A population is small or declining and there is uncertainty regarding impacts of utilisation, so use or trade is restricted.

However, application of the precautionary principle on this basis may fail to address the full range of threats faced by species and ecosystems. Exploitation of wildlife and natural resources takes place as part of a complex interaction involving people and human economies and institutions, and assessment of threats may need to take into account non-biological factors including social, economic, and institutional impacts and responses. As set out above, one set of risks that may be ignored involve loss of conservation incentives, although such risks may be diverse, complex and long-term.

The conservation impacts of CITES listings, for instance, may not be straightforward. One example is provided by the listing of an Indonesian bird, the Tanimbar corella *Cacatua goffinii* in Appendix I of CITES. This has been argued to have a number of problematic impacts (Jepson *et al.* 2001), and similar dynamics may be relevant to crocodilians. Concern about biological impacts of international trade of the corellas from Indonesia led to successful calls for banning international trade through listing in Appendix I. Listing was based on the precautionary principle, as biological information on species status was lacking. This action has been argued to have led to a range of negative conservation consequences, including leading to the resentment of local people, who perceived the bird as abundant and an agricultural pest, local hostility toward conservation NGOs, and consequent abandonment of plans for a protected area in the region. Such long-term and indirect conservation threats were not taken into account in the application of the precautionary principle.

A direct link between biological status and policy/management response is a reasonably common feature of policy and advocacy relating to conservation of wildlife. Under CITES, listing in Appendix I and prohibition of commercial trade is consequent on biological status characteristics, coupled with a finding that the species is in trade. The convention text does not require attention to non-biological threat factors, such as socio-economic factors or management context, or explicitly require consideration of the conservation impacts of the listing. Likewise, in many countries’ national legislation, harvest or trade restrictions follow automatically from assessment of biological status.

*What are the socio-economic impacts of applying the precautionary principle?*

Faced with urgent priorities of poverty alleviation and development, some argue that poor nations can ill afford the “luxury” of a precautionary approach, or that precaution must be interpreted within the overriding priority of poverty alleviation. Alternatively, some argue that adopting a precautionary approach to biodiversity conservation is necessary to sustain the basis for all future resource use and development.

The impacts of the precautionary principle on livelihoods, particularly of the rural poor, are not straightforward. Non-precautionary approaches to biodiversity conservation and NRM may lead to overexploitation and degradation of the natural resource base on which the poor often rely. In particular, where precautionary approaches to resource use are not applied to (or are evaded by) commercial/industrial interests, this can lead to appropriation of or exploitation of resources on which local people are dependent. However, where the precautionary principle is relied on as an
argument to restrict use or trade of wild resources such as crocodilians by local people, it may have serious impacts on livelihoods and income. Listing of a species on precautionary grounds under CITES, for instance, may close off livelihood options for local people reliant on trade of the resource. Applying a precautionary approach in protected area management may mean excluding local communities from use of resources from within such areas. Furthermore, it will be problematic when the precautionary principle is implemented in such as way that the burden of proof to show lack of harm is placed on local communities with little technical expertise or resources.

precautionary principle in NRM and conservation are likely to be complex and dependent on governance context. Who bears the obligations and burdens and who gains the benefits of precaution? Should these be taken into consideration when precaution is applied? Whose perspectives, view and priorities influence precautionary decision-making? And how can precautionary governance frameworks seek to ensure equity in application?

Can the precautionary principle be misused to impose the values or approaches of dominant groups?

The precautionary principle becomes relevant when scientific or objective knowledge is an insufficient guide to action. Its application therefore must be guided by subjective and usually divergent values and perceptions of risks, costs and benefits. So who decides? Whose values and perceptions count?

In the context of NRM and biodiversity conservation, reliance on the precautionary principle may provide scope for arbitrary or biased perceptions of environmental risk to dictate policy and management measures, without careful analysis of risks and threats. For example, some advocates for indigenous people’s rights point out the potential for the precautionary principle to be used to oppose indigenous and local people’s use of wildlife and natural resources. In this view, the Western conservation tradition is based largely on a conception of nature as separate to humans and humans as a threat to nature, justifying strategies of exclusion. These dynamics may also shape decision-making under uncertainty at the international level. Dominant groups, primarily those from Northern countries, may impose particular perceptions of environmental risk and related conservation approaches on other countries. In the WTO and at the World Summit for Sustainable Development, for instance, developing countries have expressed concern that the precautionary principle may be used by the North to impose its own environmental agenda on developing countries, which may have both different priorities and different conservation approaches. Some see conservation approaches based on sustainable use, for instance, as more responsive to sustainable development priorities of developing countries than protectionist approaches (eg Mohammed-Katerere 2001). Northern NGOs exercise considerable influence, and in decision-making fora such as CITES may have many times the resources, representation and media impact of smaller countries.

Precaution may provide scope for “abuse” by more powerful groups to pursue undeclared motives of various forms. In most conservation policy arenas concerns for animal welfare and animal rights are not accepted as legitimate bases for decision-making, and some suspect that in these circumstances animal welfare advocates adopt rhetorical “tools of convenience”. Reliance on the precautionary principle, particularly by animal welfare NGOs, to consistently oppose wildlife utilisation and trade has prompted suspicion in some quarters that precaution provides a convenient disguise for ideological objections to use under any circumstances. In some circumstances it is not clear that any level of scientific/technical certainty would preclude such an approach. Unfortunately, the potential for such abuses may contribute to corrosion of the legitimacy of the precautionary principle within certain constituencies.

In practice, use of the precautionary principle can lead to the imposition of particular values or perspectives of more powerful groups, with potentially negative consequences for marginalised groups. In order to avoid serious inequities, therefore, reliance on the precautionary principle may need to address difficult questions of transparency and participation in decision-making, to avoid the misuse of the precautionary principle to impose particular groups’ conceptions of threat and risk.

Towards best practice guidance

The precautionary principle builds on an intuitively sensible idea: that sometimes we need to take action against harm before we are entirely scientifically certain of the harm, as otherwise it may be too late. Uncertainty in NRM and biodiversity conservation is fundamental, and the precautionary principle of obvious and widespread relevance. However, it is clear that incorporation and implementation of the precautionary principle in this area is both complex and contentious, and guidance for effective and equitable implementation will require careful consideration of a number of issues. In NRM and biodiversity conservation recognition of uncertainty, and acceptance of the precautionary principle as a governance/management tool, is inconsistent across sectors and controversial in practice. Precaution
is often equated with “protectionist”, which may ignore the complex balancing act of risks and benefits involved in conservation decisions. The meaning of the principle when sources of risk are multiple and complex, and there is no clear “low risk” strategy, is unclear. The impacts of the precautionary principle for conservation and for livelihoods may vary widely. Governance issues are crucial: including who bears the obligations and the costs of precaution, who participates in decision-making, whose perceptions, priorities and values inform decisions, and the role of science and other expertise in the decision-making process. In the NRM/conservation context, uncritical conceptions of precaution or poorly designed processes can lead to imposition of the priorities or values of “Northern” or urban constituencies on local resource users; restriction of local livelihood options through restrictions on resource access, use or trade; or imposition of inappropriate models of conservation.

These and other issues are being explored by the Precautionary Principle Project, a joint initiative of IUCN, Fauna & Flora International, TRAFFIC and ResourceAfrica, supported largely by the European Union (see www.pprinciple.net for more details). The major aim of this project is to develop best-practice guidance for the implementation of the precautionary principle in biodiversity conservation and NRM, in a manner that respects the priorities of both biodiversity conservation and of livelihoods, poverty alleviation and sustainable development. The project involves case studies, currently underway, on application of the precautionary principle in specific sectors, regions and policy arenas, regional workshops in developing countries, engagement with relevant conventions, and a final international workshop in mid-2005. Best-practice guidance will be developed through a broad consultative and review process, including through regional and international workshops, and will be actively disseminated through engagement with relevant decision-makers, conventions, donors and organisations.

**Literature**


IUCN Red List of Threatened Species - Strengths and Weaknesses

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The most prominent system used to assess levels of (mainly anthropogenic) threat faced by species, including crocodilians, is the World Conservation Union (IUCN) Red List, which assigns taxa a “threat ranking” via assessment of their past, present and future demographic and ecological characteristics, and human impacts. I will briefly review some of the strengths and weaknesses of the IUCN endangered species categorization system. For instance, IUCN threat rankings help support the legislative protection of species and guide the prioritization of conservation programs, and may also be used to inform reserve selection, constrain development and exploitation, and report on the state of the environment. Yet it in attempting to be a “universal” system, it fails to properly contextualize wide ranging species, take full account of conservation actions, and suffers from data collection biases, mismatches across different threat indices, and untested quantification of extinction risk. I will illustrate my points with some examples (crocodiles, sea turtles, tuna and small mammals) which are particularly pertinent to sustainable use of wildlife populations and their habitats.
Wildlife Management Principles and Practices in Crocodilian Conservation and Sustainable Use

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Introduction

Crocodilians are long-lived, slow maturing animals, with modest annual clutch sizes, and high natural mortality rates amongst juveniles. They exist mainly in the equatorial regions of the world where poverty is widespread, and where expenditure on wildlife conservation and management is limited by other priorities. These biological and socioeconomic traits would normally be associated with high "vulnerability" to extinction through harvesting. Yet with crocodilians, there is a long history of conservation and sustainable use working together (Hutton and Webb 2002). This paper examines some of the key wildlife management practices and principles involved in crocodilian conservation management and sustainable use, and emanates from two reports (Webb et al. 2004; Webb and Manolis 2004) prepared for the CITES Secretariat.

Basic Approaches to Management

Crocodilians are large, long-lived, late-maturing animals, with modest clutch sizes and high mortality rates amongst juveniles. Like other animals, they exist with people in ways that are complex and often unique (Fig. 1).

Figure 1. Wildlife and people exist in complex interactive landscapes.

Figure 2. Key population dynamics of a wildlife population.
The first step in quantifying the "dynamics" of this relationship is to define the boundaries and key dynamics (Fig. 2). The analogy of a farm has high utility, because all farm animals were derived from wild ones and they respond to changes in the environment in similar ways. For example, stock on farms are maintained at high levels by harvesting. If the gates were closed completely, carrying capacity would be reduced - perhaps greatly.

Management will always be a compromise between social, economic and biological variables (Fig. 3), with new influences and threats that need to be countered or adjusted for continually. Management needs to be dynamic. There is no perfect knowledge and the only definitive way of learning about management is through experimental and adaptive management. But management is itself a predictive science at its own level of resolution (Fig. 4). Management questions are best addressed by experimental management, and not by diverting scarce research resources into fine level of resolution natural history questions.

![Influences and threats](image)

*Figure 3. Dynamic variables involved in management.*

![Problem and Solution](image)

*Figure 4. Aligning the levels of resolution of problem and solution are critical to efficient management - misalignment (dashed lines) wastes resources.*

Perhaps most important, wildlife populations are dynamic entities in their own right (Fig. 5). The separate measured population dynamics at any one point in time are not fixed entities. Density-dependent influences on population dynamics are perhaps the most common. In a population at carrying capacity the dynamics are balanced in the sense that the dynamics increasing the population (immigration, reproduction) match those decreasing the population (mortality, emigration). If these were fixed entities, populations would lose their ability to recover from any form of reduction.

**Recovering Wild Populations**

One of the best models for understanding wildlife population processes is the amniotic egg (Fig. 6). A population of
cells (embryo) grows with limited food resources (yolk), water resources (albumin) and space. Emigration and immigration are controlled, and there is no mortality due to predators. The pattern of increase in living tissue over time is logistic.

Figure 6. The logistic pattern of increase in living tissue within an egg.

Figure 7. The increase in body mass from hatching to adulthood.
The pattern of increase in body mass from hatchling to adulthood is also logistic, as is the pattern of recovery of a wild population afforded effective protection after being dramatically reduced through wild harvest (Fig. 8).

[Figure 8. Recovery in biomass of a wild population of Saltwater Crocodiles Crocodylus porosus in the Northern Territory of Australia.]

The importance of this underlying logistic curve lies in the demonstration that rates of increase in any living population are continually changing - they are not constant. The further a population is reduced below carrying capacity, the faster it will try to recover.

If two hypothetical wild populations of 1000 individuals (Fig. 9) in which complete recovery took 5 years and 30 years respectively are examined, the importance of variable rates of recovery can be demonstrated (Fig. 9).

[Figure 9. Recovery curves for two hypothetical populations of 1000 individuals that took 5 years (a) and 25 years (b) to complete. Lines are for calculating population increases each year.]

For example, in the fast growing population of 1000 individuals, the maximum annual harvest (500 per year) would be extracted if the wild population was reduced by 70%. With the slow growing population, the maximum annual harvest (100 per year) is much less and would be available if the population was reduced to 40% below carrying capacity.
Management in Practice

When crocodilian populations are seriously depleted - say 95+% decrease in carrying capacity - protection is a strategy that will boost populations quickly if habitats are in tact. However, as crocodilian numbers increase, public pressure to reduce populations (control) or to extract a sustainable harvest, can be expected to mount. Crocodilians are widely considered pest species, because they compete with people for resources, and they often prey on people and domestic stock.

With Saltwater crocodiles in the Northern Territory of Australia (Fig. 10), calls for culling became very strong 9 years after protection. The negative values the public attributed to large crocodiles were reinstating themselves. Economic incentives based on sustainable use (Fig. 11) boosted the value of crocodiles in the eyes of the community, and won public support for the ongoing conservation of crocodiles.

![Figure 10](image1)

Figure 10. When numbers of wild Saltwater Crocodiles in the Northern Territory of Australia reached 20-30% of carrying capacity, incentives (through sustainable use) were needed to increase the value of crocodiles in the eyes of the community.

![Figure 11](image2)

Figure 11. Economic values (black line) increased the overall value of Saltwater Crocodiles in the eyes of the community, and won their support for conservation.
A very good example of a wild population of crocodilians being progressively used more intensively as it recovered comes with American Alligators (*Alligator mississippiensis*) in Louisiana (Fig. 12).

Figure 12. As the American alligator population in Louisiana increased, the levels of harvest were increased, and a compensation scheme was introduced (return-back-to-the-wild) to ensure sustainable use (see Webb and Manolis 2004).

If wild crocodilian populations were harvested modestly, rather than reducing populations to extract a maximum sustainable yield, the wild populations may increase (Fig. 13).

Figure 13. Final densities in harvested versus non-harvested populations of *Caiman crocodilus crocodilus* in Venezuela (Velasco *et al.* 2003).

That is, the disruption of social hierarchies in a wild population induced through hunting may significantly increase the carrying capacity (Fig. 14).

One of the clearest examples of density-dependent adjustments to reproductive rates comes from Hines and Abercrombie (1987) in Florida (Fig. 15).
The number of American alligator nests in the lake was monitored for 3 years, and adult females equivalent to the maximum number of nests was removed over the next three years. Nest numbers stabilised rather than declined, suggesting that large numbers of "potential" adult females were in the swamp, but not nesting until an opportunity presented itself through an existing adult female being removed.

Conclusions

World crocodilians are a group of long-lived, late-maturing reptiles where considerable experience with management has been gained over the last 20-30 years. This experience all indicates that they are vulnerable to severe depletion if harvested without controls, but they are also tenacious survivors. They will recover rapidly if given the opportunity, and are being managed for sustainable use in many countries.

The basic wildlife management principles which underly crocodilian conservation and management appear are well grounded in theory and practice. They form a sound base for increased experimentation at the management level of resolution, which is where new and important information remains to be gathered.
Literature


Louisiana’s Alligator Program: Adapting Management as Populations Recover and Risk of Unsustainable Use Decreases

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Abstract

The American alligator (Alligator mississippiensis) has been used commercially for its valuable leather for many years, and the management and sustained use of this resource as a conservation tool is well documented. This paper serves to briefly review the research that led to the development of sustained use programs (harvest of wild adults, and egg ranching for commercial rearing of juveniles) and how these management programs have been adapted over the last thirty years. The wild harvest of sub-adults and adults has been in place since 1972, and regulated commercial egg ranching by private landowners was initiated in 1986. Although these programs are no longer “new”, constant adaptations are made to try to improve both programs. Harvest quotas are reviewed and changed annually based on coast wide nesting surveys used as a population index. Requests by many user groups (farmers, ranchers, trappers, landowners, buyers, dealers, and other industry personnel) are received and considered as the LDWF tries to safely manage this resource to the benefit of many user groups with varied interests.

Introduction/History

The American alligator (Alligator mississippiensis) has been used commercially for its valuable leather since 1800 (Stevenson 1904). The history of trade in alligator hides has been outlined in detail (Joanen and McNease 1991) and the management and sustained use of this resource as a conservation tool has been documented (Joanen et al. 1997). This paper serves to briefly review the research and management that led to the development of a sustained use program, and how the management program in Louisiana has been adapted over the last thirty years.

A detailed narrative on the historic use of alligators in southeastern states has previously been published (Joanen and McNease 1991). This harvest was generally unregulated and alligator populations declined in the early 1950s. In 1962, the alligator season in Louisiana was closed, and research studies were undertaken which later led to a biologically sound management program.

Early research efforts focused on general life history factors, such as alligator nesting (Joanen 1969) and habitat preferences based on telemetry of nesting females, adult males, and immature alligators (Joanen and McNease 1970, 1972; McNease and Joanen 1974). Of tremendous importance was the establishment of a rigorous survey method to estimate and monitor population trends.

Aerial surveys of coastal alligator nests were initiated in 1970. Longitudinal north-south lines were flown along the entire coast of Louisiana. A total of 51 census lines were used, with 28 lines at 3.8’ intervals in the three southwestern parishes, and 23 lines at 7.5’ intervals in the remaining coastal parishes (McNease and Joanen 1978), for a sampling intensity of 0.76% of 1.3 million ha (3.2 million acres) of alligator habitat (excluding 0.4 million ha categorized as salt marsh).

Initial Wild Harvests

In 1970, the Louisiana State Legislature (Act 550) gave the Department of Wildlife and Fisheries full authority to regulate the alligator season in Louisiana (Joanen and McNease 1991). After the initial surveys were conducted in 1970 and 1971, the LDWF developed a system of hunter applications, licenses, tags, etc. to initiate an experimental harvest of wild alligators, and distribute the take according to population levels. Based on field research and the telemetry studies, a harvest conducted in autumn (when nesting female alligators are in the remote interior marsh with new hatchlings at nest sites) would select the take for adult males, or immature alligators of either sex.
In September 1972, the experimental alligator harvest was conducted in Cameron Parish, Louisiana. A total of 1350 alligators (80.3% males) were taken by 59 trappers in 13 days. A detailed analysis of the harvest was reported (Palmisano et al. 1973) and in 1973, Vermilion Parish was also included in the harvest, which was increased to 19 days. In that year, 2921 alligators were taken by 107 hunters. The program expanded with time, and Calcasieu Parish was also hunted in 1975. As nest surveys continued to show rising population trends, all coastal parishes were hunted starting in 1979; and by 1981 the harvest was expanded statewide to include all 63 parishes (Table 1).

Table 1. Wild alligator seasons in Louisiana. ** Added Iberia, St. Mary, Terrebonne, Lafourche, St. Charles, Jefferson, Plaquemines, St. Bernard and St. Tammany parishes.

<table>
<thead>
<tr>
<th>Year</th>
<th>Season Dates</th>
<th>Hunting Days</th>
<th>Parishes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>Sept. 5-17</td>
<td>13</td>
<td>Cameron</td>
</tr>
<tr>
<td>1973</td>
<td>Sept. 10-28</td>
<td>19</td>
<td>Added Vermillion</td>
</tr>
<tr>
<td>1974</td>
<td>Season Closed - Endangered Species Act of 1973</td>
<td>30</td>
<td>Added Calcasieu</td>
</tr>
<tr>
<td>1975</td>
<td>Sept. 20-Oct. 19</td>
<td>30</td>
<td>No change</td>
</tr>
<tr>
<td>1977</td>
<td>Sept. 1-30</td>
<td>30</td>
<td>No change</td>
</tr>
<tr>
<td>1978</td>
<td>Season Closed - CITES/No Export Authority</td>
<td>31</td>
<td>Added Coastal Parishes **</td>
</tr>
<tr>
<td>1979</td>
<td>Sept. 7-Oct. 7</td>
<td>31</td>
<td>Statewide (63 parishes)</td>
</tr>
<tr>
<td>1980</td>
<td>Sept. 4-Oct. 4</td>
<td>31</td>
<td>No change</td>
</tr>
<tr>
<td>1981</td>
<td>Aug. 31-Sept. 30</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

The quota for the total numbers of alligators to be allowed for harvest (how many CITES tags to be issued to landowners/trappers) is related to the population of alligator estimated to occur on each piece of property. The alligator nest count by aerial transect gives an estimate of the total population, based on the theory that a certain proportion of the entire population consists of nesting females.

Transect lines (and therefore nest counts) are categorized into marsh types, based on the vegetative types present. Certain “indicator” species of plants, depending on their salinity tolerances occur in different marsh zones. The marsh types are fresh, intermediate, brackish, and saline with increasing salinity levels in each zone. Very little (if any) alligator nesting occurs in salt (saline) marsh.

Transect lines are also categorized by location of the 63 parishes (counties) in Louisiana. Tag allotments are determined for each parish, by marsh type. For example, in 2003 in Cameron Parish, one tag was allocated for each 90 acres of fresh marsh, while 170 acres of brackish marsh were needed to qualify for one CITES tag. In the western portion of Vermilion Parish, high nesting rates were seen, and only 75 acres of intermediate or brackish marsh qualified for one CITES tag. Poorer habitat and lower nesting rates led to a quota of only one tag per 500 acres of brackish marsh in St. Bernard Parish (Table 2).

**Wild Harvest Expansion**

As the experimental harvests proved successful and the program gradually became larger, nesting surveys were intensified to ensure the harvest did not cause any detriment to the wild alligator population. Additional “B” transect lines were added in 1981 (McNease et al. 1994) at midpoints between the established lines to increase sampling intensity to a total of 106 lines. In 1999, another series of “C” lines were added (now 143 transect lines), such that some 3500 linear miles (5645 km) are flown each July. The survey takes some nine days and costs approximately US$ 60,000. The sampling intensity covers approximately 3.4% of 2.4 million acres of private coastal wetlands, and 4.2-10.4% of some 567,000 acres of public lands (federal refuges and state-owned refuges and management areas) which are surveyed intensively.

With expansion of the program beyond the coastal marsh zone, other habitat types (cypress-tupelo swamp, northern lakes, dewatered marsh, transitional/deteriorating marsh) also have tag quotas (Table 2). Further refinement of the analysis in recent years has even led to some parishes being subdivided into east and west zones.

To avoid large fluctuations in annual tag quotas due to weather-induced changes one year’s nesting effort, the tag quota was changed to being based on the average of the most recent five year surveys in approximately 1992.
Table 2. 2003 marsh alligator tag allotment by Parish (see text). (a) = marsh between Calcasieu Lake/Calcasieu River and Mermentau River will be issued at the rate of 1 tag: 175 acres in intermediate marsh and 1 tag: 225 acres in brackish marsh; (b) = the dividing line for Vermilion East and West is the Vermilion River Cutoff (4-mile cut); (c) = marsh west of Mississippi River; (d) = marsh east of Mississippi River; (e) = marsh areas which are characterized by a generally declining alligator population caused by degradation of alligator habitat.

<table>
<thead>
<tr>
<th>Parish</th>
<th>Tag Allotment/Marsh Type</th>
<th>Brackish</th>
<th>Intermediate</th>
<th>Fresh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cameron (a)</td>
<td></td>
<td>1:170</td>
<td>1:85</td>
<td>1:90</td>
</tr>
<tr>
<td>Calcasieu</td>
<td></td>
<td>1:250</td>
<td>1:110</td>
<td>1:90</td>
</tr>
<tr>
<td>Jeff Davis</td>
<td></td>
<td></td>
<td></td>
<td>1:90</td>
</tr>
<tr>
<td>Vermillion West (b)</td>
<td></td>
<td>1:75</td>
<td>1:75</td>
<td>1:125</td>
</tr>
<tr>
<td>Vermillion East (b)</td>
<td></td>
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<td>1:275</td>
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<td>Iberia</td>
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<td>St. Mary</td>
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<td>Terrebonne</td>
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<td>Lafourche</td>
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<td>St. Charles</td>
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<td>St. John the Baptist</td>
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<td>Jefferson</td>
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<td>Orleans</td>
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<td>Plaquemines West (c)</td>
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<td>1:300</td>
<td>1:200</td>
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<td>Plaquemines East (d)</td>
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<td>1:500</td>
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<tr>
<td>Plaquemines Delta</td>
<td></td>
<td>1:300</td>
<td>1:175</td>
<td>1:160</td>
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<tr>
<td>St. Bernard</td>
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<td>1:500</td>
<td>1:115</td>
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<tr>
<td>St. Tammany</td>
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<td>1:200</td>
<td>1:125</td>
<td>1:125</td>
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<tr>
<td>Tangipahoa</td>
<td></td>
<td>1:100</td>
<td>1:140</td>
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</tbody>
</table>

Cypress-Tupelo Swamp 1:200; Dewatered Marsh 1:700; Transitional Marsh (e) 1:500

As the wild harvest program in Louisiana readily appeared to be sustainable, it was adapted again in 1999 to make use of the more plentiful alligators in the 4-5’ size classes (122-183 cm). Starting in 1999, trappers were issued an additional quantity of “bonus” tags to be used on alligators less than 183 cm in length. The number of “bonus” tags issued is 10% of the trapper’s regular quota. For example, a trapper whose normal CITES tag quota is 21 would also be issued 2 bonus tags to be used on smaller alligators. The “regular” tags may be used on alligator of any size. A trapper who qualifies for 43 regular tags would be issued 4 “bonus” tags. Some 3200-3300 bonus tags have been issued annually since 1999; the average size is approximately 5’9” (175 cm) to 5’10” (178 cm). Fortunately these hides are much larger than the hides from the average farm-raised alligators in Louisiana which average 3.69-3.81 feet (112-117 cm) total length. Thus the two markets have little (if any) overlap.

The wild alligator harvest initially was limited to a few major land companies who hired local citizens to trap their quota, and trappers who harvested alligators from family owned land. Trappers would skin their own alligators, and sell the salted hides to buyers at local auctions. Alligator meat was sometimes used for home consumption.

As the wild harvest expanded, centralized processing sheds were established by dealers. Trappers bring their lot of hides to the shed, or dealers transport alligator carcasses from rural collecting points to the processing shed in refrigerated trucks. The alligator meat has become a secondary source of revenue to benefit to landowner and dealer. Refinements in the alligator skinning procedure and care of the hide have been developed to try to minimize damages in transport, skinning, and storage, to maintain and improve the quality of the raw hide. The wild harvest in Louisiana has developed into a multi-million dollar source of income for the state’s landowners and trappers (Table 3).
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B9I4E<BHF@4EF;GLC8FBAG;8J8G?4A7F<FI8EL?45BE<AG8AF<I8 )A8C<868B9CEBC8EGL@4L;4I87<I<787<AG8E8FG
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I8:8G4G<I8 @4EF;GLC8F4A7BJA8EF;<C4E86B@C4E87GB64?6H?4G8;BJ@4AL46E8FB9846;@4EF;GLC88K<FGBA846;
C<868B9CEBC8EGLGB588I4?H4G879BE#.-G4:<FFH4A68 /AG<?E868AG?LG;<F;4F588A7BA8N5L;4A7Q 4A8KGE8@8?L
?45BE <AG8AF<I8 CEB68FF 6BAF<78E<A: G;8 @4:A<GH78 B9 G;8 4??<:4GBE ;45<G4G 4A7 AH@58E B9 6B@@8E6<4? ;HAG8EF <A
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A computer based GIS/ArcView system was initiated around the year 2000 to develop digital files of each landowner’s property, with superimposed vegetative type delineations. Once finalized, this program will allow LDWF biologists to automatically incorporate the new marsh types/vegetative changes when new surveys are flown.

Farming/Ranching Program

Early alligator farms in Louisiana were generally small, family-owned operations; and often run more as a hobby/curiosity than a commercial enterprise. Extensive studies done by LDWF biologists showed alligators could be efficiently cultured and grown in captivity (see review by Joanen and McNease 1987).

To encourage a possible new industry, the initial few farmers were supplied hatchlings from eggs collected from state-owned lands, and incubated and hatched by department personnel. A program was established wherein farmers would receive hatchlings from the LDWF for ten years; by which time some of their first hatchlings received would be sexually mature and the farmer would then obtain eggs from his own captive breeders. As time passed, the captive breeding proved to be less economical than ranching of wild eggs, and the requirement to maintain captive breeders was eliminated.

Hatchling alligators fared well in heated “controlled environmental chambers” or sheds in captivity and could reach market size in one-two years. Soon the demand for hatchlings for this new industry could not be met from agency resources. The LDWF then developed guidelines and strict quotas (similar to how wild harvest quotas are determined) whereby potential ranchers might obtain eggs from suitable private wetlands, which historically have been shown to support substantial populations of alligators.

Louisiana’s alligator ranching program increased dramatically between 1986 and 1990 and has been described in detail (Elsey et al. 2001). To ensure wild alligators were not depleted as a result of egg collections, and to ensure future recruitment of sub-adult alligators to the breeding population, the LDWF initially required a quantity of juvenile alligators equal to 17% of the eggs hatched by the rancher be returned to the wild within two years of hatching. This program has been described in detail (Elsey et al. 2001). In the first three years of the release program (1988-1990) returns were limited to fewer than 15,000 alligators. Sizes at release were generally small, and averaged 91-97 cm.

In 1991, a variable return rate was established based on the estimated 17% survival from hatching to 122 cm predicted for wild juvenile alligators. Using the relationship of survival between size classes as specified in Taylor and Neal (1984), we extrapolated return rates based on expected survival rates for alligators from 91.4 cm to 152.4 cm. More alligators must be returned if the average total length is smaller, and fewer animals are required if the average length is larger. Alligators must be at least 91.4 cm and are usually less than 152.4 cm total length at release and must be free of disease or deformities to be acceptable for release (Elsey et al. 1998, 2001).

Releases were initially made from 15 March to 30 September, if the weather was suitably warm. Due to conflicts with administration of the September harvest and field staff scheduling limitations, in 2003 the ending date for releases was changed to August 25 of each year (2001 egg collection permits; releases due in 2003). The tagging, marking, data collection and release procedure have been documented in detail (Elsey et al. 2001).

Enormous effort has been made by the LDWF to monitor the fate of the alligators released to the wild. We were very concerned that we document any failings or successes of the program, as it is costly to the ranchers to fulfill the “returns to the wild” obligation. However, it is an integral necessity of the program, considering the large number of eggs collected. In recent years, up to 350,000-375,000 eggs have been collected when weather conditions/water levels led to excellent nesting efforts (Table 4).

The number of alligator farms in Louisiana peaked during 1990-1992, when some 123-134 farms were licensed at any time (although not all were actively raising alligators). Some of this growth was undoubtedly a result of exceptionally high prices for wild alligator hides in the September harvests of 1988-1990, which ranged from approximately $48 per foot to $57 per foot (thus a single “average” sized alligator of 7 feet was worth some $400 for the hide alone).

Over time, many of the new, less experienced, and smaller farms were unable to compete with the more established farms, whose larger inventories and other factors led to their ability to maintain successful operations in years of more modest prices. The number of farmers/ranchers in Louisiana gradually dropped until around 1999, when it
Table 4. Louisiana’s ranching program.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Eggs Permitted</th>
<th>Number Collected</th>
<th>Percent Collected</th>
<th>Number Hatched</th>
<th>Alligators Returned to Wild</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>2,903</td>
<td>2,903</td>
<td>100.0%</td>
<td>1,985</td>
<td>none</td>
</tr>
<tr>
<td>1987</td>
<td>19,641</td>
<td>18,041</td>
<td>91.9%</td>
<td>13,782</td>
<td>none</td>
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<tr>
<td>1988</td>
<td>90,305</td>
<td>64,887</td>
<td>71.9%</td>
<td>50,394</td>
<td>1,680</td>
</tr>
<tr>
<td>1989</td>
<td>265,051</td>
<td>181,819</td>
<td>68.6%</td>
<td>137,323</td>
<td>7,078</td>
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<tr>
<td>1990</td>
<td>366,055</td>
<td>293,412</td>
<td>80.2%</td>
<td>231,434</td>
<td>6,088</td>
</tr>
<tr>
<td>1991</td>
<td>333,451</td>
<td>198,089</td>
<td>59.4%</td>
<td>165,054</td>
<td>44,405</td>
</tr>
<tr>
<td>1992</td>
<td>297,125</td>
<td>164,892</td>
<td>55.5%</td>
<td>133,463</td>
<td>35,531</td>
</tr>
<tr>
<td>1993</td>
<td>279,405</td>
<td>155,891</td>
<td>55.8%</td>
<td>123,666</td>
<td>28,512</td>
</tr>
<tr>
<td>1994</td>
<td>362,835</td>
<td>266,408</td>
<td>73.4%</td>
<td>223,011</td>
<td>21,633</td>
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<tr>
<td>1995</td>
<td>402,830</td>
<td>314,371</td>
<td>78.0%</td>
<td>261,428</td>
<td>20,749</td>
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<tr>
<td>1996</td>
<td>467,545</td>
<td>279,237</td>
<td>59.7%</td>
<td>233,076</td>
<td>40,919</td>
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<tr>
<td>1997</td>
<td>476,115</td>
<td>377,636</td>
<td>79.3%</td>
<td>321,641</td>
<td>48,171</td>
</tr>
<tr>
<td>1998</td>
<td>539,216</td>
<td>280,870</td>
<td>52.1%</td>
<td>240,118</td>
<td>36,733</td>
</tr>
<tr>
<td>1999</td>
<td>574,731</td>
<td>382,611</td>
<td>66.6%</td>
<td>332,428</td>
<td>44,169</td>
</tr>
<tr>
<td>2000</td>
<td>593,625</td>
<td>279,217</td>
<td>47.0%</td>
<td>236,313</td>
<td>39,559</td>
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<tr>
<td>2001</td>
<td>616,465</td>
<td>357,440</td>
<td>58.0%</td>
<td>295,498</td>
<td>48,225</td>
</tr>
<tr>
<td>2002</td>
<td>639,145</td>
<td>354,711</td>
<td>55.5%</td>
<td>304,604</td>
<td>32,627</td>
</tr>
<tr>
<td>2003</td>
<td>651,207</td>
<td>356,634</td>
<td>54.8%</td>
<td>306,761</td>
<td>50,542</td>
</tr>
</tbody>
</table>

leveled off at around 60-65 farms (Table 5). Again, many of these are small “hobbyists”, or others who simply maintain a farming license in order to ranch eggs, and transfer the eggs or new hatchlings to other farmers. However, the inventory on farms is far higher now (530,000 in December 2003) than when there were over 120 farms (318,000 in December 1991).

With time, farmers experimented and have developed many techniques to improve efficiency and minimize costs of alligator production. Development of pelletized dry feeds with vitamin supplementation can avoid storage/freezer costs needed with frozen meat diets. Floating feed trays help minimize wastage. Sheds sometimes are constructed with multiple stacked levels to allow for housing of more alligators and more efficient use of heat. The use of heated refill water also encourages better feeding by maintaining constant warm temperature.

Our research and review of the ranching program documented that the released alligators are able to forage for food in the wild, grow well, have high survival rates, and successfully nest in the wild (Elsey et al. 2001). Thus, we decreased the return percentage to 14% of the eggs hatched, starting with the 2000 egg permit collection year (returns “due” in 2002; some done one year after collection in 2001). Thus, our management program was adapted when available data warranted less demanding return requirements; although very close monitoring of the effects of this change will continue.

As farm inventories increased, buyers and dealers were able to be more selective in choosing the highest grade/quality hides with which to prepare lots of hides to enter commercial trade. Increasingly stringent demands for near-perfect hides has been problematic for some farmers, as some portion of the hides produced will have damages due to scarring, bites, etc. Efforts are in place to find ways to continue to maintain excellent quality of skins produced on farms, such as use of deeper water (to avoid piling/scratching), hide boards (to limit stress and interaction with other alligators), vinyl liners (to avoid rough/abrasive surfaces), and filtered water (avoid possible infectious agents in standing water).

Similar efforts are underway to maintain high quality wild harvested hides. Some problems (such as scars from fighting due to drought-imposed crowding) are unavoidable, but efforts have been directed to improving processing procedures (transport of carcass in refrigerated trucks to avoid “slip” of scales, careful use of pressure washers to remove tissue remnants from hides, use of compressed air to assist in separation of the hide from the carcass and avoid knife/cuts to the hide, etc.).
Table 5. Farm alligator harvest in Louisiana, 1972-2002. * = tag year extends from September of the year designated to the next September (e.g. 1997 = 9/97 to 8/98). ** = sale of meat not permitted; La. Health Department regulations first allowed meat sales in 1979.

<table>
<thead>
<tr>
<th>Year *</th>
<th>No. Farms</th>
<th>No. Skins Licensed</th>
<th>No. Skins Sold</th>
<th>Avg Length (feet)</th>
<th>Value of Skins</th>
<th>Deboned Meat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Avg/foot</td>
<td>Total $US</td>
</tr>
<tr>
<td>1972</td>
<td>8</td>
<td>3</td>
<td>35</td>
<td>5</td>
<td>$8.10</td>
<td>$1,418</td>
</tr>
<tr>
<td>1973</td>
<td>8</td>
<td>5</td>
<td>103</td>
<td>6.33</td>
<td>$13.13</td>
<td>$8,561</td>
</tr>
<tr>
<td>1975</td>
<td>8</td>
<td>3</td>
<td>83</td>
<td>5.5</td>
<td>$7.88</td>
<td>$3,597</td>
</tr>
<tr>
<td>1976</td>
<td>8</td>
<td>3</td>
<td>360</td>
<td>5.75</td>
<td>$16.55</td>
<td>$34,259</td>
</tr>
<tr>
<td>1977</td>
<td>8</td>
<td>4</td>
<td>376</td>
<td>5.25</td>
<td>$12.23</td>
<td>$24,142</td>
</tr>
<tr>
<td>1980</td>
<td>8</td>
<td>1</td>
<td>191</td>
<td>4.67</td>
<td>$13.00</td>
<td>$11,596</td>
</tr>
<tr>
<td>1981</td>
<td>8</td>
<td>3</td>
<td>360</td>
<td>4.67</td>
<td>$17.50</td>
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<td>8</td>
<td>1</td>
<td>113</td>
<td>4</td>
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<td>$6,102</td>
</tr>
<tr>
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<td>14</td>
<td>6</td>
<td>1,449</td>
<td>4.58</td>
<td>$13.00</td>
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<td>12</td>
<td>7</td>
<td>2,836</td>
<td>4.25</td>
<td>$21.00</td>
<td>$253,113</td>
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<td>15</td>
<td>12</td>
<td>4,430</td>
<td>4.25</td>
<td>$21.00</td>
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<td>22</td>
<td>15</td>
<td>5,925</td>
<td>4.5</td>
<td>$23.00</td>
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<tr>
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<td>47</td>
<td>38</td>
<td>27,749</td>
<td>4.25</td>
<td>$36.00</td>
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<td>1989</td>
<td>83</td>
<td>68</td>
<td>66,737</td>
<td>3.98</td>
<td>$32.00</td>
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<tr>
<td>1990</td>
<td>123</td>
<td>80</td>
<td>88,424</td>
<td>4.03</td>
<td>$24.00</td>
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</tr>
<tr>
<td>1991</td>
<td>134</td>
<td>91</td>
<td>118,976</td>
<td>4.13</td>
<td>$15.00</td>
<td>$7,370,563</td>
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<tr>
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<td>125</td>
<td>85</td>
<td>128,026</td>
<td>4.04</td>
<td>$12.00</td>
<td>$6,206,700</td>
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<tr>
<td>1993</td>
<td>101</td>
<td>70</td>
<td>121,700</td>
<td>3.87</td>
<td>$17.00</td>
<td>$8,006,643</td>
</tr>
<tr>
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<td>89</td>
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<td>136,126</td>
<td>3.67</td>
<td>$20.00</td>
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<tr>
<td>1995</td>
<td>83</td>
<td>50</td>
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<td>3.88</td>
<td>$20.00</td>
<td>$9,735,696</td>
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<tr>
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<td>3.91</td>
<td>$15.50</td>
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<td>1997</td>
<td>75</td>
<td>36</td>
<td>169,988</td>
<td>3.74</td>
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<tr>
<td>1998</td>
<td>73</td>
<td>38</td>
<td>154,399</td>
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<tr>
<td>1999</td>
<td>64</td>
<td>35</td>
<td>187,570</td>
<td>3.64</td>
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<tr>
<td>2000</td>
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<td>35</td>
<td>219,827</td>
<td>3.81</td>
<td>$20.50</td>
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<tr>
<td>2001</td>
<td>63</td>
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<td>180,391</td>
<td>3.79</td>
<td>$20.50</td>
<td>$14,015,479</td>
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<tr>
<td>2002</td>
<td>62</td>
<td>35</td>
<td>240,143</td>
<td>3.73</td>
<td>$23.50</td>
<td>$21,049,735</td>
</tr>
</tbody>
</table>

( ___ Subject to change, numbers updated April 12, 2004).

Accelerated Experimental Wild Harvests

Although Louisiana’s alligator harvests have expanded with time as indicated by population trends seen on nesting surveys, the harvest remains tightly regulated and conservative, to ensure over-harvest does not occur. More liberal, very aggressive experimental harvests were conducted in the mid-1980s, to determine if additional alligators could be safely harvested, and to collect numerous female alligators in spring/early summer, to gather additional reproductive data (questions remain as to exactly what portion of the adult female population nests each year, and subsequently, how many alligators does one nest represent when trying to extrapolate population figures from nest counts).

A very aggressive experimental harvest was conducted on Marsh Island Refuge, a 68,000 acre brackish marsh remote island off Iberia and St. Mary parishes. An experimental quota of 3500 alligators was established for the area, which is a tag allocation of 1 tag per 20 acres, far higher than quotas generally used statewide (Table 2). The harvest was held from April 4, 1986 to July 16, 1986, and 2930 alligators were taken. Harvest was heavily skewed to old, large males. Seven hundred twenty-nine alligator over 9 feet in total length (274 cm) were taken, 723 were males and 6 were females. In the more common adult size classes (6’0” to 8’11”; 183-272 cm) 1701 alligators were harvested, 62.9% of which were females. The experiment clearly documented that spring/summer harvests target more females than the standard fall harvest, and many of the largest, oldest alligators were taken (Kinler et al. 1987).

The next year the quota was decreased to 2000 alligators which is nearly one tag per 35 acres, and although less aggressive then in 1986, still an extensive harvest. The overall average total length taken dropped to 6’0” (183 cm) in 1987, down from 8’0” in 1986 (244 cm). Quotas were decreased to approximately 1000 alligators per year for the next four years, and average sizes remained around 183 cm total length (LDWF data). The experiment clearly
documented that limitations on harvest levels must be in place, and despite the abundance of alligators in Louisiana, unregulated overharvest could occur.

A similar (but more modest) accelerated harvest was conducted on Salvador WMA from 1986-1990, with a quota of 1 alligator per 32 acres. At the accelerated harvest levels the average size taken was smaller than the statewide harvest, but populations appeared to remain stable (Kiner and Taylor 1992).

**Problems**

During the 30 years over which Louisiana’s alligator programs have evolved, some segments have proven to be ineffective or problematic to administer, and were discontinued. For the wild harvest, in the early years “special skinning instructions” were used each year, to ensure no poaching would occur. In addition to the use of CITES tags, alligator carcasses had to be skinned in a certain fashion each year, and these instructions were not made known to trappers until the day before the season opened. This prevented prior harvest and storage of large alligators before the season opened. As centralized processing sheds for alligator carcasses were developed, the special skinning instructions proved burdensome. A legally taken, CITES tagged carcass might be improperly skinned by an inexperienced employee at a processing shed, and thus technically creates an “illegal” hide. Thus, the rule requiring special skinning instructions was discontinued. Starting in 1991 every wild or farm hide produced in Louisiana is inspected by a LDWF employee, to ensure the CITES tag is properly attached and all hides in the lot are listed on the shipping manifest.

The experimental spring/summer harvest at Marsh Island clearly showed that high numbers of adult females are harvested at this time; providing further data to reinforce the decision to have the adult alligator harvest in autumn, to select for adult males or immatures of either sex. It also clearly showed that conservative quotas must be set to avoid overharvest.

The development of the egg ranching program led to most farmers discontinuing captive breeding efforts, which have been less successful (Elsey et al. 1994) and less cost efficient. Captive breeding is still underway at some farms, one advantage being that the “14% returns to the wild” are not required for egg/hatchlings produced by captive breeders.

The wild ranching program also initially allowed for the collection of hatchlings, if ranchers preferred this option (to avoid construction and maintenance of egg incubators). A much higher percentage “return rate” was due (30% at 123 cm). Problems developed with the temptation for farmers to catch “hatchlings” that were older/larger than specified, and this program was discontinued.

Another problematic area which developed gradually as farmers tried to minimize costs was that less effort may be given to maintaining strict hygiene and husbandry. Obviously costs increase (heating water, labor, feed losses) the more often the alligator sheds are washed. We strongly encourage our farmers/ ranchers to maintain aggressive husbandry efforts. Most have learned that costs saved with lack of attention to husbandry might be offset by lower quality hides being produced, which are less valuable. Occasional “disease” outbreaks are often rectified by resuming stricter hygiene/husbandry practices. Similar problems occur in other species of intensively cultured livestock such as pigs, poultry, etc.

**Future**

The current level of harvest in Louisiana is clearly sustainable, as nesting counts are stable in southwest Louisiana and still gradually increasing in southeast Louisiana (Fig. 1). Despite the harvest of wild adults and eggs in the ranching program, populations remain sufficiently healthy as to require a “nuisance” alligator program. Thousands of calls from citizens are answered yearly, and some 2000 nuisance alligators are harvested by licensed trappers each year.

**Habitat Concerns**

One threat or potential limiting factor to Louisiana’s alligator population is habitat loss. Because the vast majority of Louisiana’s alligators are in the coastal parishes, saltwater intrusion and wetlands/marsh deterioration from numerous causes are very real threats. Some 20,000 acres (31 square miles) of coastal marshes are lost annually.

Vast resources by numerous state and federal agencies have been expended to attempt to limit these losses. Projects
to restore/enhance marshes include construction of earthen terraces (to reduce wave action and turbidity), “breakwaters” and protection levees along coastlines, and freshwater diversions. The alligator benefits indirectly from these efforts to maintain/enhance wetlands. The freshwater diversion projects (Davis Pond and Caernarvon) shift water from the Mississippi River in hopes of re-establishing more favorable salinity conditions for numerous fish and wildlife species. Some preliminary data suggests alligator nesting has improved in the areas enhanced by lower marsh salinity levels (LDWF, unpublished data).

Summary

Louisiana’s alligator management programs have clearly illustrated that controlled sustained use of the species is feasible. The wild harvest has been in place over 30 years, and the egg ranching program for nearly 20 years and may appear to operate unchanged every year. However, constant adaptations are made to try to improve both programs. The annual surveys lead to review of harvest quotas and possible changes for each parish as marsh types change and nesting efforts are affected. Constant requests by user groups (farmers, egg ranchers, trappers, landowners, buyers, dealers and other industry personnel) are received and considered as the LDWF tries to safely manage the resource to the benefit of many user groups with varied interests.

Literature


International Trade and CITES - Tags, Permits and Stricter Domestic Measures

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Abstract

CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international treaty to ensure that international trade in specimens of wild animals and plants does not threaten their survival. CITES requires member countries to control the import and export of an agreed list of species that are endangered, or at risk of becoming endangered, due to inadequate controls over trade in those species or their products. CITES allows countries to adopt ‘stricter domestic measures’ (controls that are stricter than those required by CITES). This paper provides a brief description of CITES, explains permitting and tagging requirements and discusses the use of stricter domestic measures using Australia as an example.

CITES

In 1975, an international treaty was agreed to prevent international trade threatening species with extinction. This treaty is known as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Australia is one of more than 160 countries that are a Party to CITES. Each member country controls the import and export of an agreed list of species that are endangered, or at risk of becoming endangered, due to inadequate controls over trade in those species or their products.

How CITES Works

Although CITES is legally binding on the Parties that have ratified the Convention, it does not take the place of national laws. Rather, it provides a framework that must be implemented by each Party through the administration of domestic legislation at the national level.

CITES lists four criteria that Parties must meet in order to enforce the provisions of the Convention (Conf Res 8.4):

i) designate at least one Management Authority and one Scientific Authority; and
ii) prohibit trade in specimens in violation of the Convention; and,
iii) penalise such trade; or,
iv) confiscate specimens illegally traded or possessed.

While Parties may trade with non-Parties, non-Parties must still meet the same documentary standards as Parties in order to trade in CITES-listed specimens. Accordingly, non-Parties need to nominate a domestic authority that is competent to issue such documents.

CITES has established a worldwide system of controls on international trade in threatened wildlife and wildlife products by stipulating that Government permits are required for such trade. Security paper and stamps are often used for these permits to prevent forgery.

CITES documentation consists of a number of different types of documents. The main ones that are relevant to implementation include the actual text of the Convention (made up of Articles), Resolutions and Notifications. Note that CITES resolutions are not mandatory and not binding upon Parties. Resolutions are often used to interpret or provide guidance on implementing the Articles of CITES.

CITES Appendices

CITES places species into three categories based on their conservation status and the risk from trade. Lists of species in each category are compiled as three separate appendices to the Convention.
CITES Appendix I

These are species threatened with extinction and that are, or may be, affected by trade. Among the species listed are apes, lemurs, the giant panda, many South American monkeys, great whales, cheetah, leopards, tigers, elephants, all rhinoceroses, many birds of prey, cranes, pheasants, parrots, all sea turtles, some crocodiles and lizards, giant salamanders, some mussels, orchids, cycads and cacti.

CITES Appendix II

These are species that, although not presently threatened with extinction, might become so unless trade in those species is strictly controlled and monitored. CITES Appendix II also includes some non-threatened species, in order to prevent threatened species from being traded under the guise of non-threatened species that are similar in appearance.

CITES Appendix III

These are species that any CITES Party identifies as being subject to regulation within its jurisdiction for the purpose of preventing or restricting exploitation and that require the cooperation of other countries in the control of trade.

Authorities

Each Party is obliged to designate Management and Scientific Authorities.

Management Authorities are responsible for:

- authorising and issuing permits and certificates of approval;
- communicating information to other Parties and the Secretariat; and,
- reporting on compliance matters and contributing to CITES Annual Reports.

Scientific Authorities are responsible for providing scientific advice and recommendations to the Management Authorities, for example:

- biological and trade information on species proposed for listing in the Appendices;
- suitable measures to limit export of specimens on Appendix I;
- the suitability of recipients of live specimens listed on Appendix I to house and care for them;
- whether a scientific institution meets the criteria for registration to exchange CITES-listed specimens;
- whether a facility meets the criteria for captive breeding or artificial propagation in accordance with CITES; and,
- whether a management program for commercial harvested species from the wild is sustainable in accordance with CITES.

Stricter Domestic Measures

CITES allows Parties to adopt a stronger position on certain listed species than is required under the Convention. Australia recognises and uses this provision in its wildlife trade legislation – the Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act).

CITES does not prohibit the export or import of live CITES II specimens for commercial purposes. However, Australia does not permit the export of live native mammals, amphibians, reptiles or birds for commercial purposes. This is a stricter domestic measure.

Another stricter domestic measure applied by Australia is in regard to animal welfare. CITES specifies the need for animal welfare to be considered in relation to transport of live animals. The EPBC Act expands this to include welfare of animals when they are taken and/or held.

Other examples of Australia’s stricter domestic measures are provided throughout this paper.
Permits

CITES I

Article III of CITES states that trade in CITES Appendix I specimens requires the issue of both import and export permits, and that an import permit must be issued first. This Article states also that CITES I species cannot be imported for primarily commercial purposes. However, Article VII, Paragraph 4 states that a captive-bred CITES I animal shall be regarded as if it were a CITES II specimen and hence it may be traded for commercial purposes. Resolution Conf. 12.10 interprets ‘captive bred animal’ to mean an animal sourced from a CITES Secretariat Registered Captive Breeding Program. In the case of crocodilians, there are currently seven such registered programs.

Through stricter domestic measures, Australia considers all specimens of *Loxodonta africana* (African Elephant) as Appendix-I specimens, although CITES lists some populations under Appendix II for specific purposes, specified in the Appendix.

CITES II

Article IV of CITES states that export permits must be issued for the export of CITES Appendix II specimens, but does not require import permits.

Through a stricter domestic measure, Australia requires import permits for all Appendix-II specimens, except in the case of certain specimens imported as personal baggage. An export permit is required unless the specimen is covered by a personal effect exemption (see discussion under Personal effects: Australian example). The EPBC Act provides a list of taxa that always require an import permit.

Where imported CITES II specimens are not captive-bred, the wild harvest or ranching program (commercial import program) from which they are sourced must be approved by the Australian Department of the Environment and Heritage before an import permit will be issued. Overseas captive breeding operations do not need to be approved, but the CITES permit issued by the CITES Management Authority of the exporting country must list a source code of ‘C’ (Captive Bred).

Currently the only approved commercial import program is for ranched *Crocodylus porosus* and *C. novaeguineae* from Papua New Guinea.

CITES III

Article V of CITES states that an export permit is required for the export of Appendix III specimens. This relates only to those specimens from the countries listed on the Appendix. Import of specimens from the same species sourced from other countries requires a certificate of origin issued by the exporting country.

Permit Exemptions

CITES Article VII lists a number of circumstances in which a specimen is exempt from normal trade provisions (permits). These include:

- Where a specimen is being transhipped.
- Where a specimen was acquired before the provisions of CITES applied to that specimen (in many cases 1975). In this situation, specimens must be accompanied by a certificate from the exporting country certifying that they were obtained before the species was listed on CITES.
- Personal or household effects (detailed below).
- Captive bred specimens if exported with a certificate stating that it is captive bred (Article VII, paragraph 5). Resolution Conf. 12.10 limits this exemption for CITES I animals to animals bred for non-commercial purposes.
- Non-commercial loan, donation or exchange between scientific institutions registered by their country. These must be preserved specimens and labelled, as required by Resolution Conf. 11.15.
- Specimens that are part of a travelling zoo or exhibition - the requirement for a permit or certificate may be waived provided the exporter or importer registers full details of such specimens with that Management Authority. (Details of requirements can be found in Resolution Conf. 12.3).
Personal Effects: CITES Requirements

Article VII, paragraph 3, and Resolution Conf. 12.9 states that personal and household effects are exempt from permitting. These are specimens that are personally owned or possessed for non-commercial purposes and legally acquired. Personal effects are either worn or carried or included in personal baggage at the time of import or export. Household effects are part of a household move. This exemption does not apply to:

- Specimens of Appendix-I species that are souvenirs being imported by a person returning to his State of usual residence; and,
- Specimens of Appendix-II species that are souvenirs and the exporting State requires the granting of export permits.

CITES Resolution Conf. 12.9 recommends that Parties do not require export or import permits for personal effects of crocodilian species (up to four specimens per person). Once this resolution is fully implemented internationally, there should be no need to issue personal baggage permits.

Personal Effects: Australian Example

Australia does not recognise the household effects exemption but recognises the personal effects exemption in cases such as crocodile products. Australia does not require permits for crocodile products (up to 4 specimens) if imported or exported as accompanying baggage and for personal purposes.

However, not all countries recognise personal effects exemptions and therefore Australia still issues personal effect permits (one dollar crocodile permits). These permits are issued in bulk to manufacturers of Australian crocodile products.

The personal effects permits may be attached to manufactured products such as handbags, belts and wallets that are derived from animals bred under an approved Captive Breeding Program or sourced from an approved Wildlife Trade Management Plan or Wildlife Trade Operation.

A CITES personal effects permit may be used only when the product is leaving the country as hand luggage or luggage accompanying a person on the same flight or ship.

Items exported via post or courier require an individual export permit. The personal effects permits issued to the manufacturers of the products are not valid for export in these cases.

Tagging

Little significant illegal trade in crocodilians has been recorded globally in the last few years due primarily to the successful introduction of a universal tagging system for crocodilian skins exported from range States (COP12 Doc. 54.2). This system was introduced at COP6, approximately 14 years ago. The most recent amendment relating to this provision is Resolution Conf. 11.12.

The CITES Secretariat is responsible for establishing and maintaining a list of approved sources capable of manufacturing tags that meet the minimum tagging requirements. The Management Authority of each Party is responsible for ordering and distributing the tags. In addition, the Management Authority must notify the Secretariat of the details of each order for tags. If requested by the Secretariat, the Management Authority may need to provide further details on tags issued.

Crocodile skins or body parts must be individually tagged before export. The tags are non-reusable and must include the ISO two-letter code for the country of origin; a unique serial identification number; a standard species code; and, where appropriate, the year of production or harvest. The tags must have the following characteristics: a self-locking mechanism, heat resistance, inertia to chemical and mechanical processing, and alphanumeric information applied by permanent stamping.

Enforcement of CITES Regulations

Enforcement of CITES is the responsibility of each Party. In most countries, customs officers are given the task of
enforcing CITES regulations. Governments also are required to submit reports, including trade records, to the CITES Secretariat in Switzerland. To ensure effective enforcement at the international level, the CITES Secretariat acts as a clearinghouse for the exchange of information and liaison between the Parties and with other authorities and organisations.

In order to enforce compliance with CITES obligations, the CITES Standing Committee may recommend suspension of trade with non-complying Parties (either for all CITES specimens or for particular species). These recommendations would be included in Notifications to the Parties, which the CITES Secretariat distributes, usually on a monthly basis. As there are very few countries that are non-CITES Parties, this would severely restrict trade for the suspended Party.

**Literature**


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Lessons We Are Still Learning: Bioeconomic Models of Crocodile Conservation

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Sustainable use is a conservation strategy where the benefits of harvest motivates the recovery of wild populations. Early bioeconomic models failed to identify the drivers that generated conservation outcomes. Such models ignored the effects of age-structure and improvements in product quality. They also omitted investments in habitat or increases in growth rates. The treatment of uncertainty was also poorly modelled. This continues to hamper assessment of conservation risks. This is currently manifested in the promulgation of the sub-optimal precautionary principle as a tool for dealing with uncertainty.

This research presents several simple bioeconomic models. These models are motivated by the recovery of the Australian Saltwater Crocodile. The bioeconomic models demonstrate that slight improvements in their biological or economic realism reverses the pessimistic predictions (eg optimal extinction) of the earlier models.

The models show that from a policy perspective, sustainable use is either the most cost-effective or efficient conservation approach. Incentives to invest in habitat and age-cohort survival rates sustains and reinforces the recovery of crocodilian populations.

Conservation Implications of Harvesting Wild Adult Crocodilians

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Crocodilians have long generation times, high fecundity, and low egg and juvenile survival rates. Consequently, adult females have a high expected value to the population. Harvest of wild adult crocodilians has, therefore, been discouraged by conservation and wildlife trade organizations, such as the CSG and CITES. Ranching has been encouraged as the preferred low-risk option for commercial consumptive harvest of wild crocodilians. Many country and state harvest programs have embarked on capital-intensive ranching programs that have had difficulty maintaining profitability. Harvest programs of large wild crocodilians have lower potential production levels but also have lower capitalization and operational costs, and are usually profitable. Case studies of harvest programs in the United States, Venezuela and Papua New Guinea suggest that adult crocodilian harvests can be sustainable, economical for the primary harvester, implemented with manageable long-term risk to populations, and can have important conservation benefits. Each program has used a different mixture of regulations, monitoring, and enforcement strategies to achieve sustainable harvests. These successes suggest that harvest of adult crocodilians can be considered as a viable harvest option under the right conditions.
Sustainable Use: What Can Kangaroos Tell Us About Crocodiles?

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Two extensions of the current commercial use of crocodiles are under discussion in Australia, a proposal for trophy hunting of large crocodiles in the Northern Territory and a proposal to harvest eggs in Queensland. There are many similarities between kangaroo and crocodile harvesting issues. Both are a pest/problem to some, a resource to others, and iconic for everyone. Commercial use of both has been made possible only after extensive independent and objective scientific research and population monitoring, and extensive public discussion and international lobbying. Because individual States or Territories have responsibility for wildlife within their jurisdictions, harvests depend on research and monitoring at a regional level. This carries implications for the proposed harvest in Queensland where the background independent science remains to be done. Beyond science, however, safari hunting of crocodiles raises questions about humane treatment and stirs the personal distaste of many. This is true of kangaroo harvesting too, which now has community endorsement. Governments respond to community attitudes, and crocodile hunting is unlikely to be approved in Australia until community support grows. Experience with kangaroos suggests that this will follow substantial explanation and education about potential conservation and socioeconomic benefits.
National Progress Report on the Conservation of Chinese Alligator

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This paper describes the implementation of National conservation project for Chinese Alligator in the recent two years especially since the Chinese Alligator conservation project issued one of 15 species conservation projects under the Master Plan on the National Wildlife Conservation and Nature Reserve Construction approved by the National Development and Planning Commission in June 2001. For Anhui Breeding and Research Center for Chinese Alligator (ABRCCA), about 1200 Chinese Alligator hatchlings were incubated and the survival rate of the young crocodiles reached 86% in the Year 2002 and 2003. Meanwhile, the ABRCCA established two new breeding areas, refurbished the fence with the length of 3500 metres and reconstructed the old breeding ponds with the area of 0.7 ha in the Year 2003. In addition, one released pond with the area of 1 ha was constructed and 3 alligators were released to the field (the site named Hongxing, where 4 individuals were counted in 1999 by Ding et al. in 2003). For Changxing Breeding and Research Center for Chinese Alligator (CBRCCA), 163 eggs were laid and 64 hatchlings were incubated in the semi-natural condition in 2003. The area of CBRCCA was enlarged to be 10 ha and 80% breeding habitat restoration was completed in 2003. In addition, the habitat evaluation project was also finished and the results would guide the released site selection and habitat restoration for Chinese Alligator. Finally the paper presents some thoughts on the next step.

Movement Patterns of Released Captive-reared Chinese Alligators
(Alligator sinensis)

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In April 2003, 3 adult captive-reared alligators (2 female F1, F2 and 1 male M1) were released at Hongxing conservation site, Xuancheng, Anhui Province. The home ranges of these alligators were studied through radio-tracking. From April to November 2003, a total of 2124 locations were recorded, comprising 1191 locations for F1, 32 locations for F2, and 901 locations for M1. Soon after release the signal from F2 was lost, but she was re-located while basking in May 2004, with a very weak signal as a result of a broken antenna. Treating these data with minimum convex polygon tells that the home ranges of each individual are: F1, 3.5117 ha; M1, 5.0348 ha. Beginning 3 to 14 days after the release, the three alligators stayed in three different stable areas which had the symbols of territory. The male’s home range is relatively larger than the female’s. Their activity areas were limited by the reservoir’s area. They all tended to stay near the bank where the vegetation is dense. This study suggests that the release of captive-reared alligators can be an effective management technique for reintroductions or restocking this critically endangered species.
Siamese Crocodile (*Crocodylus siamensis*) Surveys in Cambodia

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Abstract

The Siamese Crocodile (*Crocodylus siamensis*) is critically endangered and Cambodia now seems to be the last stronghold of the species. Four years of surveys by the Cambodian Forestry Administration (FA) and Fauna & Flora International (FFI) have revealed that a population of less than 200 adults is widespread and highly fragmented. More than 850 km of rivers and wetlands have been surveyed since 2001, resulting in the discovery of 23 dry season crocodile sites in 6 provinces, most of which are in the southwest of the country. Only two of these sites contain significant numbers of crocodiles, with the majority of sites holding on a handful of individuals. The movement of crocodiles between these sites is poorly understood and research is continuing to elucidate population and distribution dynamics.

The Siamese Crocodiles of Cambodia continue to decline and current threats include habitat destruction, drowning in fishing nets, and the collection of live animals to stock crocodile farms. Evidence of at least 61 crocodiles being taken alive for crocodile farms has been gathered since 2001 but this is probably only a fraction of the real number. This collection continues to pose the single most serious threat to Siamese Crocodile recovery in Cambodia.

FA and FFI are continuing to work at all levels to conserve this critically endangered species, but animals continue to disappear from what is a very small and fragmented population. Unless there is a concerted effort from National and International agencies, this constant drain on the population will have irreversible and disastrous effects for the species.

Introduction

The Siamese Crocodile (*Crocodylus siamensis*) is classified as ‘Critically Endangered’ by the World Conservation Union (Hilton-Taylor 2000), and as such, is one of the most endangered of the world’s 23 crocodilian species. It has been rated by the IUCN-SSC Crocodile Specialist Group as a species with the highest need for wild population recovery (Ross 1998).

Once widespread throughout the waterways of Southeast Asia, the Siamese Crocodile was historically found in Indonesia, Malaysia, Thailand, Laos PDR, Cambodia and Vietnam. Recent reports (Ross 1998) however, suggest that its distribution may have declined by at least 90% and populations in many of its former range states are extremely depleted or extinct. The species is now considered ‘effectively extinct’ throughout most of its former range. Cambodia is now viewed as the last stronghold of the species because several hundred crocodiles still remain, mostly in scattered locations in the Cardamom Mountains (Daltry et al. 2003). A small population exists in southern Laos (Thorbjarnarson 2003), while a small re-introduced population in Vietnam persists despite initial poaching pressure (Murphy and Cong Viet 2002). The status in Indonesia is unknown, but the population is thought to be very low or extinct.

Even within Cambodia where the largest populations of Siamese Crocodiles occur, their numbers have been severely depleted (Daltry et al. 2003). The initial decline was probably caused hundreds of years ago by the conversion and alteration of their wetland habitat for rice cultivation. The continued expansion and cultivation on these wetlands, and the associated development of villages and communities along the rivers and lakes have continued to reduce the suitable habitat for the species. More recently however, the collection of crocodiles to stock crocodile farms has caused a severe decline in their numbers. The first Cambodian crocodile farms were started in 1945 (Chea Peng and Ratanakorn 1993), and the collection of wild animals intensified through the 1980s and 1990s when skin prices were high (Thuok and Tana 1994). Cambodia now hosts over 900 crocodile farms (Thuok, pers. comm.) with most being small-scale village operations.
Although Siamese Crocodiles were first described over 200 years ago, very little is known of their ecology in the wild. Slow moving rivers and freshwater swamps were the preferred habitats described by Smith (1931), but they are also known from lakes and streams (Daltry et al. 2003; Thorbjarnarson 2003). Males may reach lengths of around 4 m, but most are generally less than this size, and they are not known to pose a threat to humans. The relatively broad snout suggests it is a generalist feeder, and Daltry et al. (2003) described a diet comprising fish, reptiles, amphibians, mammals, birds and invertebrates. Although several old nests have been located in Laos and Cambodia (Baird 2001; Daltry et al. 2003; Thorbjarnarson 2003), the majority of information regarding nesting has been gathered from captive animals in zoos or farms. Nesting occurs at the start of the wet season (April/May in Cambodia) where the female lays 20-50 eggs in a mound nest (Youngprapakorn et al. 1971). Incubation takes about 70-80 days but is dependent on nest temperature (Webb and Manolis 1998).

Goals and Objectives

The Cambodian Crocodile Conservation Programme (CCCP) was established in 2001 by the Cambodian Department of Forestry and Wildlife (now Forestry Administration) and Fauna & Flora International (FFI). The Programme was formed in response to the discovery in the year 2000 of a breeding population of Siamese Crocodiles in the Cardamom Mountains in Southwest Cambodia (Daltry and Chheang 2000). This discovery was significant because the species was considered to be effectively extinct in the wild prior to this (Messel et al. 1992). The overall programme objectives aim to conserve the Siamese crocodile through an integrated approach of surveys, research, education, law enforcement, capacity building, and community-based conservation.

This paper summarises the results of Siamese Crocodile field surveys carried out by the Cambodian Crocodile Conservation Programme in Cambodia for the period 2001-2004. The primary objectives of these surveys were to:

1. Confirm the presence, status and distribution of crocodiles in the various rivers systems and waterways.
2. Estimate the minimum number of crocodiles present, based on sightings and sign.
3. Gather baseline data on Siamese Crocodile ecology, including diet, habitat use and nesting.
4. Identify the historic and current threats to the Siamese Crocodiles in Cambodia.

Methods

Surveys were carried out during the ‘dry season’ of 2001-2004. Usually, the surveys started in December and finished when the rains began in April because of rapidly raising rivers and access difficulties. Crocodiles and their sign also became increasingly difficult to locate with increasing water levels. Rain in the mountainous regions in the southwest usually started earlier than in other areas in the country, so by late April and May, the survey team shifted their attention to lowland parts and the northeast. Survey teams usually comprised 2-4 trained CCCP staff, a guide and 1-2 security personnel from the police or military. Local rangers were also encouraged to participate, to help increase their knowledge of crocodiles.

Surveys initially focused on the Cardamom Mountains, in the southwest of Cambodia for the majority of 2001-2003, as this area appeared to be the last stronghold of the species. Towards the end of the dry season in 2003 (May 2003) and 2004 (March and April 2004), surveys were undertaken in other areas in the country (Table 1) after information was gathered through interviews and previous reports.

As many of the areas posed different survey problems, there was no standard technique used to find crocodiles. Often the rivers were shallow for many kilometres or contained numerous rapids or rock bars, resulting in boat drivers refusing to work at night. Or, when rivers were suitable for night surveys, they were often isolated and in uninhabited areas, and so boats were unavailable. The thick riparian evergreen forests found fringing many of the mountainous rivers and lakes made quiet nocturnal surveys by foot virtually impossible.

The majority of surveys were conducted by day on foot, and focused mainly on searching for crocodiles or their sign. Survey teams walked the banks of rivers, lakes and wetlands looking for crocodiles, their tracks, dung or other signs indicating the presence of crocodiles. Sometimes motorised boats or canoes were available for day and night work, and spotlight surveys were undertaken where possible. Standard nocturnal spotlighting techniques were used (see Messel et al. 1981), using torches (flashlights) or headlamps to scan the waters surface to detect the red “eyeshine” of crocodiles. Crocodiles were then approached if possible, to obtain a size estimate. Small oxbow lakes were often spotlighted by foot where the vegetation allowed. The location of all sightings of crocodiles and their sign was recorded using Garmin™ global positioning systems (GPS) or 1:50,000 topographic maps.
To gain an understanding of the population size structure and to help determine the number of different individuals found (based on size) all sign were measured. The maximum dung diameter was measured and then collected for later examination and identification of undigested prey items (see Daltry et al. 2003). Tracks and footprints were measured to give estimates of crocodile size. Front and rear footprints were measured for width and length, as well as the stride and straddle of the tracks (see Daltry et al. 2003). Total length estimates of all crocodiles seen were made to the nearest 50 cm, or in 30 cm (1 foot) intervals.

Using a combination of all crocodile sightings and sign found, and based on their size and location, a conservative estimate of the minimum number of crocodiles was made for each area.

As surveys were undertaken in the dry season, crocodile locations could be described in terms of dry season sites. However, the term ‘site’ is a relative one, and two or more sites may in fact be a continuous area, especially during the wet season. For the sake of this paper we have defined a ‘site’ to include crocodiles (a group or a single animal) that are separated from others during the dry season by natural barriers such as mountains or hills, large waterfalls, tidal waters or at least 10 km of shallow (less than 1 m) river water. Areas along rivers are difficult to define in terms of ‘sites’ and so have been grouped unless there is some form of natural barrier, such as a waterfall. Ox-bow lakes have been classed as the same site as river populations unless individuals in that river are greater than 30km away (this 30 km limit has been arbitrarily chosen and has no real meaning).

Numerous informal interviews were carried out during the course of these surveys. Information gathered from local communities shed light on current and historical distributions and gave insight to current threats. Fishermen were often a wealth of knowledge regarding crocodile distribution, dispersal patterns, hunting pressures and trade, but such information was regarded as a mere “report” until it could be confirmed.

Information was also gathered on various ecological parameters, including the habitat descriptions on locations during the wet and dry seasons where crocodiles were found, and where they were not found. Information on the diet of this species was gleaned through the examination of crocodile dung and the identification of undigested prey items. Keratin (fur, feathers, scales and claws), chitin (arthropod exoskeletons) and enamel (mammalian teeth) pass through the digestive tract largely intact, while bone and soft tissues are completely digested. By examining the undigested remains of prey items, assumptions on diet can be made.

Data was also collected from nesting sites, and nests were examined where possible. Data on nest structure, habitat type and egg characteristics, including clutch age were recorded. Old nest sites were also assessed and notes taken on habitat type, even if the nest was no longer present.

2001: After rapid biodiversity surveys in 2000 had identified crocodiles in several localities in the Cardamom Mountains (Daltry and Momberg 2000), the FFI and FA team chiefly focused on surveying the crocodile population in Veal Veng Marsh, where a community-based management programme was under development (see Daltry 2002a; Hammond and Hor 2002). We also conducted rapid surveys of the nearby Krau and Koi Rivers, and the Phnom Aural Wildlife Sanctuary (Daltry 2002b).

2002: Rapid surveys by three CCCP field teams covered 12 major rivers and associated tributaries on the southern slopes of the Cardamom Mountains, flowing southwest to the Gulf of Thailand. Monitoring (repeat) surveys were undertaken in Veal Veng marsh and Anlong L’Ang on the Koi River (see Daltry et al. 2003).

2003: Numerous biodiversity surveys were conducted in partnership with WildAid (NGO) in central and southern Cardamoms, which included surveying for crocodiles (Cheang et al. 2003; Daltry and Trueholt 2003). Additional monitoring surveys were conducted in the Veal Veng marsh and Areng River populations, as well as a survey in Mondulkiri Province, in eastern Cambodia.

2004: Surveys were conducted in 8 major rivers in the central and southern Cardamoms, which again included monitoring Veal Veng marsh and Areng River populations. Surveys were also undertaken in rivers on Northeastern slopes of Cardamom Mountains, flowing to Tonle Sap Great Lake (Mekong River basin) and in other provinces in the North and East of Cambodia, including Mondulkiri, Ratanakiri, Stung Treng and Preah Vihear.
Results

Distribution and Abundance

Over 40 discrete surveys were carried out over the course of the 2001-2004 dry seasons, which covered more than 40 major rivers and streams (plus additional lakes and swamps). While some surveys may be incomplete, more than 850 km of waterways were examined, confirming at least 162 individuals in 23 discrete dry season sites (Table 1, Fig. 1). Most of these sites and crocodiles were found in the isolated Cardamom Mountains in southwest Cambodia.

Table 1. Confirmed dry season crocodile sites in Cambodia (2001-2004), with a conservative estimate of the minimum number of crocodiles found at each site.

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Site Area</th>
<th>Province</th>
<th>Estimated No. of Crocodiles (all areas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pursat River</td>
<td>Pursat</td>
<td>7+</td>
</tr>
<tr>
<td>2</td>
<td>Pim River</td>
<td>Pursat</td>
<td>1+</td>
</tr>
<tr>
<td>3</td>
<td>Veal Veng Marsh (O’Som)</td>
<td>Pursat</td>
<td>ca. 40</td>
</tr>
<tr>
<td>4</td>
<td>Koi and Krau Rivers</td>
<td>Pursat</td>
<td>14+</td>
</tr>
<tr>
<td>5</td>
<td>Russei Chrum</td>
<td>Koh Kong</td>
<td>1+</td>
</tr>
<tr>
<td>6</td>
<td>Kiew River (Upper)</td>
<td>Koh Kong</td>
<td>3+</td>
</tr>
<tr>
<td>7</td>
<td>Kiew River (Lower)</td>
<td>Koh Kong</td>
<td>1+</td>
</tr>
<tr>
<td>8</td>
<td>Kep River</td>
<td>Koh Kong</td>
<td>10+</td>
</tr>
<tr>
<td>9</td>
<td>Tatai River (Upper)</td>
<td>Koh Kong</td>
<td>2+</td>
</tr>
<tr>
<td>10</td>
<td>Tatai + Touch Rivers</td>
<td>Koh Kong</td>
<td>11+</td>
</tr>
<tr>
<td>11</td>
<td>Tatai River (Lower)</td>
<td>Koh Kong</td>
<td>5+</td>
</tr>
<tr>
<td>12</td>
<td>Areng River (Upper)</td>
<td>Koh Kong</td>
<td>1+</td>
</tr>
<tr>
<td>13</td>
<td>Areng River (Central)</td>
<td>Koh Kong</td>
<td>ca. 30</td>
</tr>
<tr>
<td>14</td>
<td>Trapeang River</td>
<td>Koh Kong</td>
<td>11+</td>
</tr>
<tr>
<td>15</td>
<td>Kompong Chey</td>
<td>Koh Kong</td>
<td>7+</td>
</tr>
<tr>
<td>16</td>
<td>Sre Ambel River</td>
<td>Koh Kong</td>
<td>2+</td>
</tr>
<tr>
<td>17</td>
<td>Kul River, Botum Sakor</td>
<td>Koh Kong</td>
<td>1+</td>
</tr>
<tr>
<td>18</td>
<td>O’Plai River (trib. of Srepok R.)</td>
<td>Mondulkiri</td>
<td>1+</td>
</tr>
<tr>
<td>19</td>
<td>O’Lieou River (trib. of Srepok R.)</td>
<td>Mondulkiri</td>
<td>1+</td>
</tr>
<tr>
<td>20</td>
<td>Sesan River</td>
<td>Ratanakiri</td>
<td>1+</td>
</tr>
<tr>
<td>21</td>
<td>Sekong/O’Chay/O’Kampa Rivers</td>
<td>Stung Treng</td>
<td>10+</td>
</tr>
<tr>
<td>22</td>
<td>O’Kandal River</td>
<td>Preah Vihear</td>
<td>1+</td>
</tr>
<tr>
<td>23</td>
<td>Sen River</td>
<td>Preah Vihear</td>
<td>1+</td>
</tr>
</tbody>
</table>

| TOTAL    |                                          |             | 162+                                   |

In the majority of sites, only a handful of individuals were found. Worrying, the crocodiles appear to be widely scattered and highly fragmented. Only 7 sites were confirmed to hold more than 10 individuals (Table 1), and several of these may in fact be continuous. Only two sites were found to have significant numbers of crocodiles; Veal Veng marsh (site #3) is estimated to contain about 40 crocodiles, while the Central Areng River (site #13) holds an estimated 30 crocodiles (Table 1).

Identifying individuals through spotlight surveys has proved to be difficult, not only because of the difficult river access and boat availability, but because of the wary nature of these crocodiles. Hunting has occurred in much of the country over the last several decades and so the remaining crocodiles have become extremely wary of noise and light, making spotlighting individuals difficult. This may have lead to us considerably underestimating the number of animals in a river or area, when based on spotlight data alone.

Repeat monitoring surveys of Veal Veng marsh, the Koi and Areng Rivers (Cardamom Mountains) were undertaken
in 2002-2004, with no reports or indications that these populations had greatly changed from previous years. There was however a report of one crocodile (approximately 1.2-1.5 m long) being captured and sold from the Areng River in 2004, while another was seen dead on a sand bank after drowning in a net (1.2 m long) also in 2004.

Habitat

Siamese Crocodiles were found in oxbow lakes, rivers (wide slow flowing lowland rivers, narrow slow flowing mountain rivers), streams and marshes. As surveys were undertaken during the dry season, the water levels were at their lowest, and crocodiles were often found in the deepest parts of the remaining water bodies (locally referred to as ‘anlongs’ in rivers). Water was at least 1.2 m deep and slow moving where crocodiles were confirmed. Crocodiles were not found in the shallow water (less than 1.2 m deep) or in the faster flowing sections of rivers or streams.

Basking or haul-out areas were often used, and were all within 10 m of the water. Generally the area was flat with a gentle slope to the water. The substrate on which crocodiles were found to bask differed depending on the surrounding riverside habitat but included sandy and grassy banks and large flat rocks. In swampy areas crocodiles basked on the higher areas which were usually covered in various grasses. The worn paths between oxbow lakes and the river were observed on numerous occasions, and these forested tracks often contained mud smeared on fallen trees, and dung. Some tracks were more than 200 m long and were often used in the dry season when water levels were low, as crocodiles moved between the lake and river.

Riparian habitat disturbance did not seem to affect the distribution of crocodiles along a river system, unless it was associated with current human presence. Areas adjacent to previously disturbed forest, such as an abandoned village or agricultural swidden, still contained crocodiles but this may be because these areas represented relatively small disturbances in large areas of the intact riparian vegetation. Crocodiles were generally not found in rivers adjacent to villages or areas active with human disturbance.

Diet

291 dung samples were collected and assessed for undigested prey items. These samples came from numerous rivers, lakes and marshes, and include samples from a wide range of crocodile sizes, from small to large animals.
Figure 2 represents the results of these pooled data and shows that Siamese Crocodiles seem to be generalist feeders, preying on a wide variety of prey items.

Further analysis is required to determine differences in diet between adults and juveniles or populations in different parts of their range. A large proportion of the dung did not contain any undigested prey items at all, but these samples were usually small sized, and hence from small animals. These crocodiles have possibly been feeding on tadpoles or frogs that were digested completely, leaving no trace of the prey. The larger dung from some areas provided numerous fish scales, while other areas showed few fish scales but many snake scales and mammal hair. This indicates that the dominant prey taken varies in different rivers and probably different times of the year.

Nesting

Four active nests were found in 2004 and are the first wild Siamese Crocodile nests documented in Cambodia. These nests will be described in detail elsewhere but are summarized in Table 2. Nesting occurred at the start of the wet season, with all clutches being laid in April. Hatchlings are expected to emerge in June, but this is dependent on climatic conditions and so may change slightly from year to year. Nests were typical vegetation mounds and 3 were found at oxbow lakes while one was in swamp habitat. Three of the nests were well shaded for most of the day except for the Nest #4 (Table 2) which was mostly exposed on a floating vegetation mat. Clutch sizes ranged from 16 to 25 (Table 2), which is considerably less than the 50 eggs recorded for *C. siamensis* in captivity (Youngprapakorn et al. 1971).

<table>
<thead>
<tr>
<th>Nest</th>
<th>CS</th>
<th>No. Banded</th>
<th>Lay Date</th>
<th>Area</th>
<th>Substrate</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>16</td>
<td>Early April ‘04</td>
<td>Areng R.</td>
<td>Bank</td>
<td>Oxbow lake</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>12</td>
<td>Early April ‘04</td>
<td>Areng R.</td>
<td>Bank</td>
<td>Oxbow lake</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>21</td>
<td>Late April ‘04</td>
<td>Veal Veng S.</td>
<td>Bank</td>
<td>Swamp</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>14</td>
<td>Mid April ‘04</td>
<td>Sre Amble R.</td>
<td>Flt. Mat</td>
<td>Oxbow lake</td>
</tr>
</tbody>
</table>

Three of the four nests were found in the same area as old nests, from either 2002 or 2003, indicating that females show some site fidelity. The nest found from a new area on an oxbow lake, had hatchlings in that lake in 2003 indicating nesting had taken place at that oxbow the previous year.

Nesting information gathered during interviews and from old nest sites corroborated data from active nest sites. A report of a clutch of 27 eggs taken in April 2001 from the Srepok River in Mondulkiri Province, and two clutches of 12 and 15 eggs taken in 1983 and 1984 from a lake in Ratanakiri Province indicate that wild Siamese Crocodiles produce lower clutch sizes than captive animals.
Nests were located at oxbow lakes and swamps (Table 2), but were also reported from the banks of the Srepok (Mondulkiri Province), Pursat and Koi Rivers (Pursat Province). River nest sites were usually within several metres of a deep water section (‘anlong’) of the river and under tree cover.

**Interviews**

Interviews provided useful information on numerous topics, but location data was often found to be out of date. Often the interviewees would inform us of rivers or lakes where crocodiles could be found, but on further investigation this information was found to be no longer true. Often we would learn that poachers had been to the area in the last 10 years or so and had taken most (or all) of the crocodiles from the area. Such reports highlighted the need to follow up on verbal reports with fieldwork, because relying on reports alone could lead to the assumption that crocodiles are abundant in the wild, and this is clearly not the case. Interviews have however revealed that the past distribution and abundance of crocodiles has been greatly reduced. Some areas which had “many” crocodiles now have very few, while the crocodiles in other areas have completely vanished.

Interview data did provide us with numerous reports of crocodiles that had been captured alive for sale to crocodile farms. From 2001-2004, we have recorded at least 61 crocodiles being caught and sold alive for the farming trade. In 85% of these cases, the crocodiles were very young individuals. Many were accidentally caught by fishermen who, rather than letting them go, sold them to traders or farmers. This figure is probably only a fraction of the real number taken, however. The wholesale collection of wild Siamese Crocodiles to stock crocodile farms could ultimately wipe out the remaining wild populations in Cambodia.

**Discussion**

**Status**

The Siamese crocodile populations in Cambodia have been severely depleted and threatening processes continue to affect the remaining scattered groups. Four years of dry season surveys in 6 Cambodian provinces have revealed that Siamese crocodiles are rare and difficult to find. Isolated groups are scattered throughout the country, but seem to be concentrated in the Cardamom Mountains in the southwest. The majority of the 23 confirmed sites contain only a handful of animals and only Veal Veng Marsh and the Areng River seem to hold significant numbers of crocodiles, with both sites confirmed as nesting areas. Both sites are now the focus of community-based conservation strategies aimed to enhance protection and strengthen local enforcement of these crocodile sites (see Daltry et al. this volume).

Although at least 162 crocodiles of all sizes have been confirmed from field surveys, this figure should be viewed as a very conservative estimate. The actual total population in Cambodia is probably considerably larger than this, but unlikely to comprise more than 200 adults. Even though only part of the country has been surveyed so far, the likelihood of finding other significant populations remains low. Most of the areas targeted for surveys so far were selected based on other reports and local knowledge.

Areas around the Tonle Sap Great Lake have been reported to contain wild Siamese Crocodiles (Thuok, pers. comm.), but given the large human population and associated development, the chances of finding substantial crocodile populations seem low. There have however been reports of hatchlings being collected from small lakes around the Tonle Sap over a number of years and so such reports need to be followed up.

**Ecological Parameters**

The baseline data gathered on various ecological parameters over the last 4 years has increased our knowledge of the Siamese Crocodile. Siamese Crocodiles seem to be a generalist species that can be found in freshwater rivers, lakes, streams and marshes. They are known to overland between lakes and rivers and can be found in wide meandering lowland rivers, or steep-sided mountain rivers up to 600 m above sea level. They can be found in rocky, sandy or muddy rivers and seem to feed on a variety of prey, including invertebrates, birds, mammals, reptiles and fish. Nesting occurs at the start of the wet season, where nests can be made on the banks of rivers, lakes or marshes, or on mats of floating vegetation. Nests seem to be found near dry season crocodile sites but contain low clutch sizes, which may result in slow population recovery times if restricting threats are removed.

Although our understanding of the Siamese Crocodiles has increased considerably since 2001, further in-depth studies are still required. Crocodiles are reported to move considerable distances up- and downstream during the
height of the wet season but these movement patterns are very poorly understood. Gaining a greater understanding of the ecology of this species is essential if local and national management and conservation strategies are to be effective.

**Threats to the Crocodiles of Cambodia**

Siamese crocodile populations have been severely depleted over the past century and many of these threatening processes continue today. The Siamese Crocodiles of Cambodia represent the last stronghold of this critically endangered species but continue to face problems that threaten their existence and hamper their recovery.

**Collection of wild crocodiles**

The single most important factor threatening the species at the moment is the continued collection of live crocodiles from the wild. The CCCP has documented 61 crocodiles of all size classes being taken alive for sale in the last 4 years, while hundreds of crocodiles (mostly hatchlings) have been taken from lakes and streams around the Tonle Sap Great Lake in the past 20 years. These wild-caught crocodiles are then sold and usually make their way from the wild into one of the 900 or so small village-based “farms,” and are then traded through middlemen or other farms, probably ending up in the larger CITES-registered farms. From here they can then be traded internationally with relative ease. There is also a thriving illegal cross-border trade to Thailand and Vietnam.

As all crocodiles are protected by law in Cambodia and listed by CITES, this is clearly illegal and opens whole suite of measures that need to be addressed. Farm monitoring needs to be stepped up, education and awareness programs initiated and stricter policing measures enacted. The core problem of Cambodia’s lack of compliance with CITES, amongst others, needs to be solved before there can be any chance of a population recovery of Siamese Crocodiles in the Cambodia.

**Habitat Destruction**

The alteration, destruction and disturbance of wetland habitats continue as the human population strives to provide enough rice and agricultural produce for its increasing demands. Even though Cambodia’s population is still small by Asian standards, the destruction of land titles during the Pol Pot Period and unfair land distribution after the war means that many poor farmers are moving into wilderness areas while good farmland lies unused. Floodplains and wetlands continue to be converted to lowland rice growing areas, while the clearing of land for slash and burn agriculture is common in forested habitats. Not only does such alteration disturb the crocodiles with the associated human disturbance, but it also has the potential to destroy nesting habitat, cause soil erosion along river banks, increase pollutants in waterways through chemical and fertiliser run-off, and decrease the prey-base on which crocodiles depend.

Cambodia does need to increase its agricultural output to sustain its rapidly growing population and to provide economic stability, but the ad-hoc and uncontrolled wholesale destruction of the forests and waterways is not the answer. Protected areas should be exactly that - protected - and not be exposed to the destructive nature of the various agricultural practices. The permanent alteration of habitat, especially along waterways, whether in protected areas or not, should be regulated to stop the destruction and degradation of riparian vegetation right to the water’s edge. To achieve positive long term benefits for the crocodiles, the environment and the people of Cambodia, a more sustainable approach to land distribution and conversion is required.

**Fishing Practices**

Unsustainable fishing practices are also used frequently in Cambodia, which can have detrimental affects on crocodiles and their habitat. The use of explosives, poisons and electro-fishing equipment continues to pose a serious threat to the existence of crocodiles in some regions. Crocodiles have reportedly been killed as a result of explosive fishing (Daltry et al. 2003).

With 75% of Cambodia’s protein coming from the fisheries sector, numerous waterways are heavily netted. This means that crocodiles frequently encounter nets, traps or set hooks, and are often caught. Drowning in nets, although not frequently reported, does occur, with the smaller animals being more susceptible. Some fishermen complain that large crocodiles destroy their fishing nets by tearing holes in them, and this can lead to killing out of retribution. Drowning in nets continues to pose a threat to the recovery of Siamese Crocodile populations, especially in areas where breeding occurs.
Killing of Crocodiles

Killing out of fear, retribution or for meat and skins, although not common, does occur. In 2004, a “large” crocodile was reportedly shot and killed after it killed a family dog in the Areng River. Reports of crocodiles being shot and skinned have been received over the past few years, with the skins of these animals usually being sold across the border to Vietnamese buyers. There have also been reports of crocodiles being killed for food although this does not seem to be a common practice.

Next steps

In respect to Siamese Crocodile conservation in Cambodia, the main priority for fieldwork is to gain a better and more complete understanding of the status and ecology of the species. Although the CCCP surveys have covered numerous river systems, especially in the Cardamom Mountains, many of the status surveys carried out to date were very rapid should be viewed as preliminary appraisals. Even areas such as Veal Veng Marsh and the Areng River, which have been visited on numerous occasions over a number of years, are still poorly understood with respect to crocodile numbers and population dynamics. More intensive surveys, perhaps using mark-recapture methods or camera-trapping, need to be conducted at these and other significant crocodile sites to gain a better understanding of crocodiles’ numbers and population biology.

Baseline surveys also need to be extended to new areas and provinces, to follow up any and all verbal reports to identify remaining populations. This will be essential to provide a more comprehensive understanding of the status of the Siamese Crocodile in Cambodia to inform the development of an appropriate national conservation strategy. As each significant ‘new’ colony is found, the CCCP will notify local authorities, communities and conservation agencies, and advise and assist them to safeguard the crocodiles and their habitat.

Although useful baseline data have been collected on various ecological parameters over the past 4 years, there is now a real need to carry out more in-depth research on the behavioural ecology of Siamese Crocodiles in the wild. In particular, the movement patterns of crocodiles within, and between sites, will be crucial to the development of relevant strategies: It is essential to know which of the known colonies are connected and which are genetically isolated. To gain a better understanding of the mobility of these populations, we intend to conduct a telemetry study during 2005.

Further studies also need to be conducted to answer and elucidate questions of seasonal and size-related movement patterns, habitat preferences and partitioning, reproductive and feeding strategies, and the use of burrows. The better our understanding of the needs and habits of the Siamese Crocodile, the more likely it is that Cambodia’s conservation strategy will be appropriate and ultimately successful.

Acknowledgements

First and foremost, we would like to thank Jenny Daltry for her outstanding work at all levels in this Programme. Not only did she initiate this programme 4 years ago, but she continues to juggle fieldwork, politics, management issues and fund-raising to provide continuing support for the Siamese Crocodiles of Cambodia.

We also thank the Director of Forestry Administration, Mr Ty Sokun, for his continuing approval of this project, and the many district and provincial governors who have kindly permitted our field surveys over the years. Field surveys in protected areas were also conducted with the approval of the Department of Nature Conservation and Protection (Ministry of Environment).

Numerous colleagues and associates from Forestry Administration and Fauna & Flora International participated in field surveys, training and interviews (in alphabetical order by family name): Aing Leang Heng, Ay Rothmony, Ian Baird/Liesje Bircheneough, Ponn Chamroeun, Chheang Dany, Em Thol, Mark Elliott, Matt Fox, Ben Hammond, Heng Sovannara, Hor Leng, Jeremy Holden, Jeremy Ironside, Keo Nara, Kuy Tong, Barney Long, Oliver Maxwell, Frank Momberg, Nhek Ratanapich, Oum Sony, Richard Paley, Sorn Piseth, Poeung Mora, Sok Sokhoeun, Sok Vannaren, Steven Swan, Tan Thara, Tith Bora, Hunter Weiler and Yeav Chhunlak. We also benefited from the help of literally dozens of military police, police, rangers, soldiers, fishermen and other local community members.

We also thank the Community Wildlife Rangers Project, Department of Fisheries, Conservation International, WildAid, Wildlife Conservation Society and World-Wide Fund for Nature for their assistance in various surveys.
Financial support was provided by the Association for Cultural Exchange, British Embassy, Canada Fund, Columbus Zoo and Aquarium, Conservation, Food and Health Foundation, Conservation International, Disney Wildlife Conservation Fund, Ellen Trout Zoo, The Heinrich Boell Foundation, Keidanren Nature Conservation Fund, and Singapore Zoological Gardens. Last, but not least, we thank the IUCN/SSC Crocodile Specialist Group for technical support and encouragement.

**Literature**


Conservation of the Critically Endangered Siamese Crocodile in Lao PDR

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Abstract

In February and September 2003 we visited sites in Attapeu and Savannakhet Provinces in southern Lao PDR to collate information on the status of wild crocodiles and develop plans for a national conservation effort to be coordinated through LARReC. Based on recent reports and signs we found at the Bung Khe site in Attapeu, a small population of crocodiles remains in the remote headwaters of the Xe Kong River system. However we were surprised to find that there appears to be a larger breeding group of crocodiles in the lower Xe Champhon River system and associated wetlands. A very small group also remains in the Xiabouli district in northwestern Savannakhet, close to the Mekong River, where evidence of a nest from 2002 was found. In most areas in this region of Lao PDR crocodiles are considered to be sacred animals and a community-based program that focuses on management of wetlands will likely be the most productive approach to crocodile conservation.

Background

The Siamese Crocodile (Crocodylus siamensis) is one of four species of crocodilians considered to be Critically Endangered by the IUCN Crocodile Specialist Group. Siamese Crocodiles were at one time widespread in lowland wetlands in southeastern Asia, but have suffered from the widespread loss of its wetland habitats, as well as intensive persecution for its skin in the 20th century. The war-ravished region of Indochina was off-limits to biological surveys until recently, and while some wild groups remain in parts of Cambodia, surveys have shown that the species has all but disappeared from Vietnam and Thailand. Siamese Crocodiles were also known historically from Java (where they are now presumed to be extirpated), and may still remain in unknown numbers in some of the backwaters of Kalimantan (Borneo). The status of crocodiles in Lao PDR, however, remains unclear.

The Siamese Crocodile is the only crocodilian known from Laos. It is listed by the IUCN as Critically Endangered, and is protected in Laos under Management Category 1. Historically, Siamese Crocodiles are thought to have been widely distributed in low elevation wetlands in Lao PDR. Much of Laos is mountainous, and suitable crocodile habitat (lakes, ponds swamps, marshes) is mainly restricted to the lowland areas along the Mekong in southern and central Laos, but there is little information on this species and its current and past distribution are poorly understood. Historical accounts indicate that crocodiles were seen in the Mekong River in Laos, particularly during the annual dry season. During the 1860s French Mekong expedition crocodiles were reported from the vicinity of Bassac (Champasak), Laos (Garnier 1996). In the 1880s, victims of cholera epidemics were disposed of by placing their bodies in the Mekong where they were consumed by crocodiles, which were said to be quite common in parts of the river (Neis 1997). Bassenne (1912) mentions that a favorite pastime of passengers on some boats ascending the Mekong was to shoot at crocodiles lying on sandbars near the town of Pakxan, just east of Vientiane. Smith (1931) stated that this species extends northward along the Mekong to about latitude 16°N, with one specimen known from Kemarat (Khemmarat), along the Mekong (which forms the border between Laos and Thailand).

In the 1950s and 1960s crocodiles were reported to be common in permanent water bodies along the Nam Lepou River, which forms the Cambodian-Lao border west of the Mekong. Salter (1993) mentioned several areas where crocodiles were historically reported in northern Laos including two areas near the capital of Vientiane; the Nam Ngum River wetlands and the Phou Khao Khouay protected area (Nam Xan, Nam Leuk, Nam Gnaang, Nam Mang). Another site even further north (ca 19° N) along the Mekong (Nam Poui protected area) was also reported by Salter (1993) to have had crocodiles as recently as the 1950s. A single individual was reported killed at the mouth of the Nam Ma (nearly 21° N) in 1990 but this was considered to be extralimital by Salter (1993).
Present Status of Crocodiles in Lao PDR

No systematic surveys for crocodiles have been carried out in Lao PDR. The status of crocodiles in Laos has been reviewed recently by Stuart (1999) and Stuart and Platt (2001), but information is based largely on anecdotal reports from interviews with local residents.

Some photographic evidence has recently documented the continued presence of Siamese crocodiles in the Phou Khao Khoutay National Biodiversity Conservation Area (NBCA). Based on visual records and sign (fresh feces, tracks), a breeding group of unknown size is believed to remain in the Bung Khe wetland system in northeastern Attapeu Province. This site has been visited on previous occasions by LARReC staff, and personnel from the Xe Pian NBCA (see below) and may represent one of the best remaining areas for crocodile conservation in the country. Crocodiles have also been documented from at least two sites in Savannakhet province (Baird 2001; Matheus 2001).

Objectives

1. To evaluate the status of crocodile populations within the Champhone, Xonbuly, Xaibouly Districts in Savannakhet Province and Sanamxai District Attapeu Province.

2. To provide broad recommendations for future conservation and management initiatives in the area.

Field Visits

In 2001, WCS began to work jointly with LARReC (Living Aquatic Resource Research Center) and the National University to initiate a conservation program for the Critically Endangered Siamese Crocodile. In February 2003 an initial visit was made to sites in Attapeu and Savannakhet Provinces in southern Lao PDR. Over a 12-day period we visited three sites and compiled information on reports of crocodiles.

In a subsequent survey in September 2003, the survey team conducted interviews in 8 villages, and daytime surveys in grasslands and bamboo and deciduous forest near wetlands. It was not possible to do nighttime surveys because the water levels were extremely high as a result of the early monsoon season rains.

Bung Khe wetlands, Attapeu Province

Location. Sanamxai District, in the Xe Pian River drainage along the southwestern slopes of the Bolovens Plateau. Two ponds were visited, Nong Khe (N 14° 42' 08.5" E 106° 28' 09.4") and Nong Ke (N 14° 42' 36.6" E 106° 27' 53.5"), just 2-3 km to the N and NE of Pindong village (N 14° 41' 36.2" E 106° 27' 29.6") situated along the old road that extends W from Sanamxai village.

Habitat. Bung Khe means crocodile marsh in the Lao language. Within this seasonally flooded area there are a number of permanent water bodies or ponds referred to as “nongs” in Lao. These ponds are dry season remnants of an extensive floodplain situated to the west of the Xe Pian River. This area is composed of a total of seven wetlands over an area of approximately 700 ha: Pa Tookhong wetland, Pa Tookhong wetland, Duak wetland, Phou Lon wetland, Dindeng wetland, Khea wetland and Thom Niam wetland nearby Pindong village. Many of the wetlands we visited were along a water course that is formed by a Pliocene-Pleistocene lava flow blocking surface water drainage to the south, creating a drainage system that feeds SE into the Xe Pian River. The plain is dominated by dry evergreen, dipterocarp and bamboo forest, and the ponds are shallow wetlands covered almost entirely by thick mats of floating vegetation (Eichhornia, Salvinia, Nymphaea, and Imperata cylindrica) sedges, Araecea, ferns) with very little open water habitat. The smaller pond (Nong Khe) was estimated to be approximately 20 ha in size and the larger one (Nong Ke) 200-250 ha. We were told that there were other small nongs to the north and that crocodiles had been reported from these as well. Bung Khe wetlands resulted from natural pond which has 700 ha of good crocodile habitat.

Human Use. There are four nearby villages that regularly use the Bung Khe wetlands (Ban Pindong, Ban Hinlat, Ban Samongneua, Ban Samontay), and the total human population in the area has been estimated at 3000 (Phiapalath et al. 2001). Fishing appears to be an important economic activity, particularly in the dry season, primarily for catfish and snakeheads. During our nocturnal survey fishermen were seen at both ponds we visited. Fishermen were reported to use hook and line and also basket traps. The edges of the ponds are also used extensively by water buffalo from nearby villages. In the late 1990s, a Vietnamese company surveyed the site to determine the economic feasibility of
extracting peat to be used as a bio-fertilizer. This company cut a road to Nong Ke through the forest, but abandoned the venture due to the unsatisfactory quality of the peat in the region.

The villages around Bung Khe are largely a mixture of ethnic minorities and the use of the wetlands has been guided to a large extent by traditional systems. The ponds themselves are considered to be sacred, and fishermen can only use traditional fishing techniques, and fish are only to be used for local consumption, not for sale.

**Crocodile Status.** This site has recently been considered as one of the last and best remaining populations of the Siamese Crocodile in Laos (Stuart 1999; Stuart and Platt 2001). Initial reports of crocodile in Bung Khe came from the Forestry Department in Attapeu Province. These reports sparked a visit to the area by WCS personnel in 1997 (D. Davenport, R. Tizard and V. Phommauangsa) who found abundant crocodile sign and heard a crocodile vocalization. LARReC personnel have made previous visits as well, and in 1998 one of us (C. Phottiy) got a brief glimpse of a crocodile in Nong Ke. Local residents report the crocodile population in the past numbered thousands of individuals, but there appears to be little basis for this estimate.

During our interviews, residents of Ban Pindong reported having seen juvenile crocodiles, suggesting that successful reproduction is taking place. However, residents had no idea of how crocodiles made nests.

During our visit we found fresh crocodile feces at a basking site in Nong Khe (from an adult-sized crocodile), and saw crocodile trails in the floating vegetation on Nong Ke. However, during our nocturnal survey (1.0 km of shoreline total at these two sites) were saw no crocodiles. Local residents report that the early rainy season (June) is the best time to see crocodiles, particularly in Nong Ke). They also indicated that crocodile would leave the ponds and enter the Xe Pian river at times during the wet season. In a nearby temple in September we found a crocodile that was reportedly given to the monks by local people. The monks did not know where the crocodile had been caught.

Our overall conclusions were that the Bung Khe wetlands contain a small number of crocodiles but that much more survey work is needed. The crocodiles in this area may be part of a diffuse population that exists in the Xe Pian, the Xe Kampho, and the lower Xe Kong River system in southernmost Laos. The adjacent Xe Kong system in Cambodia is also an area from where crocodiles have been reported.
**Conservation Issues**: Crocodiles were reportedly captured and sold in Attapeu prior to 1993 (Phiapalath et al. 2001), presumably for sale to farms in Cambodia and Thailand. However, we found no indication that commercial trade exists today.

The Bung Khe wetlands appear to offer suitable habitat for the Siamese Crocodile, however human use of the area presents a number of conflicts. The presence of fishermen in the ponds is a potential source of disturbance, and the use of basket traps could lead to crocodile mortality by drowning. The quality of the habitat is also degraded by the presence of water buffalo, which move in large groups along the edge of the ponds trampling vegetation and destroying the shoreline habitats preferred by crocodiles.

The Bung Khe region is situated very close to the boundary of the Xe Pian NBCA, a 240,000 ha protected area, one third of which is in Attapeu Province and which includes parts of the Xe Kampho, Xe Kong and Xe Pian lowlands. Attapeu Province has also declared a number of provincial protected areas (PPA), including the Nam Kong PPA (205,000 ha) in the southern third of the province (linking with the Virachay National Park in Cambodia). Another Attapeu PPA is the Xe Kampho floodplain linking the Xe Pian NBCA with the Bolovens escarpment. This latter area may potentially include the Bung Khe area.

Aside from Siamese Crocodiles, the Bung Khe region is also reported to harbor other wildlife species including leopards, leopard cats, jungle cats, otters, pangolins, gibbons, gaur, sambar deer, woolly-necked storks, green peafowl, Bengal and water monitors, king cobras and several species of turtles (Phiapalath et al. 2001; Davenport et al. 1997).

**Conservation Recommendations**
1. More survey work is needed to quantify the area of wetlands habitat and the presence/status of Siamese Crocodiles in the Bung Khe wetlands.
2. Surveys should be conducted as part of a larger effort in the lower Xe Kong, Xe Kampho and Xe Pian River systems in southern Laos.
3. Surveys should include the active participation of local communities. This activity also promotes local understanding about conservation and builds local capacity for future project implementation.
4. Initiate discussions with the four villages that share resource-use rights for the Bung Khe area concerning potential and views towards community-based management of this area.
5. Seek funding for community-based protection of the wetlands and the crocodile population
6. Consider the potential for linking management of the Bung Ke site with the adjacent Xe Pian NBCA.

**Ban Beung Boua Thong and Ban Nao Neua Lakes, Savannakhet Province**

**Location**: Three ponds along the south shore of the Xe Bangfai River adjacent to the villages of Ban Beung Boua Thong and Ban Nao Neua, Xaibouli district in northwestern most Savannakhet province. Two ponds were visited: Nong Boua (N 16° 59’ 06.6” E 104° 53’ 14.6”) and Beung Saiyan (N 16° 59’ 56.8” E 104° 52’ 17.2’’)

**Habitat**: Nong Boua is a small pond (ca. 500 m x 100 m) located immediately adjacent to the Ban Nao Neua village. At the time we visited water level was low, exposing a open sandy fringe around much of the lake. The northern edge of the lake is an evergreen forest. Although the lake was reported to have floating vegetation (mostly Eichhornia) in the past, recent bio-controls have resulted in the water body being completely free of any type of floating plants. Beung Saiyan was a much larger (ca 800 m x 5000 m) marshy area filled with extensive rooted aquatic vegetation. During the annual wet season the size of the lake grows as it floods out into areas used for agriculture during the dry season. We did not visit the third lake (Beung Boua Thong), but this lake is reported to be similar to Nong Boua but somewhat larger in size (Baird 2001).

**Human Use**: Two of the three nongs are considered to be sacred by the local communities and no fishing is allowed. The third nong, Beung Saiyan is used by eight different communities for fishing, including the use of gill nets. The seasonally exposed fringes of the marsh are also used for rice paddy and other agriculture.

**Crocodile Reports and Status**: Crocodiles were reported from this site by Baird (2001) and their presence here is well known throughout the province. Villagers are unsure of the number of number of crocodiles, but regularly see one adult (?) in Nong Boua that is very tame and frequently fed. Villagers also made reports of a larger animal (?) that moves between ponds, and smaller animals seen on occasion in Beung Saiyan.

During our visit we saw the Nong Boua crocodile (ca. 2.8-2.9 m total length) and were able to approach it closely and
take photographs. This animal is extremely tame and very used to people, and will occasionally take dogs and pigs that walk around the edge of the pond. This animal is presumably a female as it is the one that has been reported nesting by residents of the nearby village. The reproductive status of this group of crocodiles, however, remains unclear. Baird (2001) reported that the female would nest annually at one location near Beung Boua Thong, but that villagers reported the eggs never hatched. The female has apparently changed locations as she nested in the forest ca. 200 m from Nong Boua in June 2001. Villagers reported that during the previous year the crocodile had been found in the forest and was thought to be ill, so they tried to construct a shelter to cover her but gave up when she became aggressive. They assumed that she nesed here but had no clear idea what the nest actually was. We visited the nest location and found the remains of a nest mound, now composed primarily of dried mud, along with the remains of eggshells and 3 decomposed eggs. The female crocodile was reported to have spent at least one month out of the water near the nest. While it is clear that nesting is taking place the fate of the nests is unknown and requires follow-up.

**Conservation Issues.** While the residents of the two villages consider the crocodiles and the two smaller ponds to be sacred, these areas do not support adequate habitat for even a small group of crocodiles. However, the third pond, Beung Saiyan, is much larger and could potentially support a small population of crocodiles. However, community resource use in this pond is fairly intense, including fishing and seasonal agriculture.

**Recommendations**
1. Conduct a more detailed survey of wetlands and crocodiles along the lower Xe BangFai and associated wetlands
2. Initiate a dialog with villages that use the Beung Saiyan wetland and evaluate the potential for community consensus to develop a management plan for this pond that would favor the survival of crocodile—perhaps linked to ecotourism.

**Xe Champhon Wetlands, Savannakhet Province**

**Location.** In February and September 2003 we visited a limited area including a series of oxbow lakes along the western edge of the Xe Champhon River to the southeast of the village of Laonat (N 16° 22’ 31.3” E 105° 10’ 52.3”). In September we also surveyed wetlands near the villages of Taleo and Donedeng, to the east of Laonat and on the opposite side of the Xe Champhon River.

**Habitat.** We saw three oxbow lakes that were surrounded primarily by bamboo forest and a riparian fringe of *Mimosa* sp. The overall area contains approximately 300 ha of natural wetlands and another 500 ha of habitat flooded by the construction of small dams. The lakes were a mixture of open water and heavily vegetated areas with an abundance of water hyacinth (*Eichhornia* sp.). Along the western bank of the Xe Champhon River an irrigation project had dammed three smaller streams (Houy Mark My, Houy Kadane, and Houy Nong Ing), creating rice paddies and a series of marshy reservoirs and flooding and killing areas of deciduous forest. These reservoirs and inundated forest also appear to provide good crocodile habitat. The area we visited comprises just a small part of what (according to topographic maps) consists of a series of oxbows and other wetlands in the lower Xe Champhon, Nong Louang, Xe Xangxoy region. There are approximately 300 ha of wetlands around the Taleo and Donedeng villages formed by damming a small stream.

**Human Use.** The village of Laonat is mostly dedicated to agriculture, but the lakes are fished by this and other villages, particularly during the annual dry season. Fishing is done by hook and line, with baskets, and with gill nets.

**Crocodile Reports and Status.** Crocodiles were reported in this area by Salter (1993), who considered the lower Xe Champhon-Nong Louang wetlands to be one of three sites in Laos where viable populations of crocodiles may still remain. Salter (1993) reported that breeding was occurring in the oxbow lakes along the Xe Champhon and this appears to still be the case. There have been recent anecdotal reports of crocodiles being seen in the Nong Louang, a large permanent water lake located upstream of the confluence of the Xe Champhon and Xe Banghiang rivers. Also, a recent sighting (1998) of a juvenile crocodile in a pond near the village of Ban Nathom (Atsaphone district) is significant (Matheus 2001). This site is much further upstream in the Xe Champhon system, approximately 55 km NE of the Laonat site. The fact that it was a juvenile suggests that reproduction is still taking place in the area. Also, Matheus reports that the ethnic Phuthai from Ban Nathom considers the pond and the surrounding area sacred.

In September we conducted a brief visit to the Done Yanong wetlands, situated near the confluence of the Xe Champhon and the Xe Banghiang. This is an natural wetland of approximately 500 ha with three major ponds: Kout Kuang Yai,
Kout Kuang noy and Kout Kok. This area is about 500 ha with good crocodile habitat nearby paddy fields of the village. The ponds have some Eichhornia, Salvinia, Nymphaea lotus and Imperata cylindrica. We did our surveys by boat and walking. In this area we could not see any crocodile because of the flooding but local people estimate there are >20 crocodiles in the region.

In the small area we visited in February there were indications of that there had been at least two nests in 2002. One nest was reportedly collected by residents of Laonat and brought back to the village to incubate (Nong Kout Phinoy N 16° 20’ 51.8” E 105° 13’ 17.7”). Another nest in an adjacent pond (Nong Kout Mark Pheo N 16° 21’ 16.1” E 105° 13’ 02.3”) was found by a rice farmer in the area but left untouched. In November, the farmer reported seeing a group of ca. 30 hatchlings at night in a rice paddy bordering a vegetation-choked stream, with a vocalizing adult nearby. In September we were shown a hatchling crocodile that had drown after being caught in a fishing trap. The descriptions of nests (here on floating mats of vegetation), nest timing (during the wet season), and the behavior of juvenile and adult crocodiles adds veracity to the reports of the local residents we interviewed. A small number of crocodiles were reported to be in the Taleo and Donedeng wetlands and villagers reported having seen hatchlings in the recent past.

Taken together, these reports suggest that a small reproductive population of Siamese crocodiles is found along the Xe Champhon River system.

Conservation Issues. The reason why the Laonat villagers would collect and incubate eggs is unclear. Some people indicated that this was done for the novelty of the experience. However, past commercial trading for live crocodiles and skins is known from this area (Salter 1993) and there still may be a market for live animals to be sold to Thailand or Cambodian crocodile farmers.

The Xe Champhon- Nong Louang wetland system may comprise the best remaining area of Siamese Crocodile habitat is Laos. The area is currently unprotected and is subject to increasing pressure from agriculture and fishing. Due to the area’s proximity to the city of Savannakhet (1 h by car), this region could potentially develop alternative uses for these wetlands based on ecotourism.

Recommendations.
1. A high priority should be given to surveys of wetlands habitat, crocodiles, and land-use patterns in the Xe Champhon-Nong Louang region.
2. A workshop should be organized in Savannakhet to bring together a range of stakeholders, including government officials, leaders of villages from the Xe Champhon region, and ecotour operators, to discuss the potential for nature-viewing trips to this area and how this could be used to generate economic incentives to protect crocodiles/wetlands.
3. Initiate meetings in the principal villages in the region to discuss resource-use issues in these wetland habitats and their management.
4. Consider declaring this a new provincial or national protected area.

Discussion

As a principally marsh and lake dwelling species, natural habitat for this crocodile may never have been extensive in Laos. The principal habitats of Siamese crocodiles in lowland areas were probably oxbow lakes and other wetlands associated with the lower courses of Mekong tributaries, particularly in the central and southern provinces. Furthermore, it is these lowland marsh and pond habitats that are usually among the first to be affected by agriculture. Today, there appear to be relatively few areas of this habitat that do not receive intensive human use in the form of fishing, agriculture, harvesting reeds for mats, or as water buffalo resting sites. Another area of potential habitat is relatively slow moving sections of rivers and streams, and their associated wetlands, in low hills (to about 500 m elevation). It is these areas where the last remnants of Siamese crocodile populations appear to be surviving in Thailand, and where some of the best remaining groups are found in Cambodia.

Based on previous reports and the results of these preliminary visits, it is apparent that small groups of Siamese Crocodiles remain in at least three locations in Laos. Crocodiles may still be found in other areas in Laos, and further surveys in hill regions (eg Phou Khao Khoay NBCA, Xe Bang Nounan NBCA, Dong Phou Viang NBCA and the middle-upper reaches of the Xe Kaman) are clearly warranted.
However, the two most promising areas for Siamese Crocodile work in Lao PDR are:

1. Bung Khe wetland system in northeastern Attapeu province. A remnant population of Siamese Crocodiles is found in this area and potentially others in the nearby Xe Pian National Biodiversity Conservation Area.

2. The Xe Champhon and Xe Banghiang River systems in southern Savannakhet Province. Crocodiles are scattered throughout a series of natural and artificial wetlands along the Xe Champhon and upstream sections of the adjacent Xe Banghiang.

At these lowland sites most local communities appear to have a relatively benign attitude towards the crocodiles, or even consider them to be revered animals. This will provide a firm basis for developing community-based conservation programs, using crocodiles as a flagship species to protect these valuable wetlands. Linking this in with the growing tourism industry in Lao PDR, and the great interest in ecotourism, could provide a mechanism for local communities to benefit from the protection of wetlands and wetland fauna. For these sites, the approach first outlined in a WCS-Lao project proposal (B. Stuart and S. Platt) offers an excellent strategy based on a four-step process:

1. Gather baseline biological and socioeconomic information from the wetlands where Siamese Crocodile populations are known to still exist.
2. Use the results of the baseline biological surveys to identify the wetland that has the greatest likelihood of supporting a viable population of crocodiles. Designate this as a pilot wetland for management of Siamese Crocodile. Use the results of the biological and socioeconomic surveys to design a crocodile management plan for the pilot wetland.
3. Implement the crocodile management plan for the pilot wetland. Implement a biological and socioeconomic monitoring system that is designed to measure if and how the management plan is working to conserve Siamese Crocodile and meet the expectations of village and district managers.
4. Summarize results from the biological and socioeconomic monitoring. Report on lessons learned and use results to revise the management plan for the next phase.

The first step will require two components, a biological survey of the wetland habitats to estimate the status of the remaining crocodiles, and a socioeconomic survey of the communities that use those wetlands.

**Recommendations**

Overall recommendations are to:

1. Carry out more detailed surveys of wetlands, crocodile status, and land use/socioeconomic characteristics of communities around the three target wetland sites.
2. Use this information to plan a pilot wetlands conservation project with the Siamese Crocodile as the focal species.
3. Promote a public awareness campaign to build local understanding about the conservation significance of the crocodile and make a link between local livelihood as well as the wetland in the region.
4. It is highly recommended to develop and conduct long-term participatory monitoring of the crocodile. In addition to determining the population trends to help identify existing or potential management problems and possible solutions. This activity also promotes local understanding about conservation and builds local capacity for future project implementation.
5. Investigate the potential for using managed ecotourism as an alternative source of income, linked to wetlands and crocodile conservation, for local communities around the two areas in Savannakhet.

**Literature**


Overview and Conservation Priorities for the Philippine Crocodile

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Introduction
The Philippine Crocodile (Crocodylus mindorensis), or “Buwaya”, is a relatively small freshwater species averaging 1.5-2.0 m in total length, with adult males reportedly reaching 3.0 m (Brazaitis, 1973; Ross, 1998). It is one of only two species of crocodiles naturally occurring in the Philippines, the other being the much larger Estuarine or Saltwater Crocodile, C. porosus, which can also be found in many other parts of south and southeast Asia.

Very little is known of the ecology of C. mindorensis and information on its reproduction, growth and behaviour is still based largely on captive animals.

Conservation Status
Previously distributed through many parts of the Philippines, it is now thought to only exist in the wild as small remnant populations and scattered individuals in central and eastern Mindanao, and northeast and northwest Luzon (Ortega 1998; Pontillas 2000; van Weerd and General 2003; G. Rebong, pers. comm.). Anecdotal reports of crocodiles still to be found on Busuanga Island, Lake Naujan on Mindoro, and in southwest Negros Occidental have yet to be substantiated or their numbers clarified. The general consensus in 1997 was that no more than 100 adults remained in the wild (Ortega 1998). Whilst the real number may be higher than that, in view of known breeding groups in northern Luzon, there is no question that the species remains severely threatened.

Indeed, the Philippine Crocodile is now recognised by the IUCN/SSC Crocodile Specialist Group (CSG) as among the most threatened species of crocodiles in the world and is listed by the IUCN as Critically Endangered (IUCN 2002). It is legally protected in the Philippines and is listed on Appendix I of the Convention on International Trade in Endangered Species (CITES).

Initiating a Conservation Program
1. Local Management Initiatives
The Philippine Government wildlife agency responsible for the country’s wildlife is the Department of Environment and Natural Resources (DENR), particularly its Protected Areas and Wildlife Bureau (DENR-PAWB). However, like all Philippine Government agencies, the DENR-PAWB is desperately short of resources, especially appropriately trained staff and reliable funding. An additional issue facing all wildlife conservation in the Philippines is a worrying lack of knowledge and understanding of the country’s wildlife, even to the level of the national wildlife agency, due in large part to the lack of appropriate texts for students in school and university. The latter problem is slowly being addressed, but we still very much have a situation where successful development and delivery of conservation programs in the Philippines relies very heavily on DENR-PAWB staff working closely with overseas partners who have the necessary background, commitment and expertise.

The first substantive concerns about the status of C. mindorensis were tabled in 1983 following a distribution-wide survey in 1982, which estimated the wild population at 500-1000 mature individuals (Ross and Alcala 1983). This led to the Philippine Government implementing measures to address the plight of both species of crocodiles in the Philippines. As a consequence, a joint venture between the Japanese and Philippine Governments to create the Crocodile Farming Institute (CFI) was established at Puerto Princesa City on Palawan Island in 1987.

A much smaller captive breeding effort had been initiated in 1980 at Silliman University in Dumaguete City, Negros Oriental, but this relied solely on overseas funding. Occasional breeding has continued at the Silliman facility and 10 crocodiles are currently held there (Alcala et al. 1987; D. de Leon, pers. comm.).
The CFI was renamed as the Palawan Wildlife Rescue and Conservation Centre (PWRCC) in 2000. The joint venture ceased in 1994 and the PWRCC is now managed solely by the DENR. However, overall management responsibility for the facility was transferred to the National Resources and Development Corporation (NRDC), another arm of the DENR, in April 2002, but with the Protected Areas and Wildlife Bureau (PAWB) retaining responsibility for the C. mindorensis. This dual management has not helped the overall management of the captive population and Government funding shortages remain an ongoing issue.

Prior to the transfer to the NRDC, in 1999 the Director of the then CFI and 10 other CFI/PWRCC managers resigned, citing ongoing administrative problems with the DENR-PAWB head offices in Manila. Regrettably, not all these vacancies have been filled, making it impossible for the Centre to fulfill all components of its mandate, including raising community awareness. An additional strain on the Centre’s operations is uncertainty about the genetic integrity of some of the captive animals, arising from the mtDNA study initiated 1996.

Despite these pressures, breeding has been successful and the PWRCC maintained over 1169 C. mindorensis as at 1 March 2003 (G. Rebung, pers. comm.). The Centre’s facilities, whilst currently lacking the necessary operational support, still have the potential to contribute significantly to the conservation of C. mindorensis (Ortega 1998).

The species is maintained at a number of other captive facilities in the Philippines. This includes Manila Zoo, which has displayed and bred C. mindorensis for many years. Approximately 160 animals are also maintained in a range of private zoos and collections that are registered with the DENR-PAWB, but inadequate resources do not allow for collation and use of appropriate records, such as sex and age. Indeed, this is an issue across most captive facilities in the Philippines.

2. **Interest from Overseas Zoos**

Interest in C. mindorensis from overseas zoos stems from 1988, when Gladys Porter Zoo in the USA imported an adult female from Silliman University to pair with a male already at the Zoo. An additional male was also received and GPZ’s involvement with the species is covered by a Memorandum of Agreement (MOA) with the DENR. A total of 68 offspring have been produced and most subsequently distributed to other institutions:

- Eight were repatriated to the Philippines in two groups.
- 47 were sent to other US zoos, the most recent transfer being 33 to five zoos under Breeding Loan Agreements between GPZ and the receiving zoos, under the auspices of the MOA between the DENR and GPZ.

The aim of the GPZ project, supported by the American Zoo Association’s Crocodilian Advisory Group (AZA-CAG), is to establish a stable, viable captive population in North American zoos and private collections, which, in turn, allows for the generation of funds to assist *in situ* conservation of the species in the Philippines (C. Adams, pers. comm.).

Melbourne Zoo, in Australia, signed a MOA for C. mindorensis with the DENR and Silliman University in 1993. This provided the framework for the Zoo to fund upgrading of the Silliman facility and transfer of a pair of sub-adult C. mindorensis to Melbourne later that year. The original MOA expired in 1996 and new Agreement was finally signed in 2001, between the Zoo and DENR. Six young crocodiles, captive-bred at the PWRCC, were transferred to Melbourne in late 2002, but three unfortunately succumbed to stress-induced trauma within one month of arrival. Melbourne Zoo has a strong commitment to the conservation of this species and has been providing a range of *in situ* support since 1994.

There is also interest in conservation of this species from a number of European zoos, most particularly from the Danish Crocodile Zoo at Eskilstup in southern Denmark. This is supported by the DENR-PAWB, but signing of a MOA, which would allow for transfer of crocodiles, has been stalled by administrative delays. This is frustrating, as the DCZ has committed to provide *in situ* funds once crocodiles arrive and are on exhibit.

**Developing a Coordinated Program**

1. **The First Recovery Plan**

   A key participant in the establishment of the PWRCC was the Crocodile Specialist Group, whose first global
Crocodile Action Plan recommended establishment of a “national crocodile management program” as the highest priority for the Philippine Crocodile (Messel et al. 1992). The CSG also noted that the best chance for the species’ survival was captive breeding, a recommendation which was repeated in the second edition of the Plan, produced in 1998 (Ross 1998).

With the support of Melbourne Zoo, the PAWB and the CFI/PWRCC were represented at the 1998 meeting of the CSG in Singapore. This led to agreement on development of a National Recovery Plan for the Philippine Crocodile, which was published in 2000 (Banks 2000). Two chapters in the Plan are of particular importance: “Issues & Challenges”, which underpins the basis for the necessary conservation actions:

- Habitat loss: *C. mindorensis* is restricted to freshwater lakes, swamps and rivers, which have suffered greatly from pollution, over-fishing, silotation, conversion to other uses, clearing of riparian vegetation, and the introduction of exotic fish species. Further, those freshwater habitats which are covered by the protected area system receive little if any protection (PAWB/DENR and Wetlands International 1992).
- Negative community attitudes: all crocodiles in the Philippines have a poor image within the general populace and are viewed negatively at almost all levels of society. Locally known as “buwaya”, they are believed by rural people to be bearers of bad tidings and in league with the ‘dark forces of nature’. They are thus often referred to as “aswang”, or witches (Ortega 1998). The perceived aggressive nature of crocodiles do not endear them to the human population, and reported cases of problem crocodiles, most likely *C. porosus*, attacking people have reinforced the supernatural beliefs of rural people.
- Crocodiles are also the most malignled and ridiculed animals in the Philippines. In the Filipino culture, crocodiles are often compared to corrupt Government officials, greedy businessmen, tax collectors and selfish athletes.
- National policies: although there are several laws that provide for the protection of Philippine wildlife and their habitats, only one piece of national legislation specifically includes crocodiles as protected animals. The new Wildlife and Conservation Act updates many of the existing laws, but its impact on *C. mindorensis* conservation is unclear.
- Captive management: in most respects, captive management of *C. mindorensis* does not differ greatly from that of most species in the genus. However, the seasonal incompatibility that manifests itself in most groupings and pairings, including among juveniles, presents difficulties for intensive captive management.
- Ecology: the ecology of *C. mindorensis* remains poorly understood.

Conservation Objectives, each with a number of Performance Criteria and defined Actions. The primary conservation goal is to re-establish viable wild populations of *C. mindorensis* and ensure its long-term survival throughout its historic range. Recognising the implications of this objective, protection and survival within sections of its historic range may be the reality over the short-term. The objectives cover:

- Establish protected wild populations.
- Promote and encourage positive community attitudes to, and understanding of crocodiles in the Philippines.
- Co-ordinate captive management.
- Determine the species’ ecology.
- Define the extent of remaining wild populations.
- Resolve systematic relationships.
- Integrate the conservation of *C. mindorensis* with conservation of freshwater wetlands in the Philippines.
- Ensure that all relevant Government policies support conservation of the species.

2. Delivering the Plan

Overseeing implementation of the Plan is the primary responsibility of the Philippine Crocodile National Recovery Team, which was created by a Special Order of the DENR on 3 March 2000 and has eight members drawn from the DENR/PAWB, Melbourne and Gladys Porter Zoos, Stilliman University and representatives of the legislative regions in which the species occurs. The Team is supported by a four person secretariat drawn from the PAWB.

Arguably the greatest value of the Recovery Plan lies in its actual existence as a DENR-endorsed document that can be used to emphasise and reinforce the urgent need for co-ordinated action to conserve *C. mindorensis*. Achieving desired conservation outcomes for any wildlife in the Philippines is a daunting task - the Philippine economy is in decline, corruption remains widespread, information sharing is not routine, government bureaucracy
is cumbersome, the general populace is desperately poor, the birthrate is climbing, and understanding of Philippine wildlife is very low. Law and order has been an issue for the past two decades and its linkage with terrorism adds yet another dimension to a very gloomy outlook for wildlife conservation in the Philippines. Indeed, organisations like Conservation International and BirdLife International rate the Philippines as one of the highest priority areas in the world for urgent conservation action (Heaney and Regalado 1998).

Despite these problems, all of which are interwoven, successes are being gained and it is documents such as the Recovery Plan, and its associated Recovery Team, that can be used to draw the Government’s attention to relevant issues and assist it to move forward.

3. Updating the Plan

A number of significant developments have occurred since the first edition of the Recovery Plan was published. Most particularly, these include:

- Confirmation of *C. mindorensis* breeding in the Northern Sierra Madre area of northeast Luzon Island and the very promising level of community support.
- The genetic study being undertaken by Frederick Pontillas to assess the level of relatedness between the various island populations.
- The resourcing issues facing the PWRCC.
- The growth in overseas interest for supporting *in situ* conservation.

These developments require that the first edition of the Plan be reviewed to reflect the changes and a new suite of actions to be pursued. These are outlined further on in this paper.

*In situ* Initiatives

The only *in situ* program for *C. mindorensis* is located in the Northern Sierra Madre Range in far northeast Luzon Island. This commenced in 2000 following confirmation of the species’ presence in 1999. Since then, a number of surveys has been carried out, initially by the PLAN-Philippines/Northern Sierra Madre Natural Park-Conservation Project (NSMNP-CP). Some of these were conducted as a joint effort between the NSMNP-CP and the PWRCC, whilst others also involved Louisiana State University. Other more detailed studies have been undertaken by Dutch MSc students through the NSMNP-CP and the Cagayan Valley Program on Environment and Development (CVPED) (Pontillas 2000; van Weerd 2000; Oppenheimer 2002; Oudejans 2002; Rodriguez *et al.* 2000; van Weerd *et al.* 2003).

These links led to a short-term conservation plan with the Local Government Unit of San Mariano and the DENR/Protected Area Superintendent Unit (PASU) of the NSMNP (van Weerd 2002). This consisted of:

- Crocodile research and surveys.
- Awareness raising activities, including a poster developed through a Whitely Foundation Rufford Small Grant to Melbourne Zoo.
- Livelihood support.
- Local legislation and institutional arrangements.

Of particular significance is the enacting of four municipal resolutions by the Local Government Unit of San Mariano to:

1. Protect and conserve *C. mindorensis* in San Mariano, making it illegal to catch, possess, sell or hunt crocodiles in San Mariano.
2. Declare the Philippine Crocodile as a flagship species of the municipality.
3. Enable the establishment of a crocodile rescue centre/holding pen in San Mariano for crocodiles retrieved from captivity.
4. Declare a portion of the Disulap River as a Philippine Crocodile Sanctuary, including the area where a *C. mindorensis* nest was found in 2000.

All these developments were presented and explored further at the “Philippine Crocodile (*Crocodylus mindorensis*) Conservation Workshop” from 16-19 May 2002 at Isabela State University in Cabagan (Anon 2002) and summarised
at the following Regional Conference on Environment and Development (Van Weerd and General 2003).

The CROC Project, funded by the BP Conservation Program in 2003 and building on an earlier initiative of the same name, plans to continue with the community-based approach in San Mariano and in other municipalities with remaining wild crocodile populations.

**Priority Actions**

The draft Second Edition of the Philippine Crocodile Recovery Plan has been endorsed by the Recovery Team and only requires finalisation of the Forward from the DENR Secretary before it goes to print. This follows the same format as the first edition, but reflects the important developments that have occurred in the intervening three years. The revised conservation actions include:

1. **Reassess the distribution and wild status of *C. mindorensis***:
   - The species is confirmed, including breeding, from parts of north-east Luzon, but the full extent of remaining populations needs to be defined.
   - Specimens are now known from Abra Province in far north-west Luzon Island, but we have very little knowledge of their distribution in this area.
   - Recent eye-shine reports from Lake Naujan on Mindoro Island need to be explored.
   - Mindanao Island was a stronghold for the species, but current political unrest in parts of this island makes further surveys very risky.
   - South-west Negros Island needs surveying to confirm if the species is still present.
   - Survey other areas as reliable reports are received, eg a survey of Jomalig Island suggests that the species is not present there.
   - Monitor protected wild populations.

2. **Establish a list of possible release sites in the Philippines and develop conservation management plans for priority locations**:
   - Complete surveys of potential locations, on both public and private land.

3. **Promote and encourage positive community attitudes towards crocodiles in the Philippines**:
   - Some good examples exist of projects where concerted community efforts have turned around negative community attitudes towards crocodiles, eg in northern Palawan and the Northern Sierra Madre. These need to be expanded and replicated as broadly as possible.

4. **Co-ordinate the captive management of *C. mindorensis***:
   - A national registry of all captive crocodile in the Philippines is urgently needed, together with all associated specimen details.
   - Build co-ordinated regional captive programs, as part of a global program.
   - Improve the operational efficiency of the PWRCC, including reliable administrative support and evaluation of all aspects of the Centre’s operations.
   - Disperse numbers of captive *C. mindorensis* at the PWRCC to other institutions to reduce the overall risk of disease and other catastrophic events, and increase community involvement with the species.
   - Conduct a detailed analysis of PWRCC records for *C. mindorensis* - Melbourne Zoo has recently funded an ISIS Sponsorship for the PWRCC, which includes provision of data recording software.

5. **Determine *C. mindorensis* ecology**:
   - Very little is known about the species’ ecology, so projects to address this are needed urgently. Some work is underway in the Northern Sierra Madre, but more is needed.

6. **Clarify the population genetics of *C. mindorensis***:
   - The mtDNA study commenced by Frederick Pontillas through Louisiana State University is being generously continued through the good offices of the Henry Doorly Zoo in Omaha, USA.
   - Reassess current management of captive *C. mindorensis* in light of the outcomes of this important work.

7. **Build partnerships to support *C. mindorensis* conservation**:
   - Promote and facilitate breeding loan extensions, both locally and internationally. There is growing interest
in the species, both within the Philippines and overseas; fostering these will generate much-needed in situ support.
- Provide training in crocodile management and surveys within the Philippines. Very few Filipinos have these skills and there is an urgent need to expand this resource.

8. Establish reliable funding sources to support *C. mindorensis* conservation:
- In light of the shortage of Government funding from within the Philippines, it is likely that overseas support will be increasingly important. All efforts should be expanded to achieve this.

9. Ensure that all relevant Philippine Government policies support conservation of *C. mindorensis*:
- There are many pressures on the implementation of wildlife conservation policies in the Philippines, so it is important to use all available means to support government conservation efforts (eg through the Philippine Crocodile Recovery Team).

**Acknowledgements**

Numerous colleagues, many of whom are good friends, in the Philippines and elsewhere, continue to work very hard to ensure the survival of the Philippine Crocodile.

**Literature**


The Status of *Tomistoma schlegelii* (Mueller) in Malaysia

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**Abstract**

*Tomistoma schlegelii* has been known from both Peninsular Malaysia and Sarawak since the end of the 19th Century. Investigation of old localities indicates that the species may still be present, though its ability to reproduce in substantially modified habitats may be questioned. New locality records in Malaysia include at least one from a large lake in Terengganu State on the east coast of Peninsular Malaysia, and a possible new record from western Sabah. More than 70 Tomistoma are currently held captive in Malaysia, but have reproduced at only two facilities. The most serious threat to the survival of the species in Malaysia is the draining and conversion of peat and pandan swamps to agriculture on a large scale.

**Introduction**

In the late 1890s, well before any significant hunting or development activities in Sarawak, William Hornaday commented that he could not obtain a fresh specimen of *Tomistoma* as this species was “much more rare than the other one” (*C. porosus*). This view has not changed over the last 100 years, though the rarity of the species is now attributed to habitat loss and opportunistic killing.

Sebastian (1993) attempted to compile records of Tomistoma from all parts of Malaysia, which at that time expanded the number of localities known, but viewed the species as endangered. Simpson (1998) spent six weeks looking for Tomistoma in the Tasek Bera region of the Peninsular Malaysian State of Pahang, but despite widespread reports of its continued existence, encountered none. Stuebing et al. (1998) reported several new locality records for Malaysia, from Sarawak, including a nesting female in August of 1994, disturbed by an Iban farmer in the Sg Runjing (tributary of the Batang Lupar), several Tomistoma seen near the site of a 1996 crocodile attack in the Sg Tisak; and a Tomistoma observed by a local field researcher in the mid-1990s in the Sg Kakus, a tributary of the Tatau River near Bintulu.

This pattern of discovery of small numbers of Tomistoma either in areas where it was formerly reported, or unsurveyed (but appropriate) habitats, has continued. Following the 2002 Crocodile Specialist Group Meeting in Gainesville (Florida, USA), several of us have made efforts to check up on areas of Malaysia where Tomistoma was historically recorded, to review on any recent references to it in several new field guides recently published from the region, look for existing live collections in various facilities around Malaysia (and determine the origin of their holdings), and to interview anyone potentially with knowledge of the species. As a result, some new and interesting information has come to light, and while the picture of Tomistoma’s conservation status in Malaysia is not particularly rosy, there is reason to be hopeful concerning its continued survival.

**Recent Records**

A list of the most recent known localities for Tomistoma in Malaysia is given in Table 1. Almost all records obtained by the end of 2003 were either from the Perak, Pahang and Sadong (Western Sarawak) River systems.

RBS visited the Malaysian State of Perak in September, 2003, and personally investigated one of the oldest Malaysian records from the species, a locality called “Pulau Tiga” on the Perak River about 10 km upstream of the Sg Kinta (Sg = River in the Malay language). The original settlement, according to local people there, was a Chinese trading outpost disappeared in the early 1900s. Locals, however, were confident that the specimen had come from the area, and specifically mentioned the Sg Kinta (a blackwater river that now runs through largeswaths of oil palm planted in the 1970s) where the crocodile still could be found. Discussions with the Director of the Taiping Zoo (Dr. Kevin Lazarus), where four live Tomistoma are held, revealed that two specimens had been captured in southern Perak in
2003. An interview with Mr. Jasmi Abdul, State Director of the National Parks and Wildlife Office confirmed this story, and dated photos of the animals were produced as proof. There was also confirmation of the “complaints” by villagers along the Sg Kinta of the presence of Tomistoma.

Following this, on a visit to Field Museum of Natural History, RBS referred to a guide to Southeast Asia Reptiles (Chan-ard et al. 1999), in which a photograph of a small, juvenile Tomistoma is printed, along with a locality of “Kenyir Lake” (an extensive man-made lake formed above a hydro-electric dam, now a protected area) in the northeastern Peninsular Malaysian state of Terengganu. A follow up by SAMS confirmed that at least one live Tomisotma currently held in the Wildlife and National Parks’ Malacca Zoo (west coast of P. Malaysia) originated from this same area of Terengganu.

All recent records (and we assume all previous ones) are derived from areas containing extensive peat swamps, or less commonly, freshwater pandan (Pandanus sp.) swamps. These include more vague reports from the Sg Bernam (Selangor) and the lower Sg Baram (Sarawak). Recent discoveries of the species in patches of inland peat swamps, such as those associated with the Kakus River (in the Bintulu District of Sarawak) indicate that Tomistoma may be rather widespread, though restricted to “pockets” of swamp. In March 2004, local people reported that Tomistoma inhabited an area of peat/pandan swamp in the upper Binyo River, a tributary of the Kemena River in Bintulu District.

Prior to 2002, there were no confirmed reports of Tomistoma from Sabah (Whitaker 1984), but Stuebing et al. (2002) reported a firsthand sighting of two Tomistoma that had been seen on the south bank of the Klias River in April 2002, about 100 m downstream from Kampung Kota Klias. The upper Klias originates in the only extant peat swamp on the West Coast of Sabah, the now much-degraded Binsuluk Forest Reserve. In April 2003, a tourist reported that he had seen a Tomistoma in an oxbow lake off the Kinabatangan River, above the town of Sukau, in eastern Sabah. Unfortunately, the observer could not been contacted afterwards. Although this record seems dubious as it seems too far from the core of Tomistoma’s distribution within northern Borneo, in 2003 RBS was told (by Mr. Rifai of the Tarakan KSDA) of a sighting in the Sg Sebuku (3° 50’ N, 117° 10’ E) at the Malaysian border with East Kalimantan.

Malaysian Tomistoma in Captivity

The current number of captive Tomistoma held at various facilities around Malaysia is approximately 77 animals, details of which are given in Table 2. In Peninsular Malaysia, the largest number is at Malacca Zoo. As far as is known, there are no breeding facilities in Peninsular Malaysia. The length of captivity is not known with precision for any of the facilities except in Kuching. The Sarawak Forest Department’s Matang Wildlife Centre has a single female who was discovered on a nest near Engkelili (Runjing River) in 1994. The Tomistoma in captivity for the longest period are undoubtedly those in the Jong Farm in Kuching, several of which were obtained in the 1970s.

Breeding of captive Tomistoma in Malaysia is known from only the the National Zoo in Kuala Lumpur (first four hatchlings in 2003), and the Jong Crocodile Farm outside of Kuching, Sarawak. Success at the National Zoo is new, and at the Jong Farm has been limited. A total of 19 hatchlings were produced from 1996-2001, but in 2002 and 2003, although several nests were constructed, no fertile eggs were laid. So far it appears that even though the ecological conditions for successful breeding may have been achieved in several facilities, problems remain with the breeding animals themselves, in finding compatible pairs both in age and behavior.

Threats

Much of the peat swamp in western Peninsular Malaysia was converted to oil palm in the 1970s and 1980s, leaving only patches of the habitat in northern Selangor State and Southern Perak. The central State of Pahang, where Simpson’s 1998 field sites were located, has also continued to drain and develop large areas of its peat swamps, including the last substantially intact piece inland from the east coast town of Pekan. Coastal and interior swamps in Sarawak are facing rapid development for agriculture (oil palm, exotic tree plantations), and about half of the area southwest of Bintulu towards the Mukah and Oya Rivers, has already been converted. Crocodylus porosus seems to have survived conversion of forests to oil palm estates in Sabah (Stuebing 2002), but it is unknown whether Tomistoma will be as resilient. To answer this question surveys of such coastal peat swamps, including those converted circa ten years ago, are needed.

Stuebing (2002), working in Sabah on the management on Crocodylus porosus, found the latter is now rarely hunted by local people, as there were no local buyers for the skins. As Tomistoma skins are of less value commercially than

<table>
<thead>
<tr>
<th>Locality</th>
<th>State</th>
<th>Age Class</th>
<th>Date Source, Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sg Lepar</td>
<td>Pahang</td>
<td>“All sizes frequently seen”</td>
<td>Simpson <em>et al.</em> (1998)</td>
</tr>
<tr>
<td>Sg Luit</td>
<td>Pahang</td>
<td>Occurs</td>
<td>Simpson <em>et al.</em> (1998)</td>
</tr>
<tr>
<td>Sg Pahang</td>
<td>Pahang</td>
<td>“All sizes frequently seen”</td>
<td>Simpson <em>et al.</em> (1998)</td>
</tr>
<tr>
<td>Sg Rasau</td>
<td>Pahang</td>
<td>“all sizes frequently seen”</td>
<td>Simpson <em>et al.</em> (1998)</td>
</tr>
<tr>
<td>Sg Rompin</td>
<td>Pahang</td>
<td>Reported</td>
<td>Simpson <em>et al.</em> (1998)</td>
</tr>
<tr>
<td>Tasek Bera, Sg Bera</td>
<td>Pahang</td>
<td>“3-4 sightings/year”</td>
<td>Simpson <em>et al.</em> (1998); Dr. Kevin Lazarus, Taiping Zoo, September 2003</td>
</tr>
<tr>
<td>Tasek Cini</td>
<td>Pahang</td>
<td>Juv., 1997</td>
<td>Simpson <em>et al.</em> (1998); Dr. Kevin Lazarus, Taiping Zoo, September 2003</td>
</tr>
<tr>
<td>Sg Kinta *</td>
<td>Perak</td>
<td>“Common”, 2003</td>
<td>Villagers reported to Perak Wildlife Office (Ipoh), June 2003</td>
</tr>
<tr>
<td>Sg Merah (trib. of Sg Perak)</td>
<td>Perak</td>
<td>Reported, 2003</td>
<td>En. Ahmad Darubi, Kg Pulau Tiga, 2003</td>
</tr>
<tr>
<td>Sg Sungkai*</td>
<td>Perak</td>
<td>2.6 m male, June 2003</td>
<td>En. Jasmi Abdul, Perak Wildlife Office (Ipoh), September 2003</td>
</tr>
<tr>
<td>Sg Dusun *</td>
<td>Selangor</td>
<td>Occurs</td>
<td>Dr. Kevin Lazarus, Taiping Zoo, Sep. 2003</td>
</tr>
<tr>
<td>Sg Erung*</td>
<td>Selangor</td>
<td>Subadult, January 2003</td>
<td>En. Jasmi Abdul, Perak Wildlife Office ** (Ipoh), September 2003</td>
</tr>
<tr>
<td>Kuala Berang*</td>
<td>Terengganu</td>
<td>In Malacca Zoo</td>
<td>SAMS</td>
</tr>
<tr>
<td>Sg Kinabatangan *</td>
<td>Sabah</td>
<td>Reported by tourist, 2003</td>
<td>En. Zainal Abidin, ex-WWF &amp; KOCP, Sukau, 2003</td>
</tr>
<tr>
<td>Sg Klias*</td>
<td>Sabah</td>
<td>Pair sighted, April 2002</td>
<td>Stuebing (2002)</td>
</tr>
<tr>
<td>Sg Dor</td>
<td>Sarawak</td>
<td>Old record</td>
<td>Stuebing <em>et al.</em> (1998) (from 1917 record)</td>
</tr>
<tr>
<td>Sg Ensengai</td>
<td>Sarawak</td>
<td>Observed</td>
<td>Cox and Gombek (1985)</td>
</tr>
<tr>
<td>Sg Kelauh</td>
<td>Sarawak</td>
<td>Occurs</td>
<td>Cox and Gombek (1985)</td>
</tr>
<tr>
<td>Sg Kerang</td>
<td>Sarawak</td>
<td>Occurs</td>
<td>Stuebing <em>et al.</em> (1998)</td>
</tr>
<tr>
<td>Sg Kroh</td>
<td>Sarawak</td>
<td>Nesting</td>
<td>E. Lading, pers. comm. 1997</td>
</tr>
<tr>
<td>Sg Mayeng*</td>
<td>Sarawak</td>
<td>Numerous</td>
<td>Dr. C.K. Lim, pers. obs. 2003</td>
</tr>
<tr>
<td>(trib. of Sg Tatalu, Bintulu Dist.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sg Mukah</td>
<td>Sarawak</td>
<td>Old record</td>
<td>Unconfirmed (1917)</td>
</tr>
<tr>
<td>Sg Penyilam*</td>
<td>Sarawak</td>
<td>Occurs</td>
<td>Report by local residents</td>
</tr>
<tr>
<td>(trib. of Sg Kemen, Bintulu Dist.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sg Runjing</td>
<td>Sarawak</td>
<td>Nesting</td>
<td>Stuebing <em>et al.</em> (1998)</td>
</tr>
<tr>
<td>Sg Sadoi</td>
<td>Sarawak</td>
<td>Occurs</td>
<td>J. Jong, pers. comm. 1998</td>
</tr>
<tr>
<td>Sg Setarep</td>
<td>Sarawak</td>
<td>Reported</td>
<td>Stuebing <em>et al.</em> (1998)</td>
</tr>
<tr>
<td>Sg Simunjung</td>
<td>Sarawak</td>
<td>Reported</td>
<td>Stuebing <em>et al.</em> (1998)</td>
</tr>
<tr>
<td>Sg Tisak</td>
<td>Sarawak</td>
<td>Possible attack on human?</td>
<td>Stuebing <em>et al.</em> (1998)</td>
</tr>
</tbody>
</table>

those of *C. porosus*, it is unlikely that hunting has been a serious threat in Malaysia, apart from opportunistic killing, especially given the secretive nature of the species. It appears that Tomistoma is also not regarded as food by many people, as we (RBS and EL) have never heard of anyone consuming the species as food in Malaysia.

Although Bezuijen *et al.* (2002) linked the heavy logging of habitats in Sumatra to a decline in Tomistoma abundance over a period of about ten years, fewer sightings may necessarily furnish sufficient proof of a precipitous decline in a population. Other, perhaps less favored explanations, would include the animals becoming more secretive, or temporarily withdrawing from disturbed area. Death of Tomistoma in suboptimal habitats or through conflicts with *C. porosus* is a clear possibility as well, but difficult to substantiate. Upon seeing the destruction caused by non-selective logging, and being unable to find Tomistoma in that area, it is reasonable to assume that the animals are gone, but it may not be completely accurate to state that they are dead. A long-lived species such as Tomistoma does have the ability to return to an area to breed, even after many years. The purpose in making such a statement here is
Table 2. *Tomistoma schlegelii* currently held in captivity in Malaysia. Source/year: 1 = S. Anuar Mohd. Sah 2004; 2 = Dr Kevin Lazarus (Zoo Director), 2003; 3 = farm owner; 4 = J. Jong 2004. * Simpson (pers. comm., 2003) stated that these animals had come from the Baram River, but the owner reported to Mr. C.H. Tan of Miri that the Tomistoma were all imported from Indonesian Borneo (probably West Kalimantan).

<table>
<thead>
<tr>
<th>Facility</th>
<th>Location</th>
<th>No. animals</th>
<th>Origin</th>
<th>Source, year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Langkawi Crocodile Farm</td>
<td>Pulau Langkawi, Kedah</td>
<td>10</td>
<td>Singapore</td>
<td>1</td>
</tr>
<tr>
<td>Taiping Zoo</td>
<td>Taiping, Perak</td>
<td>4</td>
<td>Pahang</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1 reportedly from Bera R., Temerloh)</td>
<td></td>
</tr>
<tr>
<td>Malacca Zoo</td>
<td>Malacca</td>
<td>1M, 6F</td>
<td>Tanjung Karang, Kuala Berang (Terengganu), Perak, Selangor?</td>
<td>1</td>
</tr>
<tr>
<td>Taman Buaya</td>
<td>Malacca</td>
<td>1M, 1F</td>
<td>unknown</td>
<td>1</td>
</tr>
<tr>
<td>National Zoo</td>
<td>Kuala Lumpur</td>
<td>1M, 3F, 4 juv. (hatched)</td>
<td>unknown</td>
<td>1</td>
</tr>
<tr>
<td>Miri Crocodile Farm</td>
<td>Miri, Sarawak</td>
<td>9</td>
<td>Kalimantan*</td>
<td>3</td>
</tr>
<tr>
<td>Jong Crocodile Farm</td>
<td>Kuching, Sarawak</td>
<td>Approx. 37</td>
<td>Upper Sadong (tributaries), W. Sarawak</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>77</strong></td>
<td><strong>(approx.)</strong></td>
<td></td>
</tr>
</tbody>
</table>

not to detract from the seriousness of the situation, but to encourage conservation efforts even in areas which may seem (temporarily) “lost” to development.

In the opinion of the current authors, the most serious threat to the species in Malaysia is the draining of peatlands and pandan swamps, and their conversion to agriculture. Intensive fishing of swamps with *selambau* nets, which block entire channels and could conceivably drown many animals in the process, is also a possible source of mortality. Nevertheless, local Iban people in the Sg Binyo dismissed this idea, and said they almost never caught any crocodiles. Interestingly, some of these swamps are now being adopted (at least in Sarawak) as breeding refuges for the much prized “ikan tapa” (*Wallago* sp.). Conservation of these important fish spawning areas will augment current efforts to conserve Tomistoma, as long as there is an effort to promote public awareness for conservation of all components of the ecosystem.

**Literature**


Management of the Siamese Crocodile in Thailand

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² CITES Office, Fisheries Department, Bangkok 10900, Thailand

We present the management of the in-situ conservation and domestic as well as international trade of the Siamese Crocodile in Thailand. Like most crocodile range countries, Thailand has similar problem affecting long-term survival of wild populations, including poaching, human encroachment, loss of habitat and loss common crocodile prey. After a two-year feasibility study, the re-introduction of the Siamese Crocodile is set to release the first set of crocodiles from the temporary pond in this August. In 2003, 1191 CITES Export Permits were issued, 868 of which were issued specifically for tourist and the rest 323 permits were for live specimens, meat, salted skins, tanned skins, and leather goods. The number of export permits is increasing due to the constant growth of the market, the expansion of captive breeding farms, and the better quality of product that meet several standards such as ISO9001, GMP, and HACCP. As the number of captive operators increase, the competition for the market is unavoidable which could result in smuggling. We believe that there is a scope for greater political commitment by Thailand and its neighbours to implement the Convention and to play a full role in combating illicit trade in crocodile.

Re-introduction has become an important technique in crocodile management especially in the critically endangered species. As the public becomes increasingly interested in crocodiles, their management may become more contentious. Nevertheless, the value of these charismatic animals is high. Although crocodiles will have to be controlled and regulated in some situations, wherever possible they should be nurtured. The greatest challenges to crocodile conservation are to control the human population and to preserve as many extensive natural areas as possible. At CMAT general assembly (Bangkok, March 2004), the Standing Committee agreed that the first release is to be held on August 12, 2004 in order to celebrate Queen Sirikit’s 72nd birthday. We have prepared the pure-bred Siamese Crocodiles tested with the microsatellite technique by Kasetsart University, Bangkok. Twenty park rangers have been trained to handle crocodiles, and capable of monitoring the released population. The crocodile ecology classes have been set up in the local village to teach children how to safely live near crocodile habitats. With Government funding, survey trail, access road, and temporary compound have been built. The existing trails are being cleared for faster access to most of the survey point and will also be used by tourists as a trail. The great concern is the size of suitable habitat, which deems to accommodate no more than 100 crocodiles at present. The plan is to release 20 crocodiles a year. Therefore, the population may slowly increase in near future. In addition, Huoy Samong Dam is projected to complete within 5 years. This hopefully will create a large and suitable habitat for Siamese Crocodiles.

The market-driven conservation is the tool for the sustainable use of crocodilian because of three reasons. First, the first-graded skin is usually achieved by implementation of the intensive feeding program of juvenile crocodile in a specially designed pond. The demand for such skin quality is overwhelmed, which contrast to the demand for wild skins. In another word, the skin industry only demand for flawless skins. Second, the intensive feeding program must be done through the contracted farming system, which usually requires a large number of farmers involved in such program. Even though many large-scale crocodile farms are capable of raising tens of thousand of juvenile crocodiles, the result is much different. Finally, the greater number of crocodile farmers, the stronger the farmer organization. The organization, like CMAT, will eventually support conservation program, at least within the country. The conservation program for the crocodile in such country must follow CSG guideline or the national master plan for crocodile conservation. The crocodile farming industry within Thailand involves many people whose stocks are totally captive-bred. Such individuals have had little direct impact on the depletion of wild crocodiles. The depletion of wild stocks that resulted from the past exploitation was finally legal under WARPA (Wild Animal Reservation and Protection Act B.E. 2535) that allowed the farmers to register the farm with the government. Thus, the 17 current CITES-registered operators cannot necessarily be held responsible for the present situation in the wild. Nevertheless, through CMAT, the conservation program for the Siamese Crocodile in Thailand is finally happening. CMAT was established in 1991, and has undertaken to assist with surveys for existing populations and exploring the potential areas for re-introducing captive-bred C. siamensis into the wild. The reality of ever-decreasing wild populations, ever-increasing captive breeding populations, and continuing demand for crocodile skin continue to encourage CMAT responsibility to complete the cycle of sustainable conservation. Unlike members of some crocodile association, CMAT members well understand the role of CMAT in conservation. CMAT, thus, is able to collect fees from farmers according to the number of crocodile traded and slaughtered.

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Regarding to the Article VII paragraph 4, 5 of the Convention, specimens and by-product derived from Appendix I species reared in CITES registered operations can be traded as Appendix-II species. Consequently, the Siamese Crocodile, Appendix-I species, from CITES registered farms in Thailand can be exporte; there are 17 registered farms in Thailand. CITES is implemented in Thailand by the Wild Animals Reservation and Protection Act (WARPA) and the Plant Act (both enacted in 1992). Ministerial Regulations have been issued to supplement this primary legislation; for example to make provision for the issue of permits and certificates to regulate trade in specimens of CITES-listed species and to incorporate into the legislation the Appendices of the Convention. However, the most recent amendments to the appendices covered by WARPA are those adopted at the 8th meeting of the Conference of the Parties. New legislation is being drafted to better address CITES-related trade and it is hoped to enact this before the 13th meeting of the Conference of the Parties in Bangkok, Thailand. WARPA also regulates Thailand’s domestic utilization of wildlife and determines which native species are protected and the level of protection. The Siamese Crocodile has been listed as a protected species that can be traded, which means hunting, possessing, breeding, and trading of the specimens is regulated under such law.

Today, live specimens and most products derived from Siamese Crocodiles are being exported. 1191 CITES Export Permits were issued in 2003, 868 of which were CITES Export Permit: for tourist. The number is increasing due to constant growth of the market, expansion of captive breeding farms and number of crocodiles, better quality of product, and sanitary standard that meets the GMP, ISO, and HACCP standard. Sriracha Crocodile Farm, for example, uses 100 tons of chicken per month to feed to over 50,000 head of all sized crocodiles. However, stocks in such farm are about 10% of all crocodiles in Thailand. A rough estimate for nation-wide need for crocodile feed is approximately 40,000 tons per year. We can supply chicken to our crocodiles because Thailand is a major country producing and exporting chicken to USA, EU and Japan. This remarkable success in hatching and raising techniques for ex-situ conservation of sustainable resources can guarantee genetic stocks for the in-situ conservation.

The channel of illegal trade through the border between Thailand and Cambodia, etc., that heavily hinder conservation programs in Indo-Chinese region is currently a major concern. Small numbers of unregistered farms in Thailand continue selling live hatchlings to Cambodia without official documents. We understand that it is possible because of lack of CITES authorities at the point of import/export as well as high price and demand. Usually, CMAT charges members to run the organization activities. Thus, CMAT is losing revenue through illicit trade over the border! The Chinese Government is also losing import tax from smuggling of crocodiles through southern border. To solve the problem, both the import and export countries should come up with a solution. The border inspection must be carried out and maintain the high level of custom check to preclude the smuggling of specimens without the CITES permit.
Drought Results in Small Mugger Population of Iran

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Abstract

Gandou Protected Area, which extends in about 3800 sq. km is the main distributional area of Mugger population in Iran. Small but scattered population with about 200-300 crocodiles, occupies vast fresh water habitats like natural and artificial ponds, reservoir and rivers. The last years prolonged drought has brought very harsh situation for the crocodiles in the area so that the natural features of the area as well as the crocodiles have completely changed. Lack of water, which in turn causes lack of food, shelter and habitat, has increased the mortality rate of the weak, thin and small crocodiles. The main part of the population is suffering from existing situation. Moreover the main part of the crocodiles have aggregated to remaining available water bodies. This situation itself could result some ecological problems in the future. Unfortunately, there is not any specific management plan for the population now although as a cultural and legal point of view there are many possibilities for any conservational activities.

Introduction

Southeastern part of Iran, near Pakistan border, is the only distributional area of Mugger crocodiles in Iran, which is considered as the western limit of its global range too. The small but scattered population with about 200-300 crocodiles, inhabit in limited rivers and related water bodies as well as artificial constructed ponds close to villages.

Considering the climatic situation of the area in southeastern part of Iran, most of the existing developments like forming of small and big villages are along the main rives in the area and it means that crocodiles are in close contact with local people. However, the important subject is that the people never disturb, harm or hunt the crocodiles and even respect them as a creature living in water. The local name for the crocodiles is “Gandou” and everyone knows them by this name. Main part of the area due to its importance as crocodile habitat designated as “protected area” with an area of 3800 sq. km with the name of “Gandou” protected area. More over some parts of the area (75,000 hectares) has designated as 19th wetland of international importance of the country. The area comprises of riverine and estuarine wetlands of lower Sarbaz River, including permanent fresh water pools and marshes.

Small population of Mugger crocodile in Iran has been severely affected by prolonged drought during the past years and crocodiles have been faced with very harsh situation. Natural feature of the habitats has completely changed so that lack of raining has drastically reduced water levels in the main rivers of the area. Many ponds along these rivers dried up completely, and the remaining ponds have little water. In this situation, the main problem is that the aquatic food resources have depleted and are not easily available. Therefore, most of the crocodiles are too thin, meager and weak to seek for food or move to other ponds, which unfortunately are very far from each other. With the scarcity of food and water, many crocodiles appear notably thin and dehydrated, so that there are record of 3 kg for about 1 m long mugger. In this relation, the attack of crocodiles to the villager’s livestock has increased in some places, which caused some other problems in the area. Lack of food has increased mortality of the crocodiles so that even there is a record of five dead crocodiles in one small pond in the southeastern part of Bahukalat River and another one found dead in his burrow. In this situation, reproductive activities are likely to be affected by the lack of food and water which in turn influences the egg quality and survival rate of the hatchlings too.

Lack of water makes crocodiles to seek for and inhabit in any existing water body. Some of these resources do not seem to be the suitable habitats, like drainage or agricultural wells, which some times it is impossible for the crocodiles to leave them without the help of the man. In this regard, three crocodiles were inhabited in a small well and were removed by the help of local people and DOE guards. Although walking in long distances is one of the most important and main behaviours of Mugger crocodile, considering the far distances between the existing ponds caused by drought, as well as weakness of crocodiles movement between these water bodies seems impossible and useless attempt. Although the population is small, it is very scattered too. Considering the lack of DOE staff and existing facilities, it is difficult to cover and monitor the whole area. However, the main part of the population lives along Sarbaz, Kaju, Bahukalat and Shirin kor Rivers. There was not any record for the latest river, but as there are some permanent ponds feed by under ground water, some of the crocodiles affected by drought have introduced to these
ponds. In some ponds, the results are satisfactory, although there is not any recent report. Nowadays, the most important, reliable and largest water source in the area is Pishin Dam reservoir. DOE staff when being informed move all the crocodiles that have lost their habitats or are not in suitable situation to this water body. Therefore, the main part of the population is aggregated in this small lake and subsequently has negative ecological effects on the population, creating unnaturally competitive situation amongst the crocs as well as providing difficulties to monitor them. Another problem in the area that aggravates the drought is using of existing ponds water for agricultural purposes. There are usually some diesel pumps near each pond that transfer the water to the existing agricultural fields. Considering that the most people are poor and the agricultural activities are the only possible livelihood, it is impossible to prevent them from water exploitation. More over in the most parts of the area the water of the ponds is the only available water resource for the people’s daily usage like, drinking, washing and bath as well as for livestock. At this time, there is not any specific management and research program on the crocodile population although unfortunately, there have not been regular activities before too and that is why there are too many japes in our information in both biological and population aspects. Results from recent conducted studies, in which 15 Mugger crocodiles were captured and measured during the past two years reveal the poor nutritional status of crocodiles due to the drought (Table 1).

<table>
<thead>
<tr>
<th>No.</th>
<th>Total length (cm)</th>
<th>Tail length (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250</td>
<td>120</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
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Due to vast size of the area and lack of equipments, the mortality rate of the muggers during the drought has not been determined. On a positive note, a few ponds in southeastern Iran have enough amount of water and are home to the healthy, well-fed crocodiles. Located in front of Pishin Dam and near to the town of Rask, these ponds are fed the whole year by underground water sources.

It is possible too that mugger crocodile habitat exist in other parts of southeastern Iran that have not yet been studied: the area that borders Pakistan, especially Nahang River and its associated ponds. There are some unconfirmed reports on the movement of crocodiles, between Iran and Pakistan in this area. However, the area is generally unknown due to security concerns. An investigation of this area in cooperation with Pakistani experts would be worthwhile.

**High Potential for Conservation**

Apart from the drought, which is a natural problem, there are many different factors create high potential for the conservation of Mugger crocodile in Iran. Each of these factors, on their own turn, could be very important and very positive:
1. Crocodiles are legally listed as “Protected wild life species”
2. There are cultural and religious bans that prevents people from any harm to crocodiles
3. There is no consumptive use of meat and eggs
4. There no harvest for leather
5. There is no use for traditional medicines
Each of these factors are very difficult to achieve in other parts of the world in which, most of the existing programs are proposed to initiate such a situation.

Recommendations:

1. Regional Interaction, coordination and cooperation
2. Conducting more research and survey works especially on population status and biology to provide any needed information
3. Providing needed funding for proposed research and conservation activities (GEF, CSG)
4. Providing needed scientific and technical supports
5. Establishment of conservation and management programs
6. Planning for the establishment of rearing or breeding center
7. Providing the needed fund for establishment of rehabilitation center
8. Conducting of Regional or sub-regional workshops and training programs
9. More coordination and cooperation of CSG and Regional coordinator of CSG and initiating close contact with Madras Crocodile Bank

Discussion

Considering the aims addressed at the Action Plan, as the main reference, as well as classification of the *Crocodylus palustris* according to the available data in the class of very poor and need for conservation in the class of high (IUCN/SSC, CSG 1992), it seems that conducting and executing of base line studies on the biology and population status of Mugger in Iran for providing the needed information, and planning for starting of conservation activities is necessary. In this regard, any financial and technical support of the related organizations or NGOs will help us lot to start these activities and considering the fact that there is not any harvest on crocodiles in Iran, the results of the activities would be satisfactory indeed. Regarding with the drought and related problems, establishment of a rehabilitation center for recovering crocodiles that have severely suffered from the lack of food and habitat is an urgent need. This in turn will prevent from transferring of the crocodiles to the Pishin Dam reservoir causing population aggregation and other related problems.

Identification of the permanent water bodies in the area which are fed by underground resources could be another choice for the management of crocodiles affected by drought.

Acknowledgments

I would like to extend my great thanks to the Organizing Committee of the 17th Working Meeting of the CSG for the travel grant which enabled me to attend in the meeting. I am also grateful to Charlie Manolis, Tom Dacey and Dr. Mahnaz Mazaheri (Research Advisor of DOE) and Mr. Hosseini (Director General of Marine Environment Bureau of DOE), for their kind help.

Literature


Photo 1. Dehydrated and malnourished *C. palustris* in southeastern Iran.

Photo 2. One dead mugger in one of the dried out ponds along Shirin-kor River.
Photo 3. Most of the main ponds along the rivers have dried out.
The Conservation of Siamese Crocodile in Cambodia

Heng Sovannara

Summary

Over four years that Cambodian’s crocodile scientist cooperated with Department of Fisheries and other NGOs in Cambodia. Specially Wildlife Conservation Society to do survey around some areas that have presented. Estimated around 200 adult crocodiles occurred in Cambodia (FFI survey) as in the Cardamom Mountain; adding more have been survey by Department of fisheries and WCS founding 4 places in Sre Ambel Kohkong Province (bordering Thailand); around Tonle Sap Great Lakes and Ratanakiriy Province (border Laos) that crocodiles are remaining every years and also some places not survey yet. But still report about crocodiles from the villagers, However did survey for this year we found on nest about 21 eggs and conservation keeping for incubated.

Related management by Department of Fisheries with conservation we have a big national crocodile farmers meeting supported by DOF; WCS and Crocodile association on the extent the regulation of CITES with trade and pushing all farms be com official farms provided permit from Department of Fisheries and some from Provincial fisheries. There are 6 farms have registered with CITES for exporting crocodile.

Threat of wild population has some disturbed from human activities moving to living near crocodile habitat and used illegal activities like electro-fishing, poison, and some poacher try to catch and collected eggs for consumption and selling to middle man close to the town and then middleman sent to outside countries. Fisheries Department working strictly with on problem follow by law.

Distribution

There are many places are remaining wild crocodile population in Cambodia, some place have been survey and some not yet. But we will be continuing to survey complete all. on this we will be talk about Sre Ambel that did survey all ready accompany with B.baska project supported by WCS and DOF. Sre Ambel is the part of Koh Kong Province near bordering Cambodia and Thailand; small town and most of the people are living in rural areas making fishing, logging and t. There are around 7 villages closely crocodiles habitat; this the villagers who usually reported and saw of wild crocodiles. Based on all information related wild crocodiles from all around areas; We used the day survey methods to surveyed all the places founding 4 location crocodiles remaining Prek Kombot found one nest 21 eggs in this year also keeping for incubated in nature nesting guarding by conservation teams and other three places Prek Keantok found on crocodile about 3 m length, Prekpokatim and Tropangpeng founding crocodiles track. Estimation the population of wild crocodiles round more than 10 adults crocodiles living this areas on the wet season spread all areas and some areas survey at Cardamom mountain by FFI, around Tonle Sap Great lakes and Ratanakiriy Province border Laos country.

Threat

On the past before B.baska project started the conservation at Sre Ambel there are a lot of illegal activities (former Khmer Rouge) as boom fishing electro-fishing specially shooting and collected crocodile eggs every years for consumption and selling to mild man at Sre Ambel town and then continuing to Thailand or Phnom Penh. The people are very poor; low education and habit operation activities of fishing disturbed to the wildlife. It’s other problem from the people not permanently only short time living try to collected wild life from this areas. some wild crocodile have accidental by net and hook and automatic death.

Conservation

Department of Fisheries and Wildlife Conservation Society are supporting to do conserved wild crocodile population and did survey all the places to finding out key stone areas to protected and also on the March 2004 supporting to organized national crocodile farms meeting at Siem Reap Province attending from crocodile farmers and crocodile farmer Association, the objectives of the meeting are management and conservation. During that time Mr. Nao Thuok, director of Department of Fisheries in Cambodia toke of time to announce and clearly explain to all farmers about situation and status of crocodile around the would and especially concerning with wild protection, suggestion to farmers should be have license from DOF or province department fisheries and follow by CITES regulation and
stop to collected from the wild coming to help saving together keeping on the natural. adding more works related with management and conservation on be has DOF have been opened the small meeting all province that crocodile farms presented to push all the farms to register and provide the log book and receipt book. The purposing to get all the information from the farm of all action operating the farms as when’s start the farm? Where’s breeding stock came from? and …. etc. The crocodile farmer association is importance role to do crocodiles conservation program cooperated with farmers, Authorities, and NGOs setup action plans and submit to DOF and practical. Crocodile association will be providing crocodile for releasing if Government need.

**Action plans**

- Training on crocodile conservation
- National workshop on the CITES regulation and implementation
- Appropriate measures for protection and conservation of habitats known to have crocodiles present
- Enhance law enforcement
- Promote community participation
- Crocodile farm monitoring
- Release program in suitable habitats

**Conclusions**

- Cambodia can be considered as the last stronghold for Siamese Crocodile in this region. Around 200 wild population still inhabit the remote habitats in many places of the country. But there is a threat to these populations if appropriate management measures are not urgently undertaken. Law enforcement, capacity building and awareness raising are extremely crucial for the survival and recovery of this keystone species.

- The Fisheries Department is cooperating with all stakeholders involved especially local authorities, communities and NGOs to safeguard this remnant species to recover and exist for generations to come.

**Acknowledgements**

We would like to thank all of you who supported to protecting Siamese Crocodile in Cambodia: Mr. Nao Thuok (Director of Fisheries in Cambodia), Dr. John Thoriarison (Wildlife Conservation Society USA), Mr. Joe Walston (Director Country Program WCS in Cambodia), Crocodile Farmer Association, and all of staff in Cambodia to do related crocodile conservation.
Status and Conservation of the Siamese Crocodile
*Crocodylus siamensis* in Kalimantan (Indonesian Borneo)

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Abstract

Field surveys in 1995 and 1996 concluded that a relictual, highly disjunct population of *Crocodylus siamensis* inhabits the Mahakam River of East Kalimantan province, Indonesia (Ross *et al.* 1998). On the basis of roughly estimated suitable habitat, observations of captive juveniles and anecdotal evidence, probably less than several hundred individuals persisted at that time. No subsequent study has been undertaken. Impact on the population and habitat from the prolonged 1997-1998 drought and human pressure is unknown. Comparative mitochondrial DNA analyses indicate that *C. siamensis* in the Mahakam has been isolated from mainland SE Asian *siamensis* since the late Pleistocene (i.e. ≥10,000 ybp) (Gratten 2004). This clearly endangered (and declining?) remnant of the Kalimantan lineage needs urgent formulation and implementation of an integrated conservation program.

Introduction

The Siamese crocodile *Crocodylus siamensis* was historically and widely distributed in freshwater habitats of SE Asia, occurring from Thailand, Laos, Vietnam and Cambodia (Groombridge 1987), to Sumatra, Bangka, Java (Ross 1986), Borneo (Cox *et al.* 1993; Ross *et al.* 1998), and possibly the Celebes (Ross 1986) (Fig. 1). The species apparently persists in very small numbers in Thailand (Ratanakom 1994), Laos (Stuart and Platt 2000; Thorbjarnarson 2003) and Vietnam (Cuc 1994). A larger, apparently viable breeding population occurs in Cambodia (Thuk 1998).

![Figure 1. SE Asia, Kalimantan and the Mahakam River system of East Kalimantan Province.](image)

Outside mainland SE Asia, the only reported extant *C. siamensis* population is from the lower Mahakam River system (Fig. 1) in the Indonesian province of East Kalimantan (Ross *et al.* 1998). Due to its drastically reduced abundance, the Siamese Crocodile is listed by IUCN (2001) as Critically Endangered. The Kalimantan population
remains very poorly known. Pressing need exists for biological and socio-ecological studies, and resultant integrated conservation action if viable wild populations are to be maintained or re-established.

Methods

*C. siamensis* in Kalimantan was assessed in 1995-1996 mainly by semi-structured interviews of former crocodile hunters and skin traders, other knowledgeable residents in the vicinity of crocodile habitat, and crocodile ranchers/farmers. Open-ended questions were emphasized to obtain unbiased responses. In 1996 a laminated sheet of unnamed *Crocodile* photographs showing neck and body squamation was used to assist species identification by village informants citing local names (Ross *et al.* 1998). Direct observations and photographs were made of captive individuals in village holding facilities and farm stock.

Standard night counts of crocodiles were conducted at Danau Tanah Liat, a lake in the middle Mahakam where *C. siamensis* purportedly resided. The littoral zone was scanned for crocodile eyeshine using a bright beam of light from the bow of a paddled *perahu* (dugout). Data on survey routes, duration, water levels, weather and habitat were recorded.

Results

**East Kalimantan:** The first record of *C. siamensis* in Kalimantan was reported by Frazier and Maturbongs (1990). A 2.3 m caged individual purportedly caught in 1983 at Danau Sohuwi, was inspected and photographed at Muara Ancalong in the central Mahakam on 5 and 6 September 1990. The authors subsequently found 35 *C. siamensis* ranging from yearlings to adults at P.T. Makmur Abadi Permai crocodile farm outside Samarinda on 10 September 1990. These and four juveniles examined at C.V. Surya Raya crocodile farm in February 1991 (pers. obs.) near Tertip (N of Balikpapan) were said to originate from lakes in the central Mahakam (W. Mawengkang, pers. comm.; T. Sugianto, pers. comm., respectively).

Field surveys of palustrine crocodiles in 1995 and 1996, undertaken as part of a collaborative project by *Pusat Penelitian dan Pengembangan Biologi* (Center for Biological Research and Development) of *Lembaga Ilmu Pengetahuan di Indonesia* (LIPI) (Indonesian Institute of Sciences) and the Smithsonian Institution (SI) focused on crocodilian systematics, but produced substantial data on the occurrence of *C. siamensis* in Kalimantan, particularly East Kalimantan Province.

Nine juveniles were inspected from village holding facilities in the central Mahakam in 1995, and deduced to be offspring from at least two, possibly three or more breeding crocodiles (Ross *et al.* 1998). The smallest juvenile (59.5 cm total length), measured at Sungai Bongan (Ross *et al.* 1996), indicated that *C. siamensis* had bred in the Mahakam as recently as 1994.

By September 1996, the number of captive *C. siamensis* at C.V. Surya Raya had increased to 37 (Ross *et al.* 1998). The 33 additional individuals were received as small juveniles from the wild, acquired as incidental take from fish nets and traps in the central Mahakam, mostly from the Danau Mesangat area (T. Sugianto, owner, pers. comm.). All stock were juveniles or sub-adults (pers. obs). The number at P.T. Makmur Abadi Permai was unknown and estimated in 1995 at 35 adults and large juveniles. Some individuals showed signs of hybridization with *C. porosus*, which accounted for most stock in the farm’s common breeding pens (Ross *et al.* 1996).

By September 2003, 24 mostly adult *C. siamensis* were isolated in a common breeding pond at C.V. Surya Raya (pers. obs.), but have only produced infertile eggs (T. Sugianto, pers. comm.). The decline in number since 1996 is attributed solely to mortality. No additional individuals were said to have been acquired from the wild.

Information on *C. siamensis* habitat was obtained during the LIPI-SI surveys from crocodile hunters and fishermen, who referred to the species as *buaya badas hitam* (black *badas* crocodile) (Frazier and Maturbongs 1990) or *buaya kodok* (frog crocodile) (Ross *et al.* 1998) Informants stated that the species prefers small, mostly perennial lakes as foraging habitat and associated marshes of floating vegetation for nesting. The nesting period was recounted as approximately August through October. Wetland habitat is evidently semi-partitioned with the Malayan false gavial *Tomistoma schlegelii*, which was observed in and alleged to favor open tributaries, and found to nest in permanent swamp atop floating vegetation (Ross *et al.* 1998).

In 1997-1998 the central Mahakam experienced a severe ENSO (El Niño-Southern Oscillation) event. The semi-
nomadic D. Mesangat fishing community emigrated upriver when lakes and channels became too dry to catch fish. As of April 2004 most of the people have not returned (T. Sugiarto, pers. comm.) The effects of this prolonged drought on *C. siamensis* in the Mahakam remain unstudied.

In the central Mahakam habitat protection is extended to crocodiles in the Muara Kaman Strict Nature Reserve (62,500 ha). *Tomistoma schlegelii* was confirmed to nest in the reserve in 1996; local villagers asserted that *C. siamensis* also nested there (Ross *et al.* 1998). Throughout the Mahakam lakes region open bodies of water were found to be heavily utilized for fishing (Kurniati 1997; Ross *et al.* 1998).

**South Kalimantan:** LIPI-SI field surveys were not conducted in South Kalimantan province because areas of suitable crocodile habitat had been converted or were assessed from local information and map study as too heavily degraded to support palustrine crocodiles. However, c.15 mostly adult *C. siamensis* were observed at P T. Alas Watu Utama crocodile farm near Banjarbaru in 1995 and 1996 (Ross *et al.* 1998). The crocodiles were purportedly received in the 1980s as small juveniles from traders in Central Kalimantan. A pair reportedly nested in January 1996 but failed to produce hatchlings (Kasan, farm caretaker, pers. comm.). None of the *C. siamensis* showed signs of hybridization with numerous *C. porosus* kept in the same common breeding pond (pers. obs). Isolation of *C. siamensis* to prevent hybridization and encourage breeding success was recommended to farm management.

**Central Kalimantan:** Surveys in the Barito river system in 1996 found only anecdotal evidence of *C. siamensis*. Descriptions of *buaya kodok* at upriver villages were consistent with dorsal characteristics of the species and correctly pointed out on the *Crocodylus* sheet. At Kampung Buyui on the Sungai Ayu tributary residents said *buaya kodok* inhabited lakes and rivers, but was last seen c. 1991 (Ross *et al.* 1998).

**West Kalimanta:** *Buaya kodok* was reported by a Kubu village hunter to occur in freshwater lakes of southern river systems in the Ketapang area, and was last caught in 1982 at Sungai Pinggan in the Gunung Palung area (Ross *et al.* 1998). No evidence, even anecdotal, was found that *C. siamensis* inhabited Sungai Kapuas, the main river system of West Kalimantan Province.

**Discussion**

*C. siamensis* in Kalimantan is an intriguing artifact of the broad historical distribution of this species from the SE Asian mainland to islands of the Greater Sundas. Radiation was apparently accomplished during Pleistocene glacial periods when the region was united by dry seabeds and major paleoriver systems of the exposed Sunda Shelf (Ross 1986). These freshwater connections were intermittently disrupted by marine incursions during interglacial periods, and no direct freshwater linkage is thought to have existed between the SE Asian mainland and Borneo (Gratten 2004). Eastern Borneo was further isolated from the Sunda Shelf by the Meratus mountain range.

Comparative studies of mitochondrial DNA (mtDNA) between Kalimantan *C. siamensis* (sampled from C. V. Surya Raya stock) and the fragmented SE Asian population clearly shows the phylogenetic distinctiveness of the East Kalimantan population (Gratten 2004). On the basis of estimated mtDNA control region substitution rates, *C. siamensis* in East Kalimantan has been isolated from mainland SE Asian *siamensis* since the late Pleistocene (ie ≥10,000 ybp) (Gratten 2004).

The current status and distribution of *C. siamensis* in Kalimantan is poorly understood. The last remaining ‘stronghold’ of the species appears to be the lakes region of central Mahakam, in particular the Danau Mesangat area, and possibly other small lakes and associated marshland in the vicinity.

Although the wild population was deduced to breed as recently as 1994, records of wild capture since 1995 are lacking. This may be the result of area crocodile farmers ceasing to take of additional individuals once *C. siamensis* was identified and understood to be unlicensable for trade (T. Sugiarto, pers. comm.), and concomitant halting of juvenile capture by local fishermen. Alternatively, the population may have declined further, due in particular to the severe 1997-1998 ENSO event, and individuals were no longer netted or trapped.

Genetic studies of the Mahakam population show population bottleneck signatures, presumably indicating recent severe declines in range and size (Gratten 2004). On the basis of roughly estimated suitable habitat using basic topographic maps, observed captive juveniles and considerable anecdotal evidence, probably less than several hundred individuals persisted in 1996 (Ross *et al.* 1998).
It remains unclear if *C. siamensis* survives in the wild in Kalimantan outside the central Mahakam. Anecdotal evidence suggests an extant population was distributed in palustrine environments of Central and West Kalimantan Provinces as recently as 10-15 years ago (Ross et al. 1998). Individuals from this population may be harbored at P.T. Alas Watu Utama in Banjarbaru, underscoring the critical need to isolate and maintain them. The stock number is adequate (c. 15) for genetic studies in microsatellite diversity that may resolve their Bornean ancestry. East Kalimantan is isolated from Central, South and West Kalimantan by the Meratus mountains. This barrier may have promoted formation of a genetically distinct evolutionary unit. If so, the Banjarbaru stock comprises invaluable extant material.

Similarly, individuals isolated and maintained at C.V. Surya Raya form a reservoir of pure breeding stock that is of inestimable value. Improved techniques being implemented at present should achieve captive breeding success, and formation of a breeding nucleus that can be reared to produce additional breeding stock or juveniles to restock suitable habitat in East Kalimantan where *C. siamensis* is severely depleted or extirpated.

The remnant *C. siamensis* population in Kalimantan clearly meets the criteria for IUCN's Critically Endangered listing, and warrants highest priority for conservation action. Additional surveys are needed throughout Kalimantan to assess population status, suitable habitat, the socio-ecological and socio-economic roles of local communities, and to ultimately design a conservation strategy.

Population surveys should be as systematic as possible, but where habitat or funding mechanisms are not amenable to standard night counts or other direct count methods, a community-based effort can provide valuable feedback to gauge trends in resource use. Moreover, the involvement of local communities at every stage of the conservation initiative and delivery of tangible economic benefits to them can serve as the crucial link in achieving management objectives.

Local people can perform an important role by regularly monitoring the crocodile resource. The knowledge, skills and efforts of local communities may also prove crucial in gauging the status quo and insight into the most appropriate design and implementation mechanism for a conservation initiative.

Towards the success of a long-term conservation program, an additional incentive exists in sustainable commercial use of *C. siamensis*. This crocodilian has a “classic” hide whose fine, intricate bellyskin rivals *C. porosus* in value. Strategies such as egg harvests can effectively link economic returns from protection of critical population cohorts to the welfare of local communities (Cox and Solmu 2002). Tapping the commercial potential of *C. siamensis* in Kalimantan, although a distant option, could add a substantial conservation incentive and contribute to rural development, at least on a local scale.

Palustrine crocodile habitat in the central Mahakam ranges from seriously degraded (eg overfished, infested with water hyacinth *Eichhornia crassipes*) to marginally disturbed, and was considered important for formal protection (Kurniati 1997). The relatively compact and accessible lake system is logistically favorable for a community-based conservation initiative. A suitable rural development effort there would need to create incentives for fishing communities to achieve their basic development aspirations and simultaneously support conservation measures. This may merit a comprehensive regional development effort, probably emphasizing sustainable fisheries and ecotourism in the mid-term.

Crocodile ranchers and farmers in Kalimantan need the active support and encouragement by government of Indonesia and international organizations. These strategically located entrepreneurs and their wetland dependant local communities likely hold the keys to recovery and enduring conservation of *C. siamensis* in Kalimantan.

**Acknowledgements**

Tarto Sugianto is warmly thanked for information regarding C.V. Surya Raya farm stock and wild *C. siamensis* in East Kalimantan, and his interest to participate in conservation activities. Messrs. Welly Mawengkang (P.T. Makmur Abadi Permai), Dharmo Surya, Moelyono and Kasan (P.T. Sapto Argo Unggul/P.T. Alas Watu Utama) and T. Sugianto are remembered and thanked for granting access to farm stock. Jacob Gratten kindly shared the results of his recent studies in *C. siamensis* population genetics and along with Phil Hall contributed helpful comments in the writing of this paper. Many local residents throughout Kalimantan provided valuable information of crocodile distribution and status, and much appreciated hospitality. LIPI and the Directorate General of Forest Protection and Nature Conservation (PHPA), Ministry of Forestry, facilitated the bureaucratic requirements of conducting the LIPI-SI project, and made available outstanding field counterparts.
Literature


Conservation and Management of the Two Species of Sri Lankan Crocodiles
(Crocodylus porosus and Crocodylus palustris)

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Abstract

Sri Lanka has two of the 23 species of crocodile extant in the world today. The Mugger or Marsh crocodile (Crocodylus palustris Lesson 1831) and the Saltwater or Estuarine crocodile (Crocodylus porosus Schneider 1801). Sri Lanka is one of the few countries, which has done little with regard to researching the biology and ecology of its crocodiles. No management or conservation plans have been formulated either.

In earlier times both species were found in abundance in their respective habitats (Deraniyagala 1953). Though the status of the mugger seems to be secure in the sense that there probably are a few thousand spread throughout various water bodies, the status of the saltwater crocodile (C. porosus) is doubtful. This may be for a number of reasons, not the least being that no formal long-term study has been made on either species in Sri Lanka. It is known that crocodiles have been extirpated from a number of their habitats in the island.

This paper discusses the historical and present status of the two species in Sri Lanka. It looks at human-crocodile interventions and the environmental status of both species. The paper also poses a few questions and options for their future conservation and management in Sri Lanka. It also stresses the need for a firm and comprehensive policy on crocodiles to be adopted by the Government of Sri Lanka.

There is an opportunity to get a more innovative management systems in place in respect of both species, especially with regard to research, education etc., which in many other countries have gone hand-in-hand with improved conservation and habitat protection. Though there are sensitivities in Sri Lanka regarding the use of crocodiles for commercial purposes, it is necessary to at least discuss this aspect especially in the light of a number of success stories elsewhere.

Introduction

Crocodiles are carnivorous reptiles and are generally at the top of the predators in their ecosystem. They feed on fish and keep all species under control not allowing the larger and invasive species to dominate the ecosystem. They also feed on the weak and sick fish and help to keep the fish populations and water clean and uncontaminated by their scavenging. The presence of crocodiles is an indication of a clean aquatic environment.

Literature shows that, in earlier times, both species of crocodiles were widely distributed in suitable habitats throughout much of the country. The habitats of C. porosus include coastal mangroves, marshes, swamps and some inland water bodies. C. palustris is found widely in the different inland water bodies like tanks (man-made reservoirs), streams, rivers and other suitable water bodies. Even though earlier the two species shared habitats in many locations, they now coexist in only a few places. C. porosus is the largest living reptile and its hide is the most sought after crocodile skin in the commercial world.

Deraniyagala considered the Sri Lankan crocodiles to be different to the Indian forms. He therefore named the Sri Lankan Marsh crocodile Crocodylus palustris kimbula (Deraniyagala 1936) and the Estuarine crocodile Crocodylus porosus minikanna (Deraniyagala 1955). However, Wermuth (1960) and Whitaker and Whitaker (1982) have shown, from a larger series of specimens, that the criteria used by Deraniyagala, does not support his contention of the islands two forms to be separate subspecies.

Sri Lanka Profile

Sri Lanka is located between latitudes 5°55’- 9°51’N and longitudes 79°41’- 81°54’ with a land area of 64,742 km² or 6,463,000 hectares. Earlier Sri Lanka was a part of the Indian mainland and during the Miocene period it was
separated for the first time. However during the Pleistocene due to four drops of the level of the sea up to 100 m, there had been successive land connections and severances.

The island is divided into three climatic zones according to rainfall distribution. They are the dry zone (rainfall less than 1,900 mm per year), the wet zone (rainfall 2500-5000 mm per year). The dry and wet zones constitute 65% and 23% respectively of the island’s total land area. The intermediate zone, consisting of 12% of the land and a rainfall between 1900-2500 mm per year, lies between the dry and wet zones.

Sri Lanka posses three hectares of inland lentic waters for every square kilometre of land. This is one of the highest densities of inland lakes, tanks, ponds, man made canals and other still waters in the world (Baldwin 1991). There are about 12,000 man made lakes, known as “tanks”, located mainly in the dry zone of Sri Lanka.

Identification and General Morphology

The two species are easily distinguished by their pattern of dorsal osteoderms. The osteoderms of C. palustris are rectangular and aligned to form transverse rows. The snout of C. palustris is relatively short, wide and has four post occipital scutes. C. porosus has ellipsoid osteoderms, which are separated from one another by epidermis. It has an elongate snout. The post occipital area is covered with small, granular scales, no big scutes.

The adult C. palustris is dorsally a dark olive green shading into brown, with black or dark brown bars and spots. Ventraly, white with faint traces of dark gray transverse bands interrupted mesially. None of the black markings extend beyond two rows of scales and are relatively constant in size throughout life (Deraniyagala 1953).

C. porosus is dorsally a brassy yellow spotted and blotched with black in four or five irregular transverse rows, ventrally pale yellow with dark spots under hind limbs and subcaudals. After the animal is three metres long the dorsal colour is almost uniform black, the head and jaws yellow, and densely speckled with black (Deraniyagala 1953).
Ecology of the Two Species

Different individuals of *C. palastris* vary in their temperament. Animals from one locality might be ferocious man-eaters, while others from the neighbouring swamps or reservoirs will permit people to bathe or fish in their abodes with impunity (Deraniyagala 1953). Regarding *C. porosus* Deraniyagala (1953) says ‘This form is usually a man-eater and even today claims many human victims annually.

Ecology of the Two Species

Different individuals of *C. palastris* vary in their temperament. Animals from one locality might be ferocious man-eaters, while others from the neighbouring swamps or reservoirs will permit people to bathe or fish in their abodes with impunity (Deraniyagala 1953). Regarding *C. porosus* Deraniyagala (1953) says ‘This form is usually a man-eater and even today claims many human victims annually.

Crocodiles spend most of the time in the water but are not comfortable in waters that are deeper than about 10 metres. During drought, crocodiles that have been molested by man quit a swamp directly the water reaches a certain level that seemingly is still ample for their safety. Other individuals in jungle swamps remote from villages continue in them so long as any moisture remains (Deraniyagala 1953).

Young crocodiles emit croaks whilst adults croak and also emit a bellowing grunt, which can be heard for a great distance.

In the 1970s fisherman netted many crocodiles to make ‘jerky’ (dried meat) or to get rid of them because they were considered a nuisance (Rom Whitaker, pers. comm.) The destruction of the mangrove and marsh habitats of *C. porosus* has resulted in the depletion of its numbers. This destruction is due mainly to increasing urbanization.

Reproductive Behaviour

Some of the breeding habits of the two species differ. *C. palastris* buries its eggs in soft sandy soil and decaying leaf matter mainly on riverbanks and tanks (lakes). *C. porosus* builds a mound-like nest often using the flag plant (*Lagenthera toxicaria*), but any reeds, pandanus, palms, thick grass, etc., will also do. The vegetation with which the nest is built decomposes as time goes on and generates heat necessary for incubation.

The females of both species are sexually mature and start to breed from about 6 to 8 years (*C. palastris*) and 10 to 12 years (*C. porosus*) of age. The males mature when they are older. *C. palastris* usually breeds once a year but at the Madras Crocodile bank, they have bred twice a year (Rom Whitaker, pers. comm.). *C. porosus* breeds only once a year. It is likely that the two monsoons that occur annually in the island have a bearing on the breeding regimes of the two species.

Most females remain near their nest during incubation and protect it from predators. On hatching vocalizations made by the hatchlings induce the female to assist the hatchlings to emerge. In some cases the mother carries the tiny babies to the water in her mouth. The sex of the hatchlings is determined by temperature. More males are born during

<table>
<thead>
<tr>
<th>Species</th>
<th>Nest type</th>
<th>Eggs /clutch</th>
<th>Breeding season</th>
<th>Nesting</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. porosus</em></td>
<td>A mound-like nest of vegetation. Also a hole dug into the ground</td>
<td>40 to over 60 eggs</td>
<td>Wet season</td>
<td>Female stays near nest and defends it, Opens eggs for hatchlings to come out</td>
</tr>
<tr>
<td></td>
<td></td>
<td>An average of 50 eggs Hatching takes 80-100 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>C. palastris</em></td>
<td>Buries its eggs in soft sandy soil and decaying leaf matter Communal nesting</td>
<td>20 to 35 per clutch Hatching takes 50-65 days</td>
<td>Dry season</td>
<td>Female stays near nest and defends it, Opens eggs for hatchlings to come out</td>
</tr>
</tbody>
</table>
periods of high temperatures. The hatchlings remain together near the mother for several months, deriving a certain amount of protection from her. As they grow and become more widely dispersed and independent, the majority of the offspring perish due to predation by monitor lizards, wild pigs, feral dogs, etc. - some are even eaten by other larger crocodiles.

The survivors reach maturity between 6-12 years depending on the species. Females grow more slowly and reach maturity when much smaller than males, who continue growing and usually exceed females in size. Records show that crocodiles are long lived in the wild. Adults of both species emit loud vocalizations during the breeding season. Both species have a complex courtship display prior to mating.

The biological characteristics of crocodiles give them a resilience to recover from population depletion if the adverse conditions that caused the depletion improve. However, unregulated killing of adults can lead to rapid population reductions, particularly if combined with habitat loss.

**Range and Distribution**

With reference to the distribution of *C. palustris* Deraniyagala (1953) states ‘this sub species ranges from the saline coastal lagoons up to the swamps in the intermediate peenplain and also inhabits some of the islands to the northwest and north of Ceylon which it has reached either by crossing the sea during heavy rainy weather or by being isolated when these islands separated off from the mainland. It prefers sedentary or slow flowing water and is more terrestrial, fossorial and gregarious than its estuarine relative’.

Writing on its distribution Deraniyagala (1953) states ‘*C. porosus* is generally confined to the coastal region of the first peenplain and sometimes travels far up rivers ascending the Kalu ganga up to Ratnapura while a large individual was found dead in the Mahaweli river above Alutnuvara, a distance of over 160 kilometres (100 miles) from the sea. It occurs in the estuaries of the larger rivers, appearing to prefer water that is only faintly brackish to that which is more saline. Although numerous individuals dwell in the same lagoon, *C. porosus* is a comparatively solitary species’.

Though there is mention of *C. porosus* occurring in the Yala National Park, these are confined to the mangrove marshland area in Kumana. Although an occasional *C. porosus* may have either swum or been washed down in times of flood into the Yala National Park. However the habitat by and large does not appear to be suitable for their welfare and breeding. In recent times the Department of Wildlife Conservation (DWLC) has released one large man-eating saltwater crocodile from the Nilwala Ganga in Matara, into the Bundala National Park. They have also released another, a man-eater that was brought to the Dehiwela Zoo, in the Yala NP. However recent surveys by Rom Whitaker have not revealed the presence of *C. porosus* in the Yala NP.

*C. porosus* has a wider distribution in Sri Lanka than *C. palustris*, which is mainly restricted to the lowland dry zone of the island. Neither of these two species has been recorded higher than 150 metres above sea level.

“Salties (*C. porosus*) have a different set of specific habitat requisites compared to the ubiquitous mugger (*C. palustris*) who can make do with a mud hole or a drainage ditch if it has to. The typical habitats of the salty are the rivers and backwaters once lined with mangroves in Sri Lanka’s southwestern coast from Negambo down to Galle. There are very few salties left now in Sri Lanka, perhaps the only breeding population is in the Muthurajawela swamp near Negambo with sporadic breeding at places like the Bentota River” (Rom Whitaker, pers comm.).
In earlier times the local communities used to construct special ‘crocodile proof’ enclosures along most of the rivers that drain out into the sea in the southwest coast of the island. These enclosures were used by them to bathe in comparative safety. The fences were constructed with railway sleepers planted in the water with two opposite sides coming well up the bank. However now with the decrease in the Saltwater crocodiles less and less of these enclosures are seen.

This preliminary survey has confirmed the presence of crocodiles in the (Jaffna) peninsula. Both freshwater and saltwater crocodiles are present, and locals refer to them by their vernacular names Chaanakan and Semmookan respectively (Santiapillai 2004). For a long time it was believed that crocodiles had been extirpated from the Jaffna Peninsula.

The two species of crocodiles in Sri Lanka need to be conserved for different reasons. *C. palustris*, though abundant in the island, has its numbers decreasing in the rest of its range states. On the other hand *C. porosus*, found widely in Papua New Guinea, Australia and other countries, have a small and dwindling population in Sri Lanka.

**Present Status**

It is pertinent to record here that during the 19th Century crocodiles were found in abundance in most of the lakes and tanks of the northern and southern parts of the island Davy (1821). Tennent (1859) a foremost naturalist on Sri Lanka in the 19th century records ‘Batticola lagoon and all the still waters of this district are remarkable for the numbers and prodigious size of the crocodiles which infest them. Their teeth are sometimes so large that natives mount them with silver lids and use them for boxes to carry chunam. Samuel Baker (1853) records that all lakes in Ceylon swarms with crocodiles of very large size. Ferguson (1877) records that *C palustris* had been common in tanks in the Jaffna Peninsula

Though globally secure as a species, *C. porosus* is in extreme danger of extirpation from Sri Lanka due to the reasons given above and the attitude of the local communities towards this crocodile. The reputation it has as a man-eater being the main reason for this dislike.

Sri Lanka has a large mugger population probably numbering several thousand throughout the island. While the largest number occur in the two national parks, Yala and Wilpattu, muggers can be seen in large tanks, in rice fields, waterways and small and large rivers in the more sparsely populated areas. The mugger is strictly protected in Sri Lanka and a crocodile management and conservation project is being formulated (Whitaker, in prep.). A recent film on the mugger in Sri Lanka reveals unique underwater footage of breeding and parental care by the male. Sri Lanka holds the responsibility for the long-term survival of the mugger (Whitaker et al. 2003).

Sri Lanka also has isolated populations of *C. porosus*, mainly on the southwest coast which still has some suitable habitat left. Detailed surveys are required to establish the status and survival potential of this, now rare, species (Whitaker et al. 2003).

**Threats to Crocodiles**

Crocodiles are threatened by many human activities.

- Destruction or alteration of their natural habitat.
- Commercial overexploitation, to a lesser extent, and indiscriminate killing.
- Irresponsible land use practices leads to disturbances in the downstream habitats.
- Soil erosion and other habitat disturbances upstream, lead to the siltation of their habitats. This reduces the carrying capacity of the rivers, muddy the tank bed and banks, and reduce the quality and quantity of water available for fish, on which the crocodiles feed.
- Regular fires in the dry zone forests and riverine grasslands during the dry season can destroy the breeding grounds of crocodiles.
- Dried up water bodies during severe droughts experienced periodically also play an important part in the lives of the crocodiles.
- Destruction and clearing of wetland crocodile habitats can take many forms. The most obvious being drainage and infilling, deforestation, conversion to agricultural use.
- Pollution of aquatic habitats like rivers, streams, etc.
• The removal of the important shelter plant (*Lagenandra toxicaria*) which *C. porosus* uses for nest material along the west coast.
• Killing of crocodiles by fisherman.
• In many areas crocodile meat is dried and sold as items purported to be of medicinal value or as dried shark fish. Dried crocodile meat is a cure for asthma.
• Crocodiles living near human habitations are deliberately misnamed man-eaters or considered a potential threat to humans and their livestock, and are killed.
• Crocodile nests face egg and hatching predation from land monitors (*Varanus salvator*), stray dogs, crows and egrets. This predation if unchecked could lead to rapid decrease in crocodile populations.
• Unseasonal rains and heavy seasonal rains cause flooding, which affects crocodile nesting. Periodic flooding in the monsoon season, which is the main breeding period of *C. porosus*, washes away and destroys the nests.
• Similarly, unseasonal rains affect the nesting of *C. palustris*. Prolonged droughts too can wipe out young crocodile populations.

**Conservation and Management**

The conservation of crocodiles is therefore dependent upon good management practices, maintenance of habitats in as undisturbed state as possible and successful coexistence between crocodiles and humans.

Successful crocodile management and conservation poses many problems. Many who have to live near crocodiles usually regard them as dangerous and worthy of destruction. In other countries where crocodile conservation programs have succeeded in increasing their numbers, problems of crocodile-human conflict by man-eaters, have often increased. Therefore both species on the island require complete protection through legal means in protected areas and also preservation in captivity. Fishing, which is an important source of income to local communities, is hampered by the presence of crocodiles. However, conservation measures should also consider a more creative approach that provides incentives to people living with crocodiles to offset their real and perceived losses and costs.

The challenge for researchers and managers responsible for crocodiles is to establish programs where their population numbers are maintained at optimum levels through the conservation of resources and habitats. Effective conservation measures will ensure that the population numbers increase.

One component considered critical to the successful management of healthy wild populations is the maintenance of genetic variation. To manage a species with that goal in mind, appropriate genetic markers should be developed that allow insight into the genetic structure of the populations of interest (Davis *et al.* 2001). Since males are known to disperse greater distances than females, studies will show a male-mediated gene flow pattern within a certain population. This information would be very important for long-term conservation planning.
Policy

In Sri Lanka there is no stated policy for the conservation of crocodiles. The DWLC, which is responsible for the management and conservation of crocodiles in the wild, is backed by the Fauna & Flora Ordinance No 2 of 1937. However very little action is taken by the department with respect to crocodile management.

Recognising the important role played by crocodiles in many of the islands ecosystems. The DWLC must immediately formulate and put into practice a policy for the management and conservation of crocodiles. This policy should form the base of a management and conservation action plan. If necessary the existing laws should be amended to give strength to the implementation of the new policy.

Legislation

In early part of the 20th century crocodiles were extensively hunted for their skins. However, with the introduction of the Fauna and Flora Protection Ordinance in 1937 this large scale persecution was greatly reduced. Though crocodiles are completely protected under this ordinance, they are subject to continued killing and exploitation and face extinction. Habitat degradation, unplanned land use practices and an expanding human population, are the major threats to crocodiles in Sri Lanka. The solutions to crocodile conservation, and probably to conservation in general, lie in adapting social, economic and cultural perspectives into an integrated whole for habitat and ecosystem management.

In 1946 crocodiles were placed on Schedule IV of the Fauna & Flora Protection Ordinance, which means they could not be shot without a Special License. This license allowed one crocodile to be taken. The export of crocodile skins is now totally banned. Combined with adequate habitat protection it would seem that these laws, if enforced, would ensure the future of Sri Lanka’s crocodiles. The two factors running against that supposition are the sale of dry crocodile meat (without the risk of dealing in the skins) and the possibility of smuggling skins to India. In late 1975 the Indian excise authorities seized 86 crocodile skins at Dindigul with markings on the crate indicating that it had come from Sri Lanka via the ferry to Rameswaram (Whitaker and Whitaker 1979).

Crocodile Conservation

Crocodiles have a unique natural history that creates special challenges for their conservation. They are the largest predators in their habitats and can threaten humans and their livestock. They are also heavily affected by habitat loss and the pollution of their aquatic habitats. The extirpation from the island of either species of crocodile would result in a significant loss of biodiversity and ecosystem stability in their habitats. Actually the presence of crocodiles is good for fisheries since they control fish predators and raises the genetic quality of their prey just like any apex predator. A healthy crocodile population equals a healthy fish population.
Crocodiles are necessary in their habitats, since they directly affect wetland nutrient cycles and the fish population there. For example the Bolgoda Lake, which had *C. porosus* in the past has no crocodiles there now. Invasive species of fish have recently been introduced into this lake and are now destroying the smaller species of fish, like the knifefish (*Chitala chitala*) leading to their extirpation. However if there were crocodiles still in the Bolgoda Lake, they would have consumed the larger invasive fish (knifefish grow up to four feet and occur in the Bolgoda and Diyawanna Oya), thus allowing the smaller local fishes to exist. Crocodiles do not consume the smaller species of fish on which the invasive species predate. Crocodiles are a keystone species, which helps keep the biological balance and structure of their habitat in equilibrium.

No comprehensive survey of crocodiles in Sri Lanka has been carried out, except for that done by Whitaker and Whitaker (1977). There is a lack of information on the zoogeography, population dynamics, abundance and the distribution of crocodiles in Sri Lanka.

**Outline for a Crocodile Conservation Plan**

If an effective long-term crocodile management plan is to be formulated in Sri Lanka, the following information must be collected. This can be done through research, surveys and studies.


1. Distribution of crocodiles and land-use patterns in their habitat
   - Species status: historical, recent past and present, for both species
   - Distribution maps: known range for each species; using GIS
   - Vegetation maps: habitat types, elevation, etc.
   - Land-use maps: including ownership, concession boundaries etc. particularly as it may effect the long-term conservation of the species.

2. Threats to their survival
   - Declining populations: main causes and stakeholders involved, including rate of population reduction
   - Direct threats: hunting for meat, traditional uses (?), live capture, diseases
   - Indirect threats: traps and snares, disturbances from gem and sand mining, other habitat threats (eg prawn farming)
   - Resource extraction: legal and illegal activities in crocodile habitats in each administrative area. Destruction of tunnel banks especially in the drought prone areas. Also feral buffaloes ruining the waterholes.

3. Current legislation and conservation action relevant to crocodiles
   - National Law: current legislation and enforcement - are they adequate?
   - Traditions: relevant local traditions and beliefs
   - Protected Areas: current and proposed Parks covering crocodile habitats
   - Conservation projects: filed surveys and projects, awareness programmes, etc.
   - International Agreements: current and proposed CITES, Ramsar, etc.

Once the above information has been gathered a comprehensive management plan, consisting of the following segments, can be developed.

1. Action to conserve the two species of crocodiles
   a. Priorities for action: immediate, medium and long-term proposals
   b. Implementation: government, NGOs, private individuals
   c. Action plans: It is necessary for the following actions to be carried out prior to developing an Action Plan for the Management and Conservation of both species of crocodiles in Sri Lanka

   a. Research
      1. Determine the degree of perceived and positive threats to specific populations and to crocodiles in general
      2. Determine how effective present protection measures (if any) are to these threats
      3. Survey the distribution of crocodiles past and present
b. Protection
1. Strengthen law enforcement relating to the killing, skin trade, etc., in crocodiles
2. Designate new protected areas or alter size or status of existing PAs
3. Create new protected area designations, eg community reserves for grazing cattle, game management areas, etc.
4. Increase anti-poaching efforts in protected areas that include crocodile habitats

c. Awareness/Education
1. Awareness campaigns to be carried out in schools for children and adults, on the economic and ecological value of crocodiles
2. Include a subject related to crocodiles in schools curriculum

d. Development
1. Develop and implement plans for the proper management of crocodiles and their habitats
2. Develop and implement plans for alternate livelihoods for people whose presence has adverse impacts on crocodiles and their habitats especially in protected areas
3. Develop plans for ecotourism, research and filming opportunities in respect of crocodiles
4. Develop and implement plans where the local community would benefit from the presence of crocodiles

e. Budgets
Once the plans for crocodile conservation and management are formulated, the finances required for the implementation of these plans should also be determined. It is also important to identify the sources of funding, to carry out the activities listed in the plan, including the government, funding agencies and NGOs.

Survey

Initially it is necessary that a survey be conducted to ascertain the present status in respect of crocodiles in the wild. This information will help to formulate a pragmatic management and conservation plan. Given below is a list of the objectives of the proposed survey.
Specific Objectives

- Estimate the populations of *C. palustris* and *C. porosus*.
- Provide a national distribution map of both species of crocodile covering all tanks, rivers, lagoons, estuaries, canals and other water sources.
- Identify areas with important or high populations of both species of crocodiles.
- Identify areas of threat to crocodile populations.
- Identify nesting locations of both species of crocodile.
- Ascertain crocodile prey species.
- Ascertain threats faced by all age groups of crocodiles from eggs to adulthood.
- Investigate the status of, and threats to, the natural habitats of crocodiles throughout the island.
- Investigate the instances of ecto- and endo-parasitism when practical.
- Investigate the numbers and circumstances of crocodile attacks on humans and livestock.
- Investigate the number and sizes of crocodiles killed for human consumption.
- Propose conservation management concepts and strategies for the conservation of both species of crocodile in Sri Lanka.
- Obtain a molecular assessment of both species of Sri Lankan and Indian crocodiles.
- Encourage veterinary, wildlife management and herpetological students to participate in crocodile field research whenever possible during the course of the study, including crocodile handling, restraint and general ecology and behaviour.
- Conduct outreach awareness programmes for villagers living in and around known crocodile locations.
- Provide a comprehensive and well-illustrated report of the project’s findings within three months of its completion.

Conclusions

Conservation programmes need to start now. The development of a policy for crocodiles is the first step that the Sri Lankan Government has to take. Based on this policy a strategy has to be worked out. A management and conservation plan which should also include a budget and time scale should be developed. Trained and dedicated personnel should implement this plan if it is to help successfully save the crocodile populations in Sri Lanka.

Literature


The Current Distribution and Population Size of the Philippine Crocodile and Estuarine Crocodile in Northeast Luzon, the Philippines

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Abstract

There is hardly any reliable recent information on the distribution and population size of the two crocodile species found in the Philippines: the Estuarine crocodile Crocodylus porosus and the endemic Philippine crocodile Crocodylus mindorensis. Since the discovery of a remnant population of C. mindorensis in NE Luzon in 1999, efforts have been undertaken to systematically survey NE Luzon for additional crocodile localities. Moreover, identified localities have been monitored at least once a year. At present, six localities have been identified with permanent C. mindorensis sub-populations and two localities with C. porosus. In three localities, successful C. mindorensis breeding has been observed. The total known non-hatching population of C. mindorensis has increased since 2002 from 15 to 27, mainly because hatchlings observed in 2002 have grown. Hatchling survival rate was relatively high. A large concern however is the lack of observed breeding since 2002. Monitoring data is available for the last 5 years, enabling the presentation of population trends. New C. mindorensis sub-populations have been discovered in the Sierra Madre Mountains but surveys in the Cordillera Mountains have not yet resulted in confirmation of surviving populations. Our crocodile research efforts in the area are now shifting from field surveys towards monitoring and more in-depth ecological studies.

Introduction

Status of crocodilians in the Philippines

Two crocoddilian species are found in the Philippines: the Estuarine crocodile, Crocodylus porosus, and the Philippine crocodile, Crocodylus mindorensis. The Estuarine crocodile occurs widely from the Seychelles, Sri Lanka and India to Australia while the Philippine crocodile is endemic to the country (Groombridge 1987). Crocodylus mindorensis is listed in the IUCN Red List (Hilton-Taylor 2000) as critically endangered. The IUCN Crocodile Specialist Group considers C. mindorensis to be the most severely threatened crocodile species in the world and placed the species on the top of the priority list of crocodiles needing conservation action (Ross 1998). International trade in Philippine crocodiles is banned under CITES Appendix 1 (UNEP-WCMC 2003). Philippine crocodiles are nationally protected since 2001 under Republic Act 9147, commonly known as the Wildlife Act (DENR 2001); however this act is not implemented because the accompanying Implementing Rules and Regulations have not yet been finalised and accepted.

Previous studies and published data

Published survey data on this species are limited. The only extensive nation-wide field surveys targeted specifically at C. mindorensis were carried out by Charles A. Ross in 1981 (Ross 1982; Ross and Alcala 1983) and recently by Pontillas et al. (Pontillas 2000). The determination of the historical distribution of the Philippine crocodile is largely based on a survey of museum specimens with collection locality data (Ross and Alcala 1983). Anecdotal and regional survey data have been collated by the Crocodile Farm Institute (CFI) of Palawan (Ortega 1998). Ecology, behavior and life history of C. mindorensis have not yet been studied systematically in the wild. The only available data, mainly on breeding factors and behavior in captivity, were gathered at the CFI (Ortega 1998) and at a small captive breeding center at Silliman University on Negros island (Alcala et al. 1987).

Distribution

The Philippine crocodile is thought to have occurred widely throughout the archipelago, with the exception of Palawan Island (Ross 1982). Specimens have been collected on the islands of Luzon, Mindoro, Masbate, Samar, Negros,
Mindanao, Jolo and Busuanga (Ross 1982). Ross confirmed the presence of *C. mindorensis* on Negros and Mindanao in 1981 and presumed the presence of extant populations on Mindoro, Samar and Northeast Luzon, although he did not observe crocodiles on Mindoro and was not able to visit Samar and Luzon for security reasons (Ross 1982).

An update presented in 1994 with additional information confirmed the presence of *C. mindorensis* on Busuanga (Ortega *et al.* 1994). Ortega presented a comprehensive report on the Philippine crocodile in 1998, in which he identified Mindoro, Mindanao, Busuanga and Northeast Luzon as regions with extant populations, all based on sightings during the 1990s (Ortega 1998). However, we identified the two captive crocodiles at the provincial museum in Tuguegarao (Ramirez, pers. comm. in Ortega 1998) on which Ortega based his record of the Philippine crocodile on Northeast Luzon as *C. porosus*.

Pontillas (2000; Pontillas 2002 pers. comm.) conducted field surveys in the years 2000, 2001 and 2002 on Luzon, Mindoro, Busuanga and Mindanao, and was able to confirm Philippine crocodile presence on Luzon and Mindanao but did not observe any *C. mindorensis* on Mindoro or Busuanga. A small extant population is thought to be surviving on Negros (Alcala 2001, pers. comm.). Recently, a survey was carried out on the island of Jomalig in the Polillo Island group off the coast of Luzon to check reported sightings of crocodiles (Reyes 2003). Indirect evidence of crocodile presence was found but the presence of *C. mindorensis* could not be confirmed nor excluded (Reyes 2003).

In summary, the best available recent survey data confirm extant *C. mindorensis* populations on the islands of Luzon, Negros and Mindanao. The species has not recently been observed by field workers on Mindoro and Busuanga. Samar was identified by Ross (1982) as having probable extant populations but was, to our knowledge, never surveyed thoroughly. Clearly, much more extensive survey work is needed on all Philippine islands to gather reliable data on present *C. mindorensis* distribution and population size.

**Population size**

Ross estimated the remaining wild population at 500 to 1,000 individuals in 1982 (Ross 1982). It is not entirely clear how he arrived at this figure, having observed very few individuals during the surveys in 1981. Presumably, this estimation includes all age classes. Ortega estimated the remaining population in 1998 at “500 animals held in captivity and in the wild” (Ortega 1998). Contradictory, the CFI also reported at that time that it had a total of 1173 *C. mindorensis*, some acquired and some bred in captivity (Ortega 1998). Perhaps the estimate presented by Ortega concerns only non-hatching crocodiles. The latest population estimate used to determine the IUCN Red List status is 100 non-hatchlings and was made by the IUCN/SSC Crocodile Specialist Group (Hilton-Taylor 2000; Ross 1998). It is important to note that none of these estimates are based on counts or extrapolations of field survey data.

**Crocodile Surveys in Northeast Luzon**

**Area description**

Northeast Luzon, as used in this publication, is the area encompassing Cagayan Valley, the Northern Sierra Madre Mountains and the eastern part of the Cordillera Mountains. Cagayan River is the largest river of the Philippines. Originating in the highlands of the Sierra Madre in the East, the Cordillera in the West and the Caraballo Mountains in the South it flows north through the broad Cagayan Valley ending in the Babuyan Channel. The Sierra Madre Mountain Range is situated on the eastern side of Cagayan Valley and extends south from the extreme tip of Northeast Luzon to Quezon Province. The highest peaks of the Sierra Madre are about 2000 m. The Cordillera is situated on the western side of Cagayan Valley and covers the entire central part of northern Luzon. The highest peaks here are nearly 3000 m. The Caraballo Mountains in the South form the natural barrier between the Central Luzon plains and the Cagayan Valley.

Tuguegarao City, located centrally in the Cagayan Valley, received an average of 1727 mm of rainfall annually during 1994-1998 (range 1199-2310 mm) and is characterised by a wet season from July till December and a drier season from January till June. Mean temperature ranges from 23.5°C in January till 29.3°C in June (PAGASA 1999).

In 1997, a large portion of the Northern Sierra Madre in Isabela Province was declared a protected area under the National Integrated Protected Area System: the Northern Sierra Madre Natural Park. Crocodile surveys were carried out along the Pacific coast of this park, conforming through interviews the presence of a small population of the Estuarine crocodile (NORDECO and DENR 1997). It was until 1999 unknown that *C. mindorensis* was also present in the park.
Methods

Since 1999, crocodile surveys have been carried out by the Northern Sierra Madre Natural Park-Conservation Project (NSMNP-CP) until October 2002 (van Weerd 2002). Since then researchers have been engaged in crocodile surveys under the framework of the Crocodile Rehabilitation, Observed and Conservation (CROC) project. The Mabuwaya Foundation, registered in 2003, implements the CROC project.

Field surveys started after a local fisherman in San Mariano incidentally caught a Philippine crocodile and turned it over to field staff of the NSMNP-CP who identified it as C. mindorensis. After this surprising rediscovery of C. mindorensis on Luzon, a protocol was developed for the gathering of secondary data from local fishermen and hunters. Past and recent sightings mentioned during interviews were checked, often by hiring the informant as a guide. Field surveys consisted of searching for crocodiles, tracks, basking areas or faeces at daytime, and spotlight surveys at night. Surveys were carried out on foot by slowly following riverbanks and lake edges with a maximum of four observers. Night surveys were usually carried out from 8 pm (about one hour after sunset) till midnight. In the case of positive sightings of tracks or crocodiles, spotlight surveys were repeatedly carried out during several nights. The maximum number of one count was taken as count result. Crocodile length was estimated and sizes were pooled in the following categories: (1) up to 0.3 m (hatchling); (2) 0.3-1.5 m (juvenile/sub-adult); (3) 1.5 m and longer (adult). Identified crocodile localities were regularly revisited to monitor changes in population size and structure. Each year in May it was tried to survey identified localities for a minimum of three nights. The weather in May, the end of the drier season, is favourable for crocodile surveys as remote areas are better accessible and rivers are low enabling coverage of larger areas. Furthermore we experienced difficulties in observing crocodiles in the wetter months (June-February) because heavy rains at night often diminished visibility and the range of spotlights. The results presented here are mostly from May surveys.

Results

Distribution

Map 1 shows the current (2004) known distribution of the Philippine and Estuarine crocodile in Northeast Luzon, including suspected and recent formerly known distribution sites where crocodiles reportedly went extinct during the last 20 years. We only discuss confirmed sites in this paper. Note that we did not visit western parts of the Cordillera, Philippine crocodile presence was confirmed here by a CFI team in 2001 (Pontillas, pers. comm., 2002).

Philippine crocodile: population size and structure

Table 1 shows the currently identified localities where the Philippine crocodile is found. A total of 27 individuals have been sighted in six distinct localities of which 6 are adults and 21 are juvenile/sub-adults. At another site: Dikabulan Lake in the municipality of Palanan near the Pacific Ocean, tracks were found but it is not known whether they belong to C. mindorensis or porosus. Disulap River (N 16°57’27”; E 122°09’40”), Dunoy Lake (N 16°59’51”; E 122°09’34”), Dungsog Lake (N 17°01’02”; E 122°11’31”) and Dinang Creek (N 16°47’31”; E 122°02’31”) are all found in the municipality of San Mariano. Dicatian Lake (N 17°20’26”; E 122°16’28”) is found in the municipality of Divilacan at the Eastern side of the Sierra Madre Mountains. Dibukarot Creek is found in the municipality of Palanan, also at the Eastern side. Dunoy Lake, Dungsog Lake, Dicatian Lake and Dibukarot Creek are all situated within the Northern Sierra Madre Natural Park.

Table 1. Current distribution and population size of Crocodylus mindorensis.

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Year</th>
<th>Month</th>
<th>Adults</th>
<th>Juv./Sub-adults</th>
<th>Hatchlings</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Disulap River</td>
<td>2004</td>
<td>May</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Dunoy Lake</td>
<td>2004</td>
<td>May</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Dungsog Lake</td>
<td>2004</td>
<td>May</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Dinang Creek</td>
<td>2004</td>
<td>February</td>
<td>1</td>
<td>9</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Dicatian Lake</td>
<td>2004</td>
<td>April</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Dibukarot Creek</td>
<td>2004</td>
<td>April</td>
<td>1</td>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>6</td>
<td>21</td>
<td>0</td>
<td>27</td>
</tr>
</tbody>
</table>

Monitoring data

The following three localities in San Mariano have been monitored since their identification in 1999 and 2000: Disulap River, Dunoy Lake and Dinang Creek. In all three, successful breeding events were recorded. The conservation program in San Mariano focuses on these three key sites.

- Disulap River

Systematic surveys started in 1999 when 2 hatchlings, 2 juveniles and 1 adult were observed. Breeding must have taken place in early 1999 or late 1998 as hatchlings were still very small in March 1999. Breeding was
observed in 2000, the nest with broken eggshells and eight very small hatchlings nearby in the river were found in August 2000. In 2001 only one hatchling remained, suggesting a hatchling survival rate of 12.5%. No breeding has been observed since 2000 although 2 adults were present in 2003. In May 2004 two sub-adults and one adult were present. The number of non-hatchling crocodiles was three in 1999 and in 2004. We do not know where adults and sub-adult crocodiles move to when not observed, or whether we simply miss them during some surveys.

![Graph showing annual monitoring results in Disulap River. The black line shows the total number of non-hatchlings over the years.](image)

**Dunoy Lake**

Surveys started in 1999 but no crocodiles were observed then. In 2000, the presence of an adult was confirmed followed by the observation of two adults in 2001. Breeding occurred early 2002, 12 hatchlings were observed in March that year. Nine juveniles were found in 2003, suggesting a hatchling survival rate of 75%. In 2004 seven juveniles remained suggesting a juvenile survival rate of 78% from 2003-2004. Although the juveniles always seem to remain in the lake, the adults are not always present. We assume that adult crocodiles sometimes move to nearby Catallangan River (ca. 200 m from the lake). The number of observed non-hatchling crocodiles increased from one in 2000 to eight in 2004.

![Graph showing annual monitoring results in Dunoy Lake.](image)
• Dinang Creek

Dinang Creek was identified in 2000 as an important Philippine crocodile site. At the end of that year, four hatchlings and eight juveniles were observed. The hatchlings observed in early 2001 are from the same nest as in 2000. Breeding must have occurred in the latter half of 2000. In 2002, new hatchlings were found indicating a second successful breeding event. That year we also observed two adults. In 2003, 17 juveniles were observed. Assuming all juveniles observed in 2002 survived in 2003, hatchling survival rate over 2002-2003 was 79%. A strong typhoon hit San Mariano in July 2003 causing massive flashfloods, especially in denuded areas such as along Dinang Creek. In February 2004 only 10 crocodiles were found in the creek. Because of national election related violence in the area we were not able to survey the creek in May 2004. If really only 10 crocodiles survived, typhoon caused mortality could have been as high as 53%. The number of non-hatchling crocodiles increased from seven in 2000 to 19 in 2003, possibly decreasing to 10 in 2004.

![Graph showing crocodile population over years](image1)

**Figure 3.** Annual monitoring results in Dinang Creek.

![Graph showing combined crocodile population over years](image2)

**Figure 4.** Combined annual monitoring results in Disulap River, Dunoy Lake, Dinang Creek and Dungsog Lake.
All monitoring sites combined

Figure 4 shows the results of four San Mariano monitoring sites combined, the three sites mentioned above + Dungsog Lake, a small lake without any observed breeding. The number of non-hatchling crocodiles increased from 12 in 2000, the first year when all these sites were surveyed, to 23 in 2004. The highest number observed, in 2003 was 31. No successful breeding has been observed in 2003, possibly caused by the July typhoon. Breeding could still occur in 2004. Please note that the results presented here only refer to permanent monitoring sites in San Mariano. Sites in other municipalities are not included, nor are observations of free-roaming crocodiles.

Estuarine crocodile: population size and structure

During a survey along the Pacific coast of the Northern Sierra Madre Natural Park in March 2004, an attempt was made to survey Estuarine crocodile in addition to C. mindorensis. Interviews among fishermen and other local inhabitants identified six suspected sites (see Map 1). In two sites, the Blos River Estuary in Reina Mercedes (municipality Maconacon) and the Mangrove area of Culasi (municipality Palanan), Estuarine crocodile presence could be confirmed and documented (Table 2). Both individuals were an estimated 3.5-4 m long.

Table 2. Distribution and population size of Estuarine crocodile Crocodylus porosus in Northeast Luzon.

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Year</th>
<th>Month</th>
<th>Adults</th>
<th>Juv./Sub-adults</th>
<th>Hatchlings</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reina Mercedes</td>
<td>2004</td>
<td>March</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Culasi</td>
<td>2004</td>
<td>March</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Crocodiles in captivity in Northeast Luzon

A survey was made of possible captive crocodiles in the area. Two C. porosus were found in two different privately owned collections, they were brought to Luzon from Dumaguete City (Negros Island) when still small. Two additional C. porosus are kept in a mini-zoo near Tuguegarao City (Cagayan Province), the origin of these animals is not clear.

One C. mindorensis was found in a privately owned collection in Santiago City (Isabela Province). The owner declined to reveal the source but it is likely that this animal is of regional wild origin. Two C. mindorensis are kept in the San Mariano municipal crocodile rescue centre, these crocodiles were retrieved from fishermen who caught them in Disulap River and the Pinacanuan de Ilagan River, both San Mariano, respectively.

Discussion

A total number of 27 Philippine crocodiles is now known from six different sites in Northeast Luzon. Twenty-three crocodiles are found in the municipality of San Mariano, four in two sites along the Pacific Ocean coast. In addition, three C. mindorensis are kept in captivity in the region. The number of non-hatching crocodiles has increased since 2000 from 12 to 27, partly because of the discovery of new sites but mainly because of successful reproduction during the years 1999-2002. No breeding was observed in 2003, probably caused by a typhoon which struck the area in July of that year. The monitoring scheme which is in place in San Mariano provides valuable data to assess the threats to the extremely small population and to assess the success of conservation measures.

In 2004, two Estuarine crocodiles were observed along the Pacific coast of the Northern Sierra Madre. In addition, four C. porosus are known to be held in captivity in the region. Although not globally endangered, the Estuarine crocodile is possibly even more threatened in the Philippines than the Philippine crocodile.

Many questions remain about the ecology of the Philippine crocodile. Movement patterns are unknown. Diet is unknown. Reproductive behavior has never been studied in the wild. We aim to study the most important Philippine crocodile life-history parameters in the coming years.

Acknowledgements

The Northern Sierra Madre Natural Park-Conservation Project was implemented from 1996-2002 by Plan International
with funding from the Netherlands Government. The CROC Project is being implemented with a Grant from the British Petroleum Conservation Programme. BP also kindly provided budget for BT to attend the CSG meeting in Darwin. The Mabuwaya Foundation is hosted by the Cagayan Valley Programme on Environment and Development. We warmly thank Yaron Oppenheimer, Petra Oudejans and Richard van Alphen for their part in the crocodile surveys reported here.

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Crocodile Conservation in Sarawak

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Abstract

Estuarine crocodile (Crocodylus porosus) and false gharial (Tomistoma schlegelii) are the two known crocoddilian species found in Sarawak. The former are found to dominate most of Sarawak main rivers whilst the latter usually confine themselves to upper reaches of rivers in peat swamp forests. After undergone its black era in early and mid-1990s, where hunting was reported to be rampant, the populations of estuarine crocodiles in Sarawak are now found to be recovering quite fast in a number of rivers, with a density ranging from 3.0 individual/km in Sadong River to 8.0 individual/km in Bako River near Kuching. Whilst the ecological status of estuarine crocodiles is quite well understood the ecological status of false gharials are somehow limited. Old record on the existence of the species in Ensengei, Kroh, Runjing, Dor, Kelauh, Maying and Loagan Bunut have not been updated since late 1980s. The enforcement of the Wildlife Protection Ordinance, 1990 and the implementation of the Master Plan for Wildlife in Sarawak have contributed to the drastic increase in the crocodile population, particularly Crocodylus porosus. Both species are placed under Appendix II of the protected species list of the Ordinance. Those found to be in possession of the species without valid license from the Forest Department shall be guilty of an offence which carries a penalty of imprisonment for one year and a fine of RM 10,000. Keeping the individual species requires a licence fee of RM10/head/year, while a license fee for a crocodile farm is RM100/year. Unfortunately the increase in number of crocodiles in the wild leads to marked increase in human-crocodile conflicts. A total of 42 attacks have occurred since the last twenty-five years. Culling of potentially dangerous crocodiles in the wild does not seem to solve the conflict. While culling is allowable under the Wildlife Protection Ordinance in situ conservation of these species should go on. As such the Sarawak Forestry Corporation Pty Ltd. is now making an effort to extend its awareness program to villagers along crocodile-infested rivers and at the same time putting up ‘crocodile warning signs’ within the areas. To enhance conservation of crocodiles in the wild at least two areas been earmarked as Crocodile Reserves and eventually would be developed as hot spots for crocodile watching activities.

Introduction

Out of about 23 species of crocodilians found worldwide, only two species are found in Sarawak. These are the estuarine crocodile (Crocodylus porosus) that dominates most of Sarawak’s main rivers from the estuaries to the furthest tidal point, and a relatively smaller type, the false gharial (Tomistoma schlegelii). The latter are usually found in upper reaches of some rivers in peat swamp habitat. The two species can be easily distinguished from their external appearance. The snouts of estuarine crocodiles are normally shorter and somewhat blunt, whilst those of the false gharials are elongated and usually slimmer. Crocodiles are amongst the largest living reptiles and have changed little since the time of the dinosaurs, more than 150 million years ago. Both species represent an advanced group of reptiles from that period and they have certain features which are not found in other reptiles today. For example, the heart has four chambers and, like a mammal’s heart, can pump blood to and from the lungs without mixing (Gans 1976). The by-pass arrangement in crocodile enables them to be amphibious (ie being able to stay under water for a period of time as well as on land). In terms of global distribution, C. porosus is reported to be widely distributed from southern India, through the Gulf of Bengal and down to Peninsular Malaysia, Borneo, Indonesia, Papua New Guinea and to northern Australia (Bayliss et al. 1986).

Local Distribution and Abundance

Recent spotlight surveys in a number of rivers throughout Sarawak have shown relatively high density of estuarine crocodiles as compared to that in early 1980s. This is a good indication that the species is recovering well after its population was badly depleted during the colonial era. Surveys in early eighties indicated that relative density of estuarine crocodiles in most rivers in Sarawak were less than one crocodile per km. (Cox and Gombek 1985). As compared to the previous result the recent study along a number of rivers near Kuching, the State Capital of Sarawak, have given a range of relative density of 0.5 to almost 7 individual per km of the rivers surveyed (Fig. 2). Other surveys conducted in mid and late 1990s along rivers in central and northern part of Sarawak like the Sungai Lingga and Sungai Lupar, Sungai Sebelak, Sungai Sadong, Sungai Bakong, Sungai Niah and Sungai Sibuti have shown an
average density of around 2 crocodiles per km. The result was probably an early indication of the population recovery throughout the State.

While the population of estuarine crocodiles is known to be increasing well in their natural habitat the population status of false gharials, reported to be endemic to Borneo, is somehow not quite well known. Previous reports have indicated that the species was distributed along upper reaches of Sungai Ensengei (tributary of Batang Sadong), Sungai Kroh and Sungai Runjing, Engkelli (tributaries of Batang Lumar). Old record has indicated that the species have also been found in Sungai Dor (upper Sungai Kelauh), Sungai Maying (upper Tubau) and also Loagan Bunut in Tinjar. Extensive surveys and research are now required to assess the species current population and ecological status of the species throughout Sarawak. Most of the available data and information on the species were collected from local people. Difficulties in sighting the species in the wild, since they are more secretive in nature, and the problem to have access to its most likely habitats are the two main constraints to research on the species in Sarawak.
Conservation Status

Hunting pressure on crocodiles in Sarawak has been intense during times of the white Rajah rule in the last eighty to hundred years. Local people were offered bounties for each crocodile killed and egg collected. In some cases local extermination was a deliberate policy because crocodiles were classified as vermin (Bolton 1989), a danger to people and domestic stock. Quite apart from deliberate hunting, crocodiles have come increasingly into conflict with man because of their need for undisturbed nesting and foraging habitats. At the same time expanding human populations have made particularly heavy demands upon the same watershed habitats. As a result, wild crocodile populations throughout the state were found to be drastically declining in the eighties (Cox and Gombek 1985).

In Sarawak, under the present Wildlife Protection Ordinance 1998, *Crocodile porosus* and *Tomistoma schlegelii* are both placed under Appendix II of the protected species list. It means any person who is in possession, captures, sells, exports and imports these species, and their parts thereof without valid license shall be guilty of an offence which carries a penalty of imprisonment for one year and a fine of RM 10,000.

Keeping of these species would require a valid license (License to possess) from the State’s Department of Forestry. The fee for the “License to Possess” is RM 10.00 per head per year, if the number is less than ten heads. However it is considered as having a “Wild Animal Farm” if and when the animals are more than ten heads, and the license fee for having such a farm is RM 100 per farm per year. Currently there are two registered commercial crocodile farms throughout Sarawak where each one of the farms are housing about 3000 individual crocodiles, mainly *C. porosus*. Killing or even harassing crocodiles is strictly prohibited amongst some indigenous people in Sarawak, especially among the Ibans and the Malays. It is not simply because they are afraid of being arrested by relevant authorities for breaking the law (Wildlife Protection Ordinance, 1998) but it is more of a taboo to them. Some older generation of those people still believed that the species would take revenge some day if they are disturbed. Apart from the taboo, the restrictions by Wildlife Protection Ordinance, 1998 and the Wildlife Protection Rules on sales and keeping of the animals have also greatly contributed to the recovery of their populations in the natural habitats.

Despite the fact that there are not much direct threats to the population of *C. porosus* in the wild the conversion of peat swamp forests into agricultural lands is likely to be one of the greatest threats to *T. schlegelii* in the wild. A 9-foot female *T. schlegelii* was translocated to Semengoh Wildlife Rehabilitation Centre from a plot for paddy farm in Engkelili just before the burning season in 1995. Prior to this a 10-foot female was also surrendered to the Forest Department after it got entangled in a fish net at Sungai Ensengei, Sadong. Both animals are now being kept at the Matang Wildlife Centre near Kuching.

Human-Crocodile Conflict

Records have shown that there has been marked increase in crocodile attacks throughout Sarawak since 1980. A total of 42 attacks on human have been officially reported to the Forest Department over the last 25 years (Fig. 3). The latest victim was a 15-year old boy, attacked while casting a fish net at Layar River in Central Sarawak in March 2004. The body of the boy has never been found despite intensive effort to search for it along the river. A year prior to this incident another fisherman was also killed by the man-eater at Bako River (Fig. 4b). His body was found entangled in between nipah fronds two days later. A 10-year old boy was also fatally attacked by a crocodile in the Niah River in January 2001 while taking a dip. His body was badly mutilated by the animal (Fig. 4a).

Though found more abundantly in the Sarawak Mangrove, Sungai Santubung and Sungai Bako, as compared to elsewhere in Sarawak, about 80% of the crocodile attacks on mankind occurred along Batang Lupar and its tributaries. Preference by the predators to establish their breeding territories along the river and greater human activities in the area could possibly explain the higher incidence of attacks. The profile of the Batang Lupar River bank which is gently sloping down towards its river bed is probably an excellent breeding ground for the breeding population of its crocodiles (Stuebing 1985). At the same time human activities along the river, such as in agriculture and fishing have also increased. Clearing of forests along the river usually destroys refuges for other animals like primates and otters that usually are source of food for the reptiles. As these food animals become scarce the predators may be easily tempted to take on humans. Breeding animals would also be motivated to attack anything that intrudes into their territories. Unfortunately, these intruders are sometimes humans who also use rivers for bathing and transportation, and also as a source of food and water supply to river bank dwellers.
Management of Crocodiles in the State

Section 42 of the Wildlife Protection Ordinance 1998 (amendment 2003) provides right for general public to defend themselves, their properties and other people against any aggression by the animal. However every animal killed or captured must be reported to the nearest Forest Department as soon as possible.

Upon request, the Forest Department issues permit to cull nuisance crocodiles that are known to be dangerous to humans being or their properties such as livestock. The Department has also conducted a number of culling operations in some crocodile-infested rivers where fatal attacks have taken place. One of the sites where culling operation was conducted recently is Bako River where six individual crocodiles were killed.

Apart from issuing permits for culling and translocation of dangerous crocodiles, the Department is also making move to gazette several crocodile-infested areas as Crocodile Reserves. At the moment at least two areas in the State have been earmarked for this purpose. The first one is the Sarawak Mangrove area near Kuching, which currently is still a Forest Reserve. The other is the Ulu Kluah area, a tributary of Sungai Lingga in Sri Aman Division. It has been suggested that any dangerous crocodiles outside the Reserves could be destroyed. Once the Reserves have been put in place and officially gazetted the areas could possibly become hot spots for crocodile sighting activities. In other words they could possibly help in promoting tourism in Sarawak.
General Perceptions Toward Crocodile Conservation

Following marked increase of crocodile attacks throughout the State in recent years there seems to be an increasing number of conflicting views from the general public on how the Department is handling the crocodile conservation statewide. An editorial of one of the local newspapers published recently even suggested that the crocodiles, particularly *Crocodile porosus* should be downgraded from their present protected list into a non-protected status as their populations are now greatly increased. In some rivers their populations are probably well exceeding their respective carrying capacities. Others are of the opinion that the Department concerned should be fully responsible for every crocodile attack on man and their properties and compensation or some kind of insurance should be granted to the victim.

On the contrary another ‘school of thought’ feels that crocodile attack is a natural process in the ecosystem and that humans living along rivers should change their lifestyle, for instance, be extra careful when going into rivers, fencing-up their jetties and bathing places, etc. The most likely questions raised by this opinion group are ‘what is crocodile attacks as compared to road accidents? And ‘why are the use of cars not banned?’ Some members of this group even view that crocodile attack on man is an act of God. This group of ‘environmental fundamentalists’ who have adopted an almost religious view of their chosen field are not likely to compromise on the ongoing culling process of crocodiles in some Sarawak rivers. To some ‘killing’ is a highly sensitive issue probably because they relate to the killing of nuisance crocodiles to the killing of people. In this circumstances, the crocodile species, especially *Crocodile porosus* are not the ones that are endangered but instead local people staying along the rivers are the ones who are most likely to be endangered by the animal. Webb (1997) has stated that the conservation prospects for wildlife are not great if it has a high positive value to distant people in or from distant lands, but a low or negative value to the people who own it or live with it and have a power to keep or destroy it. Conservation, animal rights and animal welfare are three totally different issues that should not be seen as all being part of the same entity (Webb 1997). The issues of animal rights and animal welfare need to be separated and treated as legitimate problems of their own, and have little to do with conservation. In the case of crocodiles that are potentially dangerous to human and yet cannot be killed since they are protected by law there are some concerns that rights given to animals may turn out to be rights taken away from people. Thus it shows that the real problem with animal rights is not the assigning of human values to a few animals like crocodiles, but rather the justification that it may provide for treating people like animals (Cockburn 1996).

Conclusions

Whilst the issue of whether the crocodile culling and translocation should go on to a level that the animal is no longer a threat to riverbank dwellers is debatable, the conservation of this last relics of the extinct dinosaur must be continued. It might not be in a way that the reptile must be left alone in their natural habitat (rivers), but alternatively the conservation of this potentially man-eating species would best be done in legal commercialized farms. Sustainable commercialization of legally captive-bred crocodiles would at least generate revenue for the State and subsequently help to improve its economy. In this respect there is a prime need for the existing Wildlife Master Plan for Sarawak to be thoroughly reviewed to allow and encourage ex-situ conservation of crocodiles. The conservation of *Crocodile porosus* should not only be for the interest of the few fundamental conservationists, but it should also of interest to the majority of local people as well. One should not be too worry of the possible extinction of the crocodiles. The species can reproduce successfully if given the right conditions while in captivity. According to Chai (pers. com.), survival rate of crocodiles in farm is much higher than that in the natural habitat. Similarly, the animal’s population in their wild habitats normally have various means of compensating for losses in numbers due to mortality or harvest (Webb 1978). Bolton (1989) has also stated that when crocodile numbers in the wild have been reduced, for instance by hunting, the survival rate of young ones would improve. In other words, survival depends partly on the numbers or on the density of crocodiles, and the losses are greater at the higher densities.

Acknowledgements

I would like to thank the General Manager of the Protected Area and Biodiversity Conservation Unit for allowing me to attend this very important meeting on crocodiles. I also would like to thank Mr. Rob Stuebing for his time giving me some information on crocodiles. With this opportunity I also would like extend my thank to Mr. Paschal Dagang, Mr. Ganyia Liap, Mr. Henson and Mr. Uning for their untiring effort to assist me conducting the surveys all these while.
Literature


Recent Reversals in the Population Trends in the Population of Gharial in the National Chambal Sanctuary in North India; Implications and a Suggested Strategy for the Conservation of One of the World’s Most Endangered Crocodilians

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Introduction

The gharial *Gavialis gangeticus* was critically endangered in 1975 with a world population numbering less than 300 individuals (Behler 1975). This resulted in conservation action through a Government of India/FAO-UNDP Crocodile Conservation Project comprising of a head-start program with captive reared animals and the creation of the National Chambal Sanctuary, which encompasses 425 km of the Chambal River flowing along the borders of the three north Indian states of Rajasthan, Madhya Pradesh and Uttar Pradesh. These steps enabled the gharial to recover from its critically endangered condition. The Gharial population of the Chambal that had numbered 150-175 before the initiation of the project was monitored regularly and showed steady growth reaching a figure of 1289 individuals in 1998, Sharma (1999). Because of the positive trend of the gharial population in the Chambal River, it was accepted in many quarters that the status of gharial had ‘stabilized’ and the species did not require proactive conservation efforts for its survival.

Recent Reductions of Gharial Population in the Chambal River; its Nature andExtent

After 1998, the Chambal was surveyed in 2003 following a gap of four years and then again in 2004. These surveys were conducted in the months of February/March, when conditions are favorable for gharial enumeration, using methods identical to those of earlier workers. Year wise summarized results of these surveys, along with the results of surveys conducted by previous workers are given in the following table.

The population decreases were first noticed during a survey of dolphins conducted by the first author in 2001 when intense clandestine fishing operations were observed in a particular section of the river. However, in that year the survey did not extend over the entire length of the National Chambal Sanctuary and the population decreases could not be comprehensively assessed.

There is no plausible cause for the observed decrease of gharial population other than mortality due to accidents in nets of fish poachers that operate in the sanctuary. Many fishing nets were confiscated and destroyed by burning in the course of the surveys. The smallest age class of gharials showed maximum decrease in the latest surveys. This is possibly because this age class also routinely disperses downstream beyond sanctuary limits and is also the one most susceptible to mortality from accidents in nets of the mesh size most commonly used in fishing. That the mortality rate due to fishing nets can be extremely high was revealed in 2003, when 8 gharials were found dead during a survey lasting only 15 days. The observed decrease of 30-40% in the populations of adult and sub-adult gharials, in the five years between 1998 and 2003, works out to 6-8% annual reduction.

The Current Management Status of the Sanctuary

Three different management systems and hierarchies are in force in the three states in which the sanctuary lies, encompassing areas of a total of twelve administrative districts.

Rajasthan

The sanctuary in Rajasthan has no separate machinery or staff for administration of the sanctuary. This is the responsibility of the District Forest officers of five districts viz. Kota, Bundi, Sawai Madhopore, Kaila Devi and Dholpur. There are apparently no special budget allocations for the administration, nor any field-staff deployed exclusively for protection or maintenance of the sanctuary and neither is there any management plan.
Table 1. Population of Gharial in the Chambal River differentiated into 3 size classes. (To facilitate comparison of populations between years, crude population densities per river km are shown, since river stretches surveyed in different years were not identical). SA+J = sub-adults and juveniles; H+Y = hatchlings and yearlings. References: 1= Singh (1978); 2= Singh (1985); 3= Rao (1988); 4= Hussain and Choudhury (1991); 5= R.K. Sharma (unpublished information).

<table>
<thead>
<tr>
<th>Year</th>
<th>Section of River Surveyed</th>
<th>Length of River Surveyed (km)</th>
<th>Total Adults</th>
<th>Adult Density (gh/km)</th>
<th>Total SA+J</th>
<th>SA-J Density (gh/km)</th>
<th>Total H+Y</th>
<th>H+Y Density (gh/km)</th>
<th>Total Population</th>
<th>Population Density (gh/km)</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-1979</td>
<td>Sections near major breeding sites</td>
<td>~250</td>
<td>30</td>
<td>0.120</td>
<td>43</td>
<td>-</td>
<td>34</td>
<td>-</td>
<td>107</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1983-84</td>
<td>Rahuka Gaon to Pachnada**</td>
<td>315</td>
<td>37</td>
<td>0.117</td>
<td>369</td>
<td>1.171</td>
<td>45</td>
<td>0.143</td>
<td>451</td>
<td>1.432</td>
<td>2</td>
</tr>
<tr>
<td>1984-85</td>
<td>Pali*** to Pachnada</td>
<td>425</td>
<td>49</td>
<td>0.115</td>
<td>491</td>
<td>1.155</td>
<td>65</td>
<td>0.153</td>
<td>605</td>
<td>1.424</td>
<td>2</td>
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<tr>
<td>1985-86</td>
<td>Pali to Gyanpura/ Jagtauli</td>
<td>385</td>
<td>66</td>
<td>0.171</td>
<td>391</td>
<td>1.016</td>
<td>170</td>
<td>0.442</td>
<td>627</td>
<td>1.629</td>
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<tr>
<td>1988</td>
<td>Pali to Pachnada</td>
<td>425</td>
<td>114</td>
<td>0.268</td>
<td>536</td>
<td>1.261</td>
<td>170</td>
<td>0.400</td>
<td>820</td>
<td>1.929</td>
<td>4</td>
</tr>
<tr>
<td>1990</td>
<td>Pali to Pachnada</td>
<td>425</td>
<td>113</td>
<td>0.266</td>
<td>727</td>
<td>1.711</td>
<td>142</td>
<td>0.334</td>
<td>982</td>
<td>2.311</td>
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<td>1993</td>
<td>Pali to Pachnada</td>
<td>425</td>
<td>186</td>
<td>0.438</td>
<td>305</td>
<td>0.718</td>
<td>407</td>
<td>0.958</td>
<td>898</td>
<td>2.113</td>
<td>5</td>
</tr>
<tr>
<td>1994</td>
<td>Pali to Bhare</td>
<td>415</td>
<td>202</td>
<td>0.487</td>
<td>418</td>
<td>1.007</td>
<td>488</td>
<td>1.176</td>
<td>1108 (*1026)</td>
<td>2.670</td>
<td>5</td>
</tr>
<tr>
<td>1995-96</td>
<td>Pali to Bhare</td>
<td>415</td>
<td>212</td>
<td>0.511</td>
<td>445</td>
<td>1.072</td>
<td>557</td>
<td>1.342</td>
<td>1214 (*1042)</td>
<td>2.925</td>
<td>5</td>
</tr>
<tr>
<td>1996-97</td>
<td>Pali to Bhare</td>
<td>415</td>
<td>226</td>
<td>0.545</td>
<td>459</td>
<td>1.106</td>
<td>554</td>
<td>1.335</td>
<td>1241 (*1078)</td>
<td>2.993</td>
<td>5</td>
</tr>
<tr>
<td>1997-98</td>
<td>Pali to Bhare</td>
<td>415</td>
<td>0</td>
<td>0.000</td>
<td>0</td>
<td>0.000</td>
<td>0</td>
<td>0.000</td>
<td>1289 (*1121)</td>
<td>3.106</td>
<td>5</td>
</tr>
<tr>
<td>2003</td>
<td>Pali to Chakarnagar</td>
<td>395</td>
<td>150</td>
<td>0.380</td>
<td>265</td>
<td>0.671</td>
<td>99</td>
<td>0.251</td>
<td>514</td>
<td>1.301</td>
<td>5</td>
</tr>
<tr>
<td>2004</td>
<td>Pali to Chakarnagar</td>
<td>395</td>
<td>158</td>
<td>0.400</td>
<td>276</td>
<td>0.699</td>
<td>118</td>
<td>0.299</td>
<td>552</td>
<td>1.397</td>
<td>5</td>
</tr>
</tbody>
</table>

*** Pali is the upstream-most point of National Chambal Sanctuary
** Pachnada is the downstream-most point of National Chambal Sanctuary
* Total population corrected for the river section from Palito to Chakarnagar

Madhya Pradesh

The sanctuary is under the financial and administrative control of the Divisional Forest Officer, Morena Forest Division, while the executive officer is the Sanctuary Superintendent, National Chambal Sanctuary, who is an officer
of the rank of Assistant Conservator of Forests. The Sanctuary Superintendent is assisted by three Forest Rangers, one Research Ranger and sanctioned staff strength of about 28 subordinate field staff. The effective strength of executive subordinate cadre field staff, as computed in the draft management plan, works out to single personnel for guarding 40 km of river. The sanctuary being situated in non-forest areas of civil districts necessitates the involvement of the staff with the revenue and civil authorities of 3 very large districts Sheopur, Morena and Bhind of Madhya Pradesh.

The sanctuary has experienced a financial crunch for the past several years with very little available resources for so-called plan expenditure through which budget allocations are made for development works of the sanctuary. Even the ‘non-plan’ budget allocated has fallen short of the requirements for meeting expenditure on salary which has had to be supplemented with budget appropriations from financial heads that are not earmarked for the sanctuary. As a result, there has been hardly any available budget for meeting the maintenance expenditures of the sanctuary including fuel, lubricant and expenditures for regular and effective patrolling of the sanctuary that is estimated at Rs 5 lakhs (~$12,000) per annum. It will however be noticed that between 2003 and 2004 there has not been any decrease to the gharial population and in fact there is a slight improvement in the gharial populations of all age classes. This, in all probability, is because of the action taken by the MP authorities to intensify patrolling of the sanctuary with additional budget being made available for this. This step was taken in view of the abrupt and alarming decrease in the sanctuary gharial population noticed in 2003. Also river patrolling for all echelons of field staff for stipulated periods was the made mandatory by the higher authorities of the Forest Department.

A management plan has been drafted for the MP sector by the MP Forest Department. The draft management plan is well focused on the problems of conservation of aquatic biodiversity in the sanctuary and contains some innovative approaches to long term solutions to some of the problems faced by the sanctuary. However, whether the Government of MP will have political support to carry out the far reaching reforms required for implementation of the draft management plan, even if the plan is formally approved, cannot be said with any certainty at this stage. The estimated cost of implementation of this plan over a ten year period from 2003 to 2013 is Rs 777 lakhs (or US$1.8 million) so the total cost of implementation of similar plans in all the three states comprising the sanctuary would be about US$5-6 million.

Uttar Pradesh

The sanctuary is under the control of the Divisional Forest Officer, National Chambal Sanctuary. Because of some changes in the administrative structure of the Forest Department, the controlling officer and field staff have been burdened with the protection of certain forest areas lying within the sanctuary boundaries whereas formerly the management and protection of gharial and river biodiversity was their exclusive responsibility and concern.

Nature and Intensity of the Various Threats being faced by the Sanctuary

Agriculture

Agriculture is the most serious of long-term threats because it damages habitat and alienates wildlife off it. When the river recedes in summer growths of riverine succession of Tamarix on the exposed islands, which now become accessible, are hacked down to reclaim the areas for agriculture and gharial, mugger and turtle nesting sites may also be destroyed in the process. Shrinkage of stream due to reduced discharge of the river (see water abstraction below) increasingly exposes sandy riverbanks that are utilized for cultivation of cucurbit crops such as gourds and melons. As a result, increasing human activity on the river banks alienate gharial of all size classes from basking habitats and lead to permanent emigration of animals from these areas, as has occurred in the Yamuna and many other north Indian rivers, where ever riparian cucurbit cultivation is practiced. Although not quantified, it can safely be said that agricultural activity on riverbanks has steadily increased over the years.

Water Abstraction

Water abstraction for agriculture through a lift irrigation scheme in Uttar Pradesh within the last decade would definitely have impacted stream flow in downstream sections of the river. A second, major lift irrigation scheme has been approved, which is meant to supply the nearby town of Dholpur in Rajasthan with drinking water. During the recent surveys increasing numbers of small diesel pump sets were noticed being used for local agricultural irrigation. Certain midstream rocks, formerly submerged, that seem to have become exposed to heights of up to 2 m during the surveys in 2003 and 2004. There are unconfirmed reports about the planned construction of a hydroelectric dam
Rahughat. If this dam is eventually constructed, the hydrological regime of the river may be radically transformed with serious implications for gharial habitat. Apart from causing stream shrinkage, water abstraction also exposes more sand banks for potential, large-scale cucurbit horticulture with adverse impact on gharial because of reason already discussed. Unsustainable water abstraction is likely to severely and adversely impact gharial habitat to the extent that Chambal River may eventually be rendered uninhabitable for gharial.

**Fishing**

During the survey, fishing on commercial scale was observed in most of the stretches. Fishermen were seen using nylon gill nets and other advanced fishing gear. Fishing activity was recorded from 60-75% of the Chambal River flowing within the sanctuary. Interrogation of fishermen in the upper stretches revealed that they worked for fish contractors who resided in Rajasthan where planned sanctuary management is yet to come into force because of this state’s non-participation in the National Chambal Sanctuary Project. Illegal fishing is rampant and occurs on a scale, which apart from directly causing mortality of gharial in net accidents is likely to affect the food availability for gharial and reduce the carrying capacity of the river for piscivorous aquatic vertebrates like gharial, mugger, dolphin and otters. The most serious implication of fishing arises from the fact that the fishing regime has changed from the pre-sanctuary notification period to that in the current time. Previously, fishing was carried out by different contractors who acquired fishing rights auctioned by the district authorities. The contractors used the services of fishermen from outside the sanctuary areas who were forced to discontinue fishing activity and leave when the contract fishing system was scrapped. Today the local residents of the area are gradually discovering the economic benefits of fishing and once this becomes incorporated into the local economy, as is happening at present, curbing and regulating fishing will become more and more difficult if not impossible. The lawlessness of the area is well documented and fishing in certain stretches has come under the control of criminal elements making control of fishing an uphill task requiring large investments on enforcement. Fishing pressures have also become acute at the upstream and downstream most extremities of the sanctuary.

**Sand Mining**

During the survey in 2004, sand mining on the Madhya Pradesh side of the river, was recorded only on 5 sites. However, large-scale sand mining was recorded in all the 11 survey zones on the Rajasthan side. Intensive mining of building stone from the riverbed was also recorded in Zone 1 (Rameshwar-Khirkiree) at Solghata near Adavasipura. Over the years, the financial implications of sand mining at Rajghat, the only mining site that is actually auctioned by the government owned Mining Corporation, have magnified manifold. Today this site generates an annual revenue of Rs 23 crores ($5.35 million) for the state. Due to reduced river discharge most of the upper stretches of the river have shrunk to a very narrow and shallow stream, easily fordable on foot and tractors, enabling activities like sand and stone mining from the bank as well as the riverbed. These are reaching a level when they are bound to become serious threats for the biodiversity of the sanctuary. Not only is human presence at the mining sites leading to the exclusion of wildlife from these areas, but mining activity is also probably altering the geomorphology and adversely affecting wildlife habitats in unknown ways. Apart from the Rajghat site mentioned earlier, sand mining occurs clandestinely at several points along the river on a scale which is drastically and irreparably altering several important nesting and basking sites for gharial like Banwara, Ajbapura, Puren, Barenda, Gyanpura. Sand mining in Chambal sanctuary has reached an industrial scale and feeds the building construction business of several big cities of the region including the country’s capital, Delhi. While directives of India’s Apex Court go against any exploitation, whatsoever, of the natural resources of any PA, the ground reality is that the economic value of Chambal building sand is too large for its exploitation to be prevented by simple legal protection. The industry is labor intensive and a major income generator in the local economy as well, so the illegal syndicate which controls this unorganized industry, will go to great lengths to prevent any impediment to it, for which it has not only its own financial base but also local socio-political support.

**Firewood Collection**

Harvesting of fuel wood and denudation of tree cover from bordering ravenous areas leads to catchment erosion and increased stream turbidity as well as silt deposition with a resultant shrinkage of stream.

**A Strategy for the Conservation of Gharial**

The gharial, because of its great and unique scientific value, requires conservation action guaranteeing its indefinite survival. The lessons learnt from the successes and more importantly the failures of the first conservation action to
save the gharial in the Chambal and North India are as follows:

i) The permanence of political support for gharial and biodiversity conservation in any protected area cannot be taken for granted as the conservation concept still remains detached from the socio-economic aspirations of the common people.

ii) The characteristics of dispersal/migration of younger age/size classes of gharial are such that the success rate of supplementation of captive reared gharial within any localized river stretch is low, necessitating protracted and sustained supplementation to successfully restore populations.

iii) Gharials do not become permanent residents of unprotected river stretches where there is conflict and disturbance due to people.

iv) The biotic pressures on gharial are increasing at rapid rates exacerbating the complexities and dimensions of the problem of gharial conservation.

In view of the political mutability of India, any strategy to conserve the gharial should therefore be independent of anticipated permanent and sustained political support for its implementation. The following strategy is proposed for international adoption and support to save the gharial from extinction and guarantee its demographic health.

**Continual and Definite Monitoring of all Surviving Gharial Populations**

As seen in the Chambal, gharial population declines can be quite rapid. So, there is the need for continually updated accurate information on the status of all surviving gharial populations. So far, this information has been available due to efforts of a few devoted workers who appreciate the significance of scientific population monitoring. But this is not yet an institutional activity undertaken by the main agencies responsible for gharial conservation in the Chambal viz. the state Forest Departments. The practice of survey and census at regular intervals along with all financial and other support to conduct these requires to be ensured, so that status of different gharial populations is monitored without break and gharial population reductions become known at the earliest.

**Extension of Gharial Population Restoration through Head Start Programs, in all Existing Parks with the Potential for Population Restorations**

Presently, apart from the Chambal River, only the Girwa River in the Katerniaghat Sanctuary in northern Uttar Pradesh and the Ramganga River in the Corbett National Park in the state of Uttaranchal has breeding populations of gharial. Of these two populations, the Katerniaghat WLS encompasses a river section less than 5 km in length that forms prime gharial habitat. In nearly three decades, this population has not been observed to expand and colonize adjacent river sections. As such, the Girwa River in the sanctuary is a fragile and vulnerable gharial habitat where long-term conservation does not appear to be viable. Precise information about the breeding status of the Ramganga population is not available and the extent of prime gharial habitat is also believed to be extremely limited. Considering therefore, the immensity and complexity of the problems faced by the Chambal sanctuary a worst case scenario exists in which, wild gharial populations can once again decline to the level of extirpation or critical endangerment as had occurred in 1975 if conditions in this sanctuary continue to deteriorate.

A safeguard against such a situation needs to be developed by restoring the gharial populations in the two other potential gharial conservation areas, viz. the Ken and the Sone Rivers, to breeding status. Both these areas have been legally protected for over a decade or more but it has not been possible to restore their populations to breeding status (Sharma, unpublished information). This is mainly due to lack of sustained supplementation of the population with captive reared gharial. In this respect the Sone Sanctuary notified in 1981, which includes a section of the Sone River some 200 km in length and some prime gharial habitat, has the best potential for consolidated population restoration. The Ken Sanctuary, which is much smaller than the Sone and includes a relatively small river section comprising prime gharial habitat, presents a situation like the Girwa River in the Katerniaghat Sanctuary already mentioned, but considering the precarious situation confronted by the species every opportunity for developing buffer populations should be exploited to the maximum. Potential gharial conservation areas in other states such as Assam and in northeastern India and West Bengal where reintroductions of gharial in former habitats have been attempted also need to be vigorously followed up. Husbandry know-how for the captive rearing of gharial exists in north India and may be used to extend ex-situ operations wherever necessary.

**Sustained Research on Dispersal and Migration of Gharial and Refinements of Supplementation Techniques**

Because of the linear nature of gharial habitats the species, especially the younger size classes that are used in
supplementation programs, are disposed to rapid and extensive emigration that is believed to occur pre-dominantly in the down stream direction. However, there have been almost no sustained studies of the phenomenon by either mark-recapture or telemetric methods that will facilitate refinement of supplementation techniques and aid higher retention rate of released animals in sanctuaries. Many aspects of gharial biology and ecology remain largely unknown and research is required to acquire more elaborate knowledge of these as well.

Research on River Water Management and Impact of Water Abstraction

The impact of water abstraction needs quantification and study to determine the extent and rate of habitat degradation. Also the potential and implications of rainwater harvesting and storage in the Chambal catchment may be a potential solution to prevent the ultimate inhabitability of the river for gharial. This information is also extremely important for all gharial conservation areas.

Research on Environmental Impact of Different Biotic Pressures on the Chambal River as well as other Gharial Habitats and Conservation Areas

Such research is required for making management decisions that are not arbitrary and therefore do not lead to avoidable conflict with human populations residing in or on the periphery of gharial conservation areas.

Innovative Eco-Development to Raise Standards of Living of Important Target Groups of Local Residents and Eliminate their Dependence on Natural Resources required for Gharial Conservation

Eco-development is a key tool for reducing dependence of stakeholders residing in and around core gharial conservation areas on resources occurring in gharial habitats. Eco-development has not yet been an unqualified success where experimentally initiated but the impedimental problems can be identified and solved if the implementing agencies are adequately motivated have the required resources at their disposal.

Sustained and Adequate Awareness Campaigns for Different Target Groups and Stakeholders in Resources Required for Conservation of Gharial

Although the effectiveness and feasibility of awareness programs may be questioned, it is vital that every north Indian stakeholder know about the highly endangered state of the gharial and appreciates the participatory role that has to be played in conserving this species. So far efforts at increasing awareness about these issues have been opportunistic, sporadic and grossly inadequate at best. There is need to carry out a well planned, well designed campaign using all potential, formal as well as non-formal media to achieve this, and of sustaining the campaign until this has been achieved.

Mobilization of Resources to Achieve the Above

Very little financial resources, either indigenous or foreign have been forthcoming to support conservation of gharial unlike that made available for charismatic mammalian wildlife like the tiger. The quantum of funds required to exhaustively implement all the above strategies in letter and spirit, will probably require international financial assistance. Even if the international community shows willingness to contribute the necessary resources, the modalities of this assistance will require a great amount of careful consideration and reflection by both the donors and the acceptors and should have foolproof safeguards to ensure that the resources are efficiently and effectively utilized.

Acknowledgements

The second author is grateful to Rom Whitaker for a travel grant and encouragement to go to Gwalior and write this paper in collaboration with RKS. We are grateful to our respective Forest Departments for the support of our work.

Literature


Progress in India and Bangladesh

Nikhil Whitaker

Up until the 1970s, the three crocodilians of South Asia were seriously endangered, with main causes being the killing of animals for skins and meat, eating of their eggs, and the loss of habitat. In India the GOI/FAO/UNDP Crocodile Conservation Project, the Madras Crocodile Bank Trust, and State Forest Departments reversed this decline. However, after showing so much promise in its initial stages with the creation of crocodile sanctuaries and the release of over 9000 gharial, saltwater crocodiles and mugger, the project has grinded to a standstill as the Central Government has withdrawn support for crocodile conservation … a shame after so much has been achieved. Of critical importance is the situation of the gharial in the Chambal River, with a 50% decline in numbers from the last survey done in 1996. There is the emerging seriousness of crocodile/human conflict, with people being killed in Gujarat, Kerala, and Rajasthan by mugger, and at least one person a year by saltwater crocodiles in Bhirarkanika. With regards to Bangladesh, a proposal for commercial farming of saltwater crocodiles (imported from Malaysia) has recently met with approval. The Madras Crocodile Bank will be supplying mugger crocodiles as founder stock for a captive breeding program for future re-introduction into the wild.
Status of Crocodilians in South America

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The South American continent has the greatest diversity of crocodilians: 8 (35%) of the world’s 23 recognised species (Ross 1998; Table 1). The status of each species differs (Table 2). All 8 species are listed under CITES Appendix I or II, but only 3 are listed in the latest IUCN Red List (IUCN 2003).

In general all species are well studied in each country (Velasco 2000; Velasco and De Sola 2000; Velasco and Denis 2002) covering abundance, size classes, reproduction, genetics, nutrition, adaptability to captive breeding, incubation, growth in captivity, reintroduction, mark and recapture programs, human-crocodile interactions and management programs.

Table 1. South American countries containing crocodilians.

<table>
<thead>
<tr>
<th>Species</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Caiman crocodilus</em></td>
<td>Brazil, Colombia, Ecuador, Guyana, French Guinea, Peru, Suriname, Venezuela</td>
</tr>
<tr>
<td><em>Caiman yacare</em></td>
<td>Argentina, Brazil, Bolivia, Paraguay</td>
</tr>
<tr>
<td><em>Caiman latirostris</em></td>
<td>Argentina, Brazil, Bolivia, Paraguay, Uruguay</td>
</tr>
<tr>
<td><em>Melanosuchus niger</em></td>
<td>Bolivia, Brazil, Colombia, Ecuador, French Guinea, Guyana, Peru</td>
</tr>
<tr>
<td><em>Paleosuchus palpebrosum</em></td>
<td>Bolivia, Brazil, Colombia, Ecuador, French Guinea, Guyana, Paraguay, Peru</td>
</tr>
<tr>
<td></td>
<td>Suriname, Venezuela</td>
</tr>
<tr>
<td><em>Paleosuchus trigonatus</em></td>
<td>Bolivia, Brazil, Colombia, Ecuador, French Guinea, Guyana, Peru, Suriname</td>
</tr>
<tr>
<td></td>
<td>Venezuela</td>
</tr>
<tr>
<td><em>Crocodylus acutus</em></td>
<td>Colombia, Ecuador, Peru, Venezuela</td>
</tr>
<tr>
<td><em>Crocodylus intermedius</em></td>
<td>Colombia, Venezuela</td>
</tr>
</tbody>
</table>

Table 2. IUCN and CITES species status.

<table>
<thead>
<tr>
<th>Species</th>
<th>IUCN Red List</th>
<th>CITES</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Caiman crocodilus</em></td>
<td>Not listed (LC, Least Concern)</td>
<td>Appendix II, except <em>C. c. apaporiensis</em> -</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Appendix I</td>
</tr>
<tr>
<td><em>Caiman yacare</em></td>
<td>Not Listed (LC, Least Concern)</td>
<td>Appendix II</td>
</tr>
<tr>
<td><em>Caiman latirostris</em></td>
<td>Not Listed (LC, Least Concern)</td>
<td>Appendix II (ranching) in Argentina Appendix I in all other countries</td>
</tr>
<tr>
<td><em>Melanosuchus niger</em></td>
<td>LR/cd (Low Risk: Conservation Dependent)</td>
<td>Appendix II (ranching) in Ecuador subject to quota since 1997, Appendix I in all other countries</td>
</tr>
<tr>
<td><em>Paleosuchus palpebrosum</em></td>
<td>Not Listed (LC, Least Concern)</td>
<td>Appendix II</td>
</tr>
<tr>
<td><em>Paleosuchus trigonatus</em></td>
<td>Not Listed (LC, Least Concern)</td>
<td>Appendix II</td>
</tr>
<tr>
<td><em>Crocodylus acutus</em></td>
<td>VU A1ac (Vulnerable)</td>
<td>Appendix I</td>
</tr>
<tr>
<td><em>Crocodylus intermedius</em></td>
<td>CR A1c C2a (Critically Endangered)</td>
<td>Appendix I</td>
</tr>
</tbody>
</table>
Some species support sustainable use programs, such as wild harvest in Bolivia (Velasco 1998), Guyana, Paraguay and Venezuela (Velasco and De Sola 1999) with Caiman crocodilus and Caiman yacare. Other species have ranching programs, for example Caiman latirostris in Argentina (Larriera 1998, 2002) and Melanosuchus niger in Ecuador.

The other crocodilian species are subject to conservation programs. These are summarised by species and country.

**Melanosuchus niger**

With this species the situation is very interesting. On one side all international institutions agree with the IUCN and CITES classification (Low Risk: Conservation Dependent and Appendix I). But we found the species listed on Appendix II for ranching purposes in Ecuador with zero commercial quota.

In Bolivia, we found an unofficial commercial program where jail prisoners in Trinidad City, produce handmade belly skins and other products. In Brazil, principally Amazonia, Da Silveira and Thorbjarnarson (1999) report that the species is subject to harvest for meat consumption in great quantities.

Da Silveira (2001) published his PhD dissertation which proposed a sustainable use program for *M. niger* in two different areas in Brazil (Archipelago of the Anavilhanas Ecological Station and in the Mamirauá Sustainable Development Reserve, located in the Amazonas State) after 10 years of studies demonstrated an excellent population.

In the Colombian Amazonia region, a national management and conservation program is being considered, which in the short-term would change the status of the *M. niger* from endangered to vulnerable, and in the long-term transfer it to a category of low concern. The framework for the program is based on the Treaty of Amazon Cooperation TCA (1997) and the Colombo-Peruvian Plan for the integral development of the basin of the river Putumayo PPCP (1998). The plan involves indigenous communities that inhabit the region directly into the management process so that sustainable use of the species is achieved.

**Crocodylus acutus**

We found different management programs in South America. For example, Peru implemented a captive breeding program in Tumbes region. In Colombia we found two lines of work, one of captive breeding activities supported by the government with the goals to implement farms in sustainable use programmes and reintroduce crocs to wildlife. Two *C. acutus* farms are presently registered by CITES in commercial phase and another one is in the process of being registered. The Ministerio del Ambiente, Vivienda y Desarrollo Territorial have designed a National Conservation Plan for the species that includes reintroduction programs and sustainable use linked with captive breeding activities.

In Venezuela *C. acutus* have been subject to a National Action Plan since 1995 (Velasco *et al.* 2000), that includes several components:

- Populations survey
- Captive breeding and ranching
- Reintroduction
- Monitoring

One of the most important results of this program has been restocking the wild population (Velasco and Lander 1998), where it was demonstrated that released crocodiles had adapted perfectly after a year’s evaluation.

By 2003 Venezuela had released 429 *C. acutus* in wild habitats (Table 3), principally in protected areas by the Ministry of Environmental and Natural Resources (MARN) such as Wildlife Refuges.

In 2002 the Universidad Central de Venezuela, through the Faculty of Science, Coordination of Extension, evaluated the natural populations of *C. acutus* to determine the abundance, size structure, and available occupied and potential habitats. The goal was to propose reintroduction areas for the species. In total 23 locations were visited inside the historical distribution area.

In 2003 this National Action Plan was subject to an update by the Biodiversity National Office of the Ministry of Environmental and Natural Resources (MARN), where the original goal “recovering the wildlife population through collecting eggs to breeding and reintroducing the juveniles” was consolidated (MARN 2003).
Table 3. Numbers of *Crocodylus acutus* released by year and place.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cuare Wildlife Refuge</th>
<th>Los Olivos Wildlife Refuge</th>
<th>Turiamo Bay</th>
<th>Jatira-Tacarigua Dam</th>
<th>Pueblo Viejo Dam</th>
<th>Tucure Wildlife Refuge</th>
<th>Del Banco Lagoon</th>
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</tr>
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<td>1986</td>
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<td>16</td>
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<tr>
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<td>21</td>
<td>87</td>
<td>9</td>
<td>25</td>
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</table>

The actions planned to achieve this goal, are:

1. Populations surveys.
2. Collecting nests from the wild.
3. Increasing the number of farms and captive breeding facilities.
4. Releasing and/or reintroducing crocodiles to the wild.
5. Monitoring.
6. Evaluating the species status for CITES.
7. International cooperation.

*Crocodylus intermedius*

This species is one of most endangered in the world, found only in Colombia and Venezuela. Colombia classified the species as critically endangered in 1997 and designed a national plan for its recuperation and conservation (MA 2002). Based on the studies done between 1994 and 1997, a population of around 250 individuals was found in 70% of the natural area of distribution (Rodríguez 2000).

This national plan has a general goal “to prevent the extinction and to promote their recovery in the natural area of distribution.” The specific goal is to increase the population in 10 years by 50% in 500 km² and have a population around 2500 adults in the wild (MA 2002).

To achieve these goals, Colombia will implement the following actions:

1. Recovery of eggs and hatchlings from the wild.
2. Building 1200 m² of infrastructure to breed 2500 individuals.
3. Identify habits for reintroduction.
4. Define a reintroduction protocol.
5. Monitoring the reintroduced populations.
6. International cooperation.

In Venezuela the situation is better, the most recent studies reporting recovering populations in different natural habitats (Seijas and Chavez 2000; Llobet 2002; Seijas *et al.* 2002).
In 1993 Fudena together with several institutions and scientists developed an Action Plan for the recovery of \textit{C. intermedius} populations. In the following year Profauna (1994) of MARN designed a Strategic Plan with the same goal, but introducing action in the short time.

In 1990 the \textit{C. intermedius} reintroduction program began (Velasco 1999) and to date has released 3394 crocodiles into the wild (Table 4), principally in Wildlife Refuges (2) and National Parks (2).

One of the best results of the reintroduction program occurred in the Caño Guaritico Wildlife Refuge, a natural habitat of the species but prior to 1990 no \textit{C. intermedius} were found. In 1997 the first nest from reintroduced crocodiles was found. El Frío ranch established the first ranching program with the species (Ayarzagüena, pers. com.) where eggs were collected from the Wildlife Refuge.

In 2001 a Bi-National Workshop was held between Colombia and Venezuela to coordinate the conservation programs between both countries. Meetings between CITES Administrative Authorities began in 2003 to design the best manner of collaboration to recover the populations (Velasco 2001).

However, Seijas (2000, 2003) published two papers evaluating the status of the Program for the Conservation of the Orinoco caiman in Venezuela. The author believed that many of the original goals are compliment, it is necessary “redefine the goals and strategies in order to achieve the recovery of the species.”

In 2003 this Conservation program was subject to an update by the Biodiversity National Office of the Ministry of Environmental and Natural Resources (MARN), where the original goal “recovering the wildlife population through collecting eggs to breeding and reintroducing the juveniles” was consolidated (MARN 2003).

The actions planned to achieve this goal, are:

1. Collecting eggs from the wild.
2. Increasing the number of farms and captive breeding facilities.
3. Releasing and/or reintroducing crocodiles to the wild.
4. Evaluating the species status for CITES.
5. International cooperation.

Table 4. Numbers of \textit{Crocodileus intermedius} released by year and place.

<table>
<thead>
<tr>
<th>Year</th>
<th>Caño Guaritico Wildlife Refuge</th>
<th>Capanaparo Cinarucu National Park</th>
<th>Aguaro-Guariquito National Park</th>
<th>Arrau Wildlife Refuge</th>
<th>El Cedral Ranch</th>
<th>Tucupido Dam</th>
<th>Cojedes River</th>
<th>Manapire River</th>
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<td>Total</td>
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<td>69</td>
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<td>19</td>
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Acknowledgments

Our thanks to the organizers of the 17th Working Meeting of the IUCN-SSC CSG for the invitation to present this paper, especially to Dr. Grahame Webb, Charlie Manolis and Tom Dacey. Thanks to José Ayarzagüena and Hato El Frio Biological Station staff for their information. To Ronis Da Silveira for his information. Thanks to Claudia Sánchez from the Instituto Amazónico de Investigaciones (SINCHI-CITES Scientific Authority). To Dr. Jesus Ramos Director of Biodiversity National Office in Venezuela and Dr. Gonzalo Andrade Ecosystem Director in Colombia. To Adam Britton who kindly helped with English editing.

Literature


The Management of *Caiman yacare* in Range States
(Argentina, Bolivia, Brazil, Paraguay)

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(yacare@arnet.com.ar)

The yacare (*Caiman yacare* or *Caiman crocodilus yacare*) is a small crocodilian found in four countries in South America; Brazil, Argentina, Paraguay and Bolivia. The species is abundant and widely distributed in all kinds of water bodies [lakes, rivers, swamps, wet savanas (Pantanal)]. The species was exploited heavily for leather during the 1960s and 1970s but by 1990 a combination of national legislation and CITES regulations reduced legal trade. The species continues to be exploited for meat for local use and a continuing trade in illegal skins is alleged, but difficult to verify.

*Caiman yacare* is listed in Appendix II of CITES and as threatened under the U.S. Fish and Wildlife Service. Even though this species is not listed within the IUCN Red List of Threatened Animals, and according to the Status Survey and Conservation Action Plan (1998), is a low risk and minimum concern species.

In Brazil the only authorized exploitation it is based on ranching, mostly in the Pantanal region. In Argentina, even thought there is one project for the utilization of the species through a hunting program, the only current utilization is also by ranching and as a complement of *Caiman latirostris* ranching operations. On the other hand, Paraguay and Bolivia’s programs are fully based on hunting and despite the fact that apparently there is no risk for the wild populations, they clearly need further strengthening, mainly at the institutional level and general communication among stakeholders.

During the Caiman Management Program Evaluation in Paraguay (October 2001), and the Workshop for the Caiman Sustainable Use National Program Evaluation in Bolivia (April 2002), the general agreement was that populations of *C. yacare* in Bolivia and Paraguay are in good state in their major areas of distribution; however, lack of communication among the different sectors involved and lack of information by users with respect to the aim and changing technical aspects of the program were recognized as serious problems.

Finally, a workshop was held 3-5 October 2002 in Gainesville, Florida, USA, to discuss management, conservation and trade in *Caiman yacare*. Twenty-five official participants represented the four yacare Range States (Argentina, Bolivia, Brazil, Paraguay), Venezuela, USA, the meeting sponsors (US Fish and Wildlife Service, CITES Secretariat, Louisiana Fur and Alligator Council), TRAFFIC South America and the Crocodile Specialist Group. The recommendations of this workshop are still in the implementation process.
Status of *Crocodylus porosus* and *Crocodylus novaeguineae* Conservation and Management in Papua New Guinea (1981-2004)

Godfrid C. Solmu

Department of Environment and Conservation, PO Box 6601, Boroko, NCD 111, Papua New Guinea

Abstract

Following the non-conduct of the *C. porosus* survey since 1998 and *C. novaeguineae* survey since 1999, the overall management program was under scrutiny by CITES and the CSG in terms of the PNG Governments efforts, through its Management Authority the Department of Environment and Conservation to sustain this highly technical component of the monitoring program. Scientifically, economically, socially and culturally, PNG has an obligation to justify the dispensation that was agreed to in Costa Rica in 1979 to ensure that regular monitoring is being implemented to assess the effects of harvesting of both the species from the wild.

The Department was able to raise support for funding to be able to conduct both the *C. porosus* and *C. novaeguineae* surveys in 2003 and the *C. porosus* survey in 2004. Although there is missing data in the previous years due to the non-conduct of the surveys because of the limited funding support from the Government, the results from both the surveys indicate that the wild population densities of both species are healthy rather than declining. This may suggest that the increased awareness in habitat conservation and the value added incentives being derived from the resource through the 12 year *C. porosus* egg harvest program is being practiced at the community level.

However, from the trade data figures the number of skins exported from the wild excluding the ranched skins from Mainland Holdings have been consistent for the last 7 years since 1997 at approximately 25,000-30,000 skins annually. Thus, the status of the PNG population level in terms of wild harvests is considered viable for the current dispensation to enable the commercial exploitation to continue.

Introduction

The two species of crocodiles occurring in Papua New Guinea (Fig. 1) are the endemic New Guinea freshwater crocodile *Crocodylus novaeguineae* and the Indo-Pacific saltwater crocodile *Crocodylus porosus*. Their habitats extends throughout most of the lowlands of the main island of PNG landmass, with *C. porosus*, the only species occurring on the offshore larger islands.

There is some evidence that the central cordillera has effectively isolated the north and south populations in PNG; giving rise to distinct populations perhaps enough to merit subspecies classifications (Cox 1984, cited in Frazier 1988), however, no actual work has been carried out to confirm this report. Although the species share a similar geographical distribution, it can be generalized that there are more *C. porosus* in the coastal populations and more *C. novaeguineae* in the upper river systems of the Sepik, Ramu, Fly and Kikori/Purari catchment systems and isolated swamps and channels as most of the crocodiles harvested are freshwater crocodile skins that forms the majority of skins exported from PNG.

This paper discusses the significance of the implementation of the monitoring program, management and the commercial trade in compliance with the CITES and CSG requirements being implemented by the Government of PNG through the Management Authority, which is the Department of Environment and Conservation (DEC). The integral part of this program was to carry out research and monitor both the species during their peak nesting seasons and assess the effects of harvesting on the wild populations through trade, and to get the understanding needed to make adjustments and corrective decisions on the commercial trade. We are not able to provide a representative indication of the wild population throughout the country due to the major factor in funding and logistical support requirements by the Government. However, the extrapolation of the annual data from the Sepik survey with the long-term monitoring data has been presented as the indicator for the PNG situation. Both the PNG species are currently listed under Appendix II of CITES since the dispensation that was granted at the Contracting Parties of the CITES Convention meeting in Costa Rica in 1979.
The Management Program in PNG

Since the mid-1960s Papua New Guinea’s populations of *C. porosus* and *C. novaeguineae* have been actively managed to improve the biological efficiency of harvesting. In recognition of the significance of the commercial aspects of the industry and the exploitation and conservation of the wild populations, this led to the development of a legal frame work in 1966 and the enactment of the legislation as the Crocodile Trade (Protection) Act, Chapter 213 in 1969 and later amendments were made in 1974, 1982, and 1986 and recently in 2003 some amendments are now submitted to the National Executive Council (NEC) for approval and gazetted. There are thirteen regulations under the Act, dealing with control over licensing, buying, farming and exporting. Other components of the enforcement in facilitating the regulation of the industry; included relevant sections of the Fauna (Protection) and Control Act, Chapter 154, International Trade in (Fauna and Flora) Act, Chapter No. 391 and general customs regulations under the Customs Act, Chapter No. 101, and Customs Tariff (Exports) Act, Chapter No. 103.

The significant component of management retained to date by the National Government through the Management Authority are the enforcement of regulations and monitoring of the wild crocodile populations, with the exception of extension services being devolved to the Provincial Governments to be implemented by the Division of Primary Industry’s (DPI) under the Government’s reforms policy for the rural sectors. PNG has a population of 5 million people and a third of the population live in the major wetland and the mangrove estuaries. The communities living in the wetlands are subsistence farmers and depend on the crocodile industry through wild harvesting as a means of cash income to sustain their livelihood. The current funding that is available from the Government cannot assist to fund major interests of research and expansion of monitoring work to other areas due to the geographical isolations of remote crocodile habitat areas. The management recognizes this and has to refocus on the strategies for the future of the program on conservation and utilization in that crocodiles are generating sustainable revenue for the Government in terms of the commitment to investment on the long term monitoring efforts of the resource and the industry in general.
Monitoring Efforts of PNG’s Wild Populations

Whilst, determining the wild crocodile populations in PNG is of long-term significance to the industry it has been a real challenge for many years specifically since 1994 for the crocodile monitoring officers. The program has been confronted with a lot of logistical and fiscal hurdles and sometimes with methods for accurately estimating population size that are typically evasive or difficult and expensive due to geographical locations for implementation throughout the country. Funding has been a real problem that besets the consistency in implementation and the extrapolation of the raw data from the field and in instances some surveys over the recent years were not being implemented for both crocodilian species. However, cost effective and accurate alternatives has to be derived from the existing data set (Britton et al. 1998), in which for the longer term we are working towards implementing the alternate procedures for this program in that the Government understands the approach that is to be implemented.

The status of the wild populations of PNG’s two crocodile species have been estimated by aerial nests counts over approximately 75-80 km stretch along the Sepik floating vegetations as with the majority of the wild crocodilian populations being observed to be associated with intact habitat conditions elsewhere.

Timing of the nesting varies both between the species and within the species. In the Sepik area, *C. novaeguineae* nests during the short dry season and lays an average of 35.3 (17-51) eggs/clutch. In contrast, *C. novaeguineae* on the southern portion of the island nest during the wet season and lays only 21.7 (8-36) eggs/clutch (Hall 1983; Cox 1985; Hollands 1987 cited in Staton et al. 1992). Using the number of skins and animals taken from wild populations as an indicator, it can be approximated that *C. novaeguineae* out numbers *C. porosus* by a ratio of 4 or 5 to 1. From an economical standpoint, this is unfortunate as the skins of the former species are roughly 2 to 3 times more valuable that those of the latter.

The results of the survey years in this presentation highlighted the exclusion of the data that were not collected, which included; 1999-2002 for *C. porosus* (4 years) and 1997-1998, 2000-2002 for *C. novaeguineae* (5 years). The non-conduct was attributed to the down turn in the country’s economy and that the allocation for this program has been difficult to secure although numerous presentations have been made to the Government. However, this has not affected the analysis and the interpretation of the data with the regression method over the longer term with the exclusion of the missing survey years.

The current program allows for the selective harvesting of wild populations within the regulations in, which skins may be taken directly from the wild, or indirectly - after animals (or eggs) originating in the wild have been reared on a farm. In Papua New Guinea a large number of people are dependent on crocodiles as the only foreseeable source of income. In view of this, and the fact that the crocodiles have never been “on the verge of extinction” PNG has adopted a highly flexible attitude in continually reviewing management options from the available knowledge from the 23 years of monitoring and utilisation of this resource.

**Survey results for *C. novaeguineae* and *C. porosus* populations (1981-2004)**

The helicopter monitoring program for *C. novaeguineae* and *C. porosus* commenced in 1981 and 1982 respectively. The survey results as compiled to 2004 are summarised in the DEC internal reports and involves counts over 48 *C. novaeguineae* sites and 41 *C. porosus* sites. The Bell Jet Ranger-206 was hired to fly the permanent established transect lines for some sites depending on the site’s configurations. Flight paths were consistent over time and that search, speed, height and recording procedures were also maintained as reported in earlier internal and external reports. Most importantly the survey personal has also been maintained over the years for the conduct and to improve cost effectiveness in these times where the costs of helicopter hourly rates are very excessive.

The raw counts on the *C. novaeguineae* and *C. porosus* nesting effort in the wetland systems through the overlays has enabled us to detect changes and to evaluate the status of specific sites in terms of habitat conditions, the use of wetland sites, interactions between species and hunting pressures. It was observed that some sites have maintained consistent number of nest between species at each sites (eg Nyngium is a saltie site that has recorded 12 nests and 15 nests in 2003 and 2004 respectively). Simultaneously for the same site the *C. novaeguineae* nests observed in 1999 and 2003 were 2 and 3 respectively. Similarly other sites that were being observed had similar trends with increases in the number of nests where the other species is not being present or where the habitat conditions do not suit the other species.
Thus, the survey results indicated in Figure 2 represent the overall nesting effort for the (N= 21) primary sites that is representative of the 48 sites that have been consistently surveyed since 1981. The trend indicated where (x = number of years the surveys were being conducted and y = nest numbers counted for each index), the data is being inferred that for the primary sites although is declining it is considered not significant as demonstrated here that there is no significant relationship between nests counts and years; (r² = 0.056, p= 0.378). Some sites are considered as _C. porosus_ nesting sites and that the dispersal of the non-aggressive species the _C. novaeguineae_ through interactions with _C. porosus_ is evident as reported in Manolis (1995). Thus, for this set the regression equation inferred that there is only 5.6% variation in y.

![Figure 2. The trend indicating the 21 _C. novaeguineae_ primary nesting sites consistently surveyed from 1981-2003.](image)

The other subsets (N= 31) and (N= 36) (Fig. 3), are secondary sites that were consistently surveyed since 1987 and 1988 respectively. With the inclusion of 2003 results in the analysis for both subsets that have been added as the survey progresses over the years, the data rendered both the relationships to be not significant where; (r² = 0.0046, p= 0.843 and r²= 0.0059, p= 0.833). The survey over the years consistently replicated sites within three different habitat types (scrolls, oxbow lakes and overgrown channels) in which _C. novaeguineae_ normally nest.

![Figure 3. Secondary sites [N= 31 (open circles) and N= 36 (closed circles)] that have been surveyed consistently over the years and is representative of the 48 sites.](image)

The _C. porosus_ nesting effort (N= 12; Fig. 4) for the long-term over the survey period of 22 years in which the sites have been consistently surveyed. The current set of data were regressed from 1984 including the 2004 survey results depicted the following results where; r² = 0.3509, p= 0.0156. Clearly with the inclusion of the 2003 and 2004 survey results the trend renders the relationship to show significant increases as against the 1998 data, which appear to reflect the extreme seasonal effects from the preceding year in 1997.
There was an extended 12 months of dry period (El Niño) that affected the whole country. Most of the wetlands and overland oxbows and lagoons discharged into the main Sepik River, leaving the survey sites exposed and dry where extensive burnings were evident following the 1998 survey.

Two other subsets (N= 15 sites) included in 1984 and (N= 29 sites) being added in 1988, are represented in Figure 5. When regressed both relationships exhibited significant increases in nesting effort, where; $r^2 = 0.3621$, p= 0.0136; and $r^2 = 0.3038$, p= 0.0508, although there were no results from the 4 years after the 1998 survey, the nesting effort is dramatically being influenced by the 1997 seasonal effects. Thus, it can be assumed that the *C. porosus* nesting effort in the wild is still healthy and that the population is still abundant for the representative sites for the species.

It is observed that regardless of which datasets are used for both species, when the sites are regressed with the 2004 data, the results for both species indicate that the wild populations are healthy rather than decreasing or stable nesting. The *C. novaeguineae* (N= 36) and the *C. porosus* (N= 29) nesting effort could be considered to be more representative of the whole nesting habitat in the region that is perhaps more applicable to the breeding populations as a whole for both species.
Saltwater crocodiles responded in two ways to the loss of nest sites; some apparently did not breed at all (or may have bred later in the year, but we have had no indication of this), and some moved to less disturbed, remoter, areas away from the open water. This movement is indicated by the fact that the changes that were observed in nest numbers in 1997 before the El Niño and after the El Niño, were not uniform across habitats. In the most accessible habitat, the floating mats fringing open water, there was a drop of 50%, in the numbers in overgrown oxbows and channels remained constant, and there was actually a rise in the numbers of nests in the remote scroll swales. By the following seasons (ie in 2003 and 2004) the floating mats had recovered and there was a move back to the lake fringes, with scroll nests dropping in number despite the increases in nesting, indicating such areas are only sub-optimal reserve nesting sites.

When the sites were regressed given the saltwater results they indicate there was about 20% rise in nest numbers from 1998, showing that the drop that occurred in some habitats during 1998 was mainly attributable to the temporary loss of nesting habitat and not to the killing of breeding stock. It is therefore considered reasonable to assume that both species are increasing in numbers perhaps through the recruitment of younger females in to the breeding population.

**Egg Harvest Program**

The conservation aspect of the crocodile management program in PNG depends heavily on the sustained utilisation of the wild resource. Some of the most successful crocodile management programs (eg Louisiana and Florida in USA, Northern Territory of Australia, Zimbabwe) rely on wild harvested eggs as the basic stock for ranching programs (Cox and Solmu 1996). The PNG program offers similar programs and presents advantages for both conservation and commercial interest, and reduces high egg mortality in the wild also requiring less hunting effort of dispersed juveniles and providing ex situ incubation with control over fecundity and sex.

The baseline data on the nesting biology of the two crocodile species in the Sepik, including interactions with the local communities, was provided by a preceding five year investigation (Cox 1985). Combining with the analysis of the data from the aerial nests counts in those years from 1980-1985, this knowledge of nesting parameters enabled the potential costs and benefits of eggs extraction to be gauged quantitatively. At least we were able to note that 35% of surveyed *C. porosus* and a similar proportion of *C. novaeguineae* nests in the middle Sepik were harvested for human consumption. (Hollands 1985). Reported losses through other causes are also reported in Cox and Solmu (1996) and results of the harvests over the years are presented in Table 1.

<table>
<thead>
<tr>
<th>Year</th>
<th>Nests Harvested</th>
<th>% of Nests Surveyed</th>
<th>Total No. of Eggs</th>
<th>No. of Viable Eggs</th>
<th>% Viable Eggs</th>
<th>Mean Clutch Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>14</td>
<td>19.4</td>
<td>795</td>
<td>661</td>
<td>83.1</td>
<td>56.8</td>
</tr>
<tr>
<td>1986</td>
<td>17</td>
<td>23.9</td>
<td>1061</td>
<td>859</td>
<td>81.0</td>
<td>62.4</td>
</tr>
<tr>
<td>1988</td>
<td>13</td>
<td>16.1</td>
<td>793</td>
<td>647</td>
<td>81.6</td>
<td>61.0</td>
</tr>
<tr>
<td>1989</td>
<td>20</td>
<td>20.6</td>
<td>1329</td>
<td>1198</td>
<td>90.1</td>
<td>66.5</td>
</tr>
<tr>
<td>1990</td>
<td>29</td>
<td>29.6</td>
<td>1613</td>
<td>1324</td>
<td>82.1</td>
<td>57.6</td>
</tr>
<tr>
<td>1992</td>
<td>35</td>
<td>24.6</td>
<td>2066</td>
<td>1656</td>
<td>80.2</td>
<td>59.0</td>
</tr>
<tr>
<td>1994</td>
<td>29</td>
<td>25.4</td>
<td>1726</td>
<td>1545</td>
<td>89.5</td>
<td>59.4</td>
</tr>
<tr>
<td>1996</td>
<td>47</td>
<td>33.3</td>
<td>2722</td>
<td>2145</td>
<td>78.8</td>
<td>57.9</td>
</tr>
<tr>
<td>1998</td>
<td>36</td>
<td>47.5</td>
<td>1983</td>
<td>1591</td>
<td>80.2</td>
<td>55.08</td>
</tr>
<tr>
<td>2002#</td>
<td>62</td>
<td></td>
<td>3542</td>
<td>2772</td>
<td>78.3</td>
<td>57.13</td>
</tr>
<tr>
<td>2003</td>
<td>*138</td>
<td>*76.2</td>
<td>*8364</td>
<td>*6807</td>
<td>*81.4</td>
<td>*60.61</td>
</tr>
<tr>
<td>2004</td>
<td>*215</td>
<td>*46.5</td>
<td>*12,756</td>
<td>*10,261</td>
<td>*80.4</td>
<td>*59.3</td>
</tr>
<tr>
<td>Totals</td>
<td>655</td>
<td></td>
<td>38,739</td>
<td>31,467</td>
<td>81.23</td>
<td>59.14</td>
</tr>
</tbody>
</table>
As initially designed the helicopter used in conjunction with the aerial nests counts was chosen over ground transport as the means to harvest clutches. The helicopter offers the advantages of rapid conduct and control over handling and transport. Flight time devoted to harvesting would be paid for by Mainland Holdings and placement from outside the Sepik pro-rated accordingly.

The ground based harvesting with canoes was investigated in 1990 and 1992. The method was found to reduce costs and add safety compared to aerial collection, and to be more effective and applicable on a wide scale. However, with the introduction of the Sepik Wetlands Initiative program to encourage conservation of habitats with added value being placed on the eggs harvesting program, the introduction to ground harvesting was introduced in 1998 (Table 1). The impact of reducing hatching recruitment by harvesting eggs could be expected to be detected in 51-60 cm and 61-65 cm in one or two years later.

Spotlight surveys have not been conducted within the accessible parts of all harvested areas due to capacity and logistical support problems. However, the general aim is to reduce densities and to facilitate the extraction of sustainable yields (Webb et al. 1989) From figures presented in Table 1, it can be noted that there is an average of 80% viable eggs being achieved from every harvest from an average of about 60 eggs per clutch. It can be inferred that the resource owner earns more from the clutch if they are viable eggs with not time spent for catching crocodiles and that there are larger and older reproductive adults in the wild.

Ground eggs harvesting was considered as a good initiative as eggs are also being harvested from non survey sites, which allow for participation by all communities to benefit from the eggs collection program. In this way a wider community support is being encouraged in terms of minimizing habitat degradation through burning during extended dry periods.

We were not able to analyse the effects of sites that were harvested and sites that were unharvested, however similar studies showed no significant effects (Webb et al. 1989).

Taken together there were 38,739 eggs C. porosus collected from 655 wild nests from 1985-2004. Although most nests up to 1998 were collected within the survey area, the later harvests also collected outside of the survey area. Studies are now needed to quantify subtle or longer term effects whilst collections is still being encouraged during the nesting season to enhance habitat conservation, however, results from harvests to date are consistent with predictions of a minor impact.

In the program there were only 128 C. novaeguineae nests collected from 1988-1989, with a total of 4236 eggs. Due to the investment and economic decisions of Mainland Holdings and the successful existing ranching operation in PNG, it decided to abandon the C. novaeguineae eggs harvest program. This may have been attributed to the current world market prices affecting the C. novaeguineae wild skins and the return on its investment and management to collect and farm C. novaeguineae eggs.

**Exports**

Since 1981 when the International Trade in (Fauna and Flora) Act took effect, the exports of crocodilian products from PNG were regulated under the provisions of the Convention of International Trade in Endangered Species (CITES). With that regulating mechanism in place PNG has implemented enforcement activities at all levels of trade based on controlled, sustainable, and legal harvest within the limits to encourage healthy wild populations.

The trade in crocodilian skins from PNG for C. novaeguineae since 1983, indicated that the maximum exports was around 29,682 in 1990 and the minimum was 21,981, with the C. porosus at a maximum of 8150 in 1991 and a minimum of 3910 in 1986 (Luxmoore and Collins 1994). Japan still remains the number one importer of PNG wild crocodilian skins and by continually having a consistent market it is healthy for the industry to be regulated under legislation with harvests from a sustainable program that assist conservation in PNG for the long-term.

The number of skins exported from PNG for both species that included wild and ranched skins has been consistent over the years. It should be noted that the 1997 harvests recorded the largest ever export from PNG with a total of 41,683 skins, (Fig. 2) and the majority of these were wild C. novaeguineae skins due to the El Niño and the extensive dry spell throughout the country.
Although the graph did not indicate the category of the *C. novaeguineae* and *C. porosus* skins from ranched and wild skins, the majority of current ranched skins are *C. porosus* due to the current market forces. *C. novaeguineae* ranched skins constitute a very small proportion; the highest was in 1998 with 6211 skins and since then has declined to only 6 in 2002.

Although we do not have the capacity and the resources to provide the figures on the harvest data from the wild for juveniles and skins that have been purchased through the current regulations however, these information were submitted by all licence holders as conditions under the regulations by DEC for the renewal of licences.

PNG has consistently maintained its trade on legal, sustainable basis with the linkages of this to the conservation of wild crocodilians. Although PNG has produced a lot of *C. novaeguineae* wild skins there has been a shift in demand and emphasis on high value classic skins that is reflected by quality consumer products and this is reflected back down the chain of trade to the producers at the community level. Thus, the emphasis is now being placed on the farming and ranching of *C. porosus* skins to meet the demand and quality in the market place.

**Conclusions**

An indirect indication to the status in the wild population on a national level can be taken from trade statistics; it was in fact these that initially drew attention to problems of overexploitation in the 1960s. It has long been known that water levels throughout the year have a strong influence on the number of crocodiles harvested and we now know that there is also a marked correlation between the price of skins and the number exported. Due to these factors and the gradual shift towards ranching, the annual harvest totals (Fig. 2) are of little use in assessing trends in the wild population. However, the size structure of the harvest are currently being compiled to give a useful indication and that PNG is aware that both crocodiles are long lived and takes up to 10 years to reach sexual maturity for slow growing *C. novaeguineae* at 1.8–2.0 metres in length for females and 2.5 metres for males, whilst the fast growing *C. porosus* takes up to 10-15 years to reach sexual maturity at 2.2 metres for females and 2.5 metres for males. Thus, where there is a need to review the lower and the upper limits of the legal sizes of exports, the Management Authority will consult with the industry.

With the current observations from the long term monitoring data many of the nesting sites for *C. novaeguineae* are also nesting areas for *C. porosus*. Using the data from 1988, the period in which the nesting effort by *C. porosus* increased significantly, a regression analysis was carried out using the number of nests for each species in those sites where both species have nested at some time. It was observed that from 1988-2004, there was a trend although not significant is towards decreasing number of *C. novaeguineae*. Should *C. porosus* nests counts continue to increase with the current trend, it is possible that because the species is highly territorial in nature, it may prevent or exclude completely *C. novaeguineae* from nesting in areas where they currently both nest.

It is emphasised that the monitoring programme in PNG is currently in its 23rd year and the indication to date is that both species of crocodiles in Papua New Guinea are increasing in numbers. Although the cost of this highly technical component of the program is expensive due to the depreciation of the PNG Kina against the USD$, the current management programme should therefore be continued. The three surveys that have been conducted so far since 2003 has accumulated about K295,000 which is equivalent to about USD$88,500 and that the Department does not have that appropriation to facilitate for the surveys annually. However, alternative assessments in terms of the regular conduct of these surveys are being reviewed by the Management for implementation with the consideration that the program meets CITES requirements to continually monitor the species. Both species gives considerable benefit to the country, particularly to the very remote communities and that cropping should be maintained within the sustainable limits.

**Acknowledgements**

Firstly without the contributions and administrative support from the Department of Environment and Conservation especially the Secretary of the Department (Dr. Wari Iamo) and the First Assistant Secretary of Nature Conservations Division (John Genolagani) in seeking funding and the opportunity to support my involvement in this program, it would not have been possible for me to conduct these highly technical surveys. I also extend my thanks to Benny Gowep as the reliable technical field officer for the support and to be continually be available to conduct the surveys to enable the presentation on the status report of the PNG Management Program at this meeting.

Further to that I wish to extend my gratitude on behalf of the PNG Management Authority (DEC) for the support that
have been provided by the CSG, especially to the outgoing Chairman Professor Harry Messel and Dr. Perran Ross for the formal support that has been provided to the Department to ensure that the significance of the program to the species and the communities is being recognised and that funding was provided by the Government of PNG to conduct such highly costly technical surveys.

I wish to also acknowledge the contributions of the Wildlife Management International, Dr. Grahame Webb and Charlie Manolis for putting up with us at various stages to make some comments on the drafts of the survey reports that we were putting together.

To the industry I convey many thanks to the contributions from Horiuchi Trading Company of Japan, Mainland Holdings Company of Lae, Bush Development Corporation formerly of Madang and Northern Trading of Port Moresby for the support in monetary and logistical facilities towards the program during times when the economy is not doing well and the Department needs assistance. Finally to Juda Nundima of the DEC for his extra hours in the office to put together all the export figures that are presented in this report.

**Literature**


Indication of Crocodile Recovery and Management Implications in Crocodile Conservation in Sabah

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Abstract

Sabah Wildlife Department (SWD) conducted crocodile surveys in 1984 and 2002. The results from the recent surveys suggest that there has been a steady recovery of the population in the last 10-15 years. There are also unsubstantiated reports of the existence of the Malaysian Gharial (Tomistoma schlegelii) from the Klias Peninsula (southwestern Sabah). Another indicator of the recovery has been the increase in attacks in Sabah rivers that becomes the social issue. SWD has been trying to conserve the remaining riverine habitats in Segama River by establishing conservation area to provide the habitats not only crocodiles but also other protected species, with JICA assistance. The fragmentation and agricultural development pressure especially by oil palm plantation to wetland and riverine habitats that are represented in Segama River becomes significant issues in Sabah. Moreover, not many breeding sites has been confirmed. The confirmation and conservation of the breeding sites become urgent issues in crocodile management in Sabah.

Crocodile Conservation Status and Indication of Population Recovery in Sabah

A single species of crocodilian, the Estuarine Crocodile (Crocodylus porosus) is recorded from the state of Sabah in Malaysian Borneo, although there are unsubstantiated reports of the existence of the Malaysian Gharial (Tomistoma schlegelii) from the Klias Peninsula (southwestern Sabah) and Kinabatangan River. Both species are Totally Protected Species (Schedule 1) under the Sabah Wildlife Conservation Enactment, 1997.

During a survey undertaken in 1984, a total of 56 wild crocodiles were seen along approximately 1156 km of rivers in eastern and western Sabah. Surveys in 2002 revealed 253 crocodiles along approximately 223 km of many of the same rivers, an indication that C. porosus populations in Sabah, have undergone significant recovery over the past 10-15 years. Another indicator of higher crocodile densities has been the increase in sightings and attacks in Sabah rivers over the past five years.

Comparison of raw densities, and those corrected based on detectability of size class (Bayliss 1987) is given in Table 1. The comparison of the 1984 surveys and those by Stuebing et al. (1993) with recent data indicates that the Sabah population has undergone a recovery, based on:

- A ten-fold increase in observable crocodile densities for some rivers in Sabah since 1984;
- Indications of successful reproductive effort (based on percentages of small juvenile crocodiles observed); and,
- A crocodile population currently estimated to be 13,000 to 15,000 animals, a significant portion of which appear to be mature reproductive adults.

Table 1. Estimated crocodile densities in Sabah (per km of river bank). * Whitaker’s figure of 0.46/km used a formula based on Caughley (1977), which does not take into account differences in detectability based on size. ** Approximate figure, adapted from Bayliss (1987): Class 1, 0.693; Class 2, 0.735; Class 3, 0.460; EO, 0.153; Total = 505 crocodiles. Hatchling = <0.5 m total length; Class 1 = 0.5-1.0 m; Class 2 = >1.0-2.5 m; Class 3 = >2.5 m; EO = Eyes only.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Distance surveyed (km)</th>
<th>Class</th>
<th>No. of crocs sighted</th>
<th>Mini. relative density (per km)</th>
<th>Corrected relative density (per km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whitaker 1984</td>
<td>1146.0</td>
<td>1</td>
<td>13</td>
<td>31</td>
<td>0.05</td>
</tr>
<tr>
<td>Stuebing et al. 2002</td>
<td>222.8</td>
<td>3</td>
<td>178</td>
<td>31</td>
<td>2.27**</td>
</tr>
</tbody>
</table>

204
The highest densities and overall number of crocodiles are found in Sabah’s largest river, the Kinabatangan, which also has the largest area of floodplain habitat. The conspicuous recovery of Sabah crocodiles is probably attributable to several factors or influences over the past two decades, including:

- Legal protection of *C. porosus* in Sabah since 1982 (Amendments to the Fauna Conservation Ordinance 1963) and subsequent conservation measures taken by the Wildlife Department (including the gazetting of the Lower Kinabatangan Wildlife Sanctuary, one of the most extensive areas of excellent *C. porosus* habitat in Sabah). Most rural residents in Sabah know crocodiles are protected by law, and illegal hunting has decline substantially.
- Decline of the timber industry, and a related decrease in habitat disturbance and river traffic.
- Siltation from land clearing or other habitat disturbances upriver, leading to the transformation of downstream sections (shallower channels, increase in broad muddy bank, changes in fish fauna), providing ecological situations favourable for colonization by *C. porosus*.
- Stabilization of oil palm estates, whose development originally caused severe ecological disturbance when large tracts of degraded forest were felled and burnt. River banks in these areas are recovered with a stable community of secondary growth including grasses and herbs used by female crocodiles for nest construction.
- Opening of extensive areas of closed canopy swamp and riverine forest, including the loss of such forest to fires during drought in 1983, 1986 and 1998, creating larger area of suitable nesting habitat (“Padang” vegetation).
- The El Niño - southern oscillation episode of 1997-98, which may have virtually eliminated a major source of crocodile mortality, the flooding of nest, during that year.
- Beginning in the early 1990s, the progressive decline of international prices for crocodile skins by more than 60% in 2001.

Although no single factor can be identified as the primary one involve in the recovery of Sabah’s crocodile populations an inadvertent moratorium on hunting may have been among the most important. With time, a cohort of traditional crocodile hunter has passed on, and probably few if any of these local people, have been replaced.

**Crocodile Representation in Protected Area**

Sabah Parks, Wildlife Sanctuaries and other types of conservation reserves cover a broad range of habitats, including the riverine, freshwater swamp and mangrove areas inhabited by *C. porosus*. The protected areas in Sabah are shown in Figure 1. Though the breeding has not confirmed, the only three small protected areas contain significant areas of crocodile habitat:

![Figure 1. National Parks and protected areas in Sabah.](image-url)
• Kinabatangan Wildlife Sanctuary - 270.0 km²
• Kulamba Wildlife Sanctuary - 206.82 km²
• Kabili-Sepilok Forest Reserve - 42.94 km²
• In addition to these areas are several mangrove forest reserves (eg the Labuk-Sugud River estuary) and riverine reserves as dictated under Forest Department Enactment, totalling greater than 6800 km².

Based on the result of the survey conducted in 2002, a Sabah Crocodile Management Programme was developed and adopted by the Sabah Wildlife Department. The key elements addressed in the programme are summarized as follows;

• Identify and conserve breeding areas.
• Expand protected area in potential breeding areas.
• Reduce and control crocodile and human conflict.
• Public awareness on crocodile conservation.
• Confirmation and conservation of Malayan False Gharial.
• Promotion of the sustainable use programme (eg farming, ranching, eco-tourism).

A five-year Bornean Biodiversity and Ecosystem Conservation Programme (BBEC), a joint collaboration with Sabah State Government Agencies, University of Malaysia and NGOs, supported by Japan International Agency (JICA) commenced in February 2002. The Programme consists of four components namely Research and Education, Park Management, Habitat Management, and Public Awareness, aims to establish comprehensive and sustainable approach for conservation. Habitat Management Component Project led by Sabah Wildlife Department aims to establish integrated approach for habitat management in the target area. The target area for the project is Tabin, Kulamba Wildlife Reserve and adjacent area that are the potential breeding area of crocodiles. Based on the accumulated information and the survey conducted, it was identified that the lower part of Segama River is one of the few remaining wetland habitats and therefore was proposed to be a Wildlife Conservation Area under the Sabah Wildlife Conservation Enactment, 1997 (Mustafa and Kusan 2003). The map of the proposed conservation area is shown in Figure 2.

![Figure 2. Proposed Lower Segama Wildlife Conservation Area.](image-url)
The proposed area is approximately 3800 ha with 60-80% wetland, periodical salinity invasion and the three villages of minority group of people Tidong Tribe. It is obvious that the fragmentation of wetland and riverine habitats by agricultural development especially by oil palm plantation is a significant issue that is occurring in the lower Segama River. Though the proposed area is rather small, the success of the proposal is a milestone step toward the crocodile conservation and would facilitate the expansion to other potential breeding areas in Sabah. Currently, the proposal is under the process of gazetting by the Government of Sabah State.

**Forward Direction of the Crocodile Management in Sabah**

Though the past surveys conducted indicate that there is a significant recovery of the crocodile population in Sabah, the many challenges in crocodile management still remain to be tackled. Sabah Wildlife Department prioritizes the activities in the programme focusing on the following challenges;

- Identify and conserve more breeding habitats.
- Expand wetland conservation area to ensure the crocodile existence in Sabah (especially to Klias wetland).
- Promote sustainable use programme for local community.
- Monitor and manage human-crocodile conflict in crocodile areas.

These activities could only be achieved with smart partnership with private sector and communities.

**Literature**


Effects of Sustained Harvests on Wild Populations of
*Caiman crocodilus crocodilus* in Venezuela

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Abstract

Venezuela’s commercial use program for *Caiman crocodilus crocodilus* began in 1983. It allowed the harvest of mature males greater than 1.80 m total length (class IV males), on private lands. Approximately ten million hectares, involving several different ecological regions, are now included in the program, although not all areas are actually harvested. This study compares harvested and non-harvested populations, within the same ecological regions. We found that both absolute density and relative abundance of class IV males was higher in the harvested populations than in the non-harvested populations, supporting the view that sustainability has been achieved, probably through various compensatory responses of the population to the reduction, through harvest of larger males.

Resumen

El programa de aprovechamiento comercial de la baba se inicia en 1983, permitiéndose cosechar individuos que conforman la clase IV, con una longitud total superior a 1.80 m, representados únicamente por machos adultos, en tierras de propiedad privada. El área de implementación es aproximadamente diez millones de hectáreas, divididas en regiones ecológicas, pero no toda la superficie se cosecha el recurso. Este estudio realiza una comparación en áreas donde se cosecha versus áreas donde no se aprovecha el recurso. Se encuentra que en las áreas donde se aprovecha la especie, los valores de densidad y porcentaje de la clase IV, son mayores, al compararlos con los valores encontrados en áreas donde no se cosecha el recurso. Estos resultados muestran que programas de manejo bien diseñados, permiten la sustentabilidad del recurso baba y el efecto positivo sobre las poblaciones manejadas, a través de la cosecha de ejemplares adultos mayores de 180 cm de longitud total (clase IV).

Introduction

In 1971, all 23 known species of true crocodiles, alligators, caiman and gavials were considered to be endangered, threatened or declining in abundance and/or distribution. By 1996, 25 years later, 16 of those species were once again abundant and widespread, a conservation success due in no small part to incentives to conserve created through sustainable use (King 1999), and to the steady decline in illegal use and trade (Hutton and Webb 2003)

The role of economic incentives in promoting crocodilian conservation has been well established (Joanen et al. 1997; King 1999; Hutton and Webb 2003). Consumptive use, such as commercial harvesting can positively influence the conservation of wild populations. In Venezuela’s case, conservation can be enhanced in two major ways:

a. The ability to extract an economic return from a wildlife population, on private lands, where landowners are the primary beneficiaries, can provide tangible economic incentives for landowners to maintain healthy populations and habitats, and to invest in the prevention of illegal use and trade; and,

b. The selective removal of large, dominant males from the population, which are suspected to constrain the growth and attainment of maturity of sub-adult males, could be expected to lead to a series of compensatory mechanisms likely to increase the wild population (Velasco et al. 1995).

Consumptive use of crocodiles within different management programs typically involves one or more of the following strategies: “cropping”, “ranching” or “captive breeding” (Thorbjarnarson 1992; Ross 1998). Direct hunting of adults or sub-adults in the wild (cropping) is one of the major ongoing forms of consumptive use in some countries (Magnusson 1997), yet there have been few rigorous evaluations of the effects of harvest on the structure and abundance of wild crocodilian populations (Mourão et al. 1996).
Regulated harvesting of wild spectacled caimans (*Caiman crocodilus crocodilus*) has been permitted in Venezuela since 1983, under a program directed by the Ministry of the Environment and Natural Resources (MARN), through the general direction of fauna (Velasco and De Sola 1997; Thorbjarnarson and Velasco 1999). The program allows harvesting, on authorized private cattle ranches, of a proportion of the class IV caimans: that is, *C. c. crocodilus* with a total length (TL) greater than 1.80 m, which are all adult males (Velasco and De Sola 1999).

The selective harvesting of large, mature males was designed to minimize the effects of the harvest on the reproductive potential of the wild populations, by steering the harvest away from the mature females. It was also considered likely that such a harvest would allow a larger number of younger males to grow more rapidly, reach larger sizes more quickly and become reproductively active sooner than if the large, dominant, males remained in the population (Velasco *et al.* 1995).

This study reviews survey data from the main harvest areas in Venezuela which, for various reasons, contain both harvested and non-harvested populations. It attempts to quantify likely effects of harvest by comparing densities (caimans per hectare of total land) and population size structures. The null hypotheses was that harvesting would reduce densities generally, and specifically the numbers of class IV individuals.

**Study area**

The study was carried out in the western Llanos (plains) of Venezuela, abutting the Colombian border (Fig. 1). This area is subdivided into seven regions, each of which has different ecological qualitative characteristics, as described by Velasco and Ayarzagüena (1995) and six of which we examined in this study (Table 1).

Information on *C. c. crocodilus* densities and population size structures were gathered during monitoring programs undertaken by the Facultad de Ciencias, Universidad Central de Venezuela (UCV) and MARN. Information was gathered from five regions in 1996 (Alto Apure, Aguas Claras, Cajón de Arauca, Llanos Boscosos and Hoya de Arismendi) and from the Bajo Apure region in 1999. The Guárico ecological region was not evaluated because no harvest took place for 5 years (1992-1996).

![Figure 1](image-url)  
*Figure 1. Ecological region in Venezuelan plains.*
Table 1. Dominant ecological characteristics of the seven regions included within the harvest program.

<table>
<thead>
<tr>
<th>Ecological Regions</th>
<th>Garcersos $^1$</th>
<th>Loam vs Sandy $^2$</th>
<th>Grade Flooded Savannahs $^3$</th>
<th>Delta-type $^4$</th>
<th>Water Quality $^5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>Present</td>
<td>Medium</td>
<td>Medium</td>
<td>Not Present</td>
<td>Rich</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>Present</td>
<td>High</td>
<td>High</td>
<td>Present</td>
<td>Rich</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>Not Present</td>
<td>Low</td>
<td>Low</td>
<td>Not Present</td>
<td>Poor</td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>Present</td>
<td>Low</td>
<td>Low</td>
<td>Not Present</td>
<td>Medium</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>Present</td>
<td>High</td>
<td>Medium</td>
<td>Not Present</td>
<td>Rich</td>
</tr>
<tr>
<td>Llanos Boscosos</td>
<td>Not Present</td>
<td>Medium</td>
<td>Low</td>
<td>Not Present</td>
<td>Rich</td>
</tr>
<tr>
<td>Guárico</td>
<td>Present</td>
<td>High</td>
<td>High</td>
<td>Present</td>
<td>Rich</td>
</tr>
</tbody>
</table>

1 Wetlands in which herons congregate which suggested an abundance of the food used by *C. c. crocodilus*
2 Relation between loam vs sandy plains
3 Is the extent of flooded savannahs
4 Areas where the mainstreams break into ramifying channels
5 Qualitative water nutrient richness

Surveys occurred over 532,447 hectares of total land or 4.9% of the total region. Of the area surveyed, 281,082 hectares (52.8%), contained harvested populations of *C. c. crocodilus*, and 251,365 hectares (47.2%), contained non-harvested populations (Table 2).

Table 2. Area of harvested and non-harvested habitat surveyed in each ecological region. ns= not surveyed in this study.

<table>
<thead>
<tr>
<th>Ecological Region</th>
<th>Region Area (ha)</th>
<th>Area Surveyed Harvested (ha)</th>
<th>Area Surv eyed Non-Harvested (ha)</th>
<th>Total Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>2,662,296</td>
<td>59,935</td>
<td>44,208</td>
<td>104,143</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>571,389</td>
<td>50,118</td>
<td>41,415</td>
<td>91,533</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>1,009,890</td>
<td>60,895</td>
<td>30,650</td>
<td>91,545</td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>252,189</td>
<td>16,101</td>
<td>6,290</td>
<td>22,391</td>
</tr>
<tr>
<td>Llanos Boscosos</td>
<td>3,114,384</td>
<td>66,130</td>
<td>59,385</td>
<td>125,515</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>615,342</td>
<td>27,903</td>
<td>69,417</td>
<td>97,320</td>
</tr>
<tr>
<td>Guarico</td>
<td>2,620,800</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Total</td>
<td>10,846,290</td>
<td>281,082</td>
<td>251,365</td>
<td>532,447</td>
</tr>
</tbody>
</table>

Methods

All surveys were carried out during the annual dry season (March to May) in 1996 and 1999 when *C. c. crocodilus* are concentrated in remnant water bodies. Areas with both harvested and non-harvested populations were selected in each ecological region, and the population parameters were quantified as follows:

- Population abundance was estimated by night-light counts (Chabreck 1966 and Woodward and Marion 1977). A powerful spotlight was scanned over waterbodies and the number of eyeshines counted. The caimans sighted by this method represent a very high proportion (80-90%) of the total number present (Staton and Dixon 1975; Ayarzagüena 1980; Seijas 1986), and so this was taken as the measure of absolute abundance. Density was calculated as the sum of total number of animals counted at night per ecological regions divided by the sum of total land area surveyed for each ecological regions. In other words, the spotlight counts on waterbodies for particular ranches are added and divided by the total land area of those particular ranches in each ecological regions.

- The population size structure was estimated by allocating as many of the caiman sighted as possible into one of
four general size classes (Ayarzagüena 1983):

Class I - hatchlings and animals <60 cm TL  
Class II - >60 cm and <120 cm TL  
Class III - >120 cm and <180 cm TL  
Class IV - >180 cm TL

Bar histograms with the proportions of individuals in each size class (II, III and IV) allowed two types of age structures to be defined (Velasco and Ayarzagüena 1995): one with pyramidal form, which indicates a population not subjected to harvesting, and another with a staggered form indicating an exploited population, where the percentage of individuals in class IV is less than 15% of the total population (Fig. 2).

![Bar histogram](image)

Figure 2. Bar histogram. Open bars natural population not subjected to harvesting, closed bars population over exploited (Velasco and Ayarzagüena 1995).

Individuals in class I were excluded from analyses, because numbers are highly variable from year to year, and are depend on the month in which surveys are undertaken. In addition, there is a high mortality rate for hatchlings during their first year of life, and they are generally excluded from these types of analyses (Webb and Manolis 1992).

We do not use in this study statistical analysis to analyze the population abundance, because the MARN uses absolute values to calculate de densities in each ecological regions and to determinate the harvest quota in each cattle ranch (De Sola et al. 2000; Velasco and De Sola 1999).

**Results**

**Alto Apure**

Density in the harvested areas (0.30 caimans/ha) was higher than in the non-harvested areas (0.20 caimans/ha) (Fig. 3), and when adjusted for areas (Table 2) abundance in the harvested areas was twice that in non-harvested areas. The size structure in harvested and non-harvested populations had a similar, declining general form (Fig. 4), but with a higher proportion of class IV individuals in the harvested (20.60%) versus non-harvested areas (13.52%).

**Bajo Apure**

The density was higher in areas harvested (0.21 caimans/ha) than in non-harvested areas (0.17 caimans/ha)(Fig. 3), and the size distribution was pyramidal in form in both areas. Areas with harvest had a higher proportion of class IV individuals (31.18%) than those without harvest (25.91%) (Fig. 4).

**Aguas Claras**

Density in harvested areas was higher (0.17 caimans/ha) than non-harvested areas (0.12 caimans/ha) (Fig. 3).The size distribution showed differences in the relative number of classes II and III individuals (Fig. 4), but class IV made up similar proportions in both harvested (20.49%) and non-harvested in harvested areas (21.32%).
Figure 3. Density in ecological region with harvest or non-harvest.

Figure 4. Size class histogram for ecological region in areas with or non-harvest. Closed bars = with harvest; open bars = non-harvest.
Cajón de Arauca

This area had the lowest densities, and there was no difference in those recorded from the harvested and non-harvested areas (0.05 caimans/ha) (Fig. 3). In the harvested area (Fig. 4) proportions of classes II and III individuals were similar, but there was a high proportion of class IV individuals (29.03%). In non-harvested areas, the size structure was dominated by class II (56.63%) individuals and classes III and IV were relatively reduced (22.49% and 20.87%, respectively).

Llanos Boscosos

Density in the areas with harvest (0.16 caimans/ha) was much higher than in areas without harvest (0.07 caimans/ha)(Fig. 3). In harvested areas (Fig. 4), the size structure was pyramidal in form with a high proportion of class IV (31.44%) individuals relative to non harvest areas with a declining size structure from high percentages of class II and III individuals, and a low proportion of class IV (13.93%) individuals.

Hoya de Arismendi

Density in harvested areas (0.25 caimans/ha) was much higher than in non-harvested areas (0.09 caimans/ha), although total populations were similar due to respective areas (Table 2). The size structure in both harvested and non-harvested areas was pyramidal (Fig. 4), which is normally associated with non-harvested populations (Velasco and Ayarzagüena 1995). The proportion of class IV individuals was similar in harvested 17.59% and non-harvest (16.65%) areas, but low relative to most other regions.

Discussion

At the beginning of the program of commercial use of caimans in Venezuela, a census was undertaken to estimate caiman densities on each of the properties that requested permission to hunt. With time it became impossible to visit all the properties involved and so, a samples was chosen for future surveys (Seijas 1986). In these surveys, the density of caiman was expressed as caimans/ha of water. In the early years the density was reported as the number of animals per hectare of total land, including waterbodies areas (Velasco and Ayarzagüena 1992), without any attempt to distinguish between areas with or without harvest in each. This type of separation began in 1996.

One of the main results of the study is that most high density populations that have been subjected to harvesting for more than 4 years, still contain high densities of caimans, and thus a high degree of sustainability in involved.

In all but one of the regions studied the density of caimans/ha was higher in the areas which had been subject to repeated harvest than in those which had remained unharvested (Fig. 3). This is part reflects the reality that the harvesting program is a voluntary one, which is more likely to be implemented on those cattle ranching properties where caiman are most abundant in the first place. However, it also served to reinforce the observations that caiman densities are highly variable in the wild with low density populations that will never increase even in the complete absence of exploitation.

The proportion of class IV individuals were consistently higher in the harvested areas (>20%) than in the non-harvested areas (<20%). The extent to which this may be biases by differences in the population structure between hunted and non-hunted areas prior to harvest cannot be resolves. However, it does demonstrated that the harvest of class IV individuals is followed by significant recruitment into this size class, which is consistent with the observation made in other species that growth to maturity of sub-adult males may be boosted by removing the larger, older and well established from the population in question (Nichols et al. 1976; Craig et al. 1992; Velasco and Ayarzagüena 1995; Velasco et al. 1994).

It was clear from the results that one region (Aguas Claras) were markedly different to those from the others. Here density and the proportion of class IV animals was smaller in the harvested areas than in the non-harvested areas. Furthermore, the distribution of individuals amongst the size-classes was changing, in both harvested and non-harvested areas, with the highest proportion of individuals in the smallest size classes.
Conclusions

The results obtained in the censuses of 1996 and 1999, in the six management regions, support the view that Venezuela’s caiman harvest is being sustained by the wild population, and that the program of commercial use implemented by MARN in 1983, which has now been operating for 20 years, is achieving its goals. There is no indication that populations have declined significantly as a consequence of harvesting, nor that adult males have become rare, which are selectively harvested, are in short supply in the population. The program brings considerable economic benefits to the landowners involved, who now have a vested interest in caring for both caimans and their habitats. The program has also provided some unique insights into the manner in which wild caiman populations respond to controlled harvest, which has broader ramifications to the conservation and management of this widespread species in other countries.

That densities were generally higher in harvested areas than in non-harvest areas could reflect hunting biases to some degree, but does allow rejection of some of the more dire predictions about the likely impacts of harvest. High density caiman populations subject to this type of harvest (class IV males) still exist in high density despite 20 years of harvest. Examination of the population size structures suggests this is being achieved by compensatory mechanisms, favoring recruitment and the enhanced growth to maturity of sub-adult males.

Monitoring at this level of resolution should be adequate for ensuring that the Venezuelan caiman harvest is sustainable, and for giving early warning of any problems, to what related to the harvest or not. The monitoring program is thus sufficient to allow compliance with purpose of Article IV.2b of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which obligates the exporting State to provides assurances that the harvest for international trade is not detrimental to the survival of that species.

Acknowledgments

Our thanks to Mirna Quero Wildlife General Director of the Ministry of Environment and Natural Resources (MARN), the cattle ranch owners that permitted the surveys, the ranch guides for helping us to visit all water bodies, to Argenis Ochoa, Alfredo Lander, Eligio Oropesa, Gerardo Cordero, José Corazzelli, Martín Silva, Napoléon León, Rafael Eduardo Miranda, Roger Pérez-Hernández, Tomás Pino and Wilman Vásquez, for their helping in the field. Thanks to Jon Hutton, Bill Magnusson, James MacGregor and Grahame Webb for critically reading the manuscript. To Grahame Webb and Jon Hutton who kindly helped with English editing.

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Caiman yacare and Caiman latirostris Ranching Programs in Argentina

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Abstract

The sustainable use of wild animals and plants of commercial interest, leading to economic benefit and the stimulus of in situ conservation, clearly is, nowadays, the realistic approach to conserving natural ecosystems. Currently, there are three different projects operating in Argentina, through caiman ranching of the two species presents in the country.

The story of legal utilization of crocodilians in Argentina, starts in Santa Fe Province in 1990 with the self-repopulation program of Caiman latirostris, and based on it, the transfer of the Argentine population from Appendix I to II of CITES, which occurred in 1997 in Zimbabwe. Following, Chaco Province starts a similar project on a smaller scale, but working with the two species (C. yacare and C. latirostris) and finally, Formosa Province began in 2001 a project on a bigger scale, also with the two species, which is about to start the commercialisation of its production.

In Santa Fe Province were released over 14,140 yearlings (only C. latirostris); in Chaco 1668 and in Formosa 1057 just in the first year (both species in these Provinces). The harvest of eggs is currently of 10,000 per year in Santa Fe; 1000 in Chaco, and 15,000 in Formosa.

In this paper, we present information on the harvested eggs, juveniles releasing, commercial production and evolution of the monitoring of the three projects since its beginning to date.

Introduction

The northern part of Argentina represents the southern-most limit of the distribution of the Broad-snouted Caiman (Caiman latirostris) and the Yacare Caiman (Caiman yacare). Both species are distributed throughout 9 Provinces (Formosa, Santa Fe, Misiones, Corrientes, Entre Rios, Chaco, Santiago del Estero, Salta, Jujuy) in Argentina, although C. yacare occurs in higher densities above the 30° latitude and C. latirostris up to the 32° latitude (Larriera 1990).

Ranching of eggs, combined with restocking of the wild population, was considered the safest option to pursue with regard to minimizing the impact on the population. The ranching program was initiated on an experimental basis, but now, it is fully implemented as a commercial option.

Listed in Appendix I of CITES, international trade in C. latirostris products was prohibited until the Santa Fe C. latirostris ranching proposal was approved at the 10th Conference of Parties to CITES (Zimbabwe, 1997). In 1999 it was incorporated to the program the Chaco Province, and lately, Formosa Province did start also with the production. The species Caiman yacare is already listed in the Appendix II of CITES.

Santa Fe Program

The program it was carried out since its beginning from an agreement between the Agricultural Ministry of the Province of Santa Fe, and an NGO called “Mutual del Personal Civil de la Nación”. This work start in 1990 as an experimental stage, becoming commercial in 1999.

In Table 1 are shown the all numbers of harvest, juveniles releasing and commercial rearing in the Province of Santa Fe. In Table 2 we show the results of the night counts in Santa Fe since the beginning of the program

Chaco Program

The project runs here supported by an agreement between the Dirección de Fauna y Parques del Chaco, Fundación Vida Silvestre Argentina, and a cattle ranch called “El Cachapé”. 216
Table 1. Details of harvests and releases in Santa Fe Province.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1990/91</td>
<td>10</td>
<td>14</td>
<td>372</td>
<td>237</td>
<td>205</td>
<td></td>
</tr>
<tr>
<td>1991/92</td>
<td>25</td>
<td>32</td>
<td>903</td>
<td>701</td>
<td>655</td>
<td></td>
</tr>
<tr>
<td>1992/93</td>
<td>24</td>
<td>33</td>
<td>926</td>
<td>589</td>
<td>541</td>
<td></td>
</tr>
<tr>
<td>1993/94</td>
<td>50</td>
<td>62</td>
<td>1936</td>
<td>1196</td>
<td>1022</td>
<td></td>
</tr>
<tr>
<td>1994/95</td>
<td>60</td>
<td>71</td>
<td>2211</td>
<td>1646</td>
<td>1451</td>
<td></td>
</tr>
<tr>
<td>1995/96</td>
<td>84</td>
<td>112</td>
<td>3120</td>
<td>2262</td>
<td>1980</td>
<td></td>
</tr>
<tr>
<td>1996/97</td>
<td>97</td>
<td>123</td>
<td>3572</td>
<td>2394</td>
<td>2072</td>
<td></td>
</tr>
<tr>
<td>1997/98</td>
<td>58</td>
<td>107</td>
<td>1954</td>
<td>1448</td>
<td>1123</td>
<td>100</td>
</tr>
<tr>
<td>1998/99</td>
<td>70</td>
<td>128</td>
<td>2347</td>
<td>1902</td>
<td>1521</td>
<td>333</td>
</tr>
<tr>
<td>1999/00</td>
<td>76</td>
<td>152</td>
<td>2397</td>
<td>1833</td>
<td>1058</td>
<td>667</td>
</tr>
<tr>
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<td>73</td>
<td>143</td>
<td>2227</td>
<td>1526</td>
<td>670</td>
<td>830</td>
</tr>
<tr>
<td>2001/02</td>
<td>188</td>
<td>225</td>
<td>6392</td>
<td>4494</td>
<td>927</td>
<td>2992</td>
</tr>
<tr>
<td>2002/03</td>
<td>228</td>
<td>304</td>
<td>7560</td>
<td>5638</td>
<td>915</td>
<td>4524</td>
</tr>
<tr>
<td>Totals</td>
<td>1043</td>
<td>1506</td>
<td>35917</td>
<td>25866</td>
<td>14140</td>
<td>9446</td>
</tr>
</tbody>
</table>

In this province the project combine the harvest of both species (C. latirostris and C. yacare). The first studies start here in 1996, and the results of the eggs harvest since 1998 are showed in the following Table:

<table>
<thead>
<tr>
<th>Year</th>
<th>C. latirostris</th>
<th>C. yacare</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>242</td>
<td>96</td>
<td>338</td>
</tr>
<tr>
<td>1999</td>
<td>457</td>
<td>201</td>
<td>658</td>
</tr>
<tr>
<td>2000</td>
<td>1362</td>
<td>148</td>
<td>1510</td>
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<tr>
<td>2001</td>
<td>574</td>
<td>306</td>
<td>880</td>
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<td>2002</td>
<td>1236</td>
<td>625</td>
<td>1861</td>
</tr>
<tr>
<td>2003</td>
<td>848</td>
<td>475</td>
<td>1323</td>
</tr>
<tr>
<td>2004</td>
<td>148</td>
<td>287</td>
<td>435</td>
</tr>
<tr>
<td>Totals</td>
<td>4867</td>
<td>2138</td>
<td>7005</td>
</tr>
</tbody>
</table>

The total number of animals released and commercially reared is showed on the next Table:

<table>
<thead>
<tr>
<th>Year</th>
<th>Released</th>
<th>Commercial Rearing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C. latirostris</td>
<td>C. yacare</td>
</tr>
<tr>
<td>1998</td>
<td>178</td>
<td>78</td>
</tr>
<tr>
<td>1999</td>
<td>195</td>
<td>93</td>
</tr>
<tr>
<td>2000</td>
<td>325</td>
<td>36</td>
</tr>
<tr>
<td>2001</td>
<td>103</td>
<td>61</td>
</tr>
<tr>
<td>2002</td>
<td>262</td>
<td>104</td>
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<tr>
<td>2003</td>
<td>147</td>
<td>86</td>
</tr>
<tr>
<td>Totals</td>
<td>1210</td>
<td>458</td>
</tr>
</tbody>
</table>
Table 2. Cayman counts from 1990 to 2002; Class I <50 cm, Class II 50-140 cm, Class III 140-180 cm, Class IV >180 cm; Density refers to Class II-IV animals per km; *Day count during dry season in 2000.

<table>
<thead>
<tr>
<th>Location</th>
<th>Date</th>
<th>--------------</th>
<th>Class</th>
<th>--------------</th>
<th>Total</th>
<th>Dist. (km)</th>
<th>Density (/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>Los Molles</td>
<td>04/11/90</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td></td>
<td>4.5</td>
<td>1.77</td>
</tr>
<tr>
<td>Lote 5</td>
<td>06/11/90</td>
<td>21</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>6.8</td>
</tr>
<tr>
<td>Dientudo</td>
<td>10/11/90</td>
<td>14</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>5.3</td>
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<tr>
<td>Los Molles</td>
<td>02/12/91</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4.5</td>
</tr>
<tr>
<td>Caminos A</td>
<td>04/12/91</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Lote 5</td>
<td>08/11/92</td>
<td>57</td>
<td>28</td>
<td>17</td>
<td>14</td>
<td>13</td>
<td>6.8</td>
</tr>
<tr>
<td>Dientudo</td>
<td>09/11/92</td>
<td>43</td>
<td>19</td>
<td>14</td>
<td>6</td>
<td>8</td>
<td>116</td>
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<tr>
<td>Caminos A</td>
<td>02/12/92</td>
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<td>12</td>
<td>4</td>
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<td>4</td>
<td>40</td>
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<tr>
<td>Fisco</td>
<td>15/12/92</td>
<td>2</td>
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<td>1</td>
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<td>20</td>
<td>18</td>
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</table>

**Formosa Program**

The ranching program did start in this Province in 2001 based on an agreement between the “Dirección de Fauna y Parques de Formosa” (Ministerio de la Producción), and a company called “Caimanes de Formosa SRL”.

The first harvest of eggs was carried out during 2002. In this Province the eggs of both species (C. latirostris and C. yacare) are harvested, due to the fact that they leave in the same areas, and that it is not possible to distinguish between the nests of everyone.
The stock of animals of one year after the release of 1057 on November 2003 at the rearing station in the “Parque Industrial Formosa” is 7358 animals (5361 C. latirostris, 1997 C. yacare).

The number of animals hatched in this last season is 15,918 (7689 C. latirostris, 8229 C. yacare).

The cayman populations were and are studied in a total of 18 locations in Formosa Province. As an example we show following a couple of the graphic generated from this information:

**Benefits to Landowners and Conservation Value in Argentina**

Experience from Santa Fe (also seen in Chaco and Formosa) indicated that most landowners are not interested in financial gain from the programs. They appear more interested in the fact that people involved in the program do work on their land, and that they obtain good publicly from it, seen as an integral part of the conservation program. They have gained an understanding that the drying of swamps also impacts negatively on cattle production in the long-term.

The situation is different for the local inhabitants, that as employees of the cattle ranches, benefit directly from the program through payments for each nest ($USD7) that they locate and mark. Incentives have been created for the employees to not allow the killing of caimans, and to protect nesting areas, that in the past were regularly burned. Caimans now have a positive value to them. Between the three Provinces, there are about 500 people involved with the projects in one or another way.

**National Level**

The enforcement of the national and international regulations in Argentina, is under the responsibility of the Dirección Nacional de Fauna y Flora Silvestres, which is also the CITES Management Authority in the country. All the three projects are supported by a regular monitoring system annually carried out by Crocodile Specialist Group members in the different provinces, through the standard night counts and the analysis of the annual egg collection.

His office is also in charge of the administration of the universal tagging system and the national tagging system, which imply a double tagging, the first one at the slaughterhouse, and the second one as CITES tag, before the exporting if so.

**Acknowledgements**

We would like to thank Pablo Siroski, Walter Prado, Cesar Peres and Juan Carlos Orozco for the information provided on the different projects.
Geographical Study of the Commercial Management Program of *Caiman crocodilus* in Venezuela

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Abstract

The geographical variables influencing spatial distribution of Baba (*Caiman crocodilus*) in Venezuela were studied, using the data produced by the harvests and monitoring of wild population during the application of MARN Program of commercial management of this species, during the last decade. The main geomorphologic, vegetation, hydrograph, and climate conditions of the seven “ecological regions” in which the Program is currently applied are described, taking into account its influence on the biological characteristics of the species. Social-economical conditions, including the impact of the Program on the employment, land tenure and productivity also are discussed. As results of this spatial-historical analysis, a re-delimitation of the “ecological regions”, best administrative procedures and other recommendations linked to the biogeography of the species are proposed, in order to improve the Program.

Resumen

Se estudiaron las variables geográficas que influencian la distribución espacial de la Baba (*Caiman crocodilus*), utilizando los datos de cosechas y censos de las poblaciones silvestres producidos la última década, durante la aplicación del Programa de Uso Comercial de esta especie por el Ministerio del Ambiente y de los Recursos Naturales (MARN). Se describieron las principales condiciones geomorfológicas, de vegetación, hidrografía y clima de las siete “Regiones Ecológicas” en las cuales el Programa es aplicado actualmente, tomando en cuenta su influencia en las características biológicas de la especie. También se discuten las condiciones socioeconómicas, incluyendo el impacto del Programa sobre el empleo, la tenencia de la tierra y la productividad. Como resultado de este análisis espacial-histórico, se propone una re-delimitación de las “regiones ecológicas”, mejoras en los procedimientos administrativos y otras recomendaciones vinculadas a la biogeografía de la especie, en función de mejorar la aplicación del Programa.

Introduction

There is a need to understand the human activities related with wildlife as important components of the tropical ecosystems, to obtain adequate and sustainable management models including the geographical wildlife distribution. Traditionally, the wildlife management in tropical species is only directed to the administration and conservation of game species. Fortunately, as the valorization of these resources increases, the development of more precise concepts of management had improved the studies on the historical impact of the commercial use activities and the geographical distribution of the resources (Azpúrua and Gabaldón 1982; Delgado and Méndez 1996). Leopold in 1933 defined the management as “the art of using land to produce yearly sustainable harvests of wildlife animals” (Ojasti 2000). This definition involves the geographical unit (land) in the wildlife management.

The sustainable management of a wildlife resource can be defined as an application of the geographical, ecological, social-economical and cultural knowledge as basis for the decision taking on the manipulation of the structure, dynamics and habitats of the resource’s population. The sustainable use, control and conservation of the resource are directly involved with the human communities (Reed 1996; Posada *et al.* 1997; Nebel and Wright 1999; Ojasti 2000).

The CITES international regulations on trade and IUCN efforts on conservation, constitutes a general framework that needs the support of scientific and economic information on the wildlife management programs. Currently, the Venezuelan Government through the Ministry of Environment and Natural Resources (MARN) is developing since
1983 the Program of Commercial Use of wild populations of *Caiman crocodilus*, based upon the national and international legal regulations (included in Appendix II of CITES). The Program is applied in private and public properties located at the “Llanos”, floodable plains in the southwestern side of the country. *C. crocodilus* is the most abundant crocodile in Venezuela and the only one subjected to a commercial management program under government control (Velasco and De Sola 1999, 2000; Rodríguez and Rojas-Suárez 1995).

The goal of the present study is to produce recommendations to improve the Program. It encompasses data of the Program application from 1992 to 2000, to determine the geographical and ecological main characteristics of this extensive area, and also the social-economical conditions that possibly has influence on the application of the Program at the seven “ecological regions” defined by Velasco and Ayarzagüena (1995). The study includes the analysis of anthropogenic variables with influence on this species and habitats: human settlements, active human population, land tenure and use, infrastructure, and economical handling of the species derivatives (meat and skin); and also natural variables: climate, vegetation, hydrograph and geomorphology. Also, the limits of the seven “ecological regions” are discussed under geographical criteria to propose new definitions.

**Methods**

This descriptive work is directed to specify the main properties of the Babas populations under exploitation by the Program, defining the response and correlation of two numerical variables under study (Sampieri *et al.* 1991): harvests and field censuses, during the lapse of study (1992-2000) in the spatial dimension of the seven “ecological regions”, in order to establish trends and predictions.

The wild population monitoring results and the harvest data were obtained from the MARN and from the Universidad Central de Venezuela - Coordinacion de Extension, to prepare a geo-referenced database of the “ecological regions”. This database was deployed on cartographic charts scaled 1:500,000 for spatial analysis and 1:100,000 for more detailed vision of specific areas, using Geographical Information System (GIS) MAP-INFO Ver. 6.0. For the presentation of results a scale of 1:3,600,000 was used, including digitalized coverings of vegetation, geomorphology, hydrograph, and law-protected areas within the study area.

**Data on Wild Population Monitoring**

The data obtained from monitoring results started with the study of 1991-92 funded by CITES (Velasco and Ayarzagüena 1995), after nine consecutive harvests, which covered 922,581.27 ha (10.24% of the total area of the Program). From these results, the seven “ecological regions” were defined taking into account some habitat characteristics (bird concentrations, inner deltas, nutrient in water, degree of savanna flooding, and type of soil). These regions are: Bajo Apure, Alto Apure, Cajón del Arauca, Aguas Claras, Llanos Boscosos, Hoya de Arismendi, and Guárico, which still are in use by MARN for the administrative and technical functioning of the Program.

Since 1995, a cooperation agreement between MARN and the Universidad Central de Venezuela (UCV) has been scientifically supporting the Program. Under this agreement, the UCV is performing the population status and size structure of the wild populations (Profauna-IZT 1995; Colomine *et al.* 1996).

In 1996 the commercial hunt was paused, suspending all the Program activity (Quero and Velasco 1995), in order to develop a full population study considering that there were 110,000 skins in stock for the international market and the Program, considered as a model for sustainable wildlife management in tropical areas, needs to be improved with technical-scientific studies (Profauna-IZT 1996). Part of the results of this study was presented in Villarroel *et al.* (1996), including habitat evaluation and variations between regions. Other source of data includes the monitoring of ecological regions between 1999 and 2000 (UCV 1999; De Sola 2002).

**Data on Harvests**

Velasco and De Sola (1999, 2000) presented the evolution of the normative and controls applied by the MARN to the Program since 1983, including also the main information about harvests. Using these data on meat and skins produced, industrial categories, price and other information proportioned by MARN, the database on harvest was prepared.

A preliminary comparison of data from monitoring and harvests was presented in Colomine *et al.* (2002), applying SIG to analyze these variables but without take into account the geographical information about the ecological regions.
Results

Area of Study

The area of application of the Program, located at the southwestern Venezuelan Llanos (Map 1), was calculated in 10,846,290 ha (Velasco and Ayarzagüena 1995), between 9° 39’ 36” - 6° 00’ 00” North and 71° 26’ 24” - 65° 30’ 00” West. The authors defined on these extents the “ecological regions” accepted by the MARN for the application of the Program (Map 2).

One of the main problems was to establish an accurate estimation of surface and geographical limits of these “regions”. Velasco and Ayarzagüena (1995) made the first approach using a visual calculation on maps, still currently used by the MARN in the administration of the Program. The surface of the Guarico Region was lately modified (De Sola 2000). Using the SIG technique, the surfaces were re-calculated in the present work. Always trying to keep the main criteria applied by Velasco and Ayarzagüena (1995), the results show quantitative differences (Table 1).

Table 1. Original surfaces and SIG calculated surfaces of the “Ecological Regions” (in hectares).

<table>
<thead>
<tr>
<th>Ecological Region</th>
<th>Velasco and Ayarzagüena (1995)</th>
<th>SIG Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>2,662,296</td>
<td>2,555,000</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>571,389</td>
<td>553,800</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>1,009,890</td>
<td>3,440,000</td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>252,189</td>
<td>219,900</td>
</tr>
<tr>
<td>Llanos Bocosos</td>
<td>3,114,384</td>
<td>2,901,000</td>
</tr>
<tr>
<td>Guárico</td>
<td>2,620,800</td>
<td>2,291,000</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>615,342</td>
<td>922,500</td>
</tr>
<tr>
<td>Total</td>
<td>10,846,290</td>
<td>12,883,200</td>
</tr>
</tbody>
</table>

A remarkable difference of about 2 million hectares can be observed from these two estimations, mainly caused by the case of “Aguas Claras” because in 1995 there was not included the surface of a National Park and other areas in which there was no activity of the Program. The definition of “ecological region” used in the present work includes all the land within the limits of the region without any exclusion, but it is still under discussion if an “effective” area can be used instead, including only the land surface in which the Program is currently applied (De Sola 2000).

With the results of the GIS application to the geo-referenced database, a new proposal on limits of the “Ecological Regions” is presented in Map 11.

In this proposal, the “Alto Apure” region is integrated with “Cajón de Arauca”, conforming a new “Alto Apure-Arauca” region to the following limits:

- **North:** Apure River
- **West:** curve level of 200 m
- **South:** basin division of the Arauca and Capanaparo Rivers
- **East:** Road Fernando - San Juan de Payara

Taking into account the geomorphology of southern Apure State, the “Aguas Claras” including the dunes of Capanaparo-Meta Rivers is also renamed as “Hydrographic Complex Capanaparo-Cinaruco”, with the following limits:

- **North:** Alto Apure-Arauca Region
- **West:** limit Venezuela-Colombia
- **South:** Meta River
- **East:** Orinoco River

The “Bajo Apure” region is renamed as “Bajo Apure-Arauca” region, with the following limits:

- **North:** Apure River
West: Road San Fernando - San Juan de Payara
South: basin division of the Arauca and Capanaparo Rivers
East: Orinoco River

The “Guárico” region is reduced to the spatial application of the Program, excluding the eastern sector (Aguaro-Guariquito National Park and Cabruta-Santa Rita zone). Also was excluded protected area of Estero de Camaguán

The region is reduced to the following limits:

North: Curve level of 100 m
West: Road Calabozo - San Fernando
South: Apure River
East: Guariquito River

The “Hoya de Arismendi” region was renamed as “Arismendi” region and its limits are:

North: Curve level of 100 m until Papelon
West: Road Calabozo - San Fernando
South: Apure River (until Bruzual)
East: Chirgua and Portuguesa River

The “Llanos Boscosos” region is delimited as follows:

North: Curve level of 100 m until the Apure River
West: Curve level of 100 m until the Apure River
South: Apure River (until Bruzual)
East: Road Papelon - Bruzual

This new proposal on the “ecological regions” keeps the main ecological factors expressed by Velasco and Ayarzaguena (1995), and offers more precise limits and geographical characteristics, which will help to improve the technical and administrative operations of the Program.

Climate

The yearly mean precipitation is ranging between 1350 mm and 2100 mm in the study area (11 years observations from 6 meteorological stations, Map 3). The rainfall is not uniformly distributed in the whole area of application of the Program, causing local climatic variations between and within the “regions” that could affect the distribution of the species. Also, the rainfall is in general concentrated between May to October, with local differences in the moment of beginning of the rainy season.

Nevertheless, all the study area is classified as Climate Type Aw (Koeppen). Also, the area is located in a Macrothermic Zone (Thornthwaite) with yearly mean temperatures between 25.7°C (August) and 29.0°C (March), maximum and minimum of 33°C and 22°C respectively. The mean difference of temperature between day and night are above 9.5 °C.

This relative climatic homogeneity at the whole area, with two yearly rain-drought well-defined periods and moderate temperature variations, allows habitat conditions to keep stable and abundant populations of C. crocodilus. The “regions” Alto Apure, Bajo Apure and Hoya Arismendi has comparatively better conditions (high amount and diversity of water bodies and floodable savannas).

Hydrography

All the land is crossed by rivers with high hydraulic charge during the rainy season, including the Cinareco, Capanaparo, Apure, Guanare, Portuguesa, Guárico, Arauca, and Meta Rivers (Maps 4 and 5). All these rivers are derived from the Andean and Central Cordilleras.

With few exceptions, the rivers show an upstream dendrite drainage pattern, becoming parallel after cross the mountains and flow until a meander pattern when reach the lowlands, with frequent changes in course and formation of ponds near the banks. After the rainy season, the flooded areas are drained by numerous channels that disappear during the
drought, reducing to minimum the amount of water bodies. These hydrographic conditions of all the area allows the formation of a wide variety of primary habitats that can be occupied by abundant and stable populations (Villarroel et al. 1996).

There are some variations in the conditions and frequency of the water bodies and aquatic environments, related with geomorphology and soil characteristics of each region. Generally, in the regions of Alto and Bajo Apure, Cajon de Arauca and Hoya Arismendi is very frequent the physiographic unit of flooded savannas, whereas the southern units (Aguas Claras) are dominated by dunes of eolic origin with few flooding areas, and at the northern regions Llanos Bocosos and Guarico also there are few flooding areas. This is related with the amount of favorable habitats for the species.

**Geomorphology**

A very homogenous flat landscape is present in the area of study (Map 5), but if Venezuelan Government through the Ministry of Environment and Natural Resources (MARN) is developing since 1983 the Program of Commercial Use of wild populations of *Caiman crocodilus*, ive geomorphologic units are present in the study area: high plains, bank complexes, foothills, mesas and low plains (Map 6). The high plains (5% or less slope) are present at the south of the study area on the Meta River banks, and at the north extreme of Llanos Bocosos. The bank complexes are deposited on the river embankments, forming low hills at Arauca River (Alto Apure), Capanaparo and Cinaruco Rivers (Aguas Claras). The alluvial plain (0-2% slope) is the most frequent forming the floodable physiographic unit of “bancobajo-estero” savannas, with sandy soils and forest-shrub vegetation combined with depressions of clay-silt soils and grasslands, very frequent at Alto Apure, Hoya de Arismendi and Llanos Bocosos; eolic plains are located at southern areas. The foothills belongs to the mountain ranges near to the study area (5% or more slope), present in few locations at north of the study area. Finally, the mesas are wide valleys located only at the eastern side of Guárico. From these units, the plains contain the most favorable habitats for the species.

**Vegetation**

The Map 7 shows the vegetation covering of the study area (Huber 1999), with four main units: forest, savanna, shrubs and intervened areas. The most important units are savannas and forests (60% and 33% of coverage, respectively). The savannas are composed mainly of grasses and occasionally trees and shrubs are present. About 75% of the forest species are deciduous. The intervened areas are mainly deforested agricultural zones. Differences were found within the “ecological regions” regarding to the vegetation distribution (Table 2).

<table>
<thead>
<tr>
<th>Regions</th>
<th>Forests</th>
<th>Savannas</th>
<th>Intervened Areas</th>
<th>Shrubs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>815,492</td>
<td>1,699,000</td>
<td>40,508</td>
<td>2,555,000</td>
<td></td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>218,627</td>
<td>332,050</td>
<td>3123</td>
<td>553,800</td>
<td></td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>629,500</td>
<td>2,810,500</td>
<td>-</td>
<td>3,440,000</td>
<td></td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>59,600</td>
<td>160,300</td>
<td>-</td>
<td>219,900</td>
<td></td>
</tr>
<tr>
<td>Llanos Bocosos</td>
<td>1,291,090</td>
<td>738,000</td>
<td>853,330</td>
<td>18,580</td>
<td>2,901,000</td>
</tr>
<tr>
<td>Guárico</td>
<td>860,000</td>
<td>1,430,531</td>
<td>469</td>
<td>2,291,000</td>
<td></td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>388,700</td>
<td>533,800</td>
<td>-</td>
<td>922,500</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4,263,009</td>
<td>7,704,181</td>
<td>897,430</td>
<td>18,580</td>
<td>12,883,200</td>
</tr>
</tbody>
</table>

The savannas are the main coverage in six of the seven “regions”, with the exception of Llanos Bocosos dominated by forests. The forest formation is present in all the “regions”. The few amounts of intervened areas are located very close to the main cities. The shrubs areas were located only at Llanos Bocosos.

Savannas and forests are the most common habitat conditions to be occupied by this species. The periodical flooding of almost all these habitats and very low human intervention complete this general picture, very favorable for crocodilians.
Economic Features

Job Generation. The economically active human population in the area was estimated in 1,236,463 inhabitants at 2001. From these values, 235,500 (19%) are involved in farming activities. The Program is involving a variable number of public officers, landowners, intermediaries and workers (not including industrial processes). The work in the Program extent from January until July, and teams of some 8 persons of hunters and boaters performs the extraction of the animals. These teams are contracted by the intermediaries, who are in charge to obtain legal authorizations and products. To calculate the jobs generated by the program among the farmers population, an average of 313 authorizations per year was used and approximately 2500 persons per year are involved in the Program. Other 600 workers are involved in transport activities, to sum 3100 direct jobs (1.32 % of the total involved in farming activities in the area of study).

Land tenure. The property of lands in the study area can be public: municipal and national lands, including two National Parks, three wildlife refuges and three forest reserves (Map 8); Table 3 shows these protected areas (Plan Nacional de Ordenación del Territorio 1988) within each “region”.

Table 3. Protected areas within the study area (ha).

<table>
<thead>
<tr>
<th>Identification</th>
<th>Name</th>
<th>State</th>
<th>Surface (ha)</th>
<th>“Region”</th>
<th>Surface within the “Region” (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PN - 15</td>
<td>Aguaro-Guariquito</td>
<td>Guárico</td>
<td>585,750</td>
<td>Guárico</td>
<td>462,742</td>
</tr>
<tr>
<td>PN - 27</td>
<td>Cinaruco Capanaparo</td>
<td>Apure</td>
<td>584,368</td>
<td>Aguas Claras</td>
<td>561,700</td>
</tr>
<tr>
<td>PN - 43</td>
<td>Río Viejo</td>
<td>Apure</td>
<td>68,200</td>
<td>Alto Apure</td>
<td>17,050</td>
</tr>
<tr>
<td>RFS - 3</td>
<td>Estero de Chiriguare</td>
<td>Portuguesa</td>
<td>109</td>
<td>Hoya de Arismendi</td>
<td>75</td>
</tr>
<tr>
<td>RFS - 4</td>
<td>Caño Guaritico</td>
<td>Apure</td>
<td>9300</td>
<td>Alto Apure</td>
<td>9300</td>
</tr>
<tr>
<td>RFS - 6</td>
<td>De la Tortuga Arrau</td>
<td>Apure - Bolívar</td>
<td>7575</td>
<td>Aguas Claras</td>
<td>3640</td>
</tr>
<tr>
<td>RFR - 1</td>
<td>Turen</td>
<td>Portuguesa</td>
<td>116,400</td>
<td>Llanos Boscosos</td>
<td>116,400</td>
</tr>
<tr>
<td>RFR - 2</td>
<td>Ticoporo</td>
<td>Barinas</td>
<td>187,156</td>
<td>Llanos Boscosos</td>
<td>13,770</td>
</tr>
<tr>
<td>REFA - 1</td>
<td>Sabanas de Anaro</td>
<td>Barinas</td>
<td>16,331</td>
<td>Llanos Boscosos</td>
<td>4250</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1,575,189</td>
<td></td>
<td>1,211,629</td>
</tr>
</tbody>
</table>

It is not allowed by law the commercial use of C. crocodilus on these protected areas. Other public lands are under concessions to farming social cooperatives, and the Program can be applied there under special authorization by MARN. The private lands involved in the successive years of the Program are shown in Table 4.

Table 4. Land tenure type and surface of farms involved in the Program in the “ecological regions” (in hectares).

<table>
<thead>
<tr>
<th>Region</th>
<th>Public Farms</th>
<th>Surface and % in each region</th>
<th>Private Farms</th>
<th>Surface and % in each region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Surface (ha)</td>
<td>%</td>
<td>Surface (ha)</td>
</tr>
<tr>
<td>Alto Apure</td>
<td>10</td>
<td>389,706</td>
<td>19.7</td>
<td>299</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>2</td>
<td>58,364</td>
<td>16.5</td>
<td>67</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>15</td>
<td>385,255</td>
<td>40.4</td>
<td>66</td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>1</td>
<td>28,296</td>
<td>14.9</td>
<td>22</td>
</tr>
<tr>
<td>Llanos Boscosos</td>
<td>30</td>
<td>628,425</td>
<td>39.5</td>
<td>141</td>
</tr>
<tr>
<td>Guárico</td>
<td>4</td>
<td>595,528</td>
<td>54.8</td>
<td>109</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>2</td>
<td>67,799</td>
<td>9.4</td>
<td>175</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
<td>2,153,373</td>
<td>-</td>
<td>879</td>
</tr>
</tbody>
</table>

The private lands are the most important surface to the commercial use of this species. The data about these public and private farms was obtained directly from the MARN authorizations, some of them more than 10 years ago. This
can be affected by sell or other changes in the farm dimensions, which is important because the MARN is using a classification of the farms involved in the Program accordingly to its extension, as a basis for the assignment of extraction quota (Table 5; Velasco and Ayarzagüena 1995).

Table 5. Classification of farms accordingly to its surface.

<table>
<thead>
<tr>
<th>Farm</th>
<th>Surface (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Ranches</td>
<td>&gt;25,000</td>
</tr>
<tr>
<td>Ranches</td>
<td>25,000 - 12,500</td>
</tr>
<tr>
<td>Small Ranches</td>
<td>12,500 - 3500</td>
</tr>
<tr>
<td>Farms</td>
<td>3500 - 1000</td>
</tr>
<tr>
<td>Small Farms</td>
<td>&lt;1000</td>
</tr>
</tbody>
</table>

Roads. A road network has been built in the study area, conforming by national roads, local roads and branches (Map 9), with important effects on the trading of the species products. At north side of the study area the national roads 5 and 13 are found, from which other five local roads are derived crossing all the study area in north-south and eastwest directions. From all these national and local roads, a network of small roads is derived to communicate all the towns of the area.

Productivity of the Program

The amount of harvests has been diminished on the recent years since 1992 (Velasco et al. 2002), related with a contraction of the local market, and an increase of taxes. During 1998, the economic crisis of the southeastern Asian countries also influences in the reduction of the international demand.

De Sola et al. (2000) presented an analysis on the current and potential use of the wild populations of *C. crocodilus* in the country. After monitoring the wildlife populations, a density in individuals per land hectare is defined for each region and the population is divided in four size classes. The density and the proportion of individuals within the largest size class, together with the land dimensions of each farm involved, are the basis to define an extraction quota each region. From these definitions, the extraction potential in the whole area of the Program have been estimated in some 85,000 animals per year, ie 20% of the individuals belonging to the largest size class reported for each region.

Accordingly to these definitions, the potential harvest calculated for each region is summarized in Table 6 [data from 1997, modified from De Sola (2000)]:

Table 6. Population estimated, class IV individuals and potential harvest per year in each ‘Ecological Region’.

<table>
<thead>
<tr>
<th>Region</th>
<th>Land Surface (ha)</th>
<th>Population (Individuals)</th>
<th>Class IV (Individuals)</th>
<th>Potential Harvest per Year (20% Class IV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>1,843,249</td>
<td>636,312</td>
<td>152,715</td>
<td>30,543</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>357,460</td>
<td>163,276</td>
<td>38,043</td>
<td>7609</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>868,002</td>
<td>199,295</td>
<td>39,859</td>
<td>7972</td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>217,469</td>
<td>62,705</td>
<td>15,300</td>
<td>3060</td>
</tr>
<tr>
<td>Llanos Boscosos</td>
<td>1,568,388</td>
<td>446,828</td>
<td>80,429</td>
<td>16,086</td>
</tr>
<tr>
<td>Guárico</td>
<td>993,411</td>
<td>203,661</td>
<td>50,304</td>
<td>10,061</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>708,355</td>
<td>287,674</td>
<td>48,329</td>
<td>-9666</td>
</tr>
<tr>
<td>Total</td>
<td>6,556,334</td>
<td>1,999,751</td>
<td>424,979</td>
<td>84,997</td>
</tr>
</tbody>
</table>

Note that the De Sola (2000) is using the land surface that “effectively” is used in the Program to calculate the population on the basis of the densities (individuals per hectare) derived from monitoring. The total population is about 2 million individuals, while the potential harvest is calculated as 20% of the largest size class in 85,000 individuals of high quality skins.
This value of potential harvest has been never reached by the program during the last decade. The relative success of the Venezuelan wild population Program in the conservation of the species is depending on its competitiveness in regard to the international ranching production. There is a general trend of the international market to accept skins from captive breeding. The proportion of skins from management of wild populations had dramatically diminished to only 6% of the international yearly trade (MacGregor 1999). Table 7 shows some values of Venezuelan skins trade in three years of activity (Instituto Nacional de Estadistica 2003).

<table>
<thead>
<tr>
<th>Year</th>
<th>Gross Weight (kg)</th>
<th>Net Weight (kg)</th>
<th>Bolívares</th>
<th>US Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>243</td>
<td>227</td>
<td>1,519,425</td>
<td>13,500</td>
</tr>
<tr>
<td>1995</td>
<td>1285</td>
<td>1215</td>
<td>9,085,222</td>
<td>53,578</td>
</tr>
<tr>
<td>1999</td>
<td>1450</td>
<td>1300</td>
<td>19,753,800</td>
<td>32,800</td>
</tr>
</tbody>
</table>

The Venezuelan Government reduced the taxes derived form this activity (Decree 1.367 2001), in order to increase the sharing benefits to the producers, but this policy is not reflected in an increase of the production, dominated by the international market trend toward the captive breeding skins.

**Conclusions and Recommendations**

The wild populations of *C. crocodilus* are mainly associated to the floodable plains permanent water bodies, with savanna and forest formations. Special attention must be paid to the protection of those primary habitats to maintain the sustainable Program of Commercial Use on the wild populations of this species.

A yearly monitoring of the populations in the whole area of application of the Program should be developed by scientific personnel, to keep a close watching on the spatial variations and establish extraction quotas not exceeding the current criteria or the potential yearly harvest.

The economical incentives to the Program must take into account the international market situation, and the trend to favor the captive breeding production against the more conservative wild population programs. Some policy actions from international organisms can be taken in order to accomplish this goal.

The current database on monitoring and harvests is useful to develop large-scale studies on the effectiveness of the Program in the sustainable commercial use, and the conservation strategies.

The “Ecological Regions” should be redefined by MARN on the basis of the limits proposed in the present work, taking into account the more precise borders and geographical-ecological criteria to define it with GIS application.

The geographical study, which includes ecological and socio-cultural variables, is a powerful approach to support the decision making on sustainable wildlife resource management, in special when it is developed in large areas.

**Literature**


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MARNR. Resolucion N° 23 de fecha 25/01/99, publicada en Gaceta Oficial de la República de Venezuela N° 36.653 de fecha 03/03/99. Normas para el manejo Racional de la especie baby (Caiman crocodilus).


Resolución MARN No. 23 del 21/01/99, publicada en Gaceta Oficial No. 36.653 (03/03/99).


Map 1. Study area.

Map 2. Ecological regions (after Velasco and Ayarzaguena 1995).
Map 3. Precipitation.

Map 4. Hydrography.
Map 5. Topography.

Map 7. Vegetation.

Map 8. Protected areas.

Map 11. Proposal on “Ecological Regions”.
Preliminary Examination of Crocodile Bushmeat Issues in the Republic of Congo and Gabon

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Abstract

Over a five week period we visited the WCS programs in northern Congo (Kabo-Pokola and Likouala-Lac Tele areas), and coastal Gabon (Iguela region) to appraise the potential for a research program that would investigate the ecology and natural history of central Africa’s three crocodile species and the impact of the bushmeat trade on crocodile populations. In swamp forest habitats of both countries there is a significant harvest of dwarf crocodiles (*Osteolaemus tetraspis*), for local consumption as well as for sale and subsequent transport to regional or national population centers. Of the three species of African crocodiles, the dwarf crocodile is by far the most heavily hunted because its size and non-aggressive nature facilitates capture and transport to markets. Dwarf crocodiles are either bound and transported to markets live or, in the case of Gabon where outboard motors and ice are more readily available, killed and quickly transported to markets where they can be stored on ice for much longer periods. The other two African crocodiles, the Nile (*Crocodylus niloticus*) and slender-snouted (*C. cataphractus*), seem to be hunted less frequently today than they were in the past. They supplied the demand for crocodile skins until the market collapsed in the 1980s, but are still available in bushmeat markets (especially in Gabon). Very little is known about the ecology of any of the three species of central African crocodiles.

Introduction

Crocodiles are widespread in central Africa, inhabiting a wide variety of wetlands where they may play an ecologically important role as top predators. In some energy-poor environments such as swamp forests crocodiles may be one of the most dominant vertebrate species in terms of biomass. Crocodiles are traditionally an important source of protein for rural communities, particularly in low-lying, wet regions. Over the last 20-30 years, crocodile hunting has provided protein for the growing bushmeat trade, and today crocodiles can be regularly found for sale in urban markets throughout the region. Unlike mammals and birds, crocodiles can be tied up and kept alive for long periods (>1 month) which predisposes them for long-distance transport by truck or boat to urban centers. Bushmeat trade in dwarf crocodiles appears to be particularly important in Congo as these animals are relatively easy to catch, are non-aggressive, and are not too large to make transportation difficult. In Gabon, the trade is mostly in dead crocodiles. The two other species of crocodiles from the Congo (the Nile and the African slender-snouted crocodile) are larger species that have been reported occasionally from the bushmeat trade, and are also hunted at low-levels for an artisan skin trade. In the recent past, these two species were important in the global trade in crocodile skin and were hunted extensively.

The status and ecology of all three crocodiles in the region is very poorly known. The dwarf and slender-snouted crocodile are perhaps the least known of the world’s 23 species of crocodilians. Nile crocodiles have been relatively well studied in eastern and southern Africa, where they inhabit seasonal rivers and lakes, but the populations in the Congo are found in forest rivers where little is known about their ecology. In other parts of central Africa, including Gabon, Nile crocodiles may be most common in coastal habitats where they live in estuarine areas. The IUCN has listed surveys in Central and West Africa as the top conservation priority for both the slender-snouted and Nile crocodiles (Ross 1998). The impact of widespread hunting for the bushmeat trade is an important question, particularly for the dwarf crocodile.

The lack of systematic surveys makes it impossible to quantify the size of the bushmeat trade in the Congo. Most reports are anecdotal or one-time observations from a single locality. Nevertheless, there are some clear indications that crocodile are an important component of the bushmeat trade:

- In the mid-1980s, it was estimated that during a four-month period some 3500 dwarf crocodiles were transported by boat into Brazzaville (Behra 1987).
• Reports from the early 1990s suggested that large numbers of crocodiles, particularly *Osteolaemus tetraspis*, were being sold in markets in Pointe Noir, Congo (Hutton 1991).
• A WCS sponsored survey of crocodile trade from Impfondo to Brazzaville in 1993 estimated that approximately 2,000 crocodiles a year were being shipped down the Ubangui River into Brazzaville (Efoakondza 1993).
• A study of bushmeat in northern Congo in 1996 found that at one village market, in an area with abundant swamp forest, some 30% of the bushmeat for sale was crocodile (Auzel and Wilkie 2002).
• Work by Marcellin Agagna confirmed that in Congo the crocodile bushmeat trade continued at high levels in the mid-1990s.

We conducted crocodile surveys, visited bushmeat markets, and interviewed local hunters in the Republic of Congo from 15 May–5 June and in Gabon from 6–25 June. The objective of this trip was to carry out a preliminary evaluation of the status of the three crocodile species in northern Congo and the coastal region of Gabon and the use of crocodiles in the bushmeat trade.

**Republic of Congo**

In Brazzaville we visited a commercial fish market and an artisan market to collect information on crocodile meat and skin trade. We then flew north to Ouesso and, based in the Kabo logging concession, surveyed a variety of wetland habitat types, visited a bushmeat market in the town of Pokola, and conducted interviews with a range of people familiar with crocodiles and the crocodile meat trade. Traveling by pirogue we next visited Epena, the base of the WCS Likouala–Lac Tele project (Lac Tele Community Reserve), and we were able to carry out more surveys and interviews, collect ecological information on crocodiles, and visit meat markets in the regional capital of Impfondo, on the Ubangui River. The diurnal and nocturnal forays in the Likouala region were used to familiarize project staff with techniques for surveying crocodylians and collecting pertinent biological data.

**Brazzaville**

WCS Brazzaville staff members informed us that the Ouense market principally sold fish and, because crocodiles are considered by Congolese to be more closely related to fish than meat, is the only market to sell large numbers of crocodiles. In a year-long study at Brazzaville’s large Poto Poto market, crocodiles were observed only a few times (Richard Malonga, pers. comm.). While a variety of fish was being sold, we only saw one dwarf crocodile, already chopped up and being sold in pieces. The seller indicated she had another crocodile in a freezer nearby. We were told most of the crocodiles arrive via a port on the Congo River and are sold by early morning. Brazzaville’s evening market, “Dragont”, was reported to sell crocodiles but was not visited.

The main artisan market in the Plateau section of town had a variety of crocodile (*Crocodylus spp.*) skin wallets and bags being offered for sale. The main seller indicated that the skins were from Congo crocodiles that were tanned and manufactured for sale in Brazzaville. We observed approximately 30 items made of crocodile skin.

**Kabo-Pokola Region**

The Kabo and Pokola logging concessions cover approximately 760,000 ha of terra firma (upland) forest just to the south of the Nouabale-Ndoki National Park in northern Congo. Wetland habitats that could be used by crocodylians are principally rivers and streams and small areas of swamp forest, particularly along the eastern and southern limits of the concessions, in inundated swamp forest fringing streams, and open marsh areas (*bais*) associated with streams. Localized depressions in the upland forest (*yangas*) are typically open canopied with water too warm for dwarf
crocodiles but may also provide habitat for some crocodiles (possibly temporary habitat for dispersing juveniles).

The Nile crocodile was historically present in this area but today appears to be very rare. We conducted a nocturnal survey of a 28.7 km section of the Sangha River between Mombongo and Kabo without seeing any crocodiles. The absence of crocodiles from this part of the Sangha was confirmed by local residents, who indicated they could be found further downstream, approximately 40 km below the town of Pokola. Some reports also suggested that a few Nile crocodiles may be found in parts of the heavily vegetated Ndoki River. The slender-snouted crocodile was reported to be found in the *bai* marsh habitats and in open sections of smaller rivers. On 20 May we observed three slender-snouted crocodiles (juveniles and subadults) along an earthen dike road crossing the Ndoki River next to the Ndoki 2 logging camp. All three were in relatively fast moving water where the stream passed through culverts under the road. Dwarf crocodiles are found in swampy sections of forest, including low-lying forests adjacent to streams and *bais*.

Market studies conducted in this region by WCS and others suggest that crocodiles are not an important component of the bushmeat trade in most parts of the Kabo region, with two exceptions. Crocodiles appear to be hunted widely in the Terre des Kaboungas region, in the easternmost section of concession, where the terra firma projects like a peninsula into an area of extensive swamp forest. Studies in the mid-1990s, when logging roads first entered this area, found that up to 30% of the bushmeat traded was dwarf crocodile (Azuel and Wilkie 2002). The second region where hunting of dwarf crocodiles appears widespread is on the Sangha River, downstream from Pokola, in the area around Pikounda.

Pokola is the headquarters of the CIB logging operation in northern Congo and is the largest village in the region (ca. 13,000 people). One goal of WCS activities in the region has been to eliminate the transport of bushmeat outside its village of origin, and in particular control bushmeat trade from logging camps into Pokola. We visited the Pokola market and interviewed a hunter who informed us that dwarf crocodiles are commonly sold in the market, and most of these come up the Sangha River in a CIB boat that makes a trip from Pokola to Pikounda (136 km downstream) and back every two weeks. Crocodiles, particularly dwarf crocodiles, were reported to be more abundant near Pikounda which lies close to the western margin of the massive Likouala swamp forest block.

Consolidating information from interviews with several hunters, fishermen and pygmies in the Kabo region, it appears that the nesting season for dwarf crocodiles peaks between February and late April and was over by the time of our visit. This period corresponds to the major dry season in northern Congo beginning in January and lasting until March or April. It is likely that all three species build nests in the dry season to time the emergence of hatchlings with the onset of rains. We were unable to find evidence of any crocodile nests, recently hatched or otherwise, during our surveys in the Kabo region.

**Likouala Region (Lac Tele Community Reserve)**

The Lac Tele Community Reserve (LTCR) is a markedly different landscape from the Kabo-Pokola logging concessions, dominated by vast sections of swamp forest mixed with a range of other habitats including seasonally flooded forest and savannas, as well as some upland terra firma forest. Because swamp forest is difficult to access and contains few commercially valuable trees, the area is of little interest to logging companies and by and large remains intact. The reserve is Congo’s one Ramsar site (declared in 1998). In the swamp forest itself, faunal composition is different from upland forests, with most vertebrates being either arboreal or aquatic. Previous studies of bushmeat originating from areas of swamp forest suggest that crocodiles and primates are the principal prey.
Overall, we found that the Likouala aux Herbes river had a low density of Nile crocodiles in areas downstream from Epena (we observed them between the villages of Edzema and Djeke), and dwarf crocodiles were widespread, but at low densities, in both seasonally inundated and swamp forest. We were able to collect some information on the ecology and past and present hunting of both these species. The slender-snouted crocodile was also reported to be in the area, particularly in small forested rivers, but none were seen. We discovered two dwarf crocodile nests during our surveys in the swamp forests surrounding the Likouala aux Herbes River - one, found on 29 May, appeared as though its eggs (13 total) would hatch soon; the other, found on 1 June, had recently hatched.

We spent several days visiting bushmeat markets in the regional capital of Impfondo, situated on Ubangi River (which forms the boundary between Congo and the Democratic Republic of Congo (DRC)). Impfondo is connected to Epena by a paved road (ca. 70 km) and has an active commercial trade in dwarf crocodiles. During 2.5 days at Impfondo’s Bakanzí market we saw (and measured) 22 dwarf crocodiles - all adults. The sex ratio appears to be male-biased (15 males: 7 females). During our visit (dry season), most of the crocodiles were reported to be transported across the Ubangi from forests in the neighboring DRC. During the dry season, swamp forests remain difficult to access on foot and are non-navigable by boat as they are reported to be during the high water season when hunters can enter in small pirogues. Extensive wet season hunting of dwarf crocodiles was reported from the upper reaches of the Likouala, particularly in the town of Mokengi. People we interviewed agreed that many more crocodiles could be found in the market during the wet season.

The crocodiles we observed in the main Impfondo market were destined for local consumption, but a significant number of crocodiles were also reported to be sent from the Impfondo area to Brazzaville, by riverboat (mostly during the wet season when the river is high enough for large boats), and by plane.

In the Congo, the dwarf crocodile appears to be a swamp forest habitat specialist, and in some areas is hunted heavily for the bushmeat trade. Dwarf crocodiles are highly prized as bushmeat because they are small and non-aggressive, which facilitates capture and transport, and allows animals to be kept alive for periods of days or weeks, insuring that the meat will arrive fresh at the market even when no refrigeration is available. Data on the sale of bushmeat in northern Congo found that, per kilogram, the price crocodile meat was slightly higher than the average for 21 species compared (Eaton 2002). However, price per kilogram appears correlated to the size of the whole animal and not entirely based on preference. Comparing the infrequently hunted dwarf crocodile with the commonly hunted blue duiker in northern Congo, it is of interest to note that the former, with an average weight of 7.3 kg, was sold for
approximately 450 francs/kg while the latter (averaging 4.8 kg) sold for only 360 francs/kg. From this, we might conclude that either crocodile meat is preferred to blue duikers or that uncommon species might command a higher market price.

Crocodile hunting techniques

This summary of dwarf crocodile hunting techniques is from the Congo, based on information in Agnagna et al. 1996 and interviews we conducted. It seems likely that many of these same methods are used in Gabon as well, but because of the availability of ice, crocodiles that are drown in fishing nets may also be sold in markets in Gabon. The first two methods appear to be the commonly used.

1. Hooking out of burrows. Mainly used during the dry season. When a crocodile is located in a burrow this technique is used to pull it out. A sharp hook (usually fashioned from a bent steel reinforcement rod) is attached to the end of a pole or a more flexible liana and introduced into an occupied burrow. The hook is moved in and out both to confirm that a crocodile is present, and to hook it.

2. Baited hook. This is the principal technique used during the wet season. The hunter identifies a pool or flooded area frequented by a crocodile (usually based on tracks or other sign, or by banging a paddle on the side of the canoe and hearing a crocodile respond). A large fish hook is baited with decomposing fish or a frog and left at the edge of the water and tied to a nearby tree with a length of rope. Crocodiles swallow the hook and are captured when the hunter returns.

3. Hunters attract crocodiles by imitating adult/juvenile distress calls, or by making a bubbling noise by blowing into a bamboo tube with the tip underwater. Crocodiles that approach are captured with a fish spear, a forked stick, a net, or grabbed with the bare hands.

4. Hunting at night from a canoe with a flashlight and a multipronged fish spear.

5. Finding incidentally in forest pools and grabbing with bare hands.

6. Blocking up burrows with leaves/mud and pulling out dead crocodiles after they have drowned.
7. Soaking a cloth with gas and push it into a dry burrow with a stick, causing the crocodile to abandon the burrow.
8. Using a spear to stab and kill the animal while it is in the burrow.

**Dynamics of the crocodile trade in the Lac Tele Community Reserve-Impfondo region**

All three species of African crocodiles are known to occur in the LTCR area in Congo. Because the region is heavily dominated by swamp and seasonally-inundated forest, the area is particularly suitable for the African dwarf crocodile. In May-June 2003, we spent approximately two weeks in the LTCR collecting information on the status, ecology and hunting of crocodiles in the LTCR, as well as in the nearby town of Impfondo, situated to the east of the LTCR on the Ubangi River.

This preliminary study has shown that crocodiles are widely hunted throughout the region. In the LTCR, crocodiles are hunted throughout the year using a variety of techniques. During the annual low water period, crocodiles are relatively easy to locate in their underground burrows, and are pulled out using a long section of liana with a hook attached to the end. The hunter probes likely holes with the hook until he locates an occupied burrow. Once extracted crocodiles are tied up and carried out of the forest alive. Hunting of crocodiles increases during the wet season when fishing is less productive, and when flooding provides easier access to the forest in pirogues, which also greatly facilitates the transport of captured crocodiles. Based on information from a previous WCS study by Basile Efoakondza in 1993, the early dry season (Dec-April), when water levels are falling but still high enough to permit access into the forest by pirogue, is the most favorable time of the year for hunting dwarf crocodiles.

In the southern sections of the LTCR, crocodiles are hunted primarily during the early wet season (August) and are kept alive until the level of the Likouala aux Herbes River rises enough to allow commercial boat traffic (usually in September). Crocodiles are then sold to traders on the boats and taken downriver to Brazzaville by way of the Sangha and Congo Rivers.

Crocodile hunting appears to be a regular activity of certain individuals in nearly all the villages in the LTCR, but some communities are renown for their dedication to crocodile hunting. In the northern LTCR one such village is Mokengui, where hunters take crocodiles from the northern parts of the reserve as well as the extensive swamp forests further north. Captured crocodiles are transported down the Likouala aux Herbes River to a paved road in the village of Matoko, where they are sold. Traders will then transport the crocodiles into the town of Impfondo on public transport or a military truck. Just to the east of the LTCR, hunters will transport crocodiles by pirogue down the Tanga River to the village of Botola, along the same road into Impfondo.

There is also considerable commerce across the Ubangi River from the DRC into Impfondo, including crocodiles. Crocodiles that arrive in Impfondo, either from the east (DRC) or the west (Likouala region) are either sold for local consumption, or transported alive (and occasionally smoked) south to Brazzaville. During the high water period large riverboats can ply the waters of the Ubangi and will transport crocodiles, stopping at other villages along the way and thus providing traders with the opportunity to purchase more crocodiles. Crocodiles are also transported from Impfondo to Brazzaville on a regular commercial flight, tied up and bundled into the cargo compartment with the rest of the travelers’ luggage. Crocodiles are also flown out on occasion on military transports (P. Elkan, pers. comm.).

In Impfondo, crocodiles are sold in the Bakanzi morning meat and fish market with other bushmeat. Crocodiles are brought in alive before being dismembered and sold in Fcfa 500 ($US 1) piles. And adult male dwarf crocodile (12-15 kg) can be purchased whole by market sellers for Fcfa 8000-10,000 ($US 13-17).

In 1993, WCS sponsored an evaluation of the crocodile trade between Impfondo and Brazzaville. The results were presented in two interim and one final report by Basile Efoakondza and are summarized here. Some of the information in these reports appears to be incorrect (particularly regarding the sexes of crocodiles), and the surveys were not conducted in a systematic fashion, but much of the information from these reports is illuminating.

The information was gathered during five round-trip boat voyages from Brazzaville to Impfondo. Crocodiles were measured and the owners interviewed as they entered the boat. The author points out that the monitoring was not exhaustive, as animals would enter both day and night, frequently come aboard in numbers too great for one person to deal with, and many of the owners would not let him collect information. The author also spent time collecting information on crocodiles in the main market in Impfondo, and on one of his trips also traveled to Epena. Overall, the report concludes that some 2000 crocodiles a year are shipped down the Ubangi to markets in Brazzaville.

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Travel Time. Boats normally took about 10 days to travel upstream and 7 days downstream. Travel times were longer in the dry season when boat navigation was difficult (or impossible at the height of the low water period).

Species Composition. A total of 730 crocodiles were registered coming aboard the boats, of these 721 (98.8%) were dwarf crocodiles and only 9 were slender-snouted crocodiles.

Source of animals. Crocodiles were brought aboard the boat at nearly all the villages downstream of Impfondo, between Impfondo and Mossaka (situated near the mouth of the Likouala River (Table).

Animals that were sold in the Impfondo market originated in both the Republic of Congo (Likouala area) and entered Impfondo along the Epena Road, or in the Democratic Republic of Congo and were traded across the Ubangi River. In one sample of 51 animals collected over 9 days in November 1993, 43 (84.3%) came from the DRC.

Sex Ratio. Although the reports presented information on the sexes of crocodiles measured, we considered these data to be unreliable, based primarily on the fact that animals recorded as females almost certainly were males based on their size (≥140 cm TL).

Size-class distribution. The size-class distribution of 246 crocodiles that were measured by Efoakondza is presented here as a graph. These data show that hunting is clearly aimed at adult animals, principally crocodiles over 120 cm TL. The largest crocodiles in the sample were 160 cm (including one crocodile sexed as a female but almost certainly a male), and the smallest was a 90 cm TL male. The size-class distribution shows a peak in the 130-140 cm TL interval, which likely represents large adult females and young adult males. The secondary peak from 150-160 cm TL is probably comprised entirely of adult males.

Mortality. In the interim reports, with information from two voyages, the mortality rate of crocodiles on boats was estimated to be 5-6%. However, the final mortality rate was much higher - 17.8%, with a total of 130 dead crocodiles found. Dead crocodiles were butchered and sold on the boat or smoked presumably so they could continue the voyage and be sold in Brazzaville.

Prices. Crocodiles coming from the Epena region were reported to be sold for an average of about C CFA 2,000 in the town of Botala (on the Likouala-aux-Herbes near Epena). The same animal would sell for approximately C CFA 4000 in Impfondo and C CFA 6000-10,000 in Brazzaville.
Efoakondza estimated that approximately 2000 crocodiles per year were transported from Impfondo to Brazzaville during 13 voyages. Crocodiles rarely make it to Brazzaville aboard the boats. Buyers from Brazzaville markets usually meet the riverboats in Maloukou, at the upstream end of the Stanley Pool, in order to buy crocodiles at a lower price. We learned from our interviews that crocodiles were sold prior to entering Brazzaville in order to avoid government wildlife authorities searching boats for illegally transported animals.

**Gabon**

In Gabon we were based at the Iguela Lodge, adjacent to the Loango National Park, and situated on the Ngove Lagoon. Over the next two weeks we carried out day and night surveys of the Mpivie River, a portion of the southern shore of the Nkomi Lagoon, sections of the northwestern Ngove Lagoon, rivers flowing into the Ngove (the Ngove, Rabi, and Yombe), as well as a series of coastal lagoons stretching along 48 km of shoreline. On four of these outings we were accompanied by staff from the Gabonese Fish and Wildlife Department to familiarize them with survey procedures. We are able to conduct nocturnal surveys in a variety of wetlands, and were impressed with the diversity of habitats and the overall high density of all three species. Our last two days were spent collecting information on crocodile bushmeat trade in Port Gentil.

Nile crocodiles, because they nest in sandy soils, were restricted primarily to the northwestern sector of the Iguela Lagoon (adjacent to an extensive network of paleobeaches), and the many small coast wetlands that form behind the uninhabited beach of the Petit Loango NP. In these areas Nile crocodiles were widespread, but usually at relatively low densities. Based on reports (eg Behra 1987) and several interviews we conducted during our visit, the hunting of Nile crocodiles by Africans and Europeans for the skin trade was widespread during the decades of the 1960s through 1980s. Commercial hunting of the Nile and slender-snouted crocodile largely ended with the implementation of CITES restrictions and the subsequent collapse of trade in wild crocodile skins. Behra (1987) found no Nile crocodiles in his surveys of the Sette Cama region and Fernan Vaz lagoon and reported organized and widespread commercial hunting up to a few years prior. The observation of many Nile crocodiles (but few adults) during our surveys, conducted nearly 20 years after Behra’s, suggests that this species is in the process of making a slow recovery. In some of the coastal lagoons we found Nile crocodiles present in brackish waters (up to 17 ppt). Tracks suggest that crocodiles move overland between lagoons and will enter the ocean as well.

The African slender-snouted crocodile appears to be locally common in medium-sized rivers both in areas of forest (Mpivie River, Rembo Eshira) as well as areas where rivers are bordered by marsh (Rembo Ngove). Dwarf crocodiles are common in the Iguela area and are found principally in the extensive swamp forests that borders the Iguela Lagoon and some of its tributary rivers (Rembo Rabi). Dwarf crocodiles may also enter cool forest rivers (water
temperature <25° C) at night, and were also observed at night along the margins of the Iguela Lagoon where it was bordered by swamp forest. In the latter case they appear to spend the day in burrows or buried in mud in the swamp forest and then forage along the lagoon edge at night.

Hunting crocodiles for bushmeat is relatively uncommon in the Iguela lagoon region, if only as a result of the very low human population density. However, there appears to be significant hunting in some areas adjacent the park, particularly around the southern edge of the Nkomi Lagoon and the Rembo Nkomi (A. Downer, pers. comm.), where larger villages are situated. Crocodiles in these areas are taken for local consumption, or sold in markets in Omboue or Port Gentil. Unlike Congo, where crocodiles are kept alive until butchered in the markets, crocodiles enter the Omboue and Port Gentil markets dead and are kept on ice, which, unlike in Congo, is readily available in Gabon. Our preliminary observations also suggest that while dwarf crocodiles comprise the majority of crocodile bushmeat in Gabon, slender-snouted crocodiles are more commonly seen in markets than in Congo. Over a one-day period we saw 15 dwarf crocodiles and 4 slender-snouted crocodiles in the Marche La Ville, the largest of four markets in Port Gentil reported to sell crocodiles. The sale of meat from the larger slender-snouted crocodile may also be result of the availability of ice, as it allows large crocodiles to be transported to markets dead then butchered and sold over a period of several days, a process that would be difficult in Congo.

![Dynamics of the crocodile trade in the central coastal region of Gabon](image)

**Dynamics of the crocodile trade in the central coastal region of Gabon**

**Omboue Market, Nkomi (Fernan Vaz) Lagoon**

While the village of Omboue is the largest population center in the region around Iguela, it may not be a large importer of hunted crocodiles to its market. From discussions with project staff and local residents, villagers from settlements such as Saint Anne, Assaye, and Ndougou, as well as from Omboue, may hunt large numbers of crocodiles for export to Port Gentil markets. We were told of a ferry that travels once per week, stopping at each of these villages, to Port Gentil and which is used to export crocodiles and other bushmeat. Crocodile hunting, in this region at least, appears to be more opportunistic than deliberate. Most of the residents we spoke with about crocodiles said that crocodiles are killed when found entangled in fishing nets, rather than the specific target of hunting. Crocodile hunting certainly occurs in this region, but fishing appears to be the principle economic activity. The village chief of Idjembo stated that crocodile skin hunting by Europeans was widespread 30+ years ago and that people currently
living on the Mpivie River have killed all the large crocodiles (*C. cataphractus*). The chief’s lack of knowledge of crocodiles (ie stated that no crocodiles live in Iguela lagoon as it is too salty) indicated that they are not heavily hunted by this village. More time spent in village markets and talking to villagers is needed to better understand the importance of crocodiles in the local diet and in local and regional economies.

Omboue market was visited briefly only twice. An afternoon visit on 8 June found the market almost deserted with a small amount of smoked fish and some agricultural products for sale. A late morning (9:50) visit on 23 June found 3 softshell turtles (2000-4000 FCFA/ea.) and one piece of smoked turtle (likely *Trionyx* sp.). A woman with a sack full of monkeys in wheelbarrow was seen outside the market (number, species, and destination unknown), and the head of a dwarf crocodile was found floating in the water near the town’s port.

**Port Gentil**

There are several markets in Gabon’s second largest city, with the Marché de la Ville seemingly the largest and most important for the bushmeat trade. The Marché de la Ville, located near the city’s main port, appears to receive shipments of agricultural products on a daily basis but was said to be supplied with bushmeat only on Mondays and Thursdays. Vendors indicated that bushmeat arrives in pirogues returning from the Ogooué River delta. The Marché de la Ville contains numerous ice chests distributed throughout the market which, along with an ice factory located in Port Gentil, allows vendors to store and sell bushmeat throughout the week rather than only on Mondays and Thursdays. It is very likely that boats leaving Port Gentil are supplied with chests or coolers full of ice to facilitate the transport of bushmeat from large distances. This situation is fairly unique, as the distance for exporting fresh bushmeat elsewhere in central Africa is often limited by the maximum travel time which prevents spoilage of the meat (with the exception of live crocodiles). In addition, without ice vendors must either smoke the meat or sell fresh game within a day or two of it being killed. One very noticeable difference in hunting between northern Republic of Congo and Gabon is that crocodiles (especially dwarf crocodiles) are nearly always captured and transported live in Congo and nearly always killed in Gabon. The availability of ice, and therefore the ability to transport larger distances, in Gabon appears to be the most obvious explanation for the differences in hunting technique.

We were present at the Marché de la Ville on Monday (23 June, 2003) and recorded the arrival of a substantial amount of wild game (see below). Boats on Mondays and Thursdays were said to arrive in the morning and evening, but we observed several wheelbarrows full of bushmeat being brought into the market at midday. We assumed these animals were transported from the port. One man, claiming to be the hunter, was carrying 13 headless dwarf crocodiles in a wheelbarrow and informed us he had transported a total of 22 from the swamp forests surrounding the Ogooué River.

Visiting the port on a Tuesday (24 June, 2003), we saw a number of large pirogue-like boats, many with multiple outboard engines. The boats’ appearance suggested they would be able to either cross the bay or follow the coast from the Ogooué Delta. Presumably, these boats would arrive without an established schedule, leaving unclear why the Marché de la Ville receives bushmeat only twice per week. One possible explanation is the ferryboat ‘Fernan Vaz’, which was also seen at the port on Tuesday loading people and supplies for departure. We assumed this to be the ferry mentioned above, traveling once per week from Assaywe, Ndogou, Saint Anne and Omboue to Port Gentil. We were unable to verify if this boat arrived on Monday, nor if this or another ferry also arrives on Thursdays.

The port area, situated very close to the Marché de la Ville, also has a market that sells agricultural products, manufactured goods, and bushmeat. We were told that the Port Market receives pirogues (i.e. bushmeat) only on Fridays, but were unable to determine from where. No bushmeat was seen at the port during our visit.

Many of the restaurants in Port Gentil serve bushmeat on their regular menus. One restaurant near the Marché de la Ville (Cafe du Wharf) had an entire page of its menu dedicated to dishes prepared with bushmeat, including crocodile, red river hog, porcupine and antelope. A restaurant owner of European nationality was seen in the Marché de la Ville purchasing a red river hog for his business.

**Literature**


Evaluation of Wild Populations and Habitats of American Crocodile
(*Crocdylus acutus*) in Venezuela

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Abstract

The American crocodile (*Crocdylus acutus*) in Venezuela is considered an endangered species included in Appendix I of CITES. Government is developing a Conservation Program, which includes population surveys in natural habitats and ranching for reintroduction. Abundance and size structure of wild populations, and a characterization of occupied and potential habitats were carried out, in order to choose better reintroduction areas. A total of 23 locations within the historical distribution area of the species were visited, observing a total of 292 crocodiles. Size structure was: 99 hatchlings, 257 juveniles, 72 small-sized adults, 44 adults, and 29 large adults. The highest abundance was located at the Tocuyo River. The favorable environmental conditions considered for habitat characterization was the presence of stable populations, mangrove or marginal forests, potential nesting sandy beaches, affluence or predominance of freshwater, and legal protection. As negative factors, the presence of tourist activity, housing, agriculture and industrial activities, navigation, fishery, and proximity to roads were identified. Statistical tests indicated that the better marine-coast area for reintroduction was Turiamo Bay. Among freshwater environments, the most favorable were the Tocuyo and Tucurere Rivers, and the reservoirs of Játira and Burro Negro.

Resumen

El Caimán de la Costa (*Crocdylus acutus*) es una especie amenazada, incluida en el Apéndice I de CITES. El Gobierno venezolano ha desarrollado un Programa de Conservación, realizando censos poblacionales de la especie en su hábitat natura y crió en cautiverio para reintroducción. En el presente trabajo se evaluaron las poblaciones naturales en términos de su abundancia y estructura de tamaños, y los hábitats naturales de la especie, con la finalidad de proponer zonas de liberación y reintroducción. Se visitaron 23 localidades del área de distribución histórica de la especie donde se observaron 291 caimanes sin incluir los individuos pertenecientes a la clase I (99 en total). La clase II está representada por 157 ejemplares, la clase III por 71 caimanes, la clase IV por 44 individuos y la clase V por 19 ejemplares. La mayor cantidad de individuos se localizó en el Río Tocuyo (Edo. Falcón). Entre las condiciones ambientales favorables para el establecimiento de poblaciones estables de la especie se citan la presencia de manglares o vegetación marginal boscosa, playas arenosas para la anidación potencial, afluencia o predominancia de aguas dulces, protección a través de figuras legales, y presencia actual de la especie. Como factores negativos, se identifican la presencia de actividad turística, viviendas, actividades agrícola e industrial, navegación, pesca y cercanía a vías de acceso. De acuerdo a resultados estadísticos, el área marino-costera más favorable fue Bahía de Turiamo. Entre los ambientes de agua dulce, los mas favorables fueron los Ríos Tocuyo y Tucurere, así como los embalses de Játira y Burro Negro.

Introduction

The American Crocodile (*Crocdylus acutus*) is geographically distributed within the south coast of Florida (USA), all the Great Caribbean Sea, and coasts of the Pacific Ocean from Mexico and Central America, Colombia and Peru (Fig. 1). The historical area of distribution in Venezuela includes the whole marine coast. Seijas (1984, 1986a, 1990), Arteaga (1997) and Arteaga and Sánchez (1996) recorded the presence of this species in several coastal and freshwater locations.

This species is currently included in Appendix I of CITES in Venezuela. The Ministry of Environment and Natural Resources (MARN) of Venezuela started in 1993 the National Program for Conservation of the American Crocodile (*Velasco et al. 2000*), with the collection and ranching of hatchlings from Turiamo Bay (Aragua State) and Fundo Agropecuario Masaguaraal (Guárico State), to be released after one year of raising at the Cuare Wildlife Refuge (Falcón State) (*Velasco and Lander 1998*). One of the objectives of this Program is the identification of other favorable locations for reintroduction of the ranched individuals, within the historical area of distribution of this species.
There are few works on habitat characterization for this species, since most publications are related with population status. Seijas and Chávez (1990) mentioned some factors affecting the presence of the American Crocodile in several Venezuelan locations, remarking the habitat destruction and presence of human population. Platt and Thorbjarnarson (1997) reported in Belice that the alterations of beaches were seriously affecting the nesting activities and that mangrove forests were the optimal areas for the species. Soberón (2000) in Cuba also pointed out the mangrove forests with freshwater lagoons, creeks and reservoirs, as the most suitable zones for the species.

The objective of the present work were to evaluate abundance and size structure of wild populations of the American Crocodile, and the general description of habitats within its historical distribution area in Venezuela, with the aim to propose new wild locations to release ranched individuals.

**Area of Study**

The field work was carried out during August to November of 2002, at several locations on or near the Caribbean coasts of the country (Fig. 2), including mangrove areas, coastal lagoons, river mouths, channels and reservoirs, selected to evaluate its properties as habitats for the species:

**Central-Eastern Coast**

Neverí River, Píritu Lagoon, Uchire Lagoon, Caño Sur and Caño Camaronera (Uchire Lagoon), Unare River, Tacarigua Lagoon and Río Chico Channels.

**Western Coast**

Turiamo Bay, Yaracuy River, Aroa River, Paují Creek, Las Pabas II Creek, Cumaripa Reservoir, Morrocoy National Park, Cuare Wildlife Refuge, Tacarigua Reservoir, Játiru Reservoir, Tocuyo River, Tucurere River, Boca de Hueque, Los Olivitos Wildlife Refuge, Burro Negro Reservoir.

Each location was geographically referenced with GPS and cartographic charts. The data obtained were processed using a Geographic Information System (MAP-INFO).

Some of these selected locations could not be visited during the fieldwork, due to access problems: Píritu Lagoon,
Figure 2. Surveyed locations on the Caribbean coast of Venezuela.

Uchire Lagoon, Boca de Hueque, Los Olivitos Wildlife Refuge and Cumariya Reservoir, but their ecological characteristics and reports on the presence of the species allow to consider these locations within the present work.

**Methods**

The evaluation of population abundance was determined by night-light counts (Chabreck 1966; Woodward and Marion 1977). The size-class was observed using the categories of total length (TL) proposed by Seijas (1988) and Velasco and Lander (1998): Class I (<60 cm TL), Class II (60-120 cm TL), Class III (120-180 cm TL), Class IV (180-240 cm TL), and Class V (>240 cm TL).

The habitat description included the main ecological characteristics, and human population and its activities. On the basis of the requirements of the American Crocodile, subjective positive and negative features of the habitat were considered to obtain a better definition. The positive values related with favorable conditions of the habitat for this species: mangrove forest, dominant plant formation on the embankments, beaches for nesting, presence of freshwater, legal condition of the habitat (protected by law), and the presence of the species. The negative values included tourism, housing, agriculture, industry, navigation, fishery and proximity to roads. Both positive and negative factors were weighed to obtain a numerical basis for comparison of habitats, regarding the current or potential occupation by the species.

**Results and Discussion**

**Abundance and Density**

Table 1 shows the results of the 23 locations observed, with a total of 291 crocodiles surveyed (not including the Class I individuals). Linear densities were calculated on the basis number of surveyed individuals (Class I not included) and the length of the observer displacement in each habitat. The densities varied from 0.21 ind/km at Morrocoy National Park to 8.00 ind/km at Tocuyo River (Table 2). The total density recorded was 1.72 ind/km.

The results of abundance and density were compared with those reported by Seijas (1984, 1986a), Arteaga and Sánchez (1996), and Arteaga (1997) at the same locations (Table 2), to show the variation in time of the population status of the species. In general, the results of densities obtained in the present work are higher, but the difference should be related with several factors.
Table 1. Results of the surveys in number of individuals and size classes observed in the habitats.

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Table 2. Densities (ind/km) in the observed habitats and in previous reports.

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The Neveri River showed a reduction in abundance respect to previous reports. It can be related with the short displacement of the observers; almost all the surveyed animals were located near the mouth on the sea, and there are reports from farmers that more individuals have been sighted upstream. At the Tacarigua Lagoon National Park, the survey was accomplished during the daylight, so there was an underestimation of the population. Other locations revealed a slight increase in their populations, related with the hunting prohibition in these areas and the low level of human activities.

The general results indicate that all these populations are dominated by the smaller classes of size (hatchlings or juveniles). This fact is indicative that the populations are in a recovering moment, with a general trend to the increasing of size and abundance.

**Habitat Description**

**Central-Eastern Coast**

*Río Neverí*: (LN 10° 10’ 15” LW 64° 42’ 26”), was observed from its mouth on the sea, crossing the city of Barcelona. The river showed high presence of floating plants, mangroves and sandy beaches, housing and human activity.

*Piritu Lagoon*: This shallow, coastal water body is separated from the sea by a sand bar with coconut palms, and was observed from the land. It is surrounded by mangrove and deciduous forest, mainly with clay soil. Strong fishery and fences inside the lagoon were noted. No crocodiles were surveyed.

*Uchire Lagoon*: This is another coastal lagoon, also with a sand bar surrounded by high-density housing, roads and fishery. It is surrounded by patches of mangrove, grasslands and bushes. Two freshwater creeks (Caño Sur and Caño Camaronera) and the Unare River are flowing into the lagoon.

*Caño Sur*: This is an effluent of the Unare River, with mangroves and sandy beaches on both banks. Strong fishery activity was observed.

*Caño Camaronera*: Close similar to Caño Sur, with presence of floating plants. A shrimp farm is using the water of this creek.

*Unare River*: It was observed from the sandy bar to the Unare Nuevo town. Mangroves, floating plants and sandy beaches were present. More than 80 houses on the banks with high human activity were observed.

*Tacarigua Lagoon*: This is the largest of the three coastal lagoons of this area, also separated by a sandy bar from the sea. The main vegetation is mangrove in the coast and forming islands, and deciduous forest. Several freshwater creeks are effluents of the lagoon, which are included in a National Park area with limitations in the fishery and navigation but high tourist activity. A daylight-count was performed at Caño Los Monjes and Patrocinio, at the west side of the lagoon, observing the south and north banks.

*Río Chico Channels*: These are several artificial channels located in the surroundings of the Tacarigua Lagoon. One of them is the Caño Copei, observed from the mouth on the sea. Generally, it is a very strongly intervened area for navigation and sport fishery, but conserving its natural mangrove vegetation in some zones.

**Western Coast**

*Turiamo Bay*: This is a wide bay opened to the Caribbean Sea, surrounded by mangrove, deciduous forest and sandy beaches. There is a small coastal lagoon and a freshwater creek (Caño San Miguel). Is a protected area, with a harbor that serves as base to the Venezuelan Navy.

*Yaracuy River*: This was observed from the mouth on the sea until the navigation was impracticable due to obstacles. There are abundant floating plants and sandy beaches, with strong industrial, agricultural and cattle raising activity.

*Area River*: Also observed running up from the mouth on the sea. It is surrounded by mangroves, bushes and grasslands, with sandy beaches on the banks. Intense human activity (navigation, fishery, housing) was observed.

*Paují Creek*: Mangrove, deciduous forest and grasslands are covering alternatively both banks, with sandy beaches.
Las Pabas II Creek: The same as Pauji Creek.

Morrocoy National Park: The north and south coasts of this extensive protected area were observed. This is a highly intervened sector by tourism and sport fishery, and navigation of many boats. There are mangroves combined with deciduous forest and grasslands, alternated with sandy beaches, in the banks and small islands.

Cuare Wildlife Refuge: This is a small gulf surrounded by salty fields, beaches, grasslands and mangrove, in a RAMSAR protected wetland with several freshwater creeks in its banks. It is located very close to the city of Chichiriviche, other towns and tourism facilities, surrounded by several roads. There are also farming and fishery activities.

Tacarigua Reservoir: A freshwater reservoir located near the coast. The banks are surrounded by deciduous forest, alternated with sandy beaches. There is a plant for water treatment and low fishery activity or human occupation. This reservoir is linked to the Játira reservoir by a channel.

Játira Reservoir: With very similar characteristics of the Tacarigua reservoir but completely surrounded by sandy beaches, without any kind of fisheries.

Tocuyo River: Both margins with grasslands and forests, several sandy beaches; intensive agriculture and cattle raising activities.

Tucurere River: Is surrounded by mangrove and grasslands, with many sandy beaches. Few human activities were observed.

Los Olivitos Wildlife Refuge: A very wide protected area, formed by a wetland flooded with shallow marine water and surrounded by mangrove and grasslands, wit few human activities.

Burro Negro Reservoir: The freshwater reservoir is surrounded by deciduous forest, with beaches and floating vegetation, low human activity was observed.

Cumarpia Reservoir: The same conditions of the Burro Negro Reservoir.

Comparison of Habitats

To select the better areas for releasing ranched crocodilians, the positive and negative features of each habitat were weighed in a scale up to 9, adding one point for favorable characteristics and reducing one point for non-favorable ones. The lists of positive and negative environmental conditions present in each habitat are given in Tables 3 and 4, and are the basis to reach a subjective index of environmental quality in regard to the species requirements.

The ranged environmental quality values obtained for each location, were plotted against the observed density of crocodiles to apply the graphical Olmstead-Tuckey non-parametrical test (Fig. 3), divided in four areas by the respective median values of each axis. The test resulted significant for the degrees of freedom in the sample.

Accordingly to this result, the best locations to release ranched crocodilians are: the Tocuyo and Tucurere Rivers, the Jatira and Burro Negro Reservoirs, and the Turiamo Bay, all them located in the right upper quadrant of the graph reflecting high environmental quality and an appropriate density value registered during the present work.

Conclusions

A total population of 390 American Crocodilians was observed in 23 locations surveyed. The highest amount was found at the Tocuyo River, a natural freshwater environment. In freshwater reservoirs, the high population value was observed in the Játira reservoir, and the high amount in marine-coastal environment was located at Turiamo Bay.

The different surveyed populations of this species seem to be in a recovery phase, since the records in the present work were higher than previous reports, dominated by young individuals. This conclusion demands more continuous monitoring of the species in these habitats.

The habitat requirements for this species includes the presence of mangrove or forest on the banks, sandy beaches for
nesting, affluence or predominance of freshwater, protection by law of the areas. As negative factors, tourism and urbanism, together with fishery and other human activities were identified. Keeping as a goal the conservation and recovery of the wild populations of the species, it is strongly recommended the protection by law of the identified suitable habitats for releasing or re-introduction of ranched animals.

**Literature**


Table 4. Negative environmental conditions of habitats.

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Figure 3. Graph for Olmstead-Tuckey test with density and environmental quality values for each habitat.
Analysis of the Program of Conservation and Use of the Spectacled Caiman (Caiman yacare) in Bolivia, and Recommendations to Improve It

Alfonso Llobet Q.1, Luis F. Pacheco2,3 and James Aparicio E.4

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Abstract

The Program for Conservation and Use of Spectacled Caiman (Caiman yacare) in Bolivia began in 1995, with limited population surveys carried out in the lowland areas of the country. In 1997 a small-scale experimental harvest was carried out, and in the following years between 30,000 (1999) and 59,000 (2003) individuals were harvested. A first analysis of the program was carried out in 2002 in a workshop with the participation of national and international specialists. This workshop detected some problems in the development of the program, mainly related to control mechanisms. Despite subsequent recommendations, during 2003 serious flaws to the Program were detected, related to the weakness of control mechanisms exercised by Departmental Governments, unreliability in the monitoring and harvest components, unjust distribution of benefits, and violations to regulations. Here we detail some considerations that should be followed in order to improve the Program. These include: a) legal modifications to regulations to improve their applicability, b) capacity building for direct users of the Program (rural and indigenous communities, and cattlemen), c) improvement of the control systems and inspection mechanisms, d) design and implementation of a comprehensive and reliable monitoring program, and e) administration and management of spatially defined units, based on land tenure, and with greater participation of local actors to increase social control mechanisms.

Introduction

Although from the decade of the 70s we have information about the caiman of Bolivia (Donoso-Barros 1974; Lovisek 1977, 1980), the studies carried out in that time were very casual and with little transcendence for the conservation of the caiman in the country (Pacheco 1996). During the same decade, Medem carried out the first inventory at great scale whose results were published ten years later (Medem 1983), with information, for the first time, on the natural history of the caiman in Bolivia. The second great effort to gather information at a major scale about the populations of caiman was carried out in 1986, with six months of work was possible to obtain information comparable to the one gathered by Medem on the distribution of the species and the status of some populations (King and Vídez-Roca 1989). Starting from that moment, several works that offer information on the population status of the spectacled caiman (Caiman yacare) were carried out in different areas of the country like Beni, Santa Cruz and Cochabamba (Ruiz 1988; Vídez-Roca 1987, 1989; Ergueta and Pacheco 1990; Vaca 1992; Pacheco 1993; Rebolledo-Garin and Tapia-Arauz 1994; Llobet 1996; Llobet and Goitia 1997).

The studies made in 1986 showed that, although the species was practically exterminated in some areas of Beni, in other regions it was particularly abundant with densities up to 70 ind/km of shore. (King and Vídez-Roca 1989). The same situation was observed in Santa Cruz, where very low densities were reported in some areas (King and Vídez-Roca 1989; Ergueta and Pacheco 1990; Rebolledo-Garin and Tapia-Arauz 1994), meanwhile in other (as the area of San Matías), the observed aggregations (especially during the dry time) produced high densities, similar to those reported in the Venezuelan plains (Pacheco and King 1995). It is considered that at the moment the species is not endangered (Pacheco and Aparicio 1996), however it is necessary to remember that the C. yacare populations suffered in the past a strong hunting pressure, being depressed in most of their distribution area (Pacheco 1996). According to the recovery experienced by the spectacled caiman populations in the last years, a program of sustainable use of the species can be carried out, but it is necessary to respect the conditions and the harvest quotas settled down in the national rules (Godshalk 1994; Llobet and Aparicio 1999).
The use of crocodilians can be carried out in different ways: harvests of wild animals, ranching (crops of eggs and/or hatchlings for breeding in captivity) and breeding in complete captivity (farms) maintaining reproductive adults in captivity. Each system involves advantages or disadvantages in terms of the conservation value, regulation easiness and costs and economic return (David 1994); for this reason, the application of each one (or several) of these methods should be preceded of an analysis of the reality (considering biological aspects of the species, and socioeconomic characteristics of the region where it is sought to work).

The chosen model to develop a program of sustainable use of C. yacare in Bolivia was the harvesting of wild animals, based on the success demonstrated by the Venezuelan experience with C. crocodilus (Thorbjarnarson and Velasco 1998). This system requires the smaller economic investment, and the biggest beneficiaries are the owners of the lands (Velasco et al. 1995). The use is based on the sexual differences presented in the species to establish the limits of minimum size for the animals to be harvested; in such way that the harvest process is focused towards the animals bigger than 180 cm total length (TL), which are generally males, protecting this way the reproductive females. A situation that it is necessary to have in mind, is that the hunt in the nature is very difficult to regulate and it has a high risk of not being sustainable; so the crocodile populations can be diminished very easily by the removal of reproductive adults. If add to this that the great overexploitation of crocodile populations that took to many species at critical levels from the point of view of its conservation, was owed in great measure to the direct hunt (King 1989), it is easy to deduce that different control systems are needed to adjust and to correct the flaws of the program, in such a way that we can assure the implementation of the main objective: to achieve the effective conservation of the C. yacare in Bolivia.

It has been pointed out that the sustainable use can generate bigger interest in the conservation of the species to be used (Thorbjarnarson 1992; Jenkins 1993; Ross 1995); however, in Latin America the benefits of the use are not generally reinvested in programs of conservation of the same species (Hines and Abercrombie 1987; Magnusson 1995). The idea that the use can produce benefits to the conservation processes is interesting, and it arises on a base of investigation of many years that demonstrated the success of the sustainable use of crocodilians in countries like New Guinea, Venezuela, Zimbabwe, United States and Australia (Hutton and Child 1989; Joanen et al. 1990; Genolagani and Wilmot 1990; Webb et al. 1992; Velasco and De Sola 1997). In spite of these successes, the use programs can be affected or weakened if no benefit is dedicated to the conservation by the lack of an integrated plan.

It is necessary to consider like a reality the fact that the commercial use of the crocodilians is subjected to the fluctuations of the market, where many times the involved actors concentrate their efforts on the economic aspects, causing that the field of the sustainability of the resource is neglected (Magnusson 1995). The big fluctuations in the market of crocodilian products suggest that no conservation plane should be based exclusively on the success of the economic use. As any other international merchandise, the crocodilian products are object of the force of the market and the changes of prices that are beyond the control of the producers (Woodward et al. 1994). Such economic fluctuations represent a great danger for the programs of sustainable use, because they impel the economic balance toward the decrease of the production costs increasing the “temptation” to return to a non-sustainable exploitation of wild leathers (Ross 1995).

One of the problems of the projects of economic use is that they are seen as results in the economic plane, and don’t as opportunity to generate information that improves the management or increase our scientific knowledge. That is to say, if we consider that the knowledge of the dynamics of the crocodile populations is still limited, it should be assumed that this type of information also has a limited utility in the development of management plans. If we assume that the task of the investigators and administrators of resources responsible for the management of crocodilians are to establish programs with high probabilities of sustainable use of the resource (Ross 1995), then the management plans should also be constituted as a source of information on the population dynamics, as feedback to correct the errors and to assure the execution of the outlined objectives. For this reason each management plan should be intimately linked to a monitoring program (McNab 1983; Walters and Holling 1990 in Magnusson 1995).

Finally, the capacity to apply the laws is a particularly complex topic in the Latin American countries, because many times this is related with the political will to develop processes. Generally the lack of institutionalism in the government agencies is a common factor that affects negatively every conservation effort in Bolivia. A way to attack this problem is looking for support on the different international agreements (like CITES) of which Bolivia is signatory.

Chronology of the Program of Conservation and Use of the Spectacled Caiman (C. yacare) in Bolivia

In Bolivia the development of a pilot program of sustainable use of the Caiman yacare arose in 1995 with the project
“A Programme for the Sustainable Utilization and Management of Caiman in Bolivia” (King 1995; Godshalk 1994), which gave basis to promulgate in 1997 the Regulation for the Conservation and Use of the Spectacled Caiman (C. yacare) for the Departments of Santa Cruz and Beni (Supreme Ordinance - S.O. 24774, of July 31st of 1997) (Fig. 1). At the same time, the National Direction for the Conservation of Biodiversity - NDCB (now General Direction of Biodiversity-GDB), elaborated the National Program of Conservation and Sustainable Use of the Caimans of Bolivia, in which the monitoring of spectacled caiman populations (and other crocodilian species) were considered (Llobet and Aparicio 1999). With this base, the use of C. yacare was authorized, under requirements and conditions of the Regulation, and an Experimental Plan of Use of the Spectacled Caiman was settled down in areas selected by the term of 2 years. At the same time, the burning of confiscated products was established as a mechanism directed to control the illegal hunting.

![Figure 1. Map of Bolivia. The Departments where the Program of Conservation and Sustainable Use of the Spectacled Caiman was implemented are highlighted (dark grey).](image)

In November of 1997, on this legal base and with financing of the Royal Embassy of Holland, a Management Plan was elaborated (Aparicio 1997) and the use of the Spectacled Caiman began, with reduced harvesting quotas and a hunting methodology only consented with harpoon. The results of the experimental harvest allowed to determine that the hunt with harpoon was very difficult to carry out in Bolivia, basically for the lack of experience of the local people in the use of this instrument. On the other hand, the harvest quota assigned for the different cattle ranches was insufficient at least to pay the expenses of transport and of the personnel dedicated to carry out these activities.

The same year, seizures made by the Authority of Beni Department, originated disagreements and confrontations by the instruction of burning 17,609 skins of Spectacled Caiman. That instruction based on the S.O. 24774, caused that several regional institutions of that Department, headed by the Civic Committee of Beni, carried out a series of protests, causing that in 1998 a Commission of Revision of the mentioned Supreme Ordinance was conformed (directed by the Presidency of the Republic) in order to giving solution to the problems generated by the S.O. 24774. Soon after the conformation of this Commission, an Administrative Resolution (01/98) is emitted. By means of this Resolution, the Prefecture of Beni (in coordination with the Civic Committee and the Technical University of the Beni) received authorization to commercialize the 17609 skins, besides the emission of the corresponding CITES certificates for the export of the same ones.

On July 21st of 1999, the S.O. 25458 was promulgated, which grants a new legal mark for the management of wildlife, allowing the rising of the prohibition for the susceptible species of sustainable use by means of a Ministerial
Resolution. On the other hand, on 22 October of 1999, the S.O. 25555 was promulgated, which authorizes to the Ministry of Sustainable Development, to emit the Ministerial Resolution that approved a Provisional Regulation (with exception character) that allowed the use of the *C. yacare* during the year 1999.

On 30 November of 1999, the Ministerial Resolution 307/99 was promulgated, that approves the Regulation (with exception character again) for the conservation and use of the Spectacled Caiman and norm the transition among the hunt carried out in the months of October to December of 1999, and the new process to be initiate in the year of 2000. On 17 December of the same year, the Ministerial Resolution 330/99 was promulgated, which authorized the harvest and the storing of *C. yacare* skins, and it established a quota correspondent to 60.8% of the recommendation of the group of experts of the IUCN of Bolivia (Pacheco et al. 1999), distributing a general quota of 36,500 skins into: 30,000 skins for the Department of Beni, 3500 for the Department of Santa Cruz and 3000 for the Department of La Paz. Although for the elaboration of the document, the specialists of the IUCN (now authors of this work) took as a supposition that the populations of *C. yacare* had been increased after the promulgation of the S.O. 22641 (that declared a General and Indefinite Prohibition of hunting), they established a series of conditions to assure that the populations of *Caiman yacare* were not affected by an excessive harvest (Pacheco et al. 1999):

- Not to harvest in forest areas.
- To distribute the harvest in an homogeneous way in the space (savanna areas).
- To look for a mechanism that impedes the legalization of skins totally above this figure.
- If it is not possible to avoid the realization of auctions that legalize illegal leathers above the established quota, a smaller quota (as the half of was proposed) should be given.
- Not to assign quotas for the harvest of the year 2000 without carrying out the population evaluations of *C. yacare* during the dry season of 1999.

Under this context, the use of the Spectacled Caiman began in the Department of Beni, benefiting indigenous people (Central de Pueblos Indígenas del Beni - CPIB) who made use of a harvest quota of 30,000 skins in that year. In parallel, although for Ministerial Resolution Nº 330/99 a quota of 3500 skins had been granted for Santa Cruz and 3000 for La Paz, these Departments didn’t make use of the same ones.

In the year 2000, the General Direction of Biodiversity, with the support of CESO/SACO - Canada (Canadian Executive Service Organization) and the adviser Dr. Douglas Ravenstein, defined Eco-regions for the Program of Use of the Spectacled Caiman, which were elaborated with base in information analyzed by a Geographical Information System (GIS), as a proposal to be adjusted in function of new information.

During the same year, authorizations of extraction of *C. yacare* skins were not emitted by absence of necessary technical information, but there were carried out population evaluations of the species by a consultant group (PIAS 2001a, PIAS 2001b). Four eco-regions were evaluated (3, 5, 9 and 10) of the 11 defined for the use of the Spectacled Caiman, recommending a harvesting quota of 43,683 individuals for the whole Department of the Beni. The study was approved by the Advisory Council of Wildlife, being authorized a quota of 40,000 individuals for the Department of Beni, 5000 for Santa Cruz and 1500 for Pando, totaling a quota of 46,500 animals for the year 2001.

During the year 2002, was assumed that it was necessary to evaluate the development of the process and the operation of the use program to a national level. Between 2 April and 4 April of that year, in the city of Trinidad was organized a workshop with the participation of specialists, sectors and involved institutions; in this workshop some topics of interest related with the impacts of the previous crops, deficiencies and advantages of the administration, control and inspection, were discussed. In parallel, a new version of the Regulation for the Conservation and Sustainable Use of the Spectacled Caiman (*C. yacare*) was approved, through the Ministerial Resolution Nº 147/02.

In August 2002, and based on the study presented by the Prefecture of the Beni and elaborated by the consultant company Amazonia Conserva SRL (2002) and with the guarantee of Wildlife Advisory Council (group of scientific and technical institutions whose paper is to advise to the National Authority), a Ministerial Resolution (R.M. 155) was emitted authorizing a harvest of 39,132 individuals of the species in Beni Department. In parallel, the R.M. Nº 156 of the same year authorized a harvest of 5000 animals for the Department of Santa Cruz. However, for not having a study that justifies this quota in this Department, that number was approved “with exception character and only for one time”, with the purpose of not stopping the process and to obtain funds to be able to carry out a study that determines the population status of the species in the region.

During the year 2003, in the Department of the Beni, there were a series of administrative irregularities with regard
to the bid process to select the company that could work in the population counts dedicated to define harvest quota. To this situation, we need to add the results of a study with doubtful levels of reliability (product of the methodology and the analysis), so the Vice-Ministry of Natural Resources and Environment took the decision of not recognizing the study presented by the Prefecture of the Beni, and by means of which a harvest quota of 66,858 animals was requested. In this sense, and with the purpose of not affecting the social and economic sustainability of the program, the Vice-ministry decided to use the information coming from the study of 2002, and apply the harvest indexes calculated for this year to the properties legally inscribed during the administration of 2003 (R.M. 182/03), approving a quota of 22282 animals in this Department. This situation produced a discontent in some local actors, those which made a movement of rejection to the number of animals proposed by the National Authority; as part of this dissatisfaction, some actors informed that a harvest had already been made (illegal by the way) on most of the animals that the rejected study already proposed. It is necessary to remember that in October of 2003, a serious social conflict took place in Bolivia which produced the exit of the President Gonzalo Sánchez de Lozada. The new government, knowing the precariousness of their situation (product of a social climate of deep dissatisfaction and a lack of support by political parties), started a policy destined to solve and/or to avoid conflicts. In this context, the Ministry of Sustainable Development, after a trip of the Minister to the Department of the Beni, emitted the Ministerial Resolution 244/03 of December of 2003, by means of which a harvest of 40,000 animals was approved in the mentioned Department.

Talking about the Department of Santa Cruz, during the year 2003 the entity that carried out the population study of the species in some ecorregiones of the area (by means of an agreement with the Prefecture of the Department of Santa Cruz), was the Museum of Natural History Noel Kempff Mercado (MHNNKM). This institution proposed a harvest quota of 19344 animals for two ecorregiones (22 and 15) of the Department, which was approved by the R.M. 181/03. This started from the post-harvesting study of the year 2002.

About the distribution of benefits, it is important to point out that, as the animals are in private properties or Indigenous Lands (TCO’s), the Regulation for the Use of the Caiman yacare, authorizes the proprietors to sell in direct form the leathers deposited in the storing centers. In this sense, with base in the use contracts subscribed by the Departmental Prefectures of the Beni, Santa Cruz and Pando (during the different years of the Program), we have evidence that the program has generated economic benefits to different indigenous towns, rural communities and cattlemen. Nevertheless, one also has evidence (product of carried out accusations) that in numerous situations a manipulation of the producers has taken place (mainly on the part of middlemen), what has taken to that a fair and equal distribution of the benefits of the Program is not obtained. Nevertheless, also some accusations have been received establishing that, in several situations, a manipulation of the producers has taken place (mainly from the part of middlemen); this affected negatively a fair and equal distribution of the benefits of the Program.

**Errors and Lessons Learned**

From their beginnings, the Program has experienced a series of problems, which should serve as an analysis base to avoid to make the same errors in a redesign of the process of use of C. yacare in Bolivia. We don’t want to criticize the process developed up to now, but we want to use this experience like learned lessons in such a way we can think in a transparent and sustainable program from the biological, social, economic and political point of view.

The first consideration that is necessary to carry out, refers to the laws developed in Bolivia to use species. In this sense, it is necessary to point out that in all the versions of the approved rules, there were used some criteria (without doubt very successful in other countries like Venezuela) but not compatible with the reality of Bolivia.

In this sense, the errors go from the hunting technique proposed in the beginning (use of harpoon in areas where people don’t get used to use this tool), until the portion of territorial space that should be surveyed to be able to establish the population status of the species (10% of each eco-region), which is totally impossible for the access conditions and hydrological aspects of the areas inhabited by the Spectacled Caiman in Bolivia. It should be pointed out that none of the carried out population evaluations done during these years, fulfilled the requirements defined in the mentioned regulation, which settles down that counts in at least the 10% of the extension of each identified ecological region should be carried out.

The second consideration, is about the lack of relationship between the population studies carried out and the authorized harvest. We will try to give some examples about occurred situations:

- From all the harvests authorized in Beni Department (30,000 in year 1999, 40,000 in year 2001, 39,132 in year
2002 and 40,000 in year 2003), only the years 2001 and 2002 had some relationship between the carried out studies and the approved harvests.

- The studies of the years 2001 and 2002 extrapolated results of four particular eco-regions to all the Department of Beni (that has 11 ecorregiones for the program), leaving without effect the eco-regional character of the program. In that way, the definition of eco-regions becomes useless from the point of view of minimizing the bias that can take place when we made the estimations of abundance and the population structure.

- The study carried out in Santa Cruz in 2001 (PIAS 2001b), reported a population structure of C. yacare with a proportion of Class IV individuals (>180 cm total length) corresponding to 1.72% of the total population (without considering Class I individuals from their first year, or less than 50 cm total length). The regulation establishes that is not possible to harvest populations where the Class IV is smaller to 15% of the population. Even though this situation, the Ministry authorized the harvest in Santa Cruz. We can discuss about if it is possible or not to harvest populations with major or minor proportion of Class VI individuals; but the important issue is that the National Authorities didn’t obey the rule established by themselves.

- During the year 2002, according to the studies of Beni Department, a harvest of 13,054 individuals should be authorized. However, the Local Authorities authorized a harvest quota of 39,132 individuals (which was the potential of all the Department). In population terms, this means that instead of harvesting the 25% of Class IV individuals, a harvest of almost 75% of Class IV individuals occurred.

- The Ministerial Resolution N° 156, of the year 2002, granted to the Department of Santa Cruz a harvest of 5000 individuals, but in that year no monitoring process had been carried out in this Department.

- The year 2003, a harvest of 40,000 animals was authorized in the Department of the Beni without some study or technical instrument that it justifies the sustainability of this quota.

The third consideration that is necessary to carry out, also with relationship to the studies executed by the hired consultant companies, it is referred to the system of bid of the Bolivian State to hire goods and services. In this sense, according to the Bolivian norms, in a public bid preference is given to a consultant company (with ends of lucre) over an academic or scientific entity or NGO (without ends of lucre). This situation originated that the processes of evaluation of C. yacare populations were awarded to consultant companies that, in most of the cases, had scarce or any experience in the study of animal populations. The obtained product was a series of studies developed with not very reliable methodologies, with different approaches and with personal with scarce or null experience in the evaluation of caiman populations. In this way, an important quantity of information was produced, but paradoxically it can not be used to analyze the population tendencies of the species, neither to evaluate the impact of the harvest on the populations of C. yacare, because (according to that settled down by the same consultant companies), each work was carried out in different areas and with different methodologies, so it is no possible to compare the information from one year to another.

This group of situations, was increased by the operative weakness of the Scientific CITES Authority, which lacks economic support on the part of the State or of the same Program, preventing them to carry out an appropriate tracking down of the development of the same Program, and in turn disabling the emission of a no detrimental extraction opinion.

The fourth consideration that is necessary to carry out is with respect to the poor application of control systems. This poor application of control systems, produced a lack of reliability of harvests. In this sense, examples have already been mentioned in which the recommended quantity of caimans to harvest was not respected, neither the places authorized to carry out the harvests. Additionally, as a result of a workshop carried out in the city of Trinidad in April of 2002, and according to the report elaborated by Larriera (2002) an aspect that should worry, is that all the skins of legal size are not tagged in origin, allowing the buyers to select those of more size (still inside the legal measure), and only sealing these. This means an unnecessary over capture of animals that, although in the future it could diminish for the natural laws of market, it would be preferable and simple to avoid today, assuring the commercialization of all the skins of legal size. This would simply be achieved, sealing all the leathers in origin, before commercialization.

Finally, another problem refers to the lack of communication among the different involved sectors, and the disinformation of the users with concerning not alone to the spirit, but also to the changing practical aspects of the program. This situation should be recognized as a very serious problem, because the users of the Program (in many cases) don’t have a correct information about its rights and responsibilities regarding the sustainable use of the Caiman yacare in Bolivia. This scenario produced cases were owners of properties ignored completely the fact that they were inscribed in the program and that they had been carried out (theoretically) several crops in its property, although in the practice what happened was that some people took advantage with fraudulent licenses to harvest animals whose origin is not known.
Conclusions and Recommendations

It is clear that most of the inconveniences detected in the march of the program, are referred to: 1) the methodology of the “monitoring program” (that is not such) of the natural populations to determine the harvest at different levels (National, Departmental and for unit of production (indigenous lands, rural communities, and cattle ranches); 2) the internal distribution of the harvest quotas; and, 3) practical aspects of the inspection and the control. The solution of these problems will provide, on one hand a more just distribution of the benefits among the users, and on the other hand clearly will improve the standards of the harvest, avoiding over captures and the illegal transport of skins from one region to another (that today still takes place). The incorporation to the program of an instance of measure of skins in tanneries, will allow to establish an additional parameter for the monitoring of the sustainability of the program. Additionally (according to Larriera 2002), the establishment of a channel of periodic communication with the Crocodile Specialist Group (CSG), will facilitate the agile correction of the inconveniences that could arise.

It is not necessary to deny the difficulty that represents the fact that an extractive use of wildlife fulfills requirements of sustainability. The advance in this sense depends in great measure of the political will, and on pilot projects that establish the bases for the execution of projects at major scale. In this way, the sustainable use could be the right way, even though is a long and hard way in developing countries (Ojasti 2000). One of the challenges in Bolivia, is to achieve the transition of a long tradition of illegal use of wildlife towards a regulated handling of the same one, with the purpose of assuring the biological sustainability of the programs.

The sustainable use of the crocodilians has proven, in many situations, to be a successful activity from the point of view of the conservation of some species and also for its habitats. According to the situation of the populations of Caiman yacare in Bolivia, a program of use of the species can be carried out in a sustainable way, but only if it is developed inside the mark of the established norms, without forgetting that the main objective has to achieve the effective conservation of the species. For this it is necessary to establish certain considerations (some already established as recommendations of the workshop carried out in April of 2002 in Trinidad), to take into account for the redesign of the Program in Bolivia:

1. The process of use of the Spectacled Caiman is in a transition stage from an old illegal activity to a management program which has the objective to use the species in a sustainable way. This transition generates problems in the administration and control.

2. An institutional weakness of the state exists in its three levels (National, Departmental and local) to administer the program, especially in the control aspects. To improve this situation the roles of different actors should be defined, and it is necessary to reinforce the technical instances of control. Particularly, all actors should known very clearly which institution establishes the harvest quotas and rules the program at a national level.

3. The problems and experiences experimented by the Prefectures demonstrate that a different approaches exist in the administrative and operative topics, and also technicians. In this sense, it is necessary to define clear and uniforms approaches which could facilitate the administration of the resource, guaranteeing the continuity of the same one. At the moment in Bolivia it is being developed an analysis (with the participation of authorities, academic and scientific institutions, specialists and social actors) directed to define these approaches that guide in a clear way the form in that the species should be used according to the Bolivian reality.

4. A solid integration should be generated between the technical base and the administrative aspects of control. In this sense, the base of the program regarding harvest quotas should be eminently technical. If the technical aspects are not taken into account, they should be suppressed explicitly of the program, so that the responsibility of the conservation of the resource will fall on their administrators. Obviously, this is to fall in the same situation that put in risk the crocodile populations at world level.

5. The program has achieved important advances in the legal aspects, and also about social participation; but the technical aspects, of inspection and control, and the training and diffusion based on an integral program should be improved. A permanent program of diffusions an education should be developed. This should reach to all the actors of the program. The message should clarify the rights and the responsibilities of the different actors for using the species in a sustainable way.

6. The rule for the use of the C. yacare suffers uncertainties and contradictions that affects the efficient administration of the resource. A new proposal will be elaborated, and this should be discussed with the social actors. The
detailed analysis of all these uncertainties and contradictions would make necessary an article dedicated exclusively to this topic.

7. It is possible to create an advice and inspection instance at Departmental level with the participation of indigenous, cattlemen, tanners, academic and investigation Institutions, and Prefectures, with the purpose to inform, concert and investigate the administrative and technical determinations of the program. A kind of Committee Inter-institutional for the Advising of the Yacare Program. This would avoid the rejection from certain sectors to some norms and would give solidity to the decisions adopted by the national authority, because they would be already have concerted. Although it is certain that at the moment there is a Departmental Committee of the Program (at least in the Department of the Beni), the same one is not constituted equally, because some few tanners have bigger representativeness that the total of the land owners.

8. A true monitoring program should be designed that accompanies the whole process. The program should have the main objective of detecting the tendencies of the populations under use and to have a control (witness) in not harvested of populations. At the same time, the population estimates result of this program would be those that should be used to determine harvest quotas (refer to points 4 and 11 of these conclusions).

9. A process of accreditation of the institutions could be generated (non people), to have some legally authorized entities to advise in management programs of Spectacled Caiman in Bolivia. This accreditation should have a national component (the authority in wild life) and could have one international (the Crocodile Specialist Group). At the same time, it is necessary to eliminate the advantages that have the consultant companies over associations without ends of lure. It is possible to substitute the system of bids for one of agreements among scientific-academic institutions and the Departmental Prefectures. The institutions that take charge of carrying out the population evaluations, should not only be hired for a one year period, but for several (at least 5 years), so that could be minimized the variability due to observer and different methodologies.

10. The management of any species is an opportunity to study its numeric and functional answers to an interference. Bolivia has lost valuable years because didn’t take this program as an opportunity to obtain information about the ecology of Caiman yacare, which could be used to improve its current management, to propose alternative models of management and simply to increase our knowledge about crocodilians. The redraft of the Program should contemplate enough elasticity to include experiments at great scale that they could fulfill this scientific “obligation”. A way to do it is to give responsibility of the technical management (but not on the benefits, that should be in any event for the local producers) to the accredited institutions (see point 9) on certain areas that could be specifically subject to management plans designed to be executed there. The execution of management plans under different models and monitoring will give us great in the knowledge of the scientific management of C. yacare. Of course, the rector at national level should be the Monitoring Program designed by the National Authority.

11. The monitoring program at national level should be designed to be statistically able to detect the changes that it considers biologically important (Gibbs et al. 1998), and also to avoid the waste of efforts (Stirrat et al. 2001). For this purpose, the new rules should contemplate a fee which could assure the technical sustainability of the Program.

Finally, the economic incentives that the users of the program of use of the Spectacled caiman receive, particularly the owners of lands, can not only be reflected in the conservation of the species, but also in the conservation of the habitats inhabited by C. yacare. A key aspect to accomplish this, is the political will that should exist at level of the National Government and Local Governments, with the purpose of achieving a transparent and sustainable Program, not only in the biological aspect, but also from the social and economic point of view.

**Literature**


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Comparative Analysis of Habitats Occupied by *Caiman crocodilus* in Floodable Plains of Venezuela

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Abstract

Primary and secondary habitats occupied by *Caiman crocodilus* are described in 514,096 ha of Venezuelan flooding llanos, divided in 6 ecological regions. Night-light counts were done and the surface of waterbodies was estimated. Primary habitats were classified into channels, rivers and lagoons; secondary habitats in ponds and dykes, describing its dominant terrestrial vegetation and aquatic vegetation covering. Data were processed with ANOVA, with abundance of caimans as numerical variable and ecological regions, type of habitat, terrestrial vegetation and aquatic vegetation covering as classification variables. A total amount of 93,944 caimans were counted with a terrestrial density of 0.18 ind/ha. The aquatic surface was 2688.85 ha reached only 0.52% total terrestrial surface. The abundance showed significant differences between the 6 ecological regions, with maximum in primary habitats. Among secondary habitats, dykes showed the highest abundance values. Most abundant populations were founded in primary habitats with forests and small amounts of aquatic vegetation. Special measures of protection of such habitats are strongly recommended for this species, currently under management by Venezuelan Government.

Resumen

Se describen habitats primarios y secundarios ocupados por *Caiman crocodilus* (baba) en 514,096 hectáreas de llanos inundables venezolanos subdivididas en 6 regiones ecológicas. Se efectuaron censos nocturnos y se estimó la superficie de los cuerpos de agua. Los habitats primarios se clasificaron en caños, ríos y lagunas; los secundarios en préstamos (excavaciones) y módulos (diques), describiendo su formación vegetal y cobertura de vegetación acuática. Se practicó ANOVA a los datos, con el censo como variable numérica y como variables clasificadoras la región ecológica, tipo de cuerpo de agua, formación vegetal y cobertura de vegetación acuática. Se censaron 93,944 babas con una densidad de 0.18 ind/ha de terreno. La superficie acuática (2688.85 ha) alcanzó 0.52% de la superficie total. La abundancia poblacional mostró diferencias significativas entre las 6 regiones ecológicas. La máxima abundancia se observó en los ríos, mientras que lagunas y caños mostraron valores similares. Los préstamos mostraron valor mínimo y los módulos presentaron elevadas abundancias, siendo los ambientes secundarios más favorables. Las poblaciones más abundantes se encontraron asociadas a habitats primarios con vegetación marginal boscosa y vegetación acuática presente. Se debe promover su protección para favorecer a esta especie, actualmente sometida a manejo bajo control del Estado.

Introduction

The Baba (*Caiman crocodilus*) it is the most abundant crocodile in Venezuela, since the reduction of large caiman’s populations American crocodile (*Crocodylus acutus*) and Orinoco crocodile (*Crocodylus intermedius*), caused by the indiscriminate hunt. Once initiated the industrial use of Baba skins, their commercial hunt began. In 1983 the Venezuelan Government implemented the Program of Commercial Use under control of the Ministry of the Environment and Natural Resources (MARN). In 1991-92 a first evaluation of the population status was made, in terms of abundance and size class structure, after 9 continuous years of controlled crops (Velasco and Ayarzagüena 1995).

One of the most important results of that work was the description of 7 ecological regions in the area used for hunting in the Venezuelan southwestern Llanos: Alto Apure, Bajo Apure, Aguas Claras, Cajón de Arauca, Llanos Boscosos, Hoya de Arismendi and Guárico (Fig. 1).

Subsequently, during 1996 a detailed study was carried out under the Agreement between Universidade Central of Venezuela and MARN, during the Ecological Pause of the Program of Commercial Use (Quero and Velasco 1995),

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covering 6 of the 7 ecological regions with the exception of the Guárico region. In each region, the population abundance and the primary and secondary habitats were characterized, in order to establish the most favorable habitats and to propose strategies for its preservation.

Methods

1. Fieldwork

The fieldwork was carried out during the dry season (February-April) of 1996, when the animals are concentrated in the habitats that keep water during the whole year and are easy to count. The fieldwork was made by six teams of technical personnel belonging to MARN and UCV. Observations were plotted in charts 1:25,000.

Night light censuses were performed (Chabreck 1966; Woodward and Marion 1977) in order to determine the population abundance. The aquatic habitats were classified accordingly to their type in primary habitats, integrated by “caños” (intermittent natural drainages of the flooded areas), lagoons, rivers and “esteros” (savanna depressions temporarily flooded). As secondary or artificial habitats, “prestamos” (excavations for the construction of embankments), and “modulos” (cellular dykes to retain water on the savanna) were identified (Colomine 1993). The predominant plant formation was evaluated in the surroundings (forest, bushes and grasslands or their combinations), as well as the covering of aquatic vegetation. All the accessible water bodies in the selected farms were monitored, using vehicles, boats, horses or on foot. Where it was possible, the water body was completely observed; when it was impossible to get a full observation of the waterbodies, no extrapolations of the number of individuals was made. An estimation of each observed aquatic surface was accomplished.

2. Data Analysis

An Excel database was built to practice analysis of variance (anova) using Statgraphics, with total amount of individuals counted by water body as numerical variable, verifying its adjustment to normal distribution (P<0.05).
As classification factors, the following categories were used:

- Covering of Aquatic Vegetation: completely absent, present (less than 30%), abundant (30-60%), very abundant (more than 60%) and total covering (100%).
- Associated Vegetation: forest, bushes, grasslands and its combinations.
- Type of Water Body: rivers, “caños”, lagoons, “esteros”, “prestamos” and dykes.

The ANOVA provides the arithmetic average of individuals present in each classificatory category, as well as the significance level of its differences confirmed with a posteriori Duncan test (P<0.05). Variation coefficients were also calculated. Gross densities (individuals per hectare of land belonging to each property) and ecological or aquatic densities (individuals per hectare of observed water body) were estimated.

**Results**

1. Total Densities and Size Classes

The total number of water bodies surveyed was 693 (Table 1), with the lowest observations in “Hoya de Arismendi” (74) and “Cajón de Arauca” (28), due to difficulties to reach the waterbodies. The average number of individuals per water body for each region showed significant differences among the ecological regions, confirming the validity of the spatial subdivision of the whole study area proposed by Velasco and Ayarzagüena (1995). The levels of significance involved in the analysis, demonstrate variations in the spatial biotics and abiotic characteristics that could affect the quality of the habitats and its load capacities for the species.

<table>
<thead>
<tr>
<th>Region</th>
<th>Cases</th>
<th>Mean</th>
<th>STD</th>
<th>Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>140</td>
<td>199.3</td>
<td>33.97</td>
<td>**</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>74</td>
<td>187.4</td>
<td>26.94</td>
<td>***</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>163</td>
<td>147.1</td>
<td>31.58</td>
<td>***</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>115</td>
<td>10.61</td>
<td>13.65</td>
<td>***</td>
</tr>
<tr>
<td>Llanos Boscosos</td>
<td>173</td>
<td>86.5</td>
<td>24.68</td>
<td>**</td>
</tr>
<tr>
<td>Cajón de Arauca (ns)</td>
<td>28</td>
<td>37.0</td>
<td>14.75</td>
<td>*</td>
</tr>
</tbody>
</table>

The “Alto Apure” region reached the maximum average of individuals per water body. The intermediate values of “Aguas Claras”, “Bajo Apure” and “Hoya de Arismendi” did not show significant differences. Llanos Boscosos showed a significantly low average, with the largest number of observed water bodies. The value registered for “Cajón de Arauca”, with very low amount of individuals and observations, was not significant.

For the goals of the present study, the global analysis of the results in the 6 regions under study is comparable with the work made among 1991-1992 (Velasco and Ayarzagüena 1995) using the gross density (individuals per hectare of surveyed properties).

In total, 93,944 individuals were counted in 514,096 ha surveyed, with a terrestrial gross density of 0.18 ind/ha (Table 2). If the terrestrial or gross densities are compared between the ecological regions instead the average of individuals in waterbodies, a different result is obtained. In this case, “Alto Apure” and “Bajo Apure” presented the maximum densities and individuals counted. “Hoya de Arismendi”, “Aguas Claras” and “Llanos Boscosos” showed very similar intermediate values, and “Cajón de Arauca” reached the lowest density and counts.

The total aquatic surface was estimated in 2688.85 ha, which represents only 0.52% of the terrestrial surface, because the censuses were made during the period of extreme drought. The aquatic density was 34.94 ind/ha, which reflects a high concentration of animals in the water bodies that remains flooded.
Table 2. Comparison of number of individuals, surface surveyed and gross density (ind/ha) in 1992 and 1996, for 6 ecological regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>No. of Ind.</th>
<th>Surface (ha)</th>
<th>Density ‘96</th>
<th>Density ‘92</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>27,903</td>
<td>109,127</td>
<td>0.26</td>
<td>0.22</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>13,442</td>
<td>97,320</td>
<td>0.14</td>
<td>0.35</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>23,977</td>
<td>68,198</td>
<td>0.35</td>
<td>0.39</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>12,615</td>
<td>91,545</td>
<td>0.14</td>
<td>0.10</td>
</tr>
<tr>
<td>Llanos Boscosos</td>
<td>14,970</td>
<td>125,515</td>
<td>0.12</td>
<td>0.15</td>
</tr>
<tr>
<td>Cajón de Arausos (ns)</td>
<td>1037</td>
<td>22,391</td>
<td>0.05</td>
<td>0.19</td>
</tr>
<tr>
<td>Total</td>
<td>93,944</td>
<td>514,096</td>
<td>0.18</td>
<td>-</td>
</tr>
</tbody>
</table>

2. Habitat Characteristics

Aquatic vegetation

The observed covering of aquatic vegetation in water bodies was classified in 5 categories: absent, present, abundant, very abundant and totally covered. The total amount of individuals associated to water bodies completely free of aquatic vegetation was 53,009 individuals (56.5%), compared with 40,837 individuals (43.51%) in areas with presence of aquatic vegetation. Globally, there were significant differences between the categories of aquatic vegetation covering in regard to the observed average of individuals (Table 3).

Table 3. Average of individuals for each aquatic vegetation covering category (n= not significant, P<0.05).

<table>
<thead>
<tr>
<th>Aquatic Vegetation Cover</th>
<th>Cases</th>
<th>Mean</th>
<th>STD</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absent</td>
<td>353</td>
<td>150.5</td>
<td>18.5</td>
<td>**</td>
</tr>
<tr>
<td>Present (0-25%)</td>
<td>132</td>
<td>179.9</td>
<td>39.5</td>
<td>***</td>
</tr>
<tr>
<td>Abundant (30-60%)</td>
<td>84</td>
<td>102.6</td>
<td>14.8</td>
<td>**</td>
</tr>
<tr>
<td>Very Abundant (60-90%)</td>
<td>80</td>
<td>52.2</td>
<td>8.7</td>
<td>*</td>
</tr>
<tr>
<td>Total Covering (100%) (ns)</td>
<td>37</td>
<td>32.1</td>
<td>9.9</td>
<td>-</td>
</tr>
</tbody>
</table>

The maximum average of animals was registered in water bodies with aquatic vegetation present. This fact indicates the preference of the species toward habitats with certain covering of aquatic vegetation, taking into account that the efficiency of night light count method is maximum in water bodies without aquatic vegetation. So, in spite of the underestimation (not quantified) caused by this method’s limitation, the amount of individuals was highest in habitats with floating plants. If the aquatic vegetation increases, the amount of surveyed crocs diminishes until a minimum in water bodies totally covered, where the data obtained with the night light count is not reliable.

When crossing the aquatic vegetation with the surrounding vegetation, it is remarkable that the highest average of individuals (427.1) was found in water bodies with forests and aquatic vegetation present, while without floating plants the average was 184.8 with significant difference. These results coincide with previous reports (Colomine, 1993). The water bodies in savannas do not present significant difference in the average number of individuals regarding plant covering.

The comparison of average number of individuals against the aquatic vegetation covering in each ecological region offered significant differences. At “Alto Apure”, “Bajo Apure”, “Aguas Claras” and “Hoya de Arismendi”, the largest amounts were registered in habitats with aquatic vegetation present, while in “Llanos Boscosos” and “Cajón de Arauco” more crocodiles were observed in habitats without aquatic vegetation.

Associated Vegetation

The following categories of surrounding vegetation were settled down: forests, bushes, grasslands and their
combinations. More frequently, the waterbodies were associated to open grassland savannas (56.81%), while the forest habitat were less observed (17.25%). There was not significant difference in the average of animals censused with regard to the plant formation (Table 4).

Table 4. Average number of individuals in each plant formation type (P<0.05).

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Cases</th>
<th>Mean</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland</td>
<td>392</td>
<td>128.5</td>
<td>16.4</td>
</tr>
<tr>
<td>Bushes</td>
<td>39</td>
<td>81.5</td>
<td>22.3</td>
</tr>
<tr>
<td>Forest</td>
<td>119</td>
<td>185.6</td>
<td>42.8</td>
</tr>
<tr>
<td>Forest-Bush (ns)</td>
<td>2</td>
<td>23.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Grassland-Bush</td>
<td>89</td>
<td>121.6</td>
<td>19.3</td>
</tr>
<tr>
<td>Grassland-Forest</td>
<td>23</td>
<td>117.3</td>
<td>55.5</td>
</tr>
<tr>
<td>All types (ns)</td>
<td>26</td>
<td>155.8</td>
<td>59.3</td>
</tr>
</tbody>
</table>

The water bodies associated with forests presented the highest average of sighted individuals, in spite of the difficulties of access to carry out the survey. In second place, the habitats with the three types of vegetation combined followed, but this numeric result is not reliable as the association forest-bush, due to low amount of surveyed locations.

This analysis of crocs abundance in relation to the plant formation associated to the water body was practiced for each ecological regions, repeating the situation evidenced in the global analysis: no significant differences between the different vegetation types was observed, with the maximum averages in forest habitats.

**Type of Water Body**

The considered water body types were primary habitats (rivers, “caños”, lagoons, wetlands) and secondary ones (modular dykes and “préstamos”). Significant differences of the average number of individuals appeared between them. The most frequent waterbodies were lagoons, “caños” and “préstamos”. The lagoons and “caños” showed highest averages of 133.6 and 197.6 individuals respectively, without significant difference among these primary habitats. On the other hand, the “préstamos” hardly reached average of 37.3 individuals, reflecting their condition of low-capacity habitats. The surveyed dykes (33 in total) contributed with a high average number of individuals (181.8), being the most favorable secondary habitats for the species. The largest average croc amount was observed in the 7 surveyed rivers, which indicates that these primary habitats tend to be occupied by numerous populations (Table 5). At wetlands, temporary flooded areas, the lowest amount of individuals was observed, also not significant.

Table 5. Average number of individuals for water body type (ns= not significant, P<0.05).

<table>
<thead>
<tr>
<th>Type</th>
<th>Cases</th>
<th>Mean</th>
<th>STD</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rivers (ns)</td>
<td>7</td>
<td>228.4</td>
<td>148.5</td>
<td>-</td>
</tr>
<tr>
<td>“Caños”</td>
<td>224</td>
<td>197.6</td>
<td>30.0</td>
<td>***</td>
</tr>
<tr>
<td>Dykes</td>
<td>33</td>
<td>181.8</td>
<td>52.7</td>
<td>***</td>
</tr>
<tr>
<td>Lagoons</td>
<td>273</td>
<td>133.6</td>
<td>17.6</td>
<td>**</td>
</tr>
<tr>
<td>“Préstamos”</td>
<td>148</td>
<td>37.3</td>
<td>6.6</td>
<td>*</td>
</tr>
<tr>
<td>Wetlands (ns)</td>
<td>8</td>
<td>13.5</td>
<td>4.1</td>
<td>-</td>
</tr>
</tbody>
</table>

The high crocs average presented in the rivers is the result of very few observations and is not significant (Table 6), and this can be related with the fact that it is completely forbidden the hunt in these habitats.

The “caños” are the habitats where more crocs were found, with significant results regarding the other water body types. The “caños” constitutes very frequent natural drainages of variable depth in all the southwestern “Llanos” with alluvial soils, with the exception of “Agas Claras” region, where sandy dunes prevail on the soil. In the “caños” high concentrations of animals were observed, reaching an average of 303.3 individuals in the Alto Apure (Table 7), remarking that the courses of water surrounded by grasslands reached 197.5 individuals on average, while
Table 6. Average of individuals in rivers for ecological regions (non-significant differences, P<0.05).

<table>
<thead>
<tr>
<th>Region</th>
<th>Cases</th>
<th>Mean</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>2</td>
<td>47.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Llanos Boscosos</td>
<td>3</td>
<td>23.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>2</td>
<td>718.0</td>
<td>356.0</td>
</tr>
</tbody>
</table>

Table 7. Comparison of average individuals in “caños” for each ecological region (non-significant differences, P<0.05).

<table>
<thead>
<tr>
<th>Caños</th>
<th>Cases</th>
<th>Mean</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>54</td>
<td>303.3</td>
<td>78.4</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>50</td>
<td>242.3</td>
<td>93.4</td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>14</td>
<td>50.1</td>
<td>29.2</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>46</td>
<td>203.2</td>
<td>31.9</td>
</tr>
<tr>
<td>Llanos Boscosos</td>
<td>58</td>
<td>89.6</td>
<td>24.0</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>2</td>
<td>262.0</td>
<td>-</td>
</tr>
</tbody>
</table>

The forest surrounded “caños” showed a higher value (250.4 individuals). In general, one “caño” can cross forest, bush and grassland formations along its itinerary that can be very long. The water in many “caños” are segmented during the dry season, forming small lagoons in their channel full of fishes that serves as food for the crocodilians.

The natural lagoons are shallow water bodies that keep water during all the year, very frequent in all these regions. It can present circular form occupying depressions on the savanna, or horseshoe form when they are derived from bends of rivers and “caños”. It reach their maximum frequency in “Aguas Claras”, region with a landscape characterized by the presence of dunes. The lagoons can be surrounded by grasslands, bushes or forests in their margins. In these primary habitats, large concentrations of crocs were recorded with significant difference between the ecological regions, with similar values to those of the “caños” although slightly inferior. The maximum was observed on the average in the “Llanos Boscosos” (Table 8).

Table 8. Average of individuals in lagoons on each ecological region (P<0.05).

<table>
<thead>
<tr>
<th>Lagoons</th>
<th>Cases</th>
<th>Mean</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>31</td>
<td>214.7</td>
<td>41.4</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>50</td>
<td>242.3</td>
<td>93.4</td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>13</td>
<td>25.6</td>
<td>5.4</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>10</td>
<td>191.0</td>
<td>48.3</td>
</tr>
<tr>
<td>Llanos Boscosos</td>
<td>26</td>
<td>265.6</td>
<td>151.6</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>109</td>
<td>93.6</td>
<td>10.2</td>
</tr>
</tbody>
</table>

The “préstamos” are artificial excavations of small extension and depth, from which the land material is extracted for the construction of roads and dams. These secondary habitats presented very inferior values of average individuals in comparison with the primary habitats. This habitat type is very frequent at “Alto Apure”, “Bajo Apure” and “Llanos Boscosos” (Table 9).

The best secondary habitats for the species resulted the modular dikes (“módulos”). These dams builted directly on the savanna cover large extents (3000 to 10,000 ha) contained inside cellular dike-embankments, retaining water during the whole year. In these large dimensions, “caños”, lagoons, “préstamos” can be embraced. Occasionally also
forest areas are contained, transforming it into favorable habitats for the maintenance of numerous and stable populations. The regions of “Aguas Claras” and “Cajón de Arauca” does not has this type of dikes (Table 10).

Table 9. Average of individuals in “préstamos” in each ecological regions (not significant, P<0.05).

<table>
<thead>
<tr>
<th>Regions</th>
<th>Cases</th>
<th>Mean</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>44</td>
<td>53.6</td>
<td>18.7</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>24</td>
<td>32.3</td>
<td>6.2</td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>1</td>
<td>3.0</td>
<td>-</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>5</td>
<td>66.4</td>
<td>28.3</td>
</tr>
<tr>
<td>Llanos Bocosos</td>
<td>72</td>
<td>27.9</td>
<td>6.7</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>2</td>
<td>18.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Table 10. Average of individuals in dikes in each ecological region (not significant, P<0.05).

<table>
<thead>
<tr>
<th>Regions</th>
<th>Cases</th>
<th>Mean</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Apure</td>
<td>8</td>
<td>298.5</td>
<td>127.1</td>
</tr>
<tr>
<td>Bajo Apure</td>
<td>5</td>
<td>125.6</td>
<td>104.4</td>
</tr>
<tr>
<td>Cajón de Arauca</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hoya de Arismendi</td>
<td>13</td>
<td>175.5</td>
<td>98.2</td>
</tr>
<tr>
<td>Llanos Bocosos</td>
<td>7</td>
<td>100.1</td>
<td>57.2</td>
</tr>
<tr>
<td>Aguas Claras</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Finally, the “esteros”, wetlands located on depressions of open savanna, were relatively scarce in all the regions, due to the advanced dry season when the sampling was carried out. Only 8 cases were observed in “Alto Apure” with, with an average of 13.5 individuals.

Discussion

The method used for obtaining the field information is advantageous to evaluate the population status of this species, in connection with the habitats occupied. The effort applied in the surveys is acceptable for the magnitude of the obtained data and its reliability. The observers need to be trained to develop capacity to carry out the censuses and environmental evaluations in very wide territorial spaces.

The most important physical obstacle for the application of this method at this great scale is the accessibility to the water bodies. The source of more frequent error is the underestimation of abundance, caused by the presence of floating plants and the difficulty to observe the whole water body. However, the obtained volume of data allows the application of parametrical statistical methods of like the analysis of variance, with enough grades of freedom to validate the significance of the opposing differences. Even so, it is important to point out that this is only a punctual observation in time, and the obtained results are limited to the habitats condition for the moment of sampling.

In general, this species tend to occupy habitats with calm, shallow waterbodies, surrounded waters by forest, and physical-chemical relatively stable characteristics (Ayarzagüena 1983; Gorzula et al. 1988; Colomina 1993; Colomina et al. 1994). This preference is more conspicuous in the Venezuelan “Llanos”, where the Babas has a behavior closely linked to the annual hydrological cycle (Muñoz 1988), being dispersed during the rainy season with the maximum flood, and concentrated during drought on the habitats that remain with water, reaching large population densities in limited aquatic surfaces (Ojasti 1989).

The reproductive stages are linked to the habitat cycling condition: mating and nesting during the rainy season, and hatchlings appearance at the beginning of the dry season. Migrations can be produced governed by the habitat selection, in search of more favorable conditions for the reproductive phases (Muñoz 1988; Oubuter and Nanhoe 1988).

These reproductive demands explain the fact that the most abundant populations are associated to the primary,
isolated and forested habitats with floating vegetation present that can offer refuge, availability of food for all the size classes and nesting possibilities. Nevertheless, the secondary habitats also can advantageously occupied by the species to support extreme drought conditions (Ayarzagüena 1983). The large extents of the modular dikes built on the plains to enhance cattle raise, include natural areas (flooded grasslands, “caños” and lagoons) that allow the presence of abundant populations (Colomine 1993). Other populations have also been reported for reservoirs and in other places of the country (Arteaga 1989).

Significant differences in abundance were found, and the regions with more abundance and density were “Alto Apure” and “Bajo Apure”. This is valuable information for the management plan for this species, which take into account the remarkable characteristics of the waterbodies in these regions. Equally, the relatively smaller levels observed in “Cajón de Arauca”, “Aguas Claras” and “Llanos Boscosos”, demands the application of controls for the use of the species.

**Conclusions**

The subdivision in ecological regions of the area for managing the commercial hunting program of the species on the basis of environmental and population differences, was supported by the results from the present work.

The most abundant populations were associated to primary habitats (rivers, “caños” and lagoons) surrounded by forests and with presence of aquatic vegetation. Among the secondary habitats, the “préstamos” serve as refuge during the dry season, but the modular dikes are favorable for the species, due to their great extension that generally embraces forest areas and primary habitats.

The presence of abundant and permanent populations of *C. crocodilus* can be considered as indicator of high-quality habitats for associated terrestrial and aquatic wild fauna. This fact facilitates the adoption of management plans directed to achieve an effective protection of such habitats.

**Literature**


Conservation of the Philippine Crocodile *Crocodylus mindorensis*
in NE Luzon, the Philippines. An Update

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Institute of Environmental Science, Leiden University, PO Box 9518, 2300 RA Leiden, the Netherlands
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Abstract

Since the discovery of several remnant, fragmented populations of the Critically Endangered Philippine crocodile in Northeast Luzon in 1999, a conservation program has been implemented in the area using a community-based approach. The approach seems successful but several issues remain that threaten the crocodiles on the short and long term. An initial increase in the crocodile population following successful breeding in three distinct localities spurred hope for a recovery of the extremely small sub-populations. However, no breeding was observed during the last two years. A strong typhoon, which raged over the area in 2003, caused flashfloods in the deforested watersheds of the area and has taken its toll on the crocodiles as well. Awareness raising campaigns have increased local knowledge about crocodiles and most local inhabitants now support crocodile conservation. The direct killing of crocodiles has stopped, but accidental catches still occur. Law enforcement in general is weak in the area and the implementation of local crocodile conservation laws depends very much on the voluntarily willingness of local people to respect rules and regulations. Indirect threats such as the use of destructive fishery methods, agricultural encroachment and habitat conversion continue to threaten crocodiles and wetlands in general. A more comprehensive and creative Philippine crocodile conservation program in Luzon is needed to expand the first in situ conservation effort for this species.

Introduction

The Philippine crocodile *Crocodylus mindorensis* is considered to be the most severely threatened crocodile species in the world and is listed as critically endangered by the IUCN. Previously widely distributed throughout the Philippine archipelago, *C. mindorensis* is now thought to be restricted to Mindanao, Negros and Luzon. A widely-used population estimate of 100 non-hatching individuals (Ross 1998) underlines the critical status of the species, although both distribution and population size estimations are rather speculative. A previously unknown population was discovered in the foothills of the Northern Sierra Madre Mountains on Luzon in 1999, sparking hope that *C. mindorensis* might occur in other, similarly unsurveyed localities (van Weerd 2002). However, in most newly surveyed localities since 2002, crocodiles have become extinct during the last 30 years (see also Tarun et al. these proceedings). Killing of crocodiles seems to be the major cause for the decline. In Northeast Luzon, a community-based conservation approach was adopted with the aim of reaching sustainable co-habitation of crocodiles and local people. This is currently the only in situ conservation project for the species and was reported to the CSG during the 16th working meeting in Gainesville in 2002 (Van Weerd 2002). Here we present an update of the conservation activities since that report.

Threats

The main threats to the survival of *C. mindorensis* have been listed as habitat loss, pollution of rivers mainly due to mining, and the killing of crocodiles for skins, meat, amulets and out of fear or ignorance (Banks 2000a). Most Filipino’s are indifferent about crocodiles or regard them as vermin. The public image of crocodiles in the Philippines is very negative. The Filipino word for crocodile *buwaya* is commonly used to refer to corrupt politicians and to greedy people in general (Banks 2000a).

Philippine crocodile conservation

Following the report of C.A. Ross in 1982, which presented alarming results on distribution and population size of *C. mindorensis* (Ross 1982), the Crocodile Farming Institute was created on the Island of Palawan in 1987 with financial and technical assistance from the Japanese Government. The objectives were to conserve the two species of crocodiles in the Philippines and to promote the socio-economic development of local communities through the introduction of crocodile farming (Ortega 1998). In all, 235 *C. mindorensis* were acquired to establish a breeder stock. Eleven of these were directly taken from the wild; all others came from private collections (Ortega 1998). These private collections
were of wild origin. Collecting specimens from the wild, thereby decreasing wild populations, was thought defendable since wild populations were increasingly threatened and no crocodile protection and conservation measures were in place anywhere in the country (Messel et al. 1992; Ortega 1998). Captive breeding of *C. mindorensis* at the CFI has been very successful: 1276 Philippine crocodiles were alive at the farm in 2002 of which 87% was captive bred (Reborg and Sumiller 2003). However, no crocodiles have been re-introduced into the wild.

In situ conservation of the Philippine crocodile has not been pursued very actively. The Philippine Crocodile Recovery Team (PCRT) was created in 2000 to address the continuing decline of *C. mindorensis* in the wild and to strengthen international co-operation and partnerships in Philippine crocodile conservation (Banks 2000b). The PCRT developed a national recovery plan for the Philippine crocodile that was published in 2000 (Banks 2000a). The primary objective is to re-establish viable wild populations of *C. mindorensis*. The second National Biodiversity Strategy and Action Plan (Ong et al. 2002) identifies 34 priority inland water areas for conservation and research. Three sites with possible historic and/or present *C. mindorensis* populations are protected areas: (1) Naujan Lake on Mindoro, (2) Liguanas Marsh, and (3) Agusan Marsh on Mindanao. However, *C. mindorensis* has not been observed in any of these sites recently and no effective habitat management has been implemented in these areas (Banks 2000a).

**Philippine Crocodile Conservation in the Northern Sierra Madre**

Currently (May 2004), a minimum population of 27 non-hatchling crocodiles is known from Northeast Luzon of which 23 are found in the municipality of San Mariano and four in wetlands along the Pacific coast, on the eastern side of the Sierra Madre Mountains. In San Mariano, three breeding sites have been identified with permanent crocodile sub-populations: a) Dunoy Lake, b) Disulap River and c) Dinang Creek. See Tanur et al. (these proceedings) for more detailed information about the status of the Philippine crocodile in Northeast Luzon.

In 1999, a Philippine crocodile conservation program was set up in the municipality of San Mariano by the Northern Sierra Madre Natural Park-Conservation Project in collaboration with the Local Government Unit (LGU). This project phased out in 2002 and crocodile conservation activities have been taken over by the Crocodile Rehabilitation, Observation and Conservation (CROC) Project which since 2003 is being implemented by a newly established NGO named the Mabuwaya Foundation. Mabuwaya is a contraction of the Filipino words Mabuhay (Long live!) and Buwaya (Crocodile). The activities of this project in Northeast Luzon have been legitimized through a Memorandum of Agreement with the Department of Environment and Natural Resources (DENR). The project has a strong partnership with the LGU of San Mariano which has been formalized through a municipal resolution accrediting the Mabuwaya Foundation as partner in crocodile conservation.

**Philippine crocodile conservation workshop**

A 5-day stakeholder workshop was held in May 2002 in Isabela province to obtain inputs for a long-term conservation program for *C. mindorensis* in Northern Luzon. During the workshop, four major issues were identified that underlie threats to the Philippine crocodile in the area (NSMNP-CP, 2002). First, rural poverty is leading to unsustainable land use, fisheries and wildlife utilization, which are threatening crocodiles and their habitat. Unsustainable land use and use of natural resources is further driven by continued population growth (both natural and through immigration) and the lack of tenure security for local farmers. Second, the lack of awareness and information regarding crocodiles is a major obstacle for crocodile conservation. Third, the lack of law enforcement is frustrating conservation efforts. Fourth, the lack of a strong and fully capacitated organization is hindering effective coordination of the multi-stakeholder effort to conserve the Philippine crocodile in Northeast Luzon. Such an organization should make sure that all stakeholders co-operate, share information and resources and ascertain a link between conservation and development activities in the area.

**Rural poverty, unsustainable natural resource utilization and crocodile conservation**

In collaboration with the local government of San Mariano, an integrated conservation and development approach is used to tackle this issue. See Miranda et al. (these proceedings) for a more elaborate overview of the activities in San Mariano and the important role the LGU plays herein. The conservation efforts have concentrated on the establishment of community-based crocodile sanctuaries. Following community meetings, the LGU of San Mariano proclaimed the Disulap River Philippine crocodile municipal sanctuary in September 2001. The local community manages the sanctuary, which has been demarcated with informative billboards in local languages. Sustainable fishing activities are allowed in the sanctuary, except in the breeding area of *C. mindorensis*, which is totally protected.
Currently the process to declare Dinang Creek as a crocodile sanctuary is ongoing. An environmental impact assessment was conducted and the impact of sanctuary establishment on local livelihoods was assessed. Community consultations have been conducted and an agreement has been reached between the community and the LGU of San Mariano on assistance to basic community needs and the establishment of the sanctuary. The main condition put forward by local farmers was assistance in the acquisition of land titles. This process is underway, facilitated and funded by the LGU and the Mabuwaya Foundation.

**Awareness raising**

The negative public image or at best the indifference of Philippine society towards crocodiles and crocodile conservation is the single largest underlying threat to the species’ survival. Massive awareness raising and information campaigns are needed to create public support for crocodile conservation. The Mabuwaya Foundation is using a variety of instruments to achieve this in Northeast Luzon.

Information materials have been created and disseminated: two different posters (1000 copies and 4000 copies respectively) were distributed to all public places and households in target communities. These posters explain, in local languages, that the Philippine crocodile is something “to be proud of”, the motto of the awareness campaigns. Another poster (1000 copies) was made by students of the local Isabela State University. This poster calls for an end to crocodile killing. Flyers (1000 copies) were distributed to all target households. Large billboards were placed along access ways and in villages near Philippine crocodile habitats, with information about Philippine crocodile conservation in San Mariano. The Mabuwaya Foundation distributes a quarterly newsletter among its local stakeholders. One hundred and twenty schools have been visited to receive a presentation on the Philippine crocodile. School children can ask questions during these visits and posters are distributed. More than 150 High school and University students have been taken on trips to an observation tower that has been constructed in Dunoy Lake. Crocodiles can easily be observed from the tower and during the two-day adventure trip students receive much information about the crocodiles and the importance of crocodile conservation. Trips are also organized to the municipal crocodile rescue centre in San Mariano where two crocodiles are being kept that have been retrieved from fishermen.

Nine community consultations were organized in communities near critical crocodile habitats. During these consultations an introduction was given to the Philippine crocodile and the conservation project. A discussion was organized with community members to find solutions to issues pertaining to crocodile survival, freshwater habitat conservation and sustainable land use around crocodile localities. The community’s input and the results of the discussions were used to write a site-specific conservation action plan. Perhaps even more important were informal meetings with community members near crocodile habitats; all households in these communities were regularly visited by fieldworkers, staying with these families and sharing food and stories with them. Some community members, especially those that hunted crocodiles before, were hired as guides during field surveys. As a result of the awareness raising campaigns, the killing of crocodiles has largely stopped in San Mariano (Fig. 1).

![Figure 1. Reported crocodile killings in the municipality of San Mariano.](image-url)
A transformation in public attitudes towards the species has taken place. A study by Tarun (2004) among 50 respondents in two local communities (Minanga and San Jose) in San Mariano shows that most people now know the Philippine crocodile (94%) and are aware of its endemic status (82%). Only 44% of all respondents know that the Philippine crocodile is threatened but in San Jose alone this is 68%. San Jose is located near the municipal Disulap River crocodile sanctuary and has received more direct information compared to Minanga which is located ca. 15 km away. Similarly, overall 46% of respondents are aware that the Philippine crocodile is a protected species, again for San Jose alone this is much higher (64%). Only 14% of respondents see the Philippine crocodile as a pest, 92% are proud to have the Philippine crocodile in the area and 100% think the species has a right to live (Table 1). Local Philippine crocodile knowledge, awareness and support for crocodile conservation have very strongly increased since 1999 when hardly anybody in San Mariano was aware that the species is endemic and threatened. Most people then saw all crocodiles as dangerous pests, best eradicated to protect people and livestock.

Table 1. Philippine crocodile knowledge and awareness of local people in San Mariano (n= 50).

<table>
<thead>
<tr>
<th>Question</th>
<th>% of Respondents answering “Yes”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you know the Philippine crocodile?</td>
<td>94% yes</td>
</tr>
<tr>
<td>Is the Philippine crocodile endemic?</td>
<td>82% yes</td>
</tr>
<tr>
<td>Is the Philippine crocodile threatened</td>
<td>44% yes (68% San Jose)</td>
</tr>
<tr>
<td>Is the Philippine crocodile protected? (municipal ordinances)</td>
<td>46% yes (64% San Jose)</td>
</tr>
<tr>
<td>Is the Philippine crocodile a pest?</td>
<td>14% yes</td>
</tr>
<tr>
<td>Are you proud to have the Philippine crocodile in your region?</td>
<td>92% yes</td>
</tr>
<tr>
<td>Has the Philippine crocodile the right to live?</td>
<td>100% yes</td>
</tr>
</tbody>
</table>

The third main issue defined during the workshop is the lack of law enforcement that frustrates conservation efforts. The Department of Environment and Natural Resources (DENR) is responsible to implement and enforce national environmental laws. Although the Philippine crocodile itself is not clearly officially protected as long as the Wildlife Act of 2001 is not being implemented there are a variety of other laws that protect watersheds, wetlands, and endangered species within wetlands. See Miranda et al. (these proceedings) for an overview of national legislation that offers a framework for crocodile conservation. Law enforcement, or the lack thereof, by the DENR in Northeast Luzon is a controversial issue mainly because illegal logging is rampant in the area. The excuse brought forward by the DENR is the lack of operational budget, which is a serious problem, but there are many voices who speak of corruption and bribery. Hardwood logging, mainly to provide the furniture industry with raw materials, is big business in which much money is going around. This is not so much an issue whereas crocodile protection is concerned. There is simply a lack of knowledge, legislative confusion and the lack of directions from higher up, which hamper the implementation of crocodile protection measures by the DENR. A study by Guingab (2004) among 20 DENR officials to determine knowledge and awareness levels regarding the Philippine crocodile shows that although most respondents are aware of the existence of the Philippine crocodile, only 55% think it is important to conserve it and only 45% believe it is the role of the DENR to do so (Table 2). Moreover, 25% of respondents indicated they will not enforce any environmental laws because they are afraid of possible political connections of offenders which could cost them their job.

Table 2. Philippine crocodile knowledge and awareness of DENR personnel (n= 20).

<table>
<thead>
<tr>
<th>Question</th>
<th>% of Respondents answering “Yes”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you know the Philippine crocodile?</td>
<td>95% yes</td>
</tr>
<tr>
<td>Is it important to conserve crocodiles?</td>
<td>55% yes</td>
</tr>
<tr>
<td>Is DENR responsible for crocodile conservation?</td>
<td>45% yes</td>
</tr>
</tbody>
</table>
A possible solution for this issue is the formation of community protection groups. With the minimal personnel and financial resources available to the DENR, well functioning systems of tribal self-enforcement and local guards are essential (NORDECO & DENR 1997). Training and establishment of these community protection groups and local guards is one the main goals for the coming year.

The Mabuwaya Foundation

The Mabuwaya Foundation was set up in 2003 to heed the call from the May 2002 workshop to establish a local organization that would co-ordinate the Philippine crocodile research and conservation activities in Luzon. The official status of this entity also creates more possibilities for fundraising and enables it to enter into agreements with other stakeholders. The activities of the Mabuwaya Foundation are currently implemented by four paid research and conservation officers who all have their roots in Northeast Luzon and two researchers from Leiden University, the Netherlands. Many Pilipino and Dutch students contribute to research activities. The Foundation is hosted by the Cagayan Valley Programme on Environment and Development (CVPED), which is a joint research program of Isabela State University and Leiden University. Funding is limited but is currently sufficient to continue basic operations until the end of 2005. The main budget stems from the BP Conservation award received in 2003. Additional funding has been received from the Chicago Zoological Society and the Critical Ecosystem Partnership Fund (CEPF). Proposals have been submitted to the Haribon Foundation, a Philippine NGO that among others supports research activities on endangered species, and to the Small Wetlands Funding Programme of the Netherlands Committee for IUCN. A partnership agreement has been reached with WWF Philippines for crocodile research and conservation activities along the coast of the Northern Sierra Madre Natural Park where WWF is implementing a biodiversity conservation project. For any new program activities, additional funding has to be sourced. The Foundation has to be capacitated and strengthened further to play the role it is intended for.

The future

The direct threats to the Philippine crocodile in San Mariano, killing and destruction of crocodile habitat, have greatly been reduced but there are many issues that remain to be solved before a safe future glares for the species. Unsustainable fishing, agricultural encroachment, deforestation and pollution are indirect threats that have to be tackled. The conservation program has until now rather narrowly focused on the species, we want to expand the activities towards wise wetland management in general with the Philippine crocodile as flagship species. Eradicating destructive fishery methods in the municipality: dynamite fishing, electro-fishing and the use of poisonous chemicals, is a first priority. These widely used methods deplete fish stocks, food for the crocs but also very important protein additions to the diet of local people. The use of chemicals for fishing poisons rivers and creates dangerous health situations for crocodiles and people. A recovery of fish populations will benefit local people in a very visible way; many people perceive the decreased fish availability as an issue. Protection of riverbanks and finding solutions for pollution of freshwater bodies with farming chemicals is also in the interest of local people and crocodiles.

Discussion

Although captive breeding has been successful in re-establishing, and releasing hunting pressure on, wild populations of several crocodilian species in other parts of the world, in the Philippines the captive breeding program for C. mindorensis has so far not led to effective conservation actions in the wild. It must be feared that the Philippine crocodile is extinct in most of its former range but the lack of survey data makes assessments highly speculative. The discovery of remnant populations in Northeast Luzon since 1999 raises hope that the species might still be surviving in other remote parts of the country. More extensive Philippine crocodile surveys are urgently needed to clarify its present status in the wild.

The Philippine crocodile survives in the foothills of the Northern Sierra Madre. A small and fragmented population of only 27 non-hatchling crocodiles, 23 of them in the municipality of San Mariano, now represents the best documented group of individuals of this species in the wild. Breeding has been confirmed in three key sites and conservation activities focus on these sites. A community-based conservation approach has been chosen to fit best the local context. A strong partnership with a local government has led to the first real steps towards conservation of this species in the wild. Local expertise has been developed and a local foundation established to implement the research and conservation work. Funding has been secured for the coming years. The causes for the decline of the Philippine crocodile in Northeast Luzon have been identified and, together with local communities, solutions have been defined to address the threats. There is a need to widen the program towards wise wetland management in general; this would solve several issues identified during the problem assessment of May 2002.
It is too early to tell whether the Philippine crocodile, which still stands on the brink of extinction, will survive in the wild in the Northern Sierra Madre. But, in San Mariano the tide is slowly turning from indifference, continued killing of crocodiles and destruction of habitat, towards a committed local government, concerned communities and highly motivated local conservationists which are jointly protecting one of the rarest species in the world.

This is not only good news for the few surviving crocodiles in Northeast Luzon but could also be a starting point for renewed efforts to re-introduce the species in other parts of the country from the captive-bred stocks in Palawan. The San Mariano experience shows that it is possible in the Philippines to work with local communities and governments in crocodile conservation and that public opinion can be turned positive towards this goal. Lessons learned in Luzon could well be adapted for use in other parts of the archipelago. There is, however, no silver bullet strategy that will guarantee success. We’d rather suggest a shot of hail in the form of lobbying, encouragement, funding and technical support, and that should be directed at the Philippine islands.

Acknowledgements

The Northern Sierra Madre Natural Park-Conservation Project was implemented from 1996-2002 by Plan International with funding from the Netherlands Government. The CROC Project is being implemented with a Grant from the British Petroleum Conservation Programme. BP also kindly provided budget for MvW to attend the CSG meeting in Darwin. The Mabuwaya Foundation is hosted by the Cagayan Valley Programme on Environment and Development. Melbourne Zoo, through Chris Banks, provided funding for the printing of one of the Philippine crocodile awareness posters. We acknowledge above all the dedication and hard work of our colleagues Bernard Tarun, Jessie Guerrero, Dominic Rodriguez and Sammy Telan who implement the conservation strategy for the Philippine crocodile.

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False Gharials (*Tomistoma schlegelii*) in Tanjung Puting National Park, Kalimantan, Indonesia

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Abstract

An opportunistic survey undertaken in Tanjung Puting National Park, Kalimantan in 2002, revealed that false gharials (*Tomistoma schlegelii*) are readily seen in the rivers around the Camp Leakey Orangutan Research Centre. Four false gharials were seen from a tourist boat during the day, and all were unusually tolerant of boat traffic. A spotlight survey revealed 18 false gharials in 32 km of rivers, with the majority being found within Tanjung Puting National Park; 11 false gharials were seen in 7.6 km, resulting in a density of 1.4 crocodiles/km, one of the highest densities ever recorded for the species. Crocodiles ranged in size from 2-3’ to 6-7’ indicating that breeding has been occurring in the area over the last few years. Other surveys conducted in the area in 1990 revealed a similar density and population structure, suggesting that the population has been stable and reproductive for over 12 years.

This globally significant population is well protected within this well managed National Park that provides excellent peat swamp forest habitat. Further in-depth studies are required for these false gharials however, as other populations of the species continue to decline elsewhere.

Introduction

The false gharial (*Tomistoma schlegelii*) is one the most striking of the 23 species of crocodilians. The vivid markings and colouration over the snout and body, even in adults, make this slender-snouted species easily recognisable. It is now restricted to the island of Borneo, Sumatra and Peninsular Malaysia, although historically it was also found in southern Thailand, where it is now thought to be extinct (Ross 1998).

Until recently, this large freshwater species was listed as “Data Deficient” by the International Union for Conservation of Nature (IUCN 1996) and was one of the world’s least known crocodilians. Recent studies over the last 10 years however (Ramono 1994; Bezuijen et al. 1995, 1997; Ross et al. 1998; Simpson et al. 1998; Bezuijen et al. 2002), have shed some light on the distribution, ecology and status of this species. It is now classified as Endangered (Ross 1998) but in-depth studies are still required.

Tanjung Puting National Park

Tanjung Puting National Park is situated in Central Kalimantan District (Kalimantan Tengah), in the South of Kalimantan, Indonesia. It covers some 3000 square kilometres of lowland coastal forest and is covered by a complex of Nipah palms, mangrove swamps, peat swamps and tropical heath forests. Situated on a peninsula, the northern boundary is formed by part of the Sekonyer River, while the western and southern boundaries front the Java Sea (Fig. 1). It is one of the largest protected areas of tropical heath forest and peat swamp forest in Southeast Asia (Birute and Shapiro 1994).

Tanjung Puting National Park hosts a wide range of flora, with over 600 species of trees and more than 200 species of orchid known. Over 220 species of birds are found here, of which 5 are endemic to Borneo. The Park however, is best known for its populations of orangutans, which are the largest of the 9 primate species in the Park. Two species of crocodile can also be found here, the saltwater crocodile (*Crocodylus porosus*) and the false gharial (*Tomistoma schlegelii*) (Birute and Shapiro 1994).

The Camp Leakey research station lies within Tanjung Puting National Park and is situated 7.6 km upstream from its confluence with the Sekonger River (Fig. 1). It was first established in 1971 as a base for the study of wild orangutans and is now run by Orangutan Foundation International (OFI) in conjunction with the Indonesian Forest Protection and Nature Conservation Agency (PHPA). It aims to conserve orangutans and their rainforest habitat and is used by students, researchers and tourists as a base from which to conduct orangutan research and tourist activities.
Because of the influence and input from OFI to protect the orangutans and their habitat, this National Park is relatively well protected, although there has been some recent concern regarding illegal logging, mining and fishing activities (S. Brend, OFI, pers. comm.). The presence and protection afforded through OFI restricts these destructive activities, especially when compared to the wholesale forest clearing in other parts of the Kalimantan (and the country). This National Park therefore remains one of the best protected and managed National Parks in Indonesia.

**Methods**

This study was carried out while visiting Tanjung Puting National Park as a tourist, and the observations were made from one of the many tourist boats that ply the rivers between Camp Leakey in Tanjung Puting National Park, and Kumai town. Observations were made on 27-30 August 2002, from the deck of the wooden tourist boat, both during the day and at night, as it moved along the rivers.

A spotlight survey was conducted on 30 August 2002 from the bow of the tourist boat as it made the 4 hour trip from the Camp Leakey Orangutan Centre back to Kumai town. The survey started at Camp Leakey and continued downstream on the Simpan Kanan creek for 7.6 km to the junction with the Sekonyer River (and police post). The boat then entered the Sekonyer River and continued downstream until its confluence with the Kumai River, a distance of approximately 25 km. The very wide and tidal mouth of the Kumai River was not surveyed as the boat made its way upstream to Kumai town.

A strong torch light was used to scan the shoreline of the river and the water surface, to detect the crocodile ‘eyeshine.’ Once a crocodile was found, an estimate of the total length was made, if possible. As the tourist boat moved along a set route, down the middle of the river, it was not always possible to get close enough to estimate the size of the crocodile. In this case, and in the case of the crocodile diving before an estimate could be made, an ‘Eyes Only’ classification was given. Although the survey vessel was not ideal for the purpose of crocodile surveys, it was adequate to provide meaningful results.

**Results**

Observing false gharials at the waters edge during the day was not possible in the 40-60 m wide Sekonyer River, as the distance from the boat to the littoral zone was too great. However, in the 10-15 m wide Simpan Kanan Creek, it was possible to see false gharials as they rested at the waters edge or basked on the bank or a fallen tree trunk.
Four false gharials were observed during the day as the boat made the 7.6 km trip up Simpan Kanan Creek on the 28 August 2002. All were juveniles, one estimated at 3-4’ long while 3 were 4-5’ long. Two other individuals both 5-6’ long, were also seen near the Police Post at the junction of Simpan Kanan creek and Sekonyer River, during the evening on 30 August, 2002 (these 2 animals were not seen in the subsequent night survey 2 hours later). All animals were very tolerant of boat traffic and would often stay at the surface and bob in the wake as the boat passed. As the river was narrow, boats would often pass within 5m of these false gharials.

A night survey over 33km of the Simpan Kanan creek and Sekonyer River revealed 18 false gharials ranging in size from 2-3’ long to 6-7’ long. All eyeshines (EO) were assumed to be from false gharials, although saltwater crocodiles (*Crocodylus porosus*) are known to inhabit the area on occasions.

Within Simpan Kanan creek itself, eleven (11) false gharials were seen in the 7.6 km, from Camp Leakey to the confluence with the Sekonyer River, resulting in a density of 1.45 crocodiles/km (Table 1). There were no crocodiles seen in the first kilometre or so downstream of Camp Leakey, and so all observations were made within a 5 km section of Simpan Kanan Creek.

<table>
<thead>
<tr>
<th></th>
<th>Crocodiles observed (in one foot size classes)</th>
<th>Density (crocs/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km 1-2 2-3 3-4 4-5 5-6 6-7 EO Total</td>
<td></td>
</tr>
<tr>
<td>Simpan Kanan Creek</td>
<td>7.6  - 2 3 3 - - 3 11</td>
<td>1.45</td>
</tr>
<tr>
<td>Sekonyer River</td>
<td>25  - - 2 - - 2 3 7</td>
<td>0.28</td>
</tr>
<tr>
<td>Total</td>
<td>32.6 - 2 5 3 - 2 6 18</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Seven (7) false gharials were seen in the Sekonyer River, from the junction with Simpan Kanan Creek, downstream for 25 km. All of these sightings were within approximately 8 km of Simpan Kanan Creek, in the upstream portion of the Sekonyer River unit, near Simpan Kanan Creek.

Although 18 false gharials were seen during the whole survey, which covered 33 km, all observations were actually made within a section of approximately 13 km, that is, in 5 km of Simpan Kanan Creek and the first 8 km section of the Sekonyer River.

It should also be noted that a large bright red eyeshine was seen in the tidal waters 2 km from the mouth of the Sekonyer River the night before the survey (29 August 2002), and this was assumed to be that of a large saltwater crocodile (*Crocodylus porosus*). Saltwater crocodiles are sometimes seen in the Sekonyer River (S. Brend, pers. comm.).

**Discussion**

The false gharials of Tanjung Puting National Park represent a significant global population. The 18 false gharials seen during this spotlight survey compare very favorably with the results of a similar survey in 1990 (Frazier and Maturbongs 1990). Although the 1990 survey was slightly shorter (22.5 km) and covered a slightly different route, the results were very similar with a total of 16 false gharials being seen (Fig. 2). Twelve (12) of these 16 were seen within Simpan Kanan Creek, which is also similar to the results obtained during this survey, when 11 false gharials were seen.

This population has not only been stable for the past 12 years but the numbers and density found here are higher than for any other false gharial population. A density of 1.45 crocs/km was obtained for the 7.6 km stretch of Simpan Kanan Creek, from Camp Leakey to the Sekonyer River. This is the second highest density for false gharials ever recorded, the highest being obtained by Frazier and Maturbongs (1990) 12 years earlier on the same stretch of river (1.58 crocs/km).
The survey results from 2002 (this report) and 1990 (Frazier and Maturbongs), both show various size classes of false gharials were seen, including very small individuals. This indicates that breeding has been occurring in the area for at least 12 years. Although nesting has been reported to occur upstream of Camp Leakey on the Simpan Kanan Creek (B. Galdikas, OFI, pers. comm.), neither survey explored this area.

Even though both surveys reported a high abundance and healthy population of false gharials in Tanjung Puting National Park, neither could be defined as comprehensive. Both surveys were carried out in sub-optimal conditions, and not all the navigatable waterways were surveyed. Both the 1990 (Frazier and Maturbongs) and 2002 (this report) surveys only traveled part of the suitable river system, and so the potential for further false gharials to be found in a more comprehensive survey exists. The Simpan Kanan creek for example, is navigable by boat for approximately 13 km upstream from its confluence with Sekonyer River. That is, boat travel is possible for a further 5 km upstream, beyond Camp Leakey (S. Brend, OFI, pers comm.). It is therefore reasonable to assume that this upstream section could hold a similar number of false gharials to the downstream section.

Further, more comprehensive surveys are needed for this National Park in order to fully understand the distribution and abundance of the false gharials here. The importance of this population becomes even more significant as other populations elsewhere continue to decline (see below). It is therefore essential that this entire population be surveyed thoroughly, so that an accurate assessment of the population and status can be achieved.

**False Gharial Populations Elsewhere**

The understanding of distribution, abundance and status of the false gharial is generally very poor, and there are very few sites where comprehensive surveys have been conducted. Tanjung Puting National Park is one of only 3 known Indonesian sites where surveys have been conducted on more than one occasion. These repeat surveys are extremely important and allow population trends to be followed while providing baseline data on threats and ecological parameters. Figure 2 represents data from these 3 areas in Indonesia where false gharial surveys have been conducted on more than one occasion. Two of the sites are in Sumatra, the Merang River and Berbak National Park, while the third is in Kalimantan, the Tanjung Puting site.

[The data points shown in Figure 2 were extracted from various reports and represent surveys undertaken over different river lengths, under varying conditions by different people. References for the data points are as follows: Tanjung Puting NP, 1990= Frazier and Maturbongs 1990, 2002 = Simpson 2004 (this report); Berbak NP, 1990= J. Cox unpubl. data, 1997= Bezuïjen et al. 1997, 2001= Bezuïjen et al. 2001, 2002= Bezuïjen et al. 2002 (note that the 2002 point was obtained by allocating EO data in the same proportion as the identified species); Merang River, 1995= Bezuïjen et al. 1995, 1996= Bezuïjen et al. 1997, 2001= Bezuïjen et al. 2001, 2002= Bezuïjen et al. 2002.]

An assessment of the Sumatran populations have been summarised below from Bezuïjen *et al.* (2002). The Merang River population is located in South Sumatra province, Sumatra, and false gharials were all recorded from the river mouth to 67km upstream. This population has recently declined severely, from around 14 crocodiles in the 1995-
2001 period, to just 3 crocodiles in the 2002 survey. The cause of this drastic decline was attributed to a large influx of illegal loggers to the area in 2001. One large false gharial was killed in 2001, while a further 18 have been caught and are being held in villages and logging camps. The number of nests found in 2002 had also dropped to zero, no doubt due the removal of most of the false gharial population, and the destruction of the peat swamp nesting areas. Extensive damage to the habitat has been, and continues to be, caused by these illegal, well organised, well-funded logging groups.

The Berbak National Park population of false gharials is located in Jambi province, Sumatra (Fig. 2) and represents the combined data from the Air Hitam Laut River and Melaka Creek (see Bezuijen et al. 2002). This population also shows a distinct decline after 2001. Bezuijen et al. (2002) states that there is no obvious reason for this decline, but it may be attributed to large-scale forest fires in 1997-98 that burnt large tracts of potential nesting habitat.

The monitoring of false gharial populations in Indonesia has shown that known populations in Sumatra have declined dramatically since 2001 (Fig. 2). These declines can be attributed to a number of factors, including large forest fires, extensive illegal logging, killing of crocodiles and the extensive capture of wild false gharials. Due to the extensive destruction of nesting areas, and the continued presence of illegal loggers, it is doubtful whether the Merang River population (Fig. 2) will ever recover. The Berbak National Park population may recover if the habitat regenerates and threatening processes are minimised, and has the potential to expand given suitable habitat is present. The Tanjung Puting population on the other hand, shows a significant population that has been stable for the last 12 years. This population is well protected in this National Park. It is therefore crucial that this population be fully assessed, and that habitat destruction and other threatening processes continue to be minimised.

While other populations of false gharials have declined, mainly through habitat destruction and the capture of animals, the Tanjung Puting population continues to remain stable and support significant numbers of the species. The well protected nature of Tanjung Puting National Park can be attributed to the presence and commitment of Orangutan Foundational International (OFI), in conjunction with the Indonesian Forestry Protection and Nature Conservation Agency (PHPA). The work of OFI to protect the orangutans and their habitat has also had great benefits for many other species including the false gharial. The continued presence of OFI in this National Park will continue to benefit the False Gharials of Tanjung Puting.

Acknowledgments

I would like to thank Fauna & Flora International - Cambodia Programme, for the opportunity to present this paper at the 17th Working Meeting of the IUCN-SSC Crocodile Specialist Group, in Darwin, Australia. I would also like to thank FFI, and specifically Jenny Daltry, for allowing me to use facilities and reference materials at the Phnom Penh office.

Literature


A Pilot Project to Integrate Crocodile Conservation and Livelihoods in Cambodia

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Abstract

The 900 residents of O’Som Commune, Veal Veng District, share their land with at least 55 Siamese crocodiles (Crocodylus siamensis), which they have traditionally revered for generations. Since peace came to Southwest Cambodia in 1998 however, the commune’s extreme poverty and starvation, coupled with increasing access to outsiders, exposed the crocodiles to new dangers from poaching and habitat loss. The Forestry Administration, Fauna and Flora International, CEDAC (local NGO) and O’Som Commune leaders formed this project in 2001 to solve underlying problems facing both people and wildlife. Building on careful research and consultations, our activities have included the participatory development of a commune land use and natural resource management plan, in which the villagers notably agreed to protect all crocodiles and other wildlife on their land, and allocated >200 ha of Veal Veng Marsh as a crocodile sanctuary. Food production has been significantly increased in the designated agricultural zones, and new income-generating schemes are showing promise. The link between this much-needed livelihood support and the crocodiles is being constantly reinforced, and independent sources confirm that the villagers are reciprocating by actively defending them from crocodile farm collectors. Lessons learned here are now being applied to other communities in Southwest Cambodia.

Introduction

O’Som Commune

O’Som Commune is one of Cambodia’s poorest and most remote communities, situated in Pursat Province at 12°5’N, 103°15’E, at nearly 600 metres above sea level in the Cardamom Mountains. The community contains nearly 1000 people in four villages: O’Som, Chai Louk, Kamlot and Kien Jong Roak. According to Veal Veng District Government records, the O’Som Commune land area covers 171,144 ha. Approximately one third is within the Phnom Samkos Wildlife Sanctuary, under the management of the Ministry of Environment. The remainder, including all four villages and Veal Veng Marsh, is in the Central Cardamoms Protection Forest, which is managed by the Forestry Administration. The third and smallest portion (12,194 ha) lies within a logging concession, currently held by Samling International.

People have lived in this area for over 1000 years, according to local folklore and the presence of an ancient shrine beside the marsh. Martine (1997) identified them as Khmer Daeum (‘Original Khmer’). More specifically, 70% of the people are Por, an ancient Highland Khmer minority (Hammond and Hor 2002). This community used to be relatively prosperous, with its own pagodas, schools and 20 domestic elephants. When the Pol Pot Regime began in the mid-1970s, however, the villagers reportedly suffered from widespread persecution, malnutrition and slave labour. Veal Veng District remained in Khmer Rouge hands for the best part of 20 years, and it was not until the late 1990s that the final peace deals were signed and O’Som Commune rebuilt. Only about 863 people were registered by 1998, out of approximately 5000 who were present before the genocide (CARERE/UNDP/SEILA 1999; UNDP 1999).

In spite of a generation of war, many traditional customs have survived among the older villagers. Maxwell (2000) described their annual ancestor festival, when villagers tend the shrines of their ancestors and certain individuals communicate with the spirit world through trances. During the ceremony, ‘the ancestors repeatedly extolled the virtues of protecting the forest, and reminded the villagers not to hunt the animals. One spirit even criticized the waste-management system of the nearby yellow-wood processing plant, and recommended that the factory owner dig a pit, far from the stream, for the disposal of his waste’.
Of special note is the Por community’s taboo against harming certain ‘sacred’ animals, especially crocodiles and hares. There is no record of any villager having been attacked by a crocodile in O’Som, and some knowingly bathe or fish in pools containing large specimens. If a crocodile is hurt or killed, it is said that ‘Ta Jiruk’, an ancestor who has become a forest spirit, will bring sickness or death on the person or family responsible. This taboo broadly applies to all commune members, but does not automatically extend to visitors who, it seems, may catch or kill crocodiles without fear of supernatural retribution.

Siamese crocodiles

Nao and Tana (1994) predicted that Siamese crocodiles might occur in the Cardamom Mountains, but it was not until 2000 that the crocodiles were confirmed here (Daltry and Chheang 2000). There are now known to be crocodiles in at least 16 sites in the mountain, from 10 to 600 m above sea level (Simpson and Sam, this volume). Two key sites are near O’Som Commune:

1. Veal Veng Marsh

Located near the centre of the Cardamom Mountains, Veal Veng (‘Long Field’) Marsh is a unique rain- and river-fed wetland at 560 m above sea level (Fig. 1). During the dry season, the crocodiles are confined to the wettest part of the marsh, within an area of less than 50 ha. During the rainy season, the crocodiles disperse across a flooded area of 500 ha. The water level can rise by one metre across the marsh in 24 hours of heavy rain, and takes up to 25 days to empty (Carvalho et al. 2002). The marsh contains the largest known colony of Siamese crocodiles in the wild in Cambodia, with an estimated 40 individuals (Daltry et al. 2003). Nesting was confirmed here as recently as May 2004 (Simpson and Sam, this volume).

2. Koi and Krau River System

The Krau River drains the marsh and forms a tributary of the Koi River. Four crocodiles have been documented

Figure 1. Map of Cambodia, showing the location of O’Som Commune.
in the Krau River during the dry season, and a further ten occupy ‘Anlong L’Ang’, a deepwater section of the Koi River that is also used by O’Som villagers for fishing (Daltry et al. 2003). All of the individuals seen and reported along these rivers to date are adults, and no nests or juveniles have been reported. These individuals may be able to interact with the colony in Veal Veng Marsh during the rainy season.

Problems Facing the O’Som Commune and Crocodiles

When the project team first encountered the villagers in 2000, a number of interrelated problems were identified, including:

i) The villagers lacked sufficient food for up to seven months a year. Health care and schooling were almost non-existent, and life expectancy was low.

ii) Farming and income generating opportunities were limited because of low fertility, lack of know-how and lack of materials, including seeds.

iii) The villagers resorted to illegal and destructive strategies to obtain food and money, leading to ugly clashes with law enforcers.

iv) A new road was constructed in 1999, linking O’Som Commune to two cities (Pursat and Koh Kong) and the Thai border. Wildlife traders visited the commune every month, offering money for rare animals.

v) Migrant workers and entrepreneurs came to O’Som to take land, yellow vine, timber, cardamom, tree resins and other valuable resources. These outsiders did not share the commune’s taboo against harming crocodiles.

vi) The villagers lacked recognition of their rights to land or natural resources. There was nothing they could do to stop other people from taking land, wildlife or other resources.

vii) The population of O’Som Commune was small, but increasing. There was no plan in place for coping with internal population growth or immigration.

viii) Increased use of new nylon fishing nets and hooks in Veal Veng Marsh led to several young crocodiles being accidentally killed every year, as well as complaints of valuable fishing gear being broken by large crocodiles.

ix) There was no co-ordination between conservation and humanitarian welfare and development organisations, leading to real problems for people and wildlife. Aid agencies were proposing to turn the whole of Veal Veng Marsh into rice fields, for example, which would have destroyed the core crocodile population and other wildlife.

Methods and Results

O’Som Community Conservation Project

The Forestry Administration (Royal Government of Cambodia) and Fauna and Flora International founded this project in 2000 as part of the broader Cambodian Crocodile Conservation Programme. Our mission is ‘to conserve the population of Siamese crocodiles and improve the livelihoods of the people of O’Som Commune in ways that are sustainable, culturally appropriate, environmentally sound and compatible with biodiversity conservation.’

All phases of this project were developed in close partnership with the people of O’Som Commune and local authorities. The Centre d’Etude et de Developpement Agricole Cambodgien (CEDAC, a Cambodian NGO) joined the project in 2002 to provide specialist assistance to improve the community’s food security (Phase 4). The project also benefit from the support and active involvement of Conservation International, Ministry of Environment, SEILIA Development Program, and other key stakeholders.

Phase 1 - Gathering information and building relationships (2000-2002)

FFI and FA organised a series of participatory research activities and consultations to develop a better understanding of the area, the community, the crocodiles and other wildlife. The work involved specialists from FFI, FA officers and members of the local community, with additional contributions from Pursat provincial staff from the Departments of Environment, Agriculture, and Meteorology and Water Resources. The main foci of our ecological research programme included baseline studies of the status, distribution and ecology of the Siamese crocodiles (Daltry and Chheang 2000; Daltry and Tith 2002; Daltry et al. 2003) and inventories of mammals, birds, reptiles, amphibians and fish. The latter led to the identification of other endangered species and several species new to science (Long et al. 2002; Baird et al. 2002; Ohler et al. 2002). A hydrological survey of Veal Veng Marsh was also commissioned in 2002 (Carvalho et al. 2002).
We also engaged socio-economic specialists to examine the demographics, ethnicity, history, religion, education, health, economy, physical capital, agriculture and natural resource use of the O’Som Commune, and identified some of the main concerns and problems affecting their livelihoods (eg Maxwell 2000; Hammond and Hor 2002). The villagers were then taught basic mapping skills and assisted the project team to map their current and historical land use areas, including private fields. This led on to a more detailed Participatory Rural Appraisal and investigations into how to improve food production on existing farmland. Soil analyses were carried out, and confirmed the villagers’ observations that most of their existing fields were severely depleted of nutrients (Ironside et al. 2002).

FFI and FA also began an ongoing process of consultation with other stakeholders in and around Pursat province, including Cambodia Area Reconciliation and Rehabilitation (CAREERE), United Nations Development Program (UNDP), Conservation International, Ministry of Environment, and the local government. It was during this stage that the team learned of plans by CAREERE and UNDP to convert the whole of Veal Veng Marsh into rice paddy, and to settle landless internally displaced persons here (see Introduction). To their credit, UNDP retracted their support when they were informed of the global importance of the marsh for Siamese crocodiles, but not quickly enough to prevent CAREERE from donating nearly 100 buffalo in 2000 and 2001 to plough the new fields.

The information gathered during Stage 1 contributed to much of the O’Som land being taken out of logging concession and incorporated into the new 420,000 ha Central Cardamoms Protected Forest in 2002 (see Phase 3).

Phase 2 - Raising awareness of the crocodiles and other conservation issues (2001-2002)

In 2001, we seconded Mr Aing Leang Heng from the provincial Department of Education to train O’Som’s four teachers, several of whom were functionally illiterate. Over seven months, his objectives were to build better general teaching skills within the community, raise awareness of the natural environment and strengthen the relationship between the project and the commune. The environmental education sessions included raising awareness on wildlife and habitats (including the Siamese crocodiles and Veal Veng Marsh), water health, waste disposal, hygiene and tree planting. This led to a noticeable improvement in waste disposal around the villages, improved hygiene, tree planting and a decrease in the number of children observed hunting or trapping birds around the commune. Heng became accepted as part of the community and observed that “the community of O’Som demonstrated a willingness to work with outsiders on a project that did not offer huge financial rewards, but offered a long term community benefit” (Fox 2004).

Since 2001, the commune became even more aware and proud of their natural environment through the international attention that the crocodiles have received. Visits by National Geographic film crews, journalists, senior government officials, international tourists and conservation workers helped to boost community support for crocodile protection and environmental management generally. In 2002, FA and FFI invited the village leaders to design a t-shirt for their commune. They chose a picture of a crocodile with the words, in Khmer, ‘O’Som Commune, Veal Veng District’ on the front and ‘Together We Can Save Ta Jiruk’s Crocodiles’ on the rear. Every adult in the commune received a t-shirt, and the leaders frequently wear theirs to important meetings.

Phase 3 - Community land use and natural resource management planning, including the creation of a crocodile sanctuary (2002-2003)

By 2002 (the third year of the project), it was still unclear what rights the people - or crocodiles - of O’Som had to land and natural resources around the commune. This area became part of the Central Cardamoms Protected Forest in July 2002, and rangers were stationed in O’Som to stop villagers from hunting or felling trees, but not from making new wet rice fields or fishing or burning in the marsh. Using the information and experiences from Phases 1 and 2, we realised that an urgent priority was to negotiate and collaboratively agree a community land-use and management plan, and present this to the government for endorsement. The plan had to clarify exactly where and how different areas may be used for community development and conservation, and be enforceable by the commune leaders and Central Cardamom Protected Forest rangers.

The O’Som Commune land use plan was developed slowly and organically using a slightly modified form of the national Participatory Land Use Planning method (Rock 2001). A series of workshops and meetings were held in 2002 and 2003, beginning from household and village level, through commune, district and provincial levels, to national level. Almost every villager contributed to the meetings. FFI and FA provided facilitators and some technical guidance. The resulting land use plan (Figs. 2 and 3) covers the entire commune territory and follows traditional management zones where possible. These include, for example, residential areas, spirit forests, rotational forest
gazards (‘chamka’) and wet rice fields. The draft plan also incorporates specific biodiversity needs: for example, a 239 ha crocodile sanctuary, fish sanctuaries and strict wildlife preserves. All of these were at the villagers’ own suggestion.

Detailed regulations, or commune by-laws, were drawn up for each zone and major natural resource, largely following the people’s practices before the war. The implication of this plan and regulations for crocodiles will be discussed in more detail under Phase 5 below. The plan and its accompanying regulations have already secured strong support

Figure 2. Project team examining a commune sketch-map of current land use. Clockwise from bottom-left: Chay Sem (Vice Chief, O’Som Commune); Hor Leng (Community Liaison Officer, FA); Sam Han (Crocodile Field Coordinator, FA); Lang Tnh (Head of Women’s Affairs, O’Som Commune); Jeremy Ironside (Technical Adviser, FFI); a village elder; Y Naron (Agricultural Trainer, CEDAC).

Figure 3. O’Som Commune Land Use Plan.
from the local government, and will be put before the national government for official approval before the end of 2004. The villagers have also considered establishing commune-level penalties for offences by commune members that are not already covered by national laws (eg for wilfully lighting fires near the crocodile sanctuary). These generally include fines to be paid to the commune fund and/or a period of community service, depending on the severity of the crime.

The draft plan and regulations set the framework for the next phase of the project, by identifying which areas and resources may be used for income or food production.

**Phase 4 - Sustainably increasing food security and income in ways compatible with crocodile conservation (2003-2006)**

During the earlier phases, FFI and FA provided emergency assistance to help the commune, including providing over a tonne of rice and hundreds of kilograms of seeds. This clearly was not a long term solution, however, so Centre d’Etude et de Developpement Agricole Cambodgien (CEDAC) were invited to join the project to assist the farmers to improve food production on existing farmland without using harmful or expensive chemicals or damaging the environment. Working one-on-one with volunteer villagers, CEDAC began experimenting with a range of new crops and techniques around O’Som. The latter include the System of Rice Intensification, which has increased rice yields by up to six-fold elsewhere in Cambodia, using the same local varieties and without any chemicals or other costs (Uphoff et al. 2002).

The O’Som farmers have expressed satisfaction with the results so far and the commune was able to produce a much greater percentage of its own food in 2003 than since before the war (CEDAC 2003). Some families even produced a surplus. CEDAC trainers are continuing to spend at least 10 days per month in O’Som until at least end 2006, to teach, test and refine better food production and storage techniques.

The villagers are also currently receiving assistance to market agricultural produce and to develop other sources of income. O’Som Commune used to earn most of its income from harvesting wild cardamons *Amomum kreshnh*, which grow in the surrounding rainforests, and were the primary reason why villagers did not cut old-growth forests on their land in the past. We aim to reinstate the cardamom trade in 2004, to enable O’Som to generate a sustainable income of an estimated $10,000 per year. The Commune has already begun joint patrols with local Forestry Administration rangers to protect the wild crop from raiders. We are looking at other ways to generate money, such as medicinal plants and ecotourism.

To help manage these natural resources and ensure that the income is handled fairly and transparently, a Commune Natural Resources Management Committee was democratically elected in 2003, and is undergoing training by project staff. A Commune Fund has also been established to ensure that a proportion of income will be re-invested in activities that benefit the community, such as a medical clinic, and for conservation.

**Phase 5 - Management planning and implementation of the new crocodile sanctuary (2004-2006)**

During Phase 3, the O’Som Commune unanimously agreed to establish a crocodile sanctuary in Veal Veng Marsh, which encompasses all of the areas inhabited by crocodiles during the dry season, and all known nesting sites. Negotiating this boundary was largely left to the Commune Natural Resource and Management Committee, which offered alternative land to the small number of farmers who claimed land ownership within the sanctuary. No direct payments were made. Some key regulations pertaining to the sanctuary, agreed during Phase 3 workshops, include those shown in Box 1. Several of the rules shown here were ‘hinted’ by our crocodile specialists, but their adoption was left to the Commune’s choice.

Importantly, crocodiles will also benefit from strict protection outside of the sanctuary, and the Commune regulations forbid cutting of vegetation within 20 metres of any stream or river. Furthermore, the land use plan allocates a number of significant zones where no hunting or tree cutting will be permitted, including Spirit Forests (13,003 ha) and Wildlife Protection Areas (50,703 ha). The crocodile sites in the Koi and Krau Rivers fall into these categories.

In January 2004, the project team demarcated the crocodile sanctuary boundary with flagging tape and made sure that neighbouring landowners were happy with the boundary. Several farmers came forward to dispute certain sections, but these were resolved internally by the new Commune Natural Resource Management Committee. In most cases, the farmers were allocated better fields elsewhere.
At the time of writing (May 2004), work has begun on developing more detailed management guidelines for the sanctuary, addressing such issues as signage and permanent boundary demarcation, how to keep the CARERE-donated buffalo out, monitoring requirements, and wardening roles and responsibilities.

**Box 1.** Key draft regulations for the Crocodile Sanctuary (English version, January 2004)

**5.2 Conservation of Siamese Crocodiles**

**Article 32) Areas For Crocodile Conservation: (291 ha)**

To conserve the population of crocodiles in Veal Veng Marsh, the following areas have been set aside for Crocodile Conservation: Boeung Mluch, Chlorlong Svay, Romeas Ngoarb, Trapaging Kok, Spean Smach, Trapaging Stroh, Trapaging Arng Phleung, Ptool Wat and Koh Treah [place names within the Marsh].

**Article 33) Hunting, Possession and Sale of Crocodiles and their parts**

A) No hunting of crocodiles or all other forms of animals in the crocodile sanctuary area will be allowed.
B) It is forbidden to buy, sell or trade crocodiles, crocodile eggs or products inside or outside the commune.
C) Offenders caught carrying out the above offences will be reported to the appropriate authority for prosecution under national law.

**Article 34) Fishing**

A) The use of gill nets and fishing with hooks is prohibited as well as all equipment described in Article 40 of these regulations.
B) Permitted equipment - Fishing with Ungrhut (cone-shaped basket), Samnug (castnet) and Cheang (scoop) is permitted by commune members in the sanctuary area. Members must take care not to disturb crocodiles while fishing.
C) The use of illegal fishing gear will incur penalties outlined under Article 36, 37 and 38 of the Fisheries Law.

**Article 35) Preservation of Crocodile Habitat**

A) Changing of the crocodile habitat is not permitted. This includes:
   • Cutting of trees or plants
   • Changing of water flow by digging new paddy fields, channels or building paddy bunds in the sanctuary.
   • Making camps or buildings.
   • Buffalo grazing in the crocodile reserve (if this occurs, observers should tell the owners to move buffaloes).
B) Fires: No fires to be lit within 20 metres of the reserve boundary or within the reserve.
C) Disturbance to nesting areas: There must be no disturbance to known nesting areas and/or nesting crocodiles. nesting crocodiles are not to be approached, and nests must not be touched.
D) Collection of eggs: Crocodile eggs are not to be collected.

**Discussion**

**Impact for O’Som Commune**

This project is still a work-in-progress, but has already produced some clear, positive benefits for O’Som Commune. Not least of these are (a) identifying and acknowledging the community’s rights to land and resources in this area, and (b) increased food production on existing farmland, both in terms of quantity and diversity. Within the first year of assistance from CEDAC, some of the participating families have produced a surplus of food to sell. One commune member, Mr Ut Krin, reported ‘Our farming is better now than before [the project]. We use less land but still have enough yield to raise our families.’

Some families have also benefited from increased income. So far, this has largely been direct, for example through project staff and guests paying for accommodation, transport and guides, but soon the commune will be generating income from the sales of crops and, if all goes to plan, wild cardamoms and perhaps other renewable natural resources. The cost of living with crocodiles is small - a few villagers complained about crocodiles breaking gill nets, but this should be mitigated by using other fishing techniques in the crocodile sanctuary (Box 1). Many families in O’Som Commune still lack enough food or money, however, and we must try to ensure that the benefits are shared.
The links between improving livelihoods and the continued survival of the crocodiles and other wildlife is being continually re-enforced, not only by project staff, but by villagers themselves. One family took the initiative to construct a brightly painted wooden guesthouse in 2002, which they named the ‘Kropeu Meas’ or ‘The Golden Crocodile’!

**Impact for crocodiles and other wildlife**

O’Som Commune members report that they have successfully prevented outsiders from taking crocodile eggs or hatchlings, simply by informing them of draft by-laws. Corroborating this, a motodop driver from Pursat town was recently heard complaining ‘I used to take baby crocodiles from Veal Veng Marsh to sell, but now the people won’t let me. There are lots of baby crocodiles there now, and I can only look at them’ (pers. comm. to Keo Nara). During routine monitoring by the CCCP field team in 2004, an unprecedented number of hatching scats were recorded along fixed transects in the marsh (Boyd Simpson and Sam Han, unpublished data). Mr Som Lork, the Second Commune Assistant, said ‘The crocodiles are increasing very much. When we go fishing with nets, small crocodiles are attracted to our fish.’

We have also observed a conspicuous decrease in hunting and deforestation by the indigenous families. Remarkably, at their own initiative, O’Som villagers began forming joint patrol parties with the government rangers in 2003 to patrol the forests to exclude illegal hunters and loggers. Some worrying forest encroachment was observed by immigrant families near Chai Louk village in 2002 and 2003, but the commune leaders have ordered them to stop. Mr Chey Sem, Vice Chief of the Commune Natural Resources and Management Committee, commented that ‘Now, no one dares to cut the forest or hunt wild animals, or to encroach on community land for housing or farming.’

**Applicability to other communities and crocodile populations**

This pilot project with O’Som Commune demonstrates that it is possible to engage communities in protecting crocodiles, while also helping to solve their livelihoods problems. Here, the incentive to protect the crocodiles has been primarily
cultural, building firstly on long established taboos against harming crocodiles, and secondly on an appreciation that the animals have served as a ‘lever’ to gain new respect and extra help from NGOs and the government. In this latter regard, this project shares similarities with the promising community-based conservation programme for Philippine crocodiles in San Mariano Municipality, Luzon (Miranda et al. 2004).

Cambodia is considered the last ‘stronghold’ for Siamese crocodiles, with a total wild population of probably no more than 200 adults (Simpson and Han 2004). At least eight communes in Cambodia still have crocodiles living nearby throughout the year (Daltry et al. 2003; unpublished data, 2004). These animals are threatened by collection for farms and trade, and many populations are in additional danger of losing their wetland habitats: even in protected areas, the laws against clearing forests are stricter and more widely recognised than the legislation protecting wetlands from conversion to rice fields. Enlisting the cooperation of local communities in the protection of crocodiles and wetlands is therefore crucial to bolster, but not substitute entirely, more conventional tactics such as establishing protected areas and strengthening law enforcement.

While community-based approaches to wildlife conservation are still rare in Cambodia, it is worth noting that engaging communes in participatory land use planning and the management of wildlife and natural resources are very much in line with both the Cambodian Government’s emerging policy of decentralisation (eg Wehrmann and Sy 2002) and the National Biodiversity Strategy and Action Plan (Royal Government of Cambodia 2002).

The ‘O’Som model’ probably ought not be simply lifted and copied as a blueprint, however, because every community and area is different. The key to success is undoubtedly in the approach to finding the most appropriate solution to meet the local needs. This process must be genuinely participatory, build on the best available scientific information, be conducted at the community’s own pace, and have support from both the local authorities and national government. Table 1 summarises some of the key characteristics of the O’Som project. It is also likely that the best results will be gained with communities that are, like O’Som Commune, tightly knit and have lived in the same area for generations (Fox 2003).

In 2003, FFI and the Ministry of Environment embarked on a similar process with communities living inside the Phnom Samkos Wildlife Sanctuary and Phnom Aural Wildlife Sanctuary, as part of the Cardamom Mountains Wildlife Sanctuaries Project. At the time of writing, Conservation International and the Forestry Administration have also

Table 1. Comparison of this project with the classic Integrated Conservation and Development Project model in Asia (data from Wells et al. 1999).

<table>
<thead>
<tr>
<th>Short-term (usually 3 years)</th>
<th>Long-term (10 years +)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak understanding of ecosystem</td>
<td>Founded on sound, if incomplete, ecological research</td>
</tr>
<tr>
<td>Variable understanding of local people</td>
<td>Founded on detailed socio-economic research</td>
</tr>
<tr>
<td>Externally designed by experts</td>
<td>Internally designed in participatory manner</td>
</tr>
<tr>
<td>‘Blueprints and log-frames’: solutions are prescribed and constrained by donor agencies</td>
<td>Adaptive: able to respond to new opportunities and challenges from month to month</td>
</tr>
<tr>
<td>Weak linkages between conservation and development</td>
<td>Linkages actively sought and encouraged (eg income from renewable forest products)</td>
</tr>
<tr>
<td>Large budget distorts local economies: eg ICDPs in Indonesia (N= 21):</td>
<td>Value for money. Modest budget is more in keeping with the local economy</td>
</tr>
<tr>
<td>Mean: $973,000 per project/year</td>
<td>$30,000-50,000/year</td>
</tr>
<tr>
<td>Mean: $5.58 per hectare/year</td>
<td>$0.18-0.29 per hectare/year</td>
</tr>
<tr>
<td>Technical input from short-term, highly paid consultants from overseas</td>
<td>Engage national organisations where possible, and experts based within the region who make repeated visits</td>
</tr>
<tr>
<td>Weak on government support</td>
<td>Strong government involvement (district, provincial, national)</td>
</tr>
<tr>
<td>Monitoring of project impact upon human livelihoods, but not biodiversity or environment</td>
<td>Monitoring of project impact upon human livelihoods and biodiversity and environment</td>
</tr>
<tr>
<td>Ignore other factors affecting biodiversity (ie assume local people are the only threat)</td>
<td>Directly tackling other factors (eg working with rangers to halt poaching by outsiders)</td>
</tr>
</tbody>
</table>
begun replicating the O’Som approach with two more communes in the Central Cardamom Mountains (Sarah Milne, pers. comm.). Several of these communes have small numbers of wild Siamese crocodiles in their vicinity, and the programme managers are already keen to ensure that their needs are incorporated.

**Project sustainability**

Will there still be Siamese crocodiles living around O’Som Commune in ten, twenty or a hundred years? Will the Commune continue to gain a better standard of living, without compromising the natural qualities of Veal Veng Marsh and other crucial areas for wildlife?

It is sobering to note that many Integrated Conservation and Development Projects (ICDPs) have failed, at least in Asia. A recent World Bank report on 21 ICDPs in Indonesia, for example, concluded that even after spending $130 million of foreign donor grants (in addition to substantial investments from the Government of Indonesia), hardly any could ‘realistically claim that biodiversity conservation has been or is likely to be significantly enhanced as a result of current or planned project activities’ (Wells *et al.* 1999)! Similar reports have emerged from Vietnam, where a number of serious design flaws were identified (Anon 2000).

Although the O’Som Community Conservation Project can point to measurable benefits (above), four years is not enough to prove whether this will be any more sustainable than the previous examples. Throughout every stage of project development, however, we have made every effort to avoid common design mistakes and made sure that the community feels a high level of project ownership. Table 1 summarises the main ways in which this project differs from some of its predecessors. We will continue to monitor the community and crocodiles every year in order to evaluate project impact and sustainability.

**Acknowledgements**

We thank the Director of Forestry Administration, Mr Ty Sokun, for his continuing approval of this project. This project has also benefited from the hard work and dedication of O’Som Commune and many Forestry Administration and Fauna and Flora International colleagues and consultants (in alphabetical order by family name): Aing Leang Heng, Ay Rothmony, Ian Baird, Helene Barnes, Liesje Birchenough, Laurence Carvalho, Ponn Chamroeun, Sengueun Chandy, Em Thol, Mark Elliott, Matt Fox, Ben Hammond, Hor Leng, Jeremy Holden, Jeremy Ironside, Kuy Tong, Barney Long, Oliver Maxwell, Frank Momberg, Oum Sony, Richard Paley, Sorn Piseth, Poeung Mora, Sam Han, Boyd Simpson, Sok Sokhoeun, Sok Vannaren, Steven Swan, Gail Thacker, Tan Thara, Tith Bora, and Hunter Weiler. The CEDAC team comprise Dr Yang Saing Koma, Sim Sameoun, Y Naron and Yi Kimthany.

We are also grateful to the Veal Veng District Governor and Pursat Provincial Governor, the Pursat Department of Agriculture, Department of Environment, and Department of Hydrology and Water Resources, CI-FA Cardamom Conservation Program, Seila, and the Community Wildlife Rangers Project. The research, conservation and livelihoods support activities were sponsored by the Association for Cultural Exchange, British Embassy, Canada Fund, Columbus Zoo and Aquarium, Conservation, Food and Health Foundation, Conservation International, Disney Wildlife Conservation Fund, Ellen Trout Zoo, The Heinrich Boell Foundation, Keidanren Nature Conservation Fund, McKnight Foundation, and Singapore Zoological Gardens. Last, but not least, we thank the IUCN/SSC Crocodile Specialist Group for technical support and encouragement.

**Literature**


Local People in Crocodilian Conservation - the African Context

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Abstract

Three species of crocodilian exist in sub-Saharan Africa together with 700 million people. Human populations are mostly rural and are growing rapidly. Wetland habitats are being degraded through settlement, agriculture and deforestation. There is a diversity of attitudes held rural African people towards crocodiles but this relationship is seldom a positive one. Most African countries have histories of pre-colonial, colonial and post-independence phases and all of these have contributed to the current state. All the species have been used for meat and/or skins at some point and other utilisation options for rural communities are limited. Recent work in DRC and Kenya illustrate the changes in crocodile populations, the use and abuse of these, the impact of human/crocodile conflict and the lack of effective regulation and technical capacity.

Introduction

Subject to likely future taxonomic revisions, Sub-Saharan Africa (south of approximately 15°N) and the Nile valley are occupied in suitable habitats by three species of crocodilians, the Nile crocodile *C.niloticus*, the African slender-snouted crocodile *C. cataphractus* and the West African dwarf crocodile *Osteolaemus tetraspis*. Each species has more or less specific habitat requirements, *C. niloticus* being a generalist that is hence most widespread, occurring in most aquatic habitats that have a suitable temperature regime. *C. cataphractus* and *O. tetraspis* are have more specific requirements for Equatorial swamp forest and riverine habitats. All the species play an ecologically important role as top predators and both in terms of individual body mass and biomass they are Africa’s largest predatory species. Our knowledge of the ecology of the two smaller species is limited and our understanding of the status, detailed distribution, population dynamics and threats to all the African crocodilians leaves much to be desired.

The human population of Africa is broadly concentrated in same area, avoiding the arid zones of the Sahara, the horn of Africa and the Namib and Kalahari deserts. There are relatively high densities of human population in the Ethiopian highlands, in Nigeria and neighbouring countries, around the African great lakes and in the Rift Valley, in some cases over 300 people per km².

There are 38 countries in Sub-Saharan Africa covering a total of 23 million km². Nearly 700 million people, giving an average density of 30 people per km², inhabit this area. Most importantly the human population is increasing rapidly with the median age being less than 18 years old and the population growth rate in the range of 2-4% per annum. There are at least 600 distinct ethnic groups many of which still follow indigenous animist and tribal beliefs. While Africa is rich in resources these are often poorly managed and for the benefit of minorities, such that the average GDP per capita for sub-Saharan Africa is many cases less than $US 1000 per year.

The conservation of crocodilians therefore has to operate subject to this framework of human requirements. This paper is intentionally descriptive and aims to focus on the issues and challenges of conserving a predator that today conflicts with human interests in an environment where the classical philosophies of preservation and conservation may have restricted impact and the effective management of wild crocodilians is limited.

Local People and Attitudes

The vast majority of Africans live in a rural situation and pursue subsistence pastoralism, agriculture, hunting and fishing. Their settlements are often constrained by access to permanent water, which is taken from rivers, streams, dams and lakes as underground water and/or piped water are infrequently found. Communities living near water bodies draw water directly using buckets and containers and normally bathe and wash clothing directly in the river or lake. All livestock are watered directly from the water body. Opportunities for cash income generation are limited. There is often limited access to primary education facilities and only a small proportion of children receive secondary
schooling. Similarly rural health centres provide only limited services and may be separated by considerable distances. Roads and communication infrastructure in such areas is mostly rudimentary. In such situations the activities of most people are directed at provision of food and water for daily existence. The wildlife occupying such rural areas may be hunted or trapped as a source of food or in some situations the community sells concessions for sport hunting, however wherever wildlife actually or potentially interferes with human activity through incidental attacks, crop raiding or predation these individual animals or the species as a whole is regarded as a “problem animal”. Many of the activities of rural Africans described above expose them to risks of conflict with Nile crocodiles.

With the difficulties of survival under these circumstances and the relatively low levels of education, it should not be surprising that many people have a narrow focus on issues pertinent to their survival. Where wildlife actually or potentially makes their life more difficult their first desire is to have this wildlife removed permanently. The concept of wildlife conservation is therefore something of a luxury unless living with wildlife can be shown to bring some simple and tangible benefit.

The attitudes of people in Africa towards crocodiles can be seen in three phases; pre-colonial, colonial and post-colonial. In the pre-colonial period, ie approximately pre-1900, there were significantly smaller human populations than exist today, communications were limited to word of mouth and all travel was on foot or by boat. It is apparent that local people were well aware of the presence of crocodiles and the danger that they sometimes posed. In areas where crocodiles were known to be aggressive (eg the Shire valley, Malawi) there are records of barriers being constructed and used to protect points for the collection of water. In other areas, for example along the Congo River, crocodiles were not apparently regarded as a threat at all.

In pre-colonial times there appears to have been a strong ritual and spiritual significance attached to crocodiles. To some extent this remains to the present day. For example, in some areas people believe that the spirits of their ancestors may reside in certain crocodiles. Some families and clans may identify a species of animal, including the Nile crocodile as their “totem”, in this case no clan member may harm or eat an animal of that species. In parts of West Africa trial by ordeal was used by tribal chiefs to judge guilt in people accused of various crimes, this included the crossing of crocodile “infested” waters by the accused. There is a widely held belief thatwitch doctors and witches can tame crocodiles and use them for their craft, in which case a crocodile attack may be the result of being cursed by the witchdoctor or an enemy who has hired the witchdoctor for this purpose. There are also various beliefs that some crocodile body parts have medicinal value and that the bile and the brain are extremely poisonous. Certain tribes are traditionally accustomed to eating crocodile meat and their eggs while others will not touch it.

In the colonial period, extending from approximately 1900 to 1960, there was an influx of missionaries, hunters, traders and administrators of western European origin. They provided the first written record of the existence of crocodile populations in Africa and of the relationship between local people and crocodiles. The colonials, with little knowledge of crocodiles and discovering that they sometimes attacked and ate humans, judged them to be vermin and “disgusting and ungentlemanly”. The colonial period was characterised by attempts to eradicate crocodiles, initially as vermin and later to facilitate the development of commercial fishing, particularly on the African Great Lakes, as it was believed that the abundance of crocodiles consumed so much fish as to render commercial fishing unviable. This later developed into hunting specifically for the skins to provide a ready and lucrative market in Europe. This hunting effectively collapsed in the 1950s as most accessible populations had been severely diminished.

The status of crocodiles and their conservation in the post-colonial period since the 1960s has been well documented in the scientific literature. The wildlife conservation authorities of newly independent African countries inherited a situation in which many crocodile populations were at low density and that compared to the large mammalian species such as elephants and rhinoceros, the conservation of crocodiles was a low priority. Since then there has been considerable growth of the human population occurring concurrently with a recovery in the populations of crocodiles. There has also been significant development of rural areas, facilitating habitation of new areas and improving communications such that the reporting of incidents of conflict with crocodiles is more frequent. Many of the spiritual aspects of the pre-colonial era have been retained. The efforts made by people in earlier times to protect themselves by consistent use of barriers etc appears to have been replaced by a modern reliance on assistance from the authorities to remove the crocodiles.

**Crocodiles and their Management - or the Lack of It**

The post-colonial era has also seen the development of sustainable use of wildlife as a means to provide rural people with the simple and tangible benefits referred to above in order to persuade them to conserve. In relation to crocodiles,
the process of ranching was first seen as a suitably robust means to achieve this through payment of a levy on all crocodile eggs collected in community land. Various other options with better returns but greater technical requirements have since been proposed. The demand of the market for extremely high quality skins and the narrow profit margin for producers has led the evolution of ranching/farming into a highly technical process that is now not well suited to community projects with limited funds and technical expertise. Ranching also has negligible impact on the population of crocodiles resident in an area.

The removal of crocodiles in the form of a harvest for the skins and meat can also be sustainable if properly managed. This can have the positive aspects of reducing the number of large crocodiles that are the cause of most conflict incidents and at the same time generating an income to the community from the sale of their skins and other products.

Human/crocodile conflict, the degradation of crocodile habitat as a result of human activity and the commercial trade in crocodile meat for urban human consumption are the most significant threats to crocodilian conservation for the current decade. All relate to the interaction between humans and crocodiles. All require professional management by national wildlife authorities.

In Africa there is a significant problem with professional management of crocodile issues by most of the national wildlife authorities. Such management requires both capacity and motivation. The capacity requires the provision of both suitable staff and equipment and training for knowledge and skills. The budgets of most national wildlife authorities simply do not provide for either.

In the absence of such management, the status and future of crocodile populations is unpredictable. Two recently investigated examples illustrate this.

At Lac Mai Ndome in west, central DRC, spotlight surveys over 66 km revealed only 8 Nile crocodiles, giving an estimate of density of 0.2 crocodiles/km of shoreline. This lake was reputed to have held a significant population up to the mid-1960s. Approximately 400 hunters, originating from Senegal and other West African countries reportedly occupied the area between 1968 and 1972, hunting intensively for the skins of Nile crocodiles. In the same area there is now a large “bushmeat” market at which the meat and eggs of *C. niloticus* are highly valued. It is suggested that the uncontrolled harvest has led to a situation now where the population is being held at a very depressed level by the continued occasional offtake of adults and eggs. There is also a significant trade (est. 5000/yr) in the same market of *O. tetraspis* for local consumption and to supply the markets in Kinshasa and Brazzaville.

By contrast, in the lower reaches of the Tana River in Kenya, under equally minimal management, the crocodile population appears to have grown. Spotlight surveys of 228 km gave an estimated density of crocodiles for the whole area of between 10 and 17 crocodiles/km, approximately 50% higher than estimates made between 1988 and 1995. This population is responsible for significant conflict with humans; there were 44 cases of death or major injury between January 2000 and August 2003, the majority of victims were under 20 years of age and most attacks occurred after 1500 h while the victim was engaged in washing clothes or bathing or collecting water.

The CSG needs to assist in addressing the problems of professional management referred to above with the aim of improving the status of Africa’s largest predator.
Using Crocodiles to Teach Taxonomy: A Web Based Approach for High School Science

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²Gladys Porter Zoo, 500 Ringgold Street, Brownsville, TX 78520-7998, USA
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Abstract

The Ellen Trout Zoo in Lufkin, Texas, USA, in partnership with Lufkin High School, has developed a laboratory/technology exercise that focuses on teaching the use of a dichotomous key. High school students in the state of Texas must pass the Texas Essential Knowledge and Skills (TEKS) test to graduate. The use of dichotomous keys is one of the skills tested in the science section of that test. It was determined that the eleven species of crocodilians housed at the Ellen Trout Zoo would be a good group to develop the exercise around because of the diversity of the collection and the conservation issues facing these reptiles. A general introduction to taxonomy begins the exercise with students identifying animals to class. Then using a series of photographs that exemplify the morphological characteristics that separate the eleven species housed at the zoo, students key out eleven “mystery crocodilians”. The exercise is to be posted on the zoo’s website. This will provide a distance learning experience to a variety of audiences, regardless of location.

Introduction

In the fall of 2003 the Ellen Trout Zoo, Lufkin, Texas, was contacted by Kristi Jones, a high school science teacher, to assist in the development of a laboratory manual exercise to teach the use of a dichotomous key. The manual was to be developed using local businesses and facilities to provide “real life” example of science concepts tested at the high school level. This project was part of a master’s degree program.

The State of Texas Education Agency requires that students be tested to evaluate students’ skills in a variety of areas, including science. Students are tested at grade level 8, 10 and 11. The concepts are outlined in the Texas Essential Knowledge and Skills objectives. In the section 8 Science concept states: “The student knows applications of taxonomy and can identify its limitations. The student is expected to:

(A) collect and classify organisms at several taxonomic levels such as species, phylum, and kingdom using dichotomous keys.”

With 11 species of crocodilians as part of our animal collection (Table 1), this was an opportunity to introduce students to these fascination and endangered reptiles.

<table>
<thead>
<tr>
<th>American Alligator</th>
<th>Alligator mississippiensis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese Alligator</td>
<td>Alligator sinensis</td>
</tr>
<tr>
<td>Spectacled Caiman</td>
<td>Caiman crocodilus</td>
</tr>
<tr>
<td>Dwarf Caiman</td>
<td>Paleosuchus palpebrosum</td>
</tr>
<tr>
<td>Smooth-fronted Caiman</td>
<td>Paleosuchus trigonatus</td>
</tr>
<tr>
<td>American Crocodile</td>
<td>Crocodylus acutus</td>
</tr>
<tr>
<td>Morelet’s Crocodile</td>
<td>Crocodylus moreletii</td>
</tr>
<tr>
<td>Mugger Crocodile</td>
<td>Crocodylus palustris</td>
</tr>
<tr>
<td>Cuban Crocodile</td>
<td>Crocodylus rhombofer</td>
</tr>
<tr>
<td>Siamese Crocodile</td>
<td>Crocodylus siamensis</td>
</tr>
<tr>
<td>West African Dwarf Crocodile</td>
<td>Osteolaemus tetraspis tetraspis</td>
</tr>
</tbody>
</table>
Methods

An introduction to taxonomy was written which included historical background information on the binomial nomenclature and Carl Linnaeus. Students are then asked to look at a series of photographs of zoo animals and classify them to the class level. Students then move from this general exercise to an explanation of a dichotomous key.

An in-house key was developed for the eleven species of crocodilians housed at the Ellen Trout Zoo (Appendix 1). The purpose of this key is to teach high school students and is not meant to be a definitive key on crocodilians. Existing keys to crocodilians were consulted to evaluate characteristics that are easily observed. (Brazaitis 2001; CITES 2000). Teachers are encouraged to bring classes to the zoo to observe animals first hand, but budget or scheduling restraints may prevent them from actually coming to the zoo. Therefore a set of photographs depicting each of the eleven species was developed. Basic morphological attributes of the species housed at the zoo were identified and digitally photographed. Characteristic morphological structures (ie nuchal scales, post-occipital scales and whorls) were outlined and labeled on the appropriate photographs. Three to five photographs of each species were taken. Photographs included profiles of the animals’ head, toes, and scation on back, sides, and tails to illustrate the components of the key. A “mystery number” was assigned to each species for organization of the photographs and a way to evaluate the student’s skill at following the key through to the correct scientific name of the crocodilian. To help insure that students actually follow the key, an answer key is not supplied in the exercise. Teachers must contact the zoo educator to get the answers and this also provides the zoo with feedback on who and how many teachers will be using the key.

The original format for the exercise was to be part of a laboratory manual to be distributed to teachers in Angelina County, Texas. The school districts in this county range from Lufkin Independent School District with an enrollment of 8200 students to Zavalla Independent School District with and enrollment of only 430 students and possess a range of resources. The project of developing a laboratory manual was abandoned when one of the teachers dropped out. It was then decided that the exercise would be reformatted to be placed on the zoo’s website (www.ellentroutzoo.com). This new format eliminated the printing costs, provided a technology component to the program and provided an access to a wider audience.

Results

Currently, the high school teacher who is working with the zoo is testing the key with her 10th grade students. Evaluation and adjustments will be completed in time for the 2004-2005 school year.

Plans are also being formulated to expand the program to include natural history of the crocodilians in the zoo’s animal collection. This will also outline conservation issues facing these reptiles.

Literature


Appendix 1. Key to the crocodilians of Ellen Trout Zoo

1A. Mandibular teeth (lower jaw) fit inside the maxillary (upper jaw) teeth and are hidden when the jaws are closed .......... 2 family Alligatoridae.

1B. Mandibular teeth fit between the maxillary teeth and remain visible when the jaws are closed ....3 family Crocodylidae.

2A. Not more than 6 large nuchal scales arranged in a cluster ..... 4 genus *Alligator*

2B. At least 8 large nuchal scales arranged in a cluster ..... 5.

4A. Eight longitudinal rows of large scutes; webs between toes; green iris; more than 22 teeth on one side of lower jaws ..... *Alligator mississippiensis.*

4B. Six longitudinal rows of large scutes; no webs between toes; brown iris; less than 22 teeth on one side of lower jaw ..... *Alligator sinensis.*

5A. No bony ridge connects the front corners of the eyes, brown iris ..... 6.

5B. Bony ridge connects the front corners of the eyes (like a bridge on glasses), green iris ..... *Caiman crocodilus.*

6A. Only one row of post occipital scales ..... *Paleosuchus trigonatus.*

6B. Two rows of post-occipital scales ..... *Paleosuchus palpebrosus.*

3A. Snout short (about as long as snout is broad); brown iris, upper eyelid is ossified and is smooth .... *Osteolaemus tetraspis.*

3B. Snout is one and one-half times the length of the skull at the front corner of the eyes; green iris; upper eyelid is wrinkled and partially ossified ..... 7.

7A. Large scales on sides are irregular in size and arrangement ..... 8.

7B. Large scales on side are uniform in arrangement ..... 9.

8A. Four large nuchal scales with two small scales along side and two behind the large ones ..... *Crocodileus acutus.*

8B. Six large nuchal scales ..... 10.

9A. On sides of the tail there are irregular, small scales between whorls and scales along sides of tail and there are no spots on the mandible ... *Crocodileus siamensis.*

9B. On sides of the tail there are no irregular, small scales between the whorls and scales along sides of tail and there are spots on the mandible ..... *Crocodileus rhombifer.*

10A. Nuchal scales are the same size ..... *Crocodileus palustris.*

10B. Nuchal scales are not the same size ..... *Crocodileus moreletti.*
Developing Crocodilian Education in Public Schools: Promoting Awareness and Conservation

Harold E. Nugent

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This presentation will, first, examine the theoretical role that each of three entities can play in developing environmental education in public schools. These three entities and their respective contributions are 1) the local community with its special needs determines the priority of content and approach, 2) the Crocodile Specialist Group provides the scientific knowledge, material, and field sites, and, 3) the State (and local) Department of Education contributes the appropriate formatting of curriculum. Two modes of presentation, interpretive and educational (cognitive), are then overviewed with the goal of integrating the modes while at the same time accommodating the four learning styles of the students. The second part of the presentation consists of a sampling from a model unit entitled “The Incredible Survivors: The American Alligator and the American Crocodiles.” This unit designed for use in public school will illustrate a variety of media as well as integrating the scientific knowledge with current theory and practice in teaching critical thinking. Such student-centered activities as activating competencies and categories, using universal intellectual strategies, creating superordinate and subordinate concepts, and infusing problem solving will be demonstrated. The presentation will conclude with a discussion of the use of this content and approach beyond the classroom. Environmental education resources such as Exploring the Oak Savanna, Cuba’s Societal Component, National Key Deer Refuge Manual, and the Florida Keys Environmental Story Resource and Teacher’s Manual will be highlighted. A number of handouts and resource bibliographies will be distributed. Sample environmental curriculum will be available after the presentation and at the Poster Sessions.
Devolving Crocodile Conservation to the Local Level: the Case of Philippine Crocodile Conservation in the Municipality of San Mariano, Northeast Luzon, the Philippines

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Abstract

A small and fragmented Philippine crocodile Crocodylus mindorensis population survives in the remote rivers and creeks of the municipality of San Mariano, Northeast Luzon. The local government unit has played a pivotal role in the in-situ conservation strategy for this critically endangered endemic crocodilian. Defying cultural prejudice, it has declared the Philippine crocodile as the flagship species of the municipality. Municipal ordinances were passed prohibiting the killing of crocodiles and establishing a municipal crocodile sanctuary. So far the results have been promising: people in San Mariano do no longer see crocodiles as dangerous pests but as something to be proud of. The purposively killing of crocodiles, the most important and direct threat for Philippine crocodiles, has virtually stopped. The Philippine crocodile conservation program in San Mariano appears to be a success story in the legislative efforts to devolve power and authority of the national agencies to the local level. However, the long-term effectiveness of this approach for crocodile conservation is still uncertain. In this paper we describe the challenges facing a local government that aims to protect crocodiles in remote areas characterized by poverty, insecure land tenure, violent insurgency, and a contemporary history of rapid resource depletion.

Introduction

The Philippine crocodile (Crocodylus mindorensis) is a small freshwater crocodylian endemic to the Philippines. Intensive commercial hunting, unsustainable fishing, and habitat loss have decimated the population below critical threshold levels throughout the Philippine archipelago (Ross and Alcala 1983; Ross 1998; van Weerd and van der Ploeg 2004). The Philippine crocodile is classified as Critically Endangered (Hilton-Taylor 2000).

Responding to this alarming situation, the national Philippine government established an ex-situ conservation program in 1987: the Palawan Wildlife Rescue and Conservation Center (PWRCC). The PWRCC is formerly known as the Crocodile Farming Institute (CFI). The Japanese International Co-operation Agency (JICA) provided financial and technical support to establish the crocodile farm from 1987 to 1994, amounting to a total of SUS1.5 million. Captive breeding was considered the only hope for survival of the species (Messel et al. 1992; Banks 2000). The PWRCC has successfully bred the Philippine crocodile in captivity but no crocodiles have been re-introduced to the wild. Negative community attitudes towards crocodiles and the absences of any form of effective protection of the species and its habitat make the re-introduction of C. mindorensis extremely difficult (Banks 2000).

The Department of Environment and Natural Resources (DENR) is the mandated government agency for environmental protection. The Protected Areas and Wildlife Bureau (PAWB), one of six bureaus under the cabinet secretary of the DENR, is tasked with the protection of the country’s wildlife, including its crocodiles. The DENR is located in Manila and decentralized to the 12 administrative regions, and subsequently to the Provincial Environment and Natural Resource Offices (PENRO), and the Community Environment and Natural Resource Offices (CENRO). The PAWB is decentralized to regional sub-offices, called Protected Area and Wildlife Sections (PAWS). Aside from proposing several wetlands as crocodile sanctuaries, the PAWB does not have an in-situ conservation program for the Philippine crocodile. Although there is no specific national legislation protecting crocodiles in the Philippines, there are several national policies that offer a legal framework for the protection and in-situ conservation of C. mindorensis (Box 1).

However, there are various problems that hamper the implementation of a national conservation program for the Philippine crocodile. The main act that would protect the species nationwide, the “wildlife act” (Republic Act No. 9147 of 2001, see box 1), is currently not being implemented because the accompanying Implementing Rules and
Box 1: A legal arsenal for Philippine crocodile conservation

A series of Presidential Declarations (PD), issued by President Ferdinand Ramos during the so-called Martial Law period (1972-1986), gives some legal protection to the critically endangered Philippine crocodile and its freshwater habitat:

a. PD No. 1152, the Philippine Environment Code, calls for a rational exploitation of threatened wildlife resources. Chapter II-Wildlife, Section 29 identifies measures for rational exploitation that include: (i) regulating the marketing of threatened wildlife resources; (ii) reviewing existing rules and regulations on exploitation and formulating guidelines for systematic and effective enforcement; and (iii) conserving threatened species of fauna, increasing their rate of reproduction, maintaining their original habitat, habitat manipulation, population control in relation to the carrying capacity of any given area, banning indiscriminate and destructive means of catching of hunting them” (Oposa 2002: p.13). Take note of the apparent internal discrepancies in the clauses. These are, however, outside the scope of this paper;

b. PD No. 2146 requires an Environmental Impact Statement (EIS) for all activities in areas “which constitute the habitat for any endangered species of indigenous Philippine wildlife” (Oposa 2002: p. 21);

c. PD No. 1067, the Water Code of the Philippines, identifies the basic legal principles related to the appropriation, control and conservation of freshwater resources. Article 51 specifies that “the banks of rivers and streams and the shores of the sea and lakes throughout the entire length and within a zone of […] twenty meters in agricultural areas, and forty in forest areas are subject to the easement of public use” (Oposa 2002: p. 437). Article 74 states that “swamps and marshes which are owned by the state and which have primary value for waterfowl and propagation of other wildlife purposes may be reserved and protected from drainage operation and development” (Oposa 2002: p. 439);

d. PD No. 705, the Revised Forestry Code of the Philippines, and subsequent amendments, redefined the use of, access to and control over public forests. Section 16 specifies that “strips of mangrove or swampland at least twenty meters wide, along shorelines facing oceans, lakes and other bodies of water, and strips of land at least 20 meters wide facing lakes, may not be classified as alienable and disposable land” (Oposa 2002: p. 84).

The People’s Power Revolution of 1996 created an atmosphere of radical policy reform in the field of natural resource management and environmental protection (Vitug 2000). The following national policies relevant for crocodile conservation were enacted after 1986:

a. Republic Act No. 7586, the National Integrated Protected Areas System (NIPAS) Act of 1992, defines the terms of establishing protected areas in the Philippines. Hunting of wildlife is prohibited in habitats of rare and endangered animals under NIPAS, except in some specific circumstances (for example for traditional or religious purposes of indigenous communities). A large part of San Mariano falls under the Northern Sierra Madre Natural Park, which is one of the 10 priority sites in the NIPAS Act (see below under Republic Act No. 9125).

b. Republic Act No. 9147, the Wildlife Resources Conservation and Protection Act of 2001, usually referred to as the “Wildlife Act” aims to: “(i) conserve and protect wildlife species and their habitats; (ii) regulate the collection and trade of wildlife; (iii) Pursue, with due regard to the national interest, the Philippine commitment to international conventions; (iv) initiate or support scientific studies on the conservation of biodiversity” (Oposa 2002, p.117). The Republic Act specifically mentions the jurisdiction of DENR over crocodiles and other wetland species; the Department of Agriculture (DA) on the other hand has jurisdiction over all declared aquatic critical habitats and all aquatic resources.

c. Republic Act No. 8485, otherwise known as the Animal Welfare Act of 1998, regulates the treatment of captive animals. The killing of crocodiles, the Act specifies, can only be done “through humane procedures” (Oposa 2002: p.171). No difference is made between C. porosus and C. mindorensis.

d. Republic Act No. 8550, the Philippines Fisheries Code of 1998, ensures the rational and sustainable development, management and conservation of the fishery and aquatic resources in Philippine waters and protects the right of local fisherfolk. Chapter 2, Section 11, mentions that the “Department shall declare closed seasons and take conservation measures for rare, threatened and endangered species in concurrence with concerned government agencies” (Oposa 2002: p. 385). Note that this Act is to be implemented by the Department of Agriculture (DA). All other Acts in this box fall under the jurisdiction of DENR. Also contrary to the other Acts presented here is the clear definition of terms provided in the Act. Endangered, rare and/or threatened species are defined as “ aquatic plants, animals […] in danger of extinction as provided for in the existing fishery laws, rules and regulations of the Protected Areas and Wildlife Bureau of the DENR and in CITES” (Oposa 2002: p. 380).

e. Republic Act No. 9125, the Northern Sierra Madre Natural Park Act of 2002, is of special importance for San Mariano. The forested areas of San Mariano were largely identified as strict protection zones in the general management plan of the NSMNP. A crocodile habitat management zone was also identified in San Mariano, which encompasses the watersheds of the Catalangan and Disulap rivers within the park (DENR 2001). However, most crocodiles in San Mariano are found outside the park and buffer zone boundaries.

Regulations (IRR) have not yet been accepted. The DENR is a huge bureaucratic organization plagued by budget deficits. There is as of now no national government funding available for Philippine crocodile conservation. Environmental law enforcement by the DENR is usually weak and sometimes corrupted. An overriding policy framework for Philippine wetlands is absent (DENR and UNEP 1997).
There are other possibilities to implement crocodile conservation activities. The Local Government Code of 1991 (Republic Act No 7160) devolves much decision power to local governments. It transforms local governments from mere administrators to managers of communities. They can adopt their own local legislation. Local governments can enter into agreements with NGOs and People Organisations (POs). Local governments can adopt their own natural resource utilization laws and can offer local protection to threatened species through municipal ordinances. The devolved function of government agencies, among them the DENR, provides the municipal authorities, in theory at least, with considerable influence over Philippine crocodile conservation.

A short history of crocodiles in San Mariano

The municipality of San Mariano covers an area of 1469.5 km² in the eastern part of Isabela Province. It consists of a small town, San Mariano, and 36 villages, locally called barangays, in the sloping foothills of the Northern Sierra Madre Mountains. Three main rivers dissect the municipality: the Catalangan River, the Disabungan River and the Pinacanuan de Ilagan River.

The Philippine crocodile used to be common in the wetlands of San Mariano. Early Spanish accounts talk about the “crocodile infested rivers” of the province of Isabela. The indigenous peoples of the area, the Agta and Kalinga, lived in low density in the foothills of the Sierra Madre. They depended heavily on the rivers and streams for fish, but had very limited impact on the crocodile population. These indigenous communities still have strong cultural taboos on eating crocodile meat, and in many cases attach supernatural powers to the animals. In 1896, the Spanish colonizers established an administrative center on the convergence of the Pinacanuan and Disabungan Rivers, and called it San Mariano. It marked a turning point in the political control of the area and the fate of the Philippine crocodile.

After the Philippine Revolution of 1898 and under the new colonial administration of the United States, San Mariano experienced an influx of Christian Ibanag migrants (Huigen 2004). This group claimed the best agricultural lands along the extensive riverbanks and flood plains for the cultivation of upland rice, root crops, vegetables and bananas. The Kalinga and the Agta were respectively assimilated or pushed further into the forests. Crocodiles were associated with the devil and regularly killed, but human population density was too low to severely threaten C. mindorensis: in 1939 there were 7046 people in San Mariano.

Large-scale commercial logging of the vast forests in the municipality began after the Second World War. With the construction of Maharlika highway in the 1960s, linking northern Luzon with Manila, logging corporations quickly expanded their operations to the Sierra Madre. During the logging boom from 1969 to 1992, 22,000 ha of primary dipterocarp forests were logged annually in the region. Large groups of impoverished immigrants from the densely populated Ilocos area followed the logging companies and settled in the region. As of today, the majority (53%) of the people in San Mariano are of Ilocano origin (Huigen 2004). The pioneers can still recall the days that crocodiles were widely distributed in San Mariano; in the 1960s people still regularly observed large crocodiles in the Pinacanuan and Disabungan Rivers. The frontier attitude of these days led to rapid and destructive resource extraction (de Groot 2003). Like everything else during those ‘years of plunder’ (Broad and Cavanagh 1993), crocodiles were mainly seen as a commodity. In the 1970s, commercial hunters from Mindanao systematically searched the river systems of the municipality killing crocodiles for hides (Oudejans 2001). The violent insurgency during the Martial Law Years (1976-1986) also had a negative effect on crocodile population. There are several cases in which members of the Armed Forces or of the communist New Peoples Army (NPA) killed crocodiles to safeguard the local people from these supposedly dangerous creatures or to provide food for isolated rebel camps. A widespread possession of firearms made crocodiles more vulnerable to humans.

After democracy was restored to the country by the People’s Power Revolution of 1986, the new constitution introduced major policy reforms. In response to the centralized and autocratic government of Marcos, when the small and well-connected elite in Manila profited from resource destruction, local governments were given more autonomy. Civil society blossomed, and a wide variety of environmental non-governmental organizations (NGOs) advocated environmental protection and rural development, a process that was also fuelled by renewed international attention (Van den Top and Persoon 2000; Vitug 2000). In San Mariano, several NGOs concentrated on the protection of the Northern Sierra Madre Natural Park that was established in 1997. These efforts were concentrated on the mountains and remaining high elevation forest. The plight of the Philippine crocodile, found in low elevation areas outside the park, was ignored, simply by the fact that nobody knew about its existence in the municipality. Social and economic changes continued to threaten these remnant crocodile populations. Dynamite, cyanide or electro fishing regularly killed crocodiles. Freshwater habitat was rapidly converted in agricultural lands fueled by a strong growing human population; in 2000 San Mariano had 40,995 inhabitants (Huigen 2004).
As a result, the crocodile population collapsed and only a very small and fragmented population of Philippine crocodiles survived in remote areas of the municipality. Inaccessibility and remoteness seem to have offered some form of protection to these crocodiles. In one locality, Disulap River, the presence of limestone cliffs and underwater caves provide excellent hiding places. More important, however, seems to be the presence of indigenous communities. In two localities, Dunoy Lake and Dinang Creek respectively, the Agta and Kalinga could have easily killed the Philippine crocodiles had they wished so. Traditional belief systems and resource use practices have prevented the killing of crocodiles. This is in stark contrast to the wetlands used and controlled by Ibanag or Ilocano farmers. The latter groups, like most people in the Philippines nowadays, regard crocodiles as a dangerous pest to be exterminated or as a delicious snack (Banks 2000).

**Crocodile conservation in San Mariano**

In March 1999, Mr. Samuel Francisco, a fisherman from the village of San Isidro, accidentally caught a Philippine crocodile hatchling in Disulap River. This accidental by-catch triggered crocodile surveys and conservation attention.

The Northern Sierra Madre Natural Park Conservation Project (NSMNP-CP), an integrated conservation and development project aimed at preserving the Northern Sierra Madre Natural Park, spearheaded the conservation activities for *C. mindorensis* in San Mariano. Surveys were carried out to determine the distribution and population size and structure of the crocodile population. Three breeding sites were identified: (a) Disulap River, (b) Dunoy Lake, and (c) Dinang Creek (van Weerd 2002) with a current (May 2004) population of 23 non-hatchling crocodiles. See Tarun et al. (these proceedings), for detailed information on Philippine crocodile distribution and population size in Northeast Luzon. After the phase-out of the NSMNP-CPD in 2002, crocodile conservation activities were continued by the CROC project, now an official Philippine NGO named Mabuwaya Foundation. Both projects relied heavily on the partnership with the Local Government Unit of San Mariano to implement crocodile conservation activities in this municipality. See Van Weerd (2002) and Van Weerd and Van der Ploeg (these proceedings) for an overview of crocodile conservation actions by both projects.

**Innovative approaches: the role of the local government unit**

A regional Philippine Crocodile Workshop that was held in San Mariano in May 2002 brought together different stakeholders to design a long-term conservation strategy for *C. mindorensis* in the Northern Sierra Madre. Crocodiles and people share the same wetland resources in San Mariano. All identified crocodile localities have people living nearby and in some cases, such as along Dinang Creek, all land surrounding the wetland has been converted into agricultural land. Resettling people from crocodile inhabited areas would not be accepted by the local people and local government in the Philippine sociopolitical context. A conventional conservation program, based on minimizing people-crocodile interactions and complete protection of crocodile habitat, is therefore not a possibility. Instead, an in-situ conservation approach was designed to address the direct threats facing the wild populations: (a) hunting for fear, food or fun, (b) the use of unsustainable and illegal fishing methods, and (c) loss of breeding and basking sites due to agricultural encroachment. The strategy focuses on the establishment and management of crocodile sanctuaries with the consent and cooperation of local people. Through a negotiation process with the local community, in the form of public consultations, specific management terms are defined that mitigate adverse effects of crocodile conservation on rural livelihoods - and vice versa. A community protection group (Bantay Sanktuwaryo), composed of local people would monitor the sanctuary and enforce its rules and regulations (van Weerd and General 2003). This people-first, or community-based, approach fits neatly in the national conservation rhetoric of the DENR, of the national government and of civil society in general after the People’s Power Revolution of 1986.

**Disulap River crocodile sanctuary**

On 7 September 2001, the municipal council of San Mariano approved municipal ordinance No 01-17, declaring the upper 10 km of Disulap River a municipal Philippine crocodile sanctuary. Public consultation meetings with the local government and the community had preceded the proclamation of the protected area. During these meetings it was tried to balance conservation goals with the developmental needs of the community. The boundaries of the sanctuary were negotiated upon and it was decided to limit fishing, hunting and agricultural activities in the sanctuary. The issue drawing most discussion was the establishment of a buffer zone on both sides of the river. Here, no agricultural activities would be allowed in order to restore crocodile habitat, protect the riverbanks from erosion, and minimize disturbance and human-crocodile interactions. After negotiations, a 10 m buffer zone was proposed and unanimously supported by the local people. Note that according to the Water Code of the Philippines (PD No. 1067, see box 1), a 20 m strip along all water bodies is supposed to be “subject to the easement of public use”. This code is
not being enforced at all throughout the country and very few people are aware of its existence. It illustrates the difficulty the national government has in implementing its own laws. The communities near Disulap River did not accept a 20 m buffer-zone and since we depend heavily on community support we decided to settle with 10 m.

The regulations of the sanctuary include: (1) no hunting or disturbing crocodiles and other wildlife, (2) no destructive fishing methods, (3) no cultivation and infrastructure development in the buffer-zone (4) in the buffer-zone: no deforestation and in currently cultivated areas reforestation has to take place, and (5) nesting areas can be closed for entry.

The municipal council of San Mariano also approved the following ordinances:

1. Municipal Ordinance No. 1999-025, prohibiting the collection and annihilation of the Philippine crocodiles in the municipality.
2. Municipal Ordinance No. 2000-002 declaring the Philippine crocodile as the flagship species of the municipality.

**Dinang Creek crocodile sanctuary**

The declaration of a second sanctuary, Dinang Creek, is currently being prepared. Several community consultations were held and Dinang Creek proves to be more difficult than Disulap River. The community is asking for tangible benefits from crocodile conservation and does not settle with arguments of intrinsic value, pride, the role of crocodiles in maintaining healthy ecosystems and wetland conservation in general. One of the main issues in Dinang Creek is land ownership. None of the farmers cultivating the area surrounding the creek has an official land title. Declaring a crocodile sanctuary with a buffer-zone which would include some currently cultivated land is seen as “land grabbing”. Land grabbing: acquiring a title over land which has been cultivated by somebody else (usually by wealthy outsiders who have the right political connections), is a serious problem in the Philippines that is heavily opposed by remote farming communities who usually can not do anything about it if it happens. In these communities, there is considerable support for communist rebels, the NPA, who oppose land grabbing with violence.

We therefore had to look into possibilities to provide land titles for the farmers along Dinang Creek first. We supported a land survey which has been carried out by the DENR and a land possession map has been prepared, a prerequisite to acquire titles. The application process for titles has started. Supporting the acquisition of land titles not only creates goodwill and fair land distribution. Farmers who own the land they cultivate are much more likely to invest in it. Currently, corn is the main crop cultivated along Dinang Creek that requires considerable inputs in the form of fertilizer and pesticides/insecticides which eventually end up in the creek. Deforestation to create more Cornfields adds to erosion. Farmers in San Mariano are very much willing to shift to agro-forestry, a form of agriculture that increases the farmer’s income and which is much more environmentally friendly. However no farmer is going to invest in such a long-term project if ownership over his land is not secure.

To further solicit community support, four wells have been built at strategic locations along the creek. All water needed by the community was being taken from the creek. These wells will minimize people-crocodile interactions, will provide clean drinking water and will minimize pollution of the creek with washing detergents. The wells will have painted crocodiles on them, reminding users everyday of the fact that it is there because of the crocodiles. The community has agreed with crocodile sanctuary establishment. Once land titles have been awarded the municipal council will propose a new ordinance declaring Dinang Creek the second Philippine crocodile sanctuary in the municipality.

The declaration of Dinang Creek as crocodile sanctuary is a partnership between the Mabuwaya Foundation and the municipality of San Mariano. The consultations were carried out by municipal representatives and staff from the NGO. Costs of the activities are shared as well. Rural development (the main goal of the municipality) and crocodile conservation (the main goal of the Mabuwaya Foundation) can thus be achieved in an integrated fashion.

**The Narra Project**

A similar project is undertaken by a multi-partnership of the municipality of San Mariano, WWF Philippines, the People’s Organization of the village of San Isidro and the Mabuwaya Foundation. The Native Advocacy for Rural Reconstruction and Agroforestry (NARRA) Project won a small grant from the Worldbank in December 2003 and aims to reforest denuded areas along crocodile habitat in San Isidro. Reforestation will be done with native trees of which seedlings will be collected in nearby remaining forest. In addition, native fruit trees will be planted which will
benefit the local community within 5 years. The local government provides logistical support and will construct a farm to market road. WWF and the Mabuwaya Foundation deliver technical support and some additional funding. The People’s Organization, which is the main beneficiary of the project, will provide labor. This simple and inexpensive project benefits both the local community and the crocodiles in nearby Dunoy Lake and Disulap River. Perhaps most importantly it shows local communities in a tangible way that there are benefits connected to crocodile conservation: the Worldbank provided the grant because crocodile conservation is one of the objectives of the project.

Issues

Major issues that remain to threaten the recovery of crocodiles in San Mariano are:

Law enforcement: Not everybody is respecting the local ordinances that protect the Philippine crocodile in San Mariano and the rules and regulations of the crocodile sanctuary. Not everybody is aware of these ordinances and some people simply do not care. Law enforcement is weak. San Mariano has only 24 policemen and these are mainly active in population centers, not along the 10 km Disulap River crocodile sanctuary or in other remote parts of the municipality. Crocodile protection by DENR personnel is hampered by the lack of operational budget, confusion about legislation protecting the crocodiles, a lack of knowledge and awareness among DENR personnel regarding crocodiles (see Van Weerd and Van der Ploeg, these proceedings) and the lack of directions from higher up regarding crocodile protection. A possible solution is the creation of para-legal community protection groups (Bantay Sanktuwaryo). These groups have to undergo a basic training in law enforcement and have to be accredited by the DENR to become official. A community that is empowered to protect its own natural resources from abuse by outsiders is more likely to act on this than unmotivated or incapacitated national law enforcers. Awareness raising campaigns have to ensure that everybody within the community itself is convinced of the need to protect crocodiles and wetlands. Difficulties arise if there are still community members who continue illegal activities such as dynamite fishing or killing of crocodiles, and if the local protection group would not act on this. In that case a national law enforcement agency, police or DENR, would still have to be called in.

Tenurial security and unsustainable land use practices: San Mariano is very much an “open access” municipality. There is little control on land use and on the creation of new cultivated areas. Immigration from land seeking farmers from other provinces, nowadays mainly from Ifugao Province, continues. These settlers look for areas not yet occupied and generally practice slash and burn farming in the “frontier” area, the strip of land between the intensively cultivated and usually titled lands near San Mariano town and the steep forested slopes of the Northern Sierra Madre. The permanent crocodile localities in San Mariano are found in this frontier area as well. Farmers in this area do not officially possess the land they cultivate, the process to get land titled, or to obtain stewardship over lands that are officially classified as forest land, is bureaucratic and expensive. They therefore do also not invest in a shift to more sustainable and environmentally friendly farming such as agro-forestry. Another issue is that these generally very poor farmers would not have the means to do so would they wish to. The LGU is assisting in land titling and in the shift to sustainable land use, among others through trainings and technical assistance. Funding is limited though and the lack of tenurial security and the use of unsustainable land use practices remains a threat to crocodiles, the environment in general and the economic prosperity of frontier farmers. Limiting immigration is a very difficult issue to discuss in the Philippines but is certainly needed to prevent further degradation of the frontier area and crocodile habitats.

Inadequate national support: All LGUs in the Philippines receive national funding, the so-called Internal Revenue Allotment (IRA) and collect municipal taxes. Crocodile conservation activities should normally be funded and implemented by the DENR but as mentioned before, there is no government budget for this. The LGU is bound to rules on budget items and cannot spend large amounts on crocodile conservation.

Discussion

The devolution of powers from the National Government to the Local Government Unit, formalized in the Local Government Code of 1991, offers an excellent opportunity for effective crocodile conservation in the Philippines in the absence of a sound national government crocodile conservation program. Local governments can adopt their own municipal legislation protecting crocodiles and crocodile habitat. The crocodile conservation program in San Mariano, a partnership between the local government and NGOs, has led to promising results: the number of crocodiles killed in the municipality has decreased from 13 in 1998 to 1-3 per year since crocodiles became locally protected in 2000. The number of non-hatching crocodiles has increased from 12 in 2000 to 31 in 2003. Unfortunately, in 2004 only 23 crocodiles were counted, the decrease is possibly attributable to a strong typhoon that hit San Mariano in
July 2003 causing massive flashfloods. Disulap River has been declared a municipal crocodile sanctuary, the first real protected area for the Philippine crocodile in the country. Several issues remain, the most important being the lack of law enforcement and the widespread occurrence of unsustainable land use practices. We believe that in upland areas of the Philippines, where poor farmers and crocodiles share the same area, only integrated conservation and development (ICD) offers prospects for successful crocodile conservation. Creating tangible benefits from crocodile conservation to local communities is of great importance to win and sustain local support. Partnerships of local governments, NGOs and local communities can lead to inexpensive, effective ICD programs that benefit both crocodiles and people.

Acknowledgements

The Northern Sierra Madre Natural Park-Conservation Project was implemented from 1996-2002 by Plan International with funding from the Netherlands Government. The CROC Project is being implemented with a Grant from the British Petroleum Conservation Programme. BP also kindly provided budget for MvW to attend the CSG meeting in Darwin. Chris Banks of Melbourne Zoo made it possible for JM to attend the meeting. The Mabuwaya Foundation is hosted by the Cagayan Valley Programme on Environment and Development. We thank Mayor Jesus Miranda of San Mariano for his brave vision of a prosperous San Mariano that is also home for the Philippine crocodile. We thank Bernard Tarun, Jessie Guerrero, Dominic Rodriguez and Sammy Telan for their hard work and dedication for the people and crocodiles of San Mariano.

Literature


Proposal for the Sustainable Use of the Spectacled Caiman (Caiman yacare) in Indigenous Lands of the Bolivian Amazonia

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Abstract

Population evaluations of the Spectacled Caiman (Caiman yacare) were carried out between 1999 and 2000 in the Tacana Indigenous Land, in the Beni River basin (Bolivian Amazonia). The relative abundance of the Caiman was determined around five communities using night counts. The population density ranged from 2.03 to 123.78 individuals/km of shore, and an overall population structure of Class IV individuals (≥180 cm Total Length) of 25.6% was determined. These population characteristics suggest that sustainable use through annual harvests is possible for this region. Participative community workshops in 2003 enabled a community management program that incorporates aspects of fair benefit distribution (among communities, supra-communal organization, and direct harvesters of the resource), communal organization (associations of caiman managers), control of the evaluations and harvests, and commercialization of the resource in the national market. This proposal presents an alternative for managing this resource that promotes greater administrative transparency, and promises increased benefits for the direct harvesters. This management model can also contribute to the process of improving the National Program for Spectacled Caiman, developed by the Ministry of Sustainable Development, to achieve a true sustainable use of the species. Nevertheless, internal control mechanisms and the harvest by people from outside the indigenous land require further discussion.

Introduction

In Bolivia, the pilot program for sustainable use of the Spectacled Caiman (Caiman yacare) started in 1995 with the project “A Programme for the Sustainable Use and Management of Caiman in Bolivia” (King and Godshalk 1997; Godshalk 1994). In 1997, this program promulgated the “Regulation for the Conservation and Use of the Caiman (C. yacare)” for Santa Cruz and Beni Departments. This same year the experimental phase of Caiman Management Plans was developed and applied at cattle ranches in the Beni Department.

Once concluded the experimental phase and incorporated the modifications, in 2000 the new “Regulation for the Conservation and Use of the Caiman” in ecological regions established by Ravenstein (2000) of CESO/SACO - Canada started. In 2002, a new evaluation of the Program was conducted by adjusting the regulation that is working currently.

Through this process, since June 2000, the Wildlife Conservation Society (WCS) and the Indigenous Council of the Tacana People (CIPTA) have been working together to formulate and to implement a Strategy for Sustainable Development in the Tacana Indigenous Land using the Management of the Natural Resources, and structured through a zoning based on the current and potential use of the communities, expressing their own perspective of how to use the Indigenous land.

Starting from the verification of the necessity of developing initiatives of management of the natural resources and the new Strategy, in 2000, WCS and CIPTA agreed to support a thesis for the evaluation of the populations of Spectacled Caiman in the Tacana Indigenous Land. During the first evaluation of the water bodies in the communities of the Ixiamas region, no population of Caimans was found for harvest. However, during the 2001 evaluation in which the study was extended to the communities found along the Beni River, various populations of Caimans with a good population size were found and were considered to be able to be harvested in a sustainable way (Ríos 2003).

On the other hand, in 2002, the Prefecture of the Department of La Paz began the process of legal harvest of caimans and evaluated the population status of the Spectacled Caiman in the northern part of the Department. Two of the
areas evaluated were Tacana communities located along the Beni River, inside the Tacana Indigenous Land.

By virtue of all the efforts taken, it was considered convenient to establish a process of sustainable use of Caimans in the Tacana Indigenous Land, based on the scientific studies and under a regulatory system and communal and supra-communal controls. These controls should work with the aid of the competent authority, which are organized at the community level and assumes specific responsibilities for the conservation and the commercial use of the Caiman. The communities are constituted in juridical body with obligations according to law and at the same time are the direct beneficiaries without midlemen. This can be achieved with the support of the CIPTA and the technical and scientific advices of the WCS-Bolivia.

Study Area

The project will be developed inside the Tacana Indigenous Land, which is found in the Abel Iturralde Province at the north of the La Paz Department. The Tacana Indigenous Land has a requested extension of 769,891 ha (Ríos 2003), of which 325,327 ha have been entitled up to the date (Fig. 1).

![Figure 1. Map of the Tacana Indigenous Land, Provincia Iturralde, Department of La Paz.](image)

In accordance with Ríos (2003), the area where Caiman populations have been recorded with possibilities of commercial use is the east part of the Tacana Indigenous Land and is located in the canton of San Buenaventura (toward the east of the Tacana territory).

This area belongs to the Amazon basin, inside of the sub-basin of the River Beni, and presents periodic floods by the overflow of the local rivers, which defines an ecosystem of flooded plains (Ríos 2003).

The watercourses of this region are originated from the Andean mountains or from savanna, which influences their chemical composition and associate biota. The river with the biggest flow in the area is the Beni, which has an Andean origin. There are also many meanders in the region (Ríos 2003).
A humid tropical climate is found with a short period of drought in this area. A rainy season lasts from November to May and dry season lasts from June to October. The annual precipitation is 2500 mm; however, considerable fluctuations of the annual precipitation are found from year to year (Ríos 2003).

The average temperature is 27°C with a reduced seasonal and daily temperature variation, except during the cold fronts or “surasos”, which cause a considerable decrease in the temperature and are frequent during the dry season (Ríos 2003).

The population found in the area of the pilot project is mostly of the Tacana ethnic, but members of other ethnicities also exist. In the area ten communities are found in the alluvial plain along the Beni River. These communities have a communal area, and an area of use of natural resources (Ríos 2003).

**Methods**

For this implementation phase, the thesis by Ríos (2003) was used as baseline. This document presents a list of communities in the Tacana Indigenous Land, where exhaustive evaluation of the abundance and population structure of the Caiman in the different water bodies was conducted. The communities selected for this study were those where the populations of the Caiman could be used for the commercial purpose. These were the communities of Carmen del Emoro, San Antonio de Tequeje, and Cachichira, all of which are found along the Beni River.

The information provided by Ríos (2003) was supplemented with some censuses conducted at the communities of Villa Fátima and Esperanza de Enapurera, by the Prefecture of La Paz in 2002, which are found in the report “Study of Zoning and Evaluation of the Caiman Populations (Caiman yacare) in the Department of La Paz”.

To calculate the abundance of Caimans, the index of abundance was used for water body (lagoons, lakes, rivers, and streams) provided by Ríos (2003) and Prefecture of La Paz (2002). If both studies evaluated the same water body, the average of the index of abundance was calculated. Later the total perimeter of the water body was calculated using ARC VIEW GIS 3.2. Once estimated the total perimeter, the number of Caimans per km of riverbank was projected.

**Results**

The population size and age structure at the area of each community is reported in Tables 1-5. A total population of 9297 caimans was found, with an overall population structure of Class IV individuals (≥180 cm Total Length) of 25.6%. According to Bolivian law, with this data, it would be possible to calculate a harvest quota of 427 individuals.

<table>
<thead>
<tr>
<th>Water Body</th>
<th>Density (per km of shore)</th>
<th>Perimeter (km)</th>
<th>Estimated Population Size</th>
<th>Proportion of Class IV</th>
<th>No. of Class IV Indiv.</th>
<th>Harvest Quota Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arroyo Undumo</td>
<td>14.97</td>
<td>25.0</td>
<td>374.25</td>
<td>22.73</td>
<td>85.07</td>
<td>21</td>
</tr>
<tr>
<td>Laguna Japón</td>
<td>51.66</td>
<td>13.8</td>
<td>712.91</td>
<td>7.21</td>
<td>51.40</td>
<td>13</td>
</tr>
<tr>
<td>Lago Barrientos</td>
<td>76.32</td>
<td>6.0</td>
<td>457.92</td>
<td>8.34</td>
<td>38.19</td>
<td>10</td>
</tr>
<tr>
<td>Lago Juan Carlos</td>
<td>65.79</td>
<td>11.4</td>
<td>750.01</td>
<td>7.32</td>
<td>54.90</td>
<td>14</td>
</tr>
<tr>
<td>Laguna Bbosal</td>
<td>44.97</td>
<td>8.4</td>
<td>377.75</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Laguna Tacuaraul</td>
<td>37.04</td>
<td>12.5</td>
<td>463.0</td>
<td>23.26</td>
<td>107.69</td>
<td>27</td>
</tr>
<tr>
<td>Lago San Pedro</td>
<td>7.0</td>
<td>17.9</td>
<td>125.30</td>
<td>16.67</td>
<td>20.89</td>
<td>5</td>
</tr>
<tr>
<td>Laguna Sicuri</td>
<td>20.32</td>
<td>7.5</td>
<td>152.36</td>
<td>25.0</td>
<td>38.09</td>
<td>10</td>
</tr>
<tr>
<td>Río Beni (Sector 1)</td>
<td>2.03</td>
<td>46.1</td>
<td>93.58</td>
<td>33.33</td>
<td>31.19</td>
<td>8</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>3507.08</td>
<td></td>
<td>110</td>
<td></td>
</tr>
</tbody>
</table>

**Management Plan**

The general objective of the Management Plan proposed for the “Sustainable use and management of the Caiman (Caiman yacare) in the Tacana Indigenous Land, Iturralde Province, Department of La Paz”, is that the communities of the Tacana Indigenous Land will be able to realize a sustainable use of the Caiman (Caiman yacare) with larger environmental, economic, and community benefits (Aparicio 2003).
Table 2. The population size and age structure of Spectacled Caimans at the community of San Antonio del Tequeje.

<table>
<thead>
<tr>
<th>Water Body</th>
<th>Density (per km of shore)</th>
<th>Perimeter (km)</th>
<th>Estimated Population Size</th>
<th>Proportion of Class IV</th>
<th>No. of Class IV Indiv.</th>
<th>Harvest Quota Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arroyo Tequeje</td>
<td>18.12</td>
<td>25.0</td>
<td>453.0</td>
<td>18.84</td>
<td>85.35</td>
<td>21</td>
</tr>
<tr>
<td>Lago Flojo</td>
<td>55.2</td>
<td>15.8</td>
<td>872.16</td>
<td>23.08</td>
<td>201.29</td>
<td>50</td>
</tr>
<tr>
<td>Laguna Mití</td>
<td>50.22</td>
<td>4.2</td>
<td>211.93</td>
<td>24.24</td>
<td>51.37</td>
<td>13</td>
</tr>
<tr>
<td>Laguna Supa</td>
<td>13.65</td>
<td>4.73</td>
<td>64.56</td>
<td>21.28</td>
<td>13.74</td>
<td>3</td>
</tr>
<tr>
<td>Río Beni (Sector 2)</td>
<td>5.72</td>
<td>37.7</td>
<td>215.64</td>
<td>20.75</td>
<td>44.75</td>
<td>11</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>1817.30</td>
<td></td>
<td></td>
<td>98</td>
</tr>
</tbody>
</table>

Table 3. The population size and age structure of Spectacled Caimans at the community of Esperanza de Enapurera.

<table>
<thead>
<tr>
<th>Water Body</th>
<th>Density (per km of shore)</th>
<th>Perimeter (km)</th>
<th>Estimated Population Size</th>
<th>Proportion of Class IV</th>
<th>No. of Class IV Indiv.</th>
<th>Harvest Quota Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lago Corpus</td>
<td>123.78</td>
<td>5.6</td>
<td>77.17</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lago Redondo</td>
<td>12.32</td>
<td>9.4</td>
<td>115.81</td>
<td>35.72</td>
<td>41.37</td>
<td>10</td>
</tr>
<tr>
<td>Río Beni (Sector 3)</td>
<td>3.88</td>
<td>41.9</td>
<td>162.57</td>
<td>27.04</td>
<td>43.96</td>
<td>11</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>355.55</td>
<td></td>
<td></td>
<td>21</td>
</tr>
</tbody>
</table>

Table 4. The population size and age structure of Spectacled Caimans at the community of Cachichira.

<table>
<thead>
<tr>
<th>Water Body</th>
<th>Density (per km of shore)</th>
<th>Perimeter (km)</th>
<th>Estimated Population Size</th>
<th>Proportion of Class IV</th>
<th>No. of Class IV Indiv.</th>
<th>Harvest Quota Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laguna Moa</td>
<td>24.39</td>
<td>41.8</td>
<td>1019.50</td>
<td>27.56</td>
<td>280.97</td>
<td>70</td>
</tr>
<tr>
<td>Laguna Colorada</td>
<td>15.22</td>
<td>10.8</td>
<td>164.38</td>
<td>21.11</td>
<td>34.70</td>
<td>9</td>
</tr>
<tr>
<td>Laguna Majal</td>
<td>25.39</td>
<td>6.9</td>
<td>175.19</td>
<td>36.61</td>
<td>64.14</td>
<td>16</td>
</tr>
<tr>
<td>Laguna 3 Hamacas I</td>
<td>14.20</td>
<td>0.9</td>
<td>14.06</td>
<td>63.64</td>
<td>8.95</td>
<td>2</td>
</tr>
<tr>
<td>Laguna 3 Hamacas II</td>
<td>33.82</td>
<td>4.3</td>
<td>145.43</td>
<td>41.57</td>
<td>60.45</td>
<td>15</td>
</tr>
<tr>
<td>Laguna 3 Hamacas III</td>
<td>27.37</td>
<td>2.3</td>
<td>62.95</td>
<td>40.82</td>
<td>25.70</td>
<td>6</td>
</tr>
<tr>
<td>Laguna Sayuba</td>
<td>20.61</td>
<td>12.06</td>
<td>248.56</td>
<td>36.90</td>
<td>91.72</td>
<td>22</td>
</tr>
<tr>
<td>Río Beni (Sector 5)</td>
<td>3.88</td>
<td>41.9</td>
<td>162.57</td>
<td>27.04</td>
<td>43.96</td>
<td>11</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>1992.63</td>
<td></td>
<td></td>
<td>151</td>
</tr>
</tbody>
</table>

Table 5. The population size and age structure of Spectacled Caimans at the community of Villa Fátima. * These three lagoons are connected in the same system, so the results obtained from Lago Media Luna were extrapolated to Lago Tarene and Lago Nato.

<table>
<thead>
<tr>
<th>Water Body</th>
<th>Density (per km of shore)</th>
<th>Perimeter (km)</th>
<th>Estimated Population Size</th>
<th>Proportion of Class IV</th>
<th>No. of Class IV Indiv.</th>
<th>Harvest Quota Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arroyo Tarene</td>
<td>39.78</td>
<td>25.0</td>
<td>994.50</td>
<td>5.0</td>
<td>49.73</td>
<td>12</td>
</tr>
<tr>
<td>Laguna Palizada</td>
<td>3.57</td>
<td>5.0</td>
<td>17.99</td>
<td>50.0</td>
<td>9.0</td>
<td>2</td>
</tr>
<tr>
<td>Lago Media Luna</td>
<td>20.47</td>
<td>7.3</td>
<td>149.64 *</td>
<td>22.43</td>
<td>33.56</td>
<td>8</td>
</tr>
<tr>
<td>Lago Tarene</td>
<td>20.47</td>
<td>7.3</td>
<td>149.64 *</td>
<td>22.43</td>
<td>33.56</td>
<td>8</td>
</tr>
<tr>
<td>Lago Nato</td>
<td>20.47</td>
<td>7.3</td>
<td>149.64 *</td>
<td>22.43</td>
<td>33.56</td>
<td>8</td>
</tr>
<tr>
<td>Río Beni (Sector 4)</td>
<td>3.88</td>
<td>41.9</td>
<td>162.57</td>
<td>27.04</td>
<td>43.96</td>
<td>11</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>1623.97</td>
<td></td>
<td></td>
<td>49</td>
</tr>
</tbody>
</table>

The specific objectives are:

- Commercialize Caimans through the management plan that guarantees their long term availability and productivity.
- Strengthen the capacity of administration of the communities involved in the management of Caimans.
- Improve the quality of life of the families through the increment of their economic revenues.
- Foment the understanding and appreciation for Caimans at the community level through the participation in the management and the education.
The Management Plan presents five programs and seven sub programs with activities that should be developed in two phases (Aparicio 2003). The first phase, during two months in the 2003, is the implementation of the administration and is restricted to develop the Management Program and especially the sub-programs of harvest of Caimans and communal commercialization of the Caimans - distribution of benefits, and the control Program and communal protection, with the sub program of communal control of the process of the harvest. The second phase will have a two-year-duration (2004-2005), when all the programs and sub programs proposed in the Management Plan will be carried out (Aparicio 2003). All these programs are shortly described below:

1. Management Program

This program implies that the species will be subjected to the decisions and manipulations of the managers. To achieve this, it is important to combine investigation and harvest.

1.1. Sub-Program of Population Evaluation of the “Caiman”

For the implementation of the program during the pilot phase, between October and November, 2003, the information about population abundance (Prefecture of La Paz 2002; Ríos 2003) was used. However, for the next administrations new population evaluations should be carried out in the five communities involved in the Program to establish the annual harvest quota. For the development of this Sub-Program, technical personnel trained in each community will be required to carry out the evaluations and to guarantee the good field data.

The evaluations should be carried out according to the established schedule. Starting from the 2004 administration, it is expected to extend the harvest area with the objective of increasing the annual quota for each community. The objectives of this Sub-Program are:

- Evaluate the abundance and the age structure of the populations of Caimans annually in the harvest areas of each community.
- Establish whether the population of Caimans of each community should or not be subject to harvest for the year of the evaluation.
- Assign the harvest quota of Caimans for each community under management.
- Increase every year the number of water bodies subject to the evaluation of Caimans populations to determine their harvest potentiality.

1.2. Sub-Program of Harvest of “Caimans”

The harvest of wildlife is established in the Strategy of Sustainable Development of the Tacana Indigenous Land, respecting its zoning and based on the agreement with the five communities (Carmen de Emero, San Antonio de Tequeje, Esperanza de Enapure, Villa Fátima, and Cachichira), which have expressed their interest of harvesting Caimans legally at the meetings organized in these communities in August 2003.

An appropriate use of Caimans will provide multiple benefits to the local residents; however, it is necessary to implement this Sub-Program in agreement with the effective normative to guarantee the sustainability of this benefit and to maintain the viable population of the species in the area. The distribution of the harvest quota inside the community will be established in a community meeting organized by its authorities. The objectives of this Sub-Program are:

- Achieve a sustainable harvest of Caimans.
- Achieve an efficient administration of the harvest process by the communities.

1.3. Sub-Program of Commercialization of the Caiman at a Community Level and Distribution of Benefits

One of the biggest problems that the native populations and rural communities face on commercializing their wildlife is their poverty, which could cause the overexploitation of wildlife to get immediate economic benefits. To avoid the overexploitation, it is necessary that the local population decides to be a part of the management programs and that they know that the benefits will not come immediately. It is essential that the local inhabitants will be the main beneficiaries of the economic values generated by the management of wildlife, because this can motivate them to use this resource in a sustainable way, guaranteeing their
conservation. The process of commercialization should be transparent and the community itself should be inspector of the commercialization. This will guarantee the fair and equal distribution of the benefits and will guarantee the continuity of the program. The objectives of this Sub-Program are:

- Increase the family income in the communities with committing the conservation of the resource.
- The communities that harvest Caimans should conduct a fair and equal distribution of the benefits.
- The communities involved in the program should conduct a good administration of commercialization of Caimans.
- Assure the best channels and commercialization mechanisms.

2. Program of Control and Communal Protection

Bolivian rules establishes the general and indefinite prohibition for the pursuit, capture, storing, and treatment of wildlife. However, in spite of this national normative and others of Departmental and communal character, illegal hunting have been observed frequently. This makes it necessary to implement this program to preserve the legal sustainable use of the Caiman that Tacana Indigenous Land wishes to carry out.

2.1. Sub-Program of Communal Control of the Harvest Process

The wildlife management doesn’t guarantee its availability in the long term, given the prevailing economic and social conditions in Bolivia. It is indispensable to combine the actions directly related to the species management and actions that permit to control the appropriate execution of the harvest. The control conducted by the same harvesters will assure the correct application of the norms, procedures, and regulations of the management plan, including the restriction of the harvest in unauthorized water bodies, the illegal sale of leathers, and others.

The control mechanisms should be concerted in a communal regulation, so that these mechanisms have the acceptance of the harvesters and the harvesters themselves demand complement of these mechanisms. The objectives of this Sub-Program are:

- Guarantee the complement of the established dispositions in the Management Plan.
- Achieve a transparent harvest and legal commercialization of the Caimans in the Tacana Indigenous Land.

2.2. Sub-Program of Minimum Protection

The prohibition of harvesting Caimans outside of the Tacana Indigenous Land is necessary to guarantee the sustainable harvest and conservation of the species. The objective of this sub program is to avoid the illegal harvest by people outside of the program. This kind of illegal harvest can cause incorrect estimates of the harvest quota established for each community and can reduce the production of Caimans for the communities harvesters.

It is important to coordinate with the authorities: National Police and Ecological Battalion of the Armed Forces. These institutions have the legal right to conduct inspections, seizures, and other actions in the rural and urban areas close to the areas of Community Management. It is also fundamental to coordinate control efforts with the Prefecture of La Paz, which is the entity responsible for the harvest process at the Department level and responsible for making harvesters comply the effective normative on this topic. The objectives of this Sub-Program are:

- Control the effect of the human activity on the habitats and the populations of Caimans in the community.
- Control the illegal harvest of Caimans outside of the Tacana Indigenous Land.

3. Program of Scientific Investigation

The biological information of the species in the country is almost nonexistent. This makes it indispensable to implement the present program and to obtain the necessary technical and scientific data that allow us to make the management program works. The objectives of this Sub-Program are:
• Increase the knowledge about the biology and ecology of the Spectacled Caiman in Bolivia.
• Obtain the technical and scientific bases that allow to conduct the sustainable harvest of the Caiman in the Tacana Indigenous Land.

4. Monitoring Program

This program will allow to record the population dynamics of the Spectacled Caiman subject to management through a database that contains the information provided by the investigation, and the respective technical reports of the different programs and sub-programs of the Management Plan.

The communal authorities and the leaders of the CIPTA should have the information of the monitoring to make decisions to increase or decrease the harvest of the Caiman or to correct the errors that would be causing the reduction of their harvest quota. The objectives of this Sub-Program are:

• Register and evaluate the changes in the Caiman populations subject to Management.
• Have technical and scientific information necessary to take the most effective measures for the conservation and the management of the species.
• Improve the process of commercial harvest. This allows to take better measures to improve the economic benefit for the communities.

5. Program of Training, Environmental Education and Diffusion

The future of the species under management depends on the attitude that the society and people have on the process of sustainable use. Without the participation and the support of the local communities, any conservation project will be failed or their implementation will be very complicated. For this reason the programs of training, environmental education, and diffusion are essential to achieve this support.

5.1. Training Sub-Program

To avoid the errors made by the people related to the harvest of Caimans in other Departments of Bolivia, we will transmit the necessary information to the Tacana Indigenous Land, so that the communities can strengthen their organization and administration, distribute the economic income obtained by this program to the communal and supra-communal instances in a transparent system, and carry out a sustainable management of Caimans with the largest environmental, economic, and community benefit. The training of the harvesters of Caimans in the communities of the Beni River, concerning the laws and norms that regulate the process of sustainable use, should be a constant work in the Tacana Indigenous Land. The Sub-training Program should allow that the theoretical base is reinforced by the practical and objective application, increasing the knowledge of the local agents on the different processes of the management plan, to achieve the necessary support for its execution. The objectives of this Sub-Program are:

• Train the communities (those participating in the pilot project) about administrative, organizational, commercial, and legal aspects to guarantee the sustainability of the management and harvest of Caimans in the Tacana Indigenous Land.
• Train the harvesters of Caimans in techniques of evaluation and monitoring of Caiman populations.

5.2. Sub-Program of Education and Environmental Diffusion

The Non-Formal Environmental Education should directs their teaching programs to the inhabitants of the towns of San Buenaventura, Rurrenabaque, Ixiamas and the communities of the Tacana Indigenous Land.

The diffusion of the results and activities of this Management Plan will be directed not only to the communities that harvest Caimans but also at other Indigenous Lands and the Department of La Paz. This will constitute a fundamental step for the consolidation of the Pilot Project of harvest and sustainable Management of the Caiman.

The educational authorities of the communities will promote meetings among the technicians of the management program and the local professors and students, to show the ecological importance of the Caimans, their biological characteristics, and other aspects that can improve the opinion of the students concerning the
Caiman. The objectives of this Sub-Program are:

- Make the local residents obtain knowledge to be involved direct or indirectly with the Management Plan of the Caiman.
- Change of the local population’s attitude, not only with the species subject to harvest, but also with the wildlife in general, through the understanding of the importance of the conservation and the sustainable development.
- Transmit the results of the activities developed inside the management of this species to the local communities direct and indirectly involved in the program.

Conclusions

The improvement of the organizational structures of the communities that harvest Caimans will allow to improve the social control on the resource management and to assure a more transparency in the processes, giving the necessary sustainability to the process of harvest of the Caiman.

The social control exercised by the communities can, without a doubt, strengthen the control of the program, in charge of authorities, as much National as Departmental. Likewise, an appropriate coordination with national police and armed forces will allow to reduce the impact of the furtive hunters.

In the measure that the responsibility of the administration (from the registration of the animals to the commercialization of the product) will fall in the same communities that harvest Caimans, it is possible to achieve a fairer and more equal distribution of the benefits of the program.

Through the diffusion and training programs (permanent along the administration), it is possible to strengthen the information that should reach to the producers, concerning their rights and obligations on managing a resource.

The establishment of a sufficiently sensitive monitoring program, with participation of local people and the support of the scientific entities, will offer reliable information about the population status of the species and the population dynamic, which allow to take appropriate management decisions.

Nevertheless the elements considered in this proposal, it is necessary to have the political support of the responsible authorities to be able to carry out this model of management that can enrich and improve a National Program of Conservation and Harvest of the Spectacled Caiman in Bolivia.

Literature


The Increasing Role of the Internet in Crocodilian Conservation

Adam Britton¹ and Akira Matsuda²

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Abstract

The Internet is a communications revolution that enables over 750 million people worldwide to transfer information instantly. Given that conservation relies on effective communication, the Internet is a powerful tool if used correctly. However, its scope and limitations must be appreciated for it to be used effectively. Different audiences must be recognized, and activities and interactions appropriate. For example, a conservation working group benefits in quite different ways to communities involved in conservation and management plans, and not all members of each group have access to the Internet. We examine the increasing role of the Internet in crocodilian conservation, highlight specific case studies, and look at the wider implications and possibilities that this tool presents.

Introduction

The Internet is a revolution in communication. It has built on the infrastructure established by the telegraph, the telephone, radio and the computer, and now provides the means for over three quarters of a billion people to communicate, collaborate and interact regardless of their geographic location. Access requires little more than a personal computer and a telephone, and the abundance of “Internet Cafés” in many countries even obviates the need for those. Nearly everyone knows what an “e-mail address” is (or has one) and phrases like http://www.google.com are instantly familiar to many.

Brief History of the Internet

The Internet’s origins can be traced to the 1960s (Kleinrock 1961, 1964) where plans for a worldwide “Galactic Network” (Licklader and Roberts 1962) seemed like science fiction. Yet before the end of the decade ARPANET - essentially a transatlantic academic and military communication project - went online. E-mail was first demonstrated to the public in 1972, and was responsible for the first massive increase in network traffic during the 1970s (Leiner et al. 2003). The “Internet” spawned from ARPANET in the 1980s, its “open architecture” philosophy (ie anyone can contribute to its development) ensuring exponential growth. Once the commercial sector tapped into the potential of the Internet, there was no turning back - task forces were deployed to advance key areas, common protocols were developed, and possibilities expanded. The World Wide Web first appeared in 1991 and was responsible for bringing the Internet out of the research community and into the global one. The World Wide Web Consortium (W3C) continues to evolve protocols and standards on the Web, and in 1995 the Web became the number one service available on the Internet (after FTP and Telnet).

The Modern Internet

The Web enables anyone to present information in an easily accessible and readable format using a suitable browser interface. Billions of pages (Nielsen 2004) are now available, from amateurish personal messages to professional corporate services. In recent years the Web has become largely a commodity service, selling data, information and products. The biggest challenge for a Web user is finding quality information amongst the sea of pages.

In 2004, an estimated 785 million people have Internet access (Nielsen 2004; InternetWorldStats 2004). All major companies, governmental and non-governmental institutions have permanent or regular access to the Internet, plus a significant percentage of the population in both rich and - increasingly - poor countries. English-speaking users form the greatest online presence (36%) followed by Chinese (14%), Japanese (10%), Spanish (9%) and German (7%) (Global Reach 2004). Worldwide, people spend an average of 26 hours a month “surfing the Web”, but only an average 50 seconds on each web page (Nielsen 2004). Faced with so much information, most users stick to familiar sites and skip fleetingly through unfamiliar ones. The challenge of capturing most visitors’ attention is a significant one.
The Internet will continue to change with technology, the most imminent of which is real-time transport of audio and video information, bringing Internet telephony and Internet TV to the masses. The ability for anyone to make and instantly distribute their films to anyone in the world is already reality. Phones and other portable devices are becoming increasingly “wired” for the Internet. More people are going “online” in every country of the world, and access will become faster and cheaper. The Internet is no passing fad, but a paradigm change in the way the world communicates. Such a change raises interesting questions: Who owns information? Should you pay for information? Can anyone offer information and opinions? What information can you trust?

**The Internet as a Conservation Tool**

A basic premise of successful conservation is communication at any level, which makes the Internet a powerful conservation tool. To realise its potential, the requirements and expectations of different users and targets need to be appreciated.

A conservation working group such as the CSG uses the Internet in fairly obvious ways: e-mail is used to exchange information and coordinate action, web pages are used as an archive of information, to target a wider audience, and as a fund raiser. Other web pages on the Web represent the world’s largest library, although finding quality information often takes skill. The working group can target users directly or indirectly. The policies of political groups may be influenced directly by e-mail, or indirectly through information on web sites. Effective messages require visitors, and there is an art in encouraging “links” to your website.

Other targets include businesses and private sector individuals, both potential sources of support and funding. Educators and the media will actively promote the group and its issues if they are sympathetic to the message. Even those affected by the conservation problem are viable benefactors, ranging from prosperous landowners in Florida to extremely poor village communities in Cambodia. Many in this group have limited or no Internet access, but for those that do the Internet represents an opportunity to promote appropriate management and conservation solutions.

**Case Study 1 - Chinese Alligator Fund**

**Original Goal**

The goal of the Chinese Alligator Fund (CAF) was to raise awareness of the status of *Alligator sinensis* in the wild, and to raise funds that would contribute to its conservation.

**History and Motivation**

The decision to establish the CAF was based on the report made at the 15th Working Meeting of the CSG in Varadero, Cuba (Thorbjarnarson et al. 2000a) where it was clear that the remaining wild *A. sinensis* population was in serious trouble. While the principal conservation efforts involved a combination of crocodile specialists, international conventions and the Chinese Government, there was a similar desire by non-professional enthusiasts and hobbyists to contribute towards this effort. To tap this resource, Adam Britton coordinated the creation of the CAF with assistance from several key hobbyists (including Tim Wiegmann, Billy Heinbuch, Ragnar Lonn). A website was quickly established (http://www.flmnh.ufl.edu/alligatorfund) to serve as an information resource, to encourage donations, and to chart the progress of the fund.

**Raising Awareness**

The creators of the CAF believed that a lack of awareness of the conservation status of *A. sinensis* impaired fund-raising efforts, and that enthusiasts often felt powerless to assist in conservation efforts. Hence a primary goal of the CAF was to bring this conservation problem to the attention of as many potentially interested parties as possible, and to make those parties feel capable of actively contributing to *A. sinensis* conservation. This was facilitated by the creation of a web-site containing the following elements:

- A brief description of *A. sinensis*, its habitat, and its status in the wild, with links to more detailed information if desired.
- Details on how to take part in conservation efforts through:
  - downloading leaflets for distribution, detailing the CAF and its aims
  - donating money directly to the CAF through the CSG
- donating money by purchasing high quality photographic prints
- donating money by purchasing clothing and other small items from an independent online store
- raising awareness via school projects

* A list of every person who donated money and purchased prints, with a ranking “reward system” depending on the amount donated.

* Regular news updates on progress with *A. sinensis* conservation in general, progress of the CAF, total money raised to date and where this money was going

Location and web space were provided by the CSG at the Florida Museum of Natural History (FLMNH) which lent credibility and reassured visitors that donations would reach the right place. The web-site was promoted by the CSG, Internet discussion groups, and by word of mouth. The popularity of the hosting site crocodilian.com (1.5 million visitors a year directly and via the CSG) ensured that awareness of the CAF was relatively high within the “community”.

David Kirshner, an artist based in Brisbane, donated a characteristic logo for the CAF (Fig. 1) which was used on the web-site, leaflets and clothing.

![Chinese Alligator Fund logo](image)

*Figure 1. Chinese Alligator Fund logo, designed by Brisbane artist David Kirshner.*

Overall, the website was very successful once news of its existence had spread through the appropriate segments of the Internet community. The updated news pages were popular with visitors, as were the ranking pages where donors felt a degree of achievement. The website also provided an easy means of directing people to download appropriate information and leaflets.

**Use of Leaflets**

Single page, US letter-sized leaflets bearing the CAF logo, the CSG logo and a short description of the CAF were made available in two popular formats (Microsoft Word and Adobe PDF) on the website. These leaflets described the CAF, encouraged readers to visit the web-site to learn more, and contribute to conservation efforts by spreading the word, purchasing merchandise and so on. The format was kept simple and easy to print out. This encouraged motivated people to print out multiple copies to distribute with permission at zoos, reptile shows, reptile group meetings etc. Although their effectiveness was difficult to measure, they appeared to generate significant interest and many people downloaded them. With improvements in server technology, it is now very easy to obtain a direct measure of the number of times a particular file was downloaded and hence obtain a rough index of success. Given the small investment in time required to create them, and the fact that no effort by the organisers was required to distribute them, they were a successful addition to the website.
Direct Donations

Cash donations made directly to the CAF were highest in the year following its establishment (Fig. 2), the result of concerned private individuals wishing to play a small role in helping conservation efforts. When high-quality photographic prints were made available, smaller private donors preferred to purchase permanent reminders of their contribution and hence simple cash donations became rare from this sector. The bulk of cash donations then came via fund-raising drives made by larger groups (eg fund-raising days at zoos, raffles by state reptile groups in the USA), and the majority of CAF funds were obtained this way.

![Figure 2. Main donation history of the CAF. Light bars represent cash donations. Dark bars represent profits from sales of photographic prints.](image)

Direct donations are obviously a part of any fund. It was felt at the outset that the CAF would reach a particular target audience (private enthusiasts) better if it offered incentives to donate, particularly if those were collectable (eg prints). This ultimately proved a successful approach, yet did not deter societies from wishing to help through direct donations. Such societies benefited from downloadable materials available through the website (eg essays, photographs for use in talks, etc.).

Photographic Prints

High quality photographic prints were made available three months after the inception of the CAF. These were manufactured using the Ilfochrome printing process that uses high resolution paper and inks to create professional prints that do not fade over time. Although more expensive, we believed it was more important to offer archive quality prints that attracted larger donations. We also believed that purchasers would select high quality photographs over images specifically of Chinese alligators. This proved to be the case, with the two most popular images being of American alligators and saltwater crocodiles respectively, as we lacked similar spectacular images featuring Chinese alligators.

Prints were offered as “limited edition” only, each signed by the photographer and numbered out of 25. This seemed effective in encouraging rapid uptake by buyers. Each print was accompanied by an A4 letter of thanks to each supporter, bearing the CAF and CSG logos. Although standard prints were not offered, we believed that anyone
motivated enough to support the CAF would go the extra mile and pay more for a significantly higher quality print. Overall the strategy was a successful fund-raising component (22%) of the CAF (Fig. 2).

Offering prints created the greatest logistical overhead for the CAF, and relied on voluntary efforts by key organisers with limited resources. Prints were made to order, with a minimum of three orders collected before the order was made. This often meant a slight delay between placing the order and sending the print, but no buyer complained about this process. Although costs decreased slightly with larger orders, the volume of orders was rarely sufficient for large orders to accrue in a reasonable timeframe. Adam Britton bore the cost of 10 advance prints in the beginning, but this quickly ceased to be a realistic option without financial support.

The average production cost of each print was $US37 plus $US3 for postage and packaging. Prints were sold at a minimum of $US90, which ensured a minimum of $US50 was donated to the CAF with each print sold. Although some buyers provided an extra donation by paying up to $US150 per print, most paid the minimum asking price. Some people felt that $US90 was quite expensive, others felt that the quality of the prints justified the final cost. There were no complaints from buyers and everyone expressed satisfaction with the purchase.

Prints were made in Darwin, later Canberra. The buyer sent orders directly to the CSG Executive Officer (Perran Ross) in Florida and money was paid to the FLMNH in US dollars. The Executive Officer then informed the CAF (Adam Britton) of the order, and the print was dispatched when available. FLMNH later repaid Adam Britton $US40 per print to cover production costs. By asking buyers to deal directly with FLMNH, money was saved on exchange rates, a degree of security was added to the transactions, and an appropriate degree of legitimacy was conferred upon the CAF.

Prints were also sold successfully at a number of venues including reptile shows and presentations given to reptile groups and zoos. For example, a raffle of one unique print at a talk in the US raised almost $US800 in one night. Prints were sent to motivated supporters keen to sell prints at such venues. The vast majority of prints were sold to buyers in the USA.

New prints were occasionally introduced to encourage more sales, although with limited success. Assuming later prints were as appealing as earlier prints, this suggests that the majority of print sales occur when the fund-raising process is still relatively novel. These prints were only made to order, so no cost was incurred through their introduction later.

Overall, sales of photographic prints can contribute significantly to fund-raising efforts, although most sales occur early in the promotional campaign. Offering new incentives to purchase prints later in the campaign (eg new images, special offers) had limited success with the CAF, but this may have been a shortcoming in the ability to reach a new audience. The majority of orders were made on the basis of one or two “must have” photographs, with other photographs becoming essentially superfluous. However, a greater range of prints with wider applications (eg for education, competitions, awards, publicity, etc.) may have been a solution, but the organizers lacked the resources to pursue this.

In terms of logistics, virtually all print sales originated in the USA. Using a US dollar account, preferably based in the USA, was a key factor in reducing logistical costs. Close communication between the person distributing the orders and the person taking the orders was also essential, and worked well for the CAF. However, difficulties were encountered when a local photographic lab closed down, and the only cost-effective alternative was found in another state. This added a further layer of complexity to a process that ideally needs to remain simple and streamlined, but could have been avoided by having a liaison in close contact with the new photographic lab. At the time, the lab needed to be sent negatives with each print order, but now modern digital techniques mean that negatives can be scanned and stored at the lab until more prints are required. This minimizes the need to order large volumes of prints, which can be a serious problem when resources are low.

Other Merchandise

Once the CAF logo was completed, it was obvious this appealing design could be used on hats, T-shirts, mugs and other merchandise to assist fund raising. Although inquiries were made in the USA and Australia to print the logo onto t-shirts, the costs proved prohibitive without additional financial support, and the quality was always in doubt.

Eventually the Internet company Cafepress was found, which offered a cheap means of providing a wide variety of
merchandise bearing the CAF logo through a convenient web-based design and ordering system. Initial tests indicated an acceptable quality for the merchandise, and the CAF page announced the new merchandise.

The result was disappointing, with less than $US200 raised in total after several months. While a number of orders were received, the amount made after CafePress deducted their royalties meant that little cash was actually donated to the CAF. However, considering the low cost of setting up the web page (one day) and no overhead cost of maintaining the online “store”, the experiment proved an inexpensive lesson.

The main reason for the failure of the CafePress store was likely its timing - it was introduced after the initial “excitement” of the fund-raising process had died down. Had it been introduced at an early stage it is likely far more sales would have been generated. The alternative approach of investing in a stock of T-shirts can be costly when demand is low, and solutions like CafePress appear to be a better alternative if the timing is right and the targeting is appropriate.

Feedback to Donors

Two systems were created to provide donors with feedback and incentive. The first was a regularly updated news page on progress with A. sinensis conservation efforts in general, plus the role the CAF was playing in those efforts - all donors were keen to know whether their donations were actually making a difference. The second was a donor ranking system. All donations, no matter how small, were listed on the website next to the donor’s name, and were placed into one of several categories based on the total donation to date by that person or organisation. This was very effective in encouraging donors to keep donating to see their name in lights under higher ranks - several emails were received that mentioned this specifically.

It was clear that CAF donors wanted feedback - to know that they had played a small part in the conservation efforts. Although occasional newsletters sent to donors was considered, the website proved the most effective method of providing feedback to existing and new visitors.

School Projects

Only one school project was initiated, but proved to be a success. Bruce Shwedick (Crocodile Conservation Services) worked with Garrisonville Elementary in Garrisonville, Virginia, USA. Each year the school holds a “Gator Day” and CCS introduced the theme of the Chinese alligator to the students. Workshops and competitions were organised and proved very successful (Appendix I). John Behler and Adam Britton judged winning essay and painting entries and the results were displayed on the CAF website.

There is considerable scope to raise awareness of conservation activities through public education if approached correctly. In this case not only were the students introduced to an unusual species and conservation problem, but awareness spread into the local community. Such actions clearly depend on the motivation of individuals to organise appropriate events, but making materials and activities available through the website greatly assists those individuals.

Parallel Activities

Somewhat independently of the CAF, Terry Cullen (USA) and others working under the banner of the CSG were responsible for raising significant funds at major reptile shows. These were very much hands-on activities at popular annual events attended by thousands of people - something of a regional phenomenon, but an example of how a key sector of the public interested in reptiles can be harnessed to raise funds for a group they had not heard of before walking through the door.

Overall Result

Overall, the CAF raised in excess of $US15,000 (Fig. 3). Given the unconventional distribution model for the CAF, and the relatively small amounts donated by most donors, the amount raised was far in excess of expectations. Funds have been used to assist in the organization of an international conference on Chinese alligator conservation in Guangzhou ($US8000) and the remainder will likely be used on specific alligator projects under the direction of the Chinese Government. Moreover, the achievements of the CAF were brought to the attention of the Chinese Government, and proved to be politically advantageous. The CAF encouraged matching donations from larger organizations such as the Wildlife Conservation Society, and succeeded in bringing A. sinensis conservation to a
much wider audience including the international media.

![Graph showing total donation over time](image)

Figure 3. Total money raised for the CAF over time. Over two-thirds of the total was raised in the first 9 months.

**Case Study 2 - Tomistoma Task Force**

**About TTF**

CSG’s Tomistoma Task Force (TTF) is a group that is dedicated to quantifying the status of *Tomistoma schlegelii* (False Gharial, classified as Critically Endangered under the IUCN Red List) in the wild, identifying the threats to which they are exposed, and to promote conservation action.

**History and Motivation**

The decision to establish the TTF was based on the meeting made at the 16th Working Meeting of the CSG in Florida, USA. A TTF Committee was established, comprising the key players and other interested CSG members concerned with Tomistoma conservation.

The TTF Trust Fund was established under the auspices of the CSG to collect and distribute funds raised for Tomistoma conservation. The contents of the TTF Trust Fund are assigned to projects by the TTF Committee.

**Expected activities and current stage of TTF web-site**

The TTF expects to raise funds for field research, to analyse threats to crocodiles and their habitat, to raise awareness and promote public education, to understand the social background of local societies and advance conservation of Tomistoma in Indonesia and Malaysia. Use of the Internet was considered vital to facilitate these efforts.

Development of the TTF website was undertaken voluntarily, and roughly three quarters of the site’s intended features were online by January 2004. Activities outside the website were confined to communication between the TTF committee and various attempts to raise both minor and major sources of funding. Some of these activities were reported on the TTF website.
As future TTF activities (e.g. field research, conferences) take place, reports will be made available on the website. Eventually the website will include a registration zone where members and supporters can get more involved in TTF activities, and efforts to raise the profile of TTF can take off. At present, the TTF website is still at an early stage.

Development of TTF website

Basic elements and a rough structure of the website were discussed shortly after the formation of TTF. A website subcommittee was established to handle the technical issues.

1. Conceptual Structure of TTF Website

TTF Website was designed as three-layered structure by Akira Matsuda (Fig. 4). The 1st layer was designed for visitors and named “Public Area”. It contains Visitor Zone and TTF Charity Shop. Visitor’s Zone offers general information regarding TTF and conservation of *Tomistoma schlegelii*. TTF Charity Shop offers charitable merchandise of TTF. All donations and profits are put into TTF Trust Fund.

![Conceptual Structure of TTF](image)

*Figure 4. Conceptual diagram of TTF Website (Version 2004).*

The 2nd layer was designed for registered users and named “Supporter Zone”. This area will not open until TTF activities have developed further, and suitable content can be offered to registered users.

The 3rd layer was designed for TTF Committee members. It aims to facilitate communication among members who are scattered all over the world. It has the potential to greatly facilitate discussion, build consensus among active members, and to share both data and unconfirmed information. The Committee Zone identifies individual members and is protected by passwords and high level SSL security. It enables safe communication within the browser, in contrast to standard e-mail that can be eavesdropped and spoofed easily. To date, communication in this secure area has been very limited, primarily due to members’ familiarity and comfort with e-mail, and partly because the security features take some getting used to.

2. History of the TTF Website

The Committee Zone was initially developed in April 2003. It was used to gather materials from TTF members for construction of the Visitors Zone.

The Visitor Zone was opened in May 2003 with principal pages only. A total of 35 web pages were planned as menu items. Several of these were developed by TTF members and further refined by the Committee. By May 2004, 20 web pages were available. Manuscripts for remaining pages are open to TTF members, and should be complete by the end of 2004.
The Free Download Section, where leaflets can be downloaded, was started in August 2003.

The TTF Charity Shop was opened in January 2004 for a test run with minimum merchandise. The future addition of appropriate merchandise is open to the TTF Committee. Various issues with the sale of merchandise remain to be solved, such as minimizing the cost of international shipping. As with the rest of the website, the shop is run on a voluntary basis by TTF members.

The TTF Charity Shop Cafepress Branch is an extension of the TTF Website, and was established in April 2004. It offers various sundries bearing the TTF logo, and although Cafepress claim a significant royalty on each item sold, it operates completely independently of the efforts of TTF members.

3. Major elements of Visitor Zone of TTF Website

The Visitor Zone, which is the public face of the TTF on the Internet, contains the following major elements:

- A brief introduction to the TTF.
- A brief description of Tomistoma schlegelii, its habitat, significant threats and its status in the wild, with links to further information on other web-sites.
- A brief description on how to get involved with TTF and conservation efforts through:
  - Becoming a “Friend of Tomistoma” to support TTF.
  - Becoming a “Partner” to support TTF more directly.
  - The advantages of becoming a registered user.
  - Donating money by purchasing high quality photographic prints
  - Donating money by purchasing clothing and other sundries.
- A page to download leaflets about T. schlegelii and the TTF (currently in English and German).
- A list of facilities that hold T. schlegelii (currently Europe only).
- A list of supporters who register as a “Friend of Tomistoma” or “Partner”.
- A list of person who donate money to TTF.
- Regular news updates regarding TTF activities and on T. schlegelii conservation in general. This includes an article about the 2002 False Gharial Workshop held in Indonesia.
- An inquiry form.

Contents of the Visitor Zone will be enriched and enhanced as development on the TTF website continues. Web space and all costs of development of the TTF website were provided by Akira Matsuda who runs a small Internet service as a part of business providing benefit to crocodilian conservation groups.

Raising Awareness

TTF believes that a lack of awareness of the conservation status of T. schlegelii will impair both conservation and fund-raising efforts. The following methods are used to raise awareness.

1. Development of the website

   The most significant aspect of the TTF’s public profile is the website, described above.

2. Holding of local events

   Local events are held that introduce TTF to appropriate groups about conservation of Tomistoma. These are held voluntarily by TTF members (see below).

3. Leaflets

   Leaflets are available for download from the website. Initially produced in English, they are also available in German and will be translated into other languages. The aim of the leaflets is to provide an easy means of introducing people to the need for Tomistoma conservation. The leaflets are available in Adobe PDF (Portable Document Format) - a standard distribution method for electronic documents around the world.

   Additional leaflets will be produced on a voluntary basis by TTF members. Printed versions of key leaflets will
also be factored into the TTF budget.

4. Use of mass media

Exploiting the mass media to promote Tomistoma conservation has been considered, especially once field activities commence and conservation action can be demonstrated. However, securing the interest of the media will rely upon selling an interesting story. The website has the potential to reach a wide audience with a message that is under the control of TTF.

Fund raising

1. Fund raising through Internet

Internet fund-raising has been implemented through the TTF Charity Shop and Cafepress Store, and funds have started to trickle in. However, serious fund-raising will not be possible without significant media exposure and publicity of the website - an area that TTF needs to address in the near future.

2. Fund raising through local events

A number of key events are held each year by the hobbyist herpetoculture community, and the opportunity to set up a table and promote TTF and Tomistoma conservation has been taken by specific TTF members on a voluntary basis - Bruce Shwedick in the USA, Ralf Sommerlad in Germany, Colin Stevenson in Australia. The TTF Website announces the details and schedule of all fund-raising events, although at this stage most visitors to these events are unaware of the TTF. Given that a significant percentage of the hobbyist herpetoculture community has Internet access, there is real potential to promote TTF's presence at these events. The Internet can also be used to advertise educational lectures, arrange booking for events, issue special coupons, and provide follow-up services following an event. These actions depend on the motivation of specific TTF members, but providing a framework under which these actions are possible will help.

3. Charitable merchandise

A number of items of merchandise are available for sale through the TTF Web-site and at fund-raising events. The prestige items are a number of high quality photographic prints donated by TTF Committee members, similar to the approach offered by CAF. The most popular were selected within the committee using an online voting system in the Committee Zone, and offered as “limited edition” prints primarily through the website.

Postcards, T-shirts and other sundries bearing the TTF logo have been organized by members, with all profits going to the TTF Trust Fund. The biggest challenge has been finding ways of making these items available at a modest cost to ensure the greatest benefit to the TTF. As TTF gains exposure, these items should sell in modest numbers and provide a modest but useful source of funds.

Program for supporters

A “supporters program” was established to reward supports of the TTF. The concept is an attempt to encourage enthusiasts who often feel powerless to assist in wildlife conservation efforts.

1. Categories of supporters

Two categories (Table 1) were created under which to list supporters. “Friend of Tomistoma” is for private individuals who want to feel involved, and “Partner” is intended for organizations, companies or individuals who provide significant financial support for Tomistoma conservation activities.

2. Services for supporters

The newsletter and activity reports are planned as feedback for supporters and donors. These will be distributed through the TTF Website (to reduce printing costs), although printed copies will be available for public events and to send to key individuals and organizations. However, a regular and long-term commitment is required by TTF members if these are to be produced in a timely and productive manner. The benefits of these services need
Table 1. Principal features of the program for supporters.

<table>
<thead>
<tr>
<th>Features</th>
<th>Friends of Tomistoma</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual contributions</td>
<td>$US50 (rate negotiable)</td>
<td>Over $US1000</td>
</tr>
<tr>
<td>Certificates</td>
<td>Certificate of ‘Friendship’</td>
<td>‘TTF Partner’ plaque</td>
</tr>
<tr>
<td>Newsletter</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Reports</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Login to the registrant zone</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Discount on TTF merchandise</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

to be assessed. The Supporter Zone on the TTF Website will host forums where supporters can interact with TTF Committee members by sending comments and asking questions. More qualified supporters could play important roles in field studies. These services are yet to be implemented.

Major differences between CAF and TTF

1. Difference of principle aims

CAF concentrates on raising awareness and raising funds that can be applied to Chinese alligator conservation. In contrast, TTF is a working group that includes raising awareness and funds within its remit, but whose members work together to promote Tomistoma conservation, organize surveys, allocate funds and advance political issues of relevance. However, public perceptions about CAF and TTF may be similar on the surface - they are methods through which conservation goals of each species can be achieved.

CAF
1. To raise awareness of the status of *Alligator sinensis* in the wild.
2. To raise funds that would contribute to its conservation.

TTF
1. To quantifying the status of *Tomistoma schlegelii* in the wild.
2. To identify the threats to which they are exposed.
3. To promote conservation action.

2. What’s in a name?

The name “Chinese Alligator Fund” clearly describes the principal aim of the initiative - a fund-raising body for the Chinese alligator that seeks charitable donations. “Tomistoma Task Force” is less clear - the name “Tomistoma” is unfamiliar to the majority of people, and the goals of a “task force” are not necessarily obvious. It does not invoke the image of a fund or a body seeking donations. However, it was felt that using the common name “False Gharial” was unwise in some countries where “false” carries negative connotations. Given the more active nature of the TTF members, the implications of the name may be less relevant.

3. Use of media

The Chinese Alligator Fund was created in direct response to publication of the WCS report on the critical status of wild populations (Thorbjarnarson 2000b). Significant publicity arose from this in the world’s media, which helped to bring the Chinese alligator situation (and hence fund-raising efforts such as CAF) to a wider audience. No doubt the CAF’s exposure benefited significantly from this.

The CAF also benefited from exposure through an existing, popular crocodilian website (crocodilian.com), which led to a significant number of donations from an active section of the Internet community interested in crocodilians.

Key factors such as timely, multi-sector involvement, use of mass media including paper media, and use of an existing high-traffic website contributed to the success of the CAF in a relatively short time-frame.
In contrast, TTF has a lot of development ahead and is a harder “sell” to create significant conservation benefits for Tomistoma. The status of Tomistoma in the wild has still not been satisfactorily determined, and proving its critical status would lend power to the TTF’s mission. To date, TTF Website and TTF Charity Shop have had relatively few visitors - TTF needs to get the word out, and promote a compelling conservation message, for its public fund-raising efforts to take off.

Success of TTF Committee Zone

The Committee Zone of the TTF Web-site was created using dynamic content technologies to make the website interactive, in contrast to a “read only” website. It facilitates communication among the committee members who are scattered all over the world, and enhance discussions compared with e-mail. Interactive items include the ability to submit news, use threaded discussions, participate in surveys, assist in the creation of a glossary and other public content, upload files and photos of interest, add dates to a calendar, etc. In effect it turns the site into an interactive newsletter for its members.

However, these items have not been well used by the TTF Members, particularly those who have limited access to or experience with interactive web-sites. E-mail is a familiar and relatively simple technology that is widely used, and switching to a more complex - if more powerful - alternative that takes longer to access and is less intuitive is not always easy. It is clear that interactive websites need to offer significant advantages over e-mail, but not at the cost of being easy and convenient to use. E-mail will remain the primary means of communication for key issues, but certain member activities can benefit from interactive features on the website that are not possible by e-mail, particularly as activities increase and communication / interaction with the general public plays a greater role.

Overall Result

The TTF is an ongoing and evolving group that is still in its infancy. In 18 months since its inception, the TTF has brought together key players in Tomistoma conservation, established regular communication, created a detailed web resource and interactive database, begun to collate data on Tomistoma from different countries, and investigated a number of promising sources of funding for field studies. During that time, the group has raised several thousand SUS with relatively little exposure outside of the crocodilian community, with a species that has had very little media exposure.

From an Internet perspective, the TTF website is very ambitious and perhaps ahead of its time for a group unfamiliar with its potential. In many ways the website is overkill for the TTF at its current level of development, but if the TTF grows into a larger group with greater public exposure, the benefits of establishing such a powerful website will become clear. At present, without the incentive to expand beyond simple e-mail communication, the growth of the website’s content will be slow. Greater efforts need to be made to increase exposure of the website and the fund-raising mechanisms to the general public.

The cost of developing these websites is hard to judge, as they were developed voluntarily in spare time. The CAF website took one person a few days to complete, but the TTF website took several people several months to reach a functioning stage. No cost-benefit analysis has been done on these websites, but they have the potential to expand exponentially beyond their original scope once the community gets involved, as has happened many times within Internet communities.

Future Role of the Internet in Crocodilian Conservation

Internet technologies continue to develop, both in terms of what websites can offer and what users can experience. We are still exploring the potential of the Internet for crocodilian conservation, but the two case studies highlighted here are effectively pilot studies of the medium’s potential.

The most imminent advances in technology will be the speed at which information can be transmitted and downloaded via the Internet. Real-time delivery of high quality video and audio are not far off, enabling Internet Television and live online broadcasts to nearly a billion people simultaneously. The power to communicate ideas will expand exponentially as more people have access to these technologies, and large online communities will become an effective means of coordinating conservation action.

Even with existing technologies, we have barely scratched the surface of what is possible on the Internet. Most
crocodilian websites are effective in offering an archive of information on general crocodilian science and natural history, but there is considerable scope for improvement. The CSG website has the potential to become the central hub for its conservation activities, starting with its Task Forces which are the focus for priority species. Not only will this improve communication and conservation action within the group, it will communicate the need for conservation to a wider group of people that are becoming increasingly detached from the natural world. Such actions are vital if awareness is to be increased and funds raised for conservation efforts.

There is a need for a research-quality archive of species on the Internet - something that is of benefit to scientists working in the field on a variety of issues. The website offers the means by which such information archives can be updated as new information becomes available, and new findings can be presented to the community for analysis. However, to be effective members will have to embrace this new medium and contribute towards its success.

**Literature**


Appendix I

Program of school fundraising activities by Bruce Shwedick:

_Gainesville Elementary School Celebrates “Gator Day” 2001_

The students and teachers of Garrisonville Elementary in Garrisonville, Virginia, USA celebrate the gator, their school’s mascot on the first Friday of every March. This event is not only about school spirit, it also is utilized to promote reading.

Bruce Shwedick has been the guest speaker at Gator Day for over a dozen years now and in 2001 he thought it was appropriate to emphasize the plight of the Chinese Alligator. He invited the school’s third, fourth and fifth graders to create art and to write essays about the Chinese Alligator and it’s struggle for survival.

The students were invited to participate in the first “Help Save the Chinese Alligator Art and Essay Contest”. The students were given two months to create their art and write their essays. The school was provided with a copy of John Thorbjarnarson’s recent article about the Chinese Alligator featured in Wildlife Conservation magazine and the students were encouraged to visit www.crocodilian.com to learn more about the Chinese Alligator.

The student’s work was judged during the AZA Crocodile Biology and Captive Management School held at the St. Augustine Alligator Farm. Judges included John Behler, the Curator of Herpetology at the Wildlife Conservation Park/Bronx Zoo, Dr Adam Britton and Bruce Shwedick.

The winner of the art contest is Cara Lawn. Jennifer Park and Beth Van Briesen won honorable mention. The winner received a copy of “I Didn’t Know That Crocodiles Yawned to Keep Cool”. Jennifer and Beth received copies of “The Legend of Gomek” and “The Missing Gator of Gumbo Limbo”. A tie was declared in the essay contest between Cara Lawn and Courtney Cook and each winner received a copy of “Alligators and Crocodiles” by J. Behler and D. Behler.

The students of Garrisonville Elementary have learned a lot about this unique and endangered crocodilian. We encourage you and your students to read more about the Chinese Alligator and to utilize the “Earth Dragon Classroom Activity Worksheet”.

_Earth Dragon Classroom Activity Worksheet_

GRADES K - 6

I. Introduce the Chinese Alligator using books, articles, websites and videotapes related to crocodilians followed by classroom discussion.

A. General characteristics of a crocodilian: aquatic reptile, cold-blooded, covered in scales, long jaws with sharp teeth, four strong limbs, toes on hind feet slightly webbed, elliptical pupil, powerful tail, egg-laying.
B. Crocodilian groups: alligators, caimans, crocodiles and gharial.
C. Chinese Alligator: geographical range, size and diet.

II. Chinese Alligator ecology. Classroom discussion.

A. Habitat - where do Chinese Alligators live and with what other animals do they share their environment?
B. Burrows - why do Chinese Alligators dig burrows? What impact do these burrows have on people?
C. What has caused the Chinese Alligator to become an endangered species?

III. Activities.

A. Art - students can create artwork that could feature the Chinese Alligator, its habitat and the native plants, animals and the people that share the habitat.
B. Creative writing - imagine that you lived near the Chinese Alligator, what would you want to tell your friends and parents about it? Imagine that you spent the day visiting wild Chinese Alligators and write a story about your adventure.
C. Geography - how many miles do Chinese Alligators live from your home?

GRADES 3-6

I. Natural History.

A. Review the general characteristics of crocodilians and the specific characteristics of alligators, caimans, crocodiles and the gharial.

B. Discuss Chinese Alligator reproduction including nest construction, egg-laying and maternal care.

II. Conservation.

A. Discuss what is being done to save the Chinese Alligator from extinction. Examples: captive breeding, protection by laws, establishing protected reserves and changing people’s attitudes about alligators.

III. Activities.

A. Written and oral reports - what is the difference between the Chinese Alligator and the American Alligator? Consider the differences in their appearance, size, habitat and the ways they are utilized by people.

B. Find out if there is a Chinese Alligator in a zoo near you. Take its photograph and collect more Chinese Alligator facts to share with your class.

C. Find out what you can do to help the Chinese Alligator and other endangered species at your zoo or in the wild. Share what you find with your class.

VOCABULARY

1. crocodilian or crocodylian - any member of the taxonomic group “Crocodylia”.
2. caiman - a diverse group of tropical alligators from Central and South America.
3. gharial - an extremely slender-snouted crocodylian from India.
4. T’u-lung - the “Earth Dragon”. A traditional name for the alligator in China.
5. Anhui - the Province in China where most wild Chinese Alligators remain.

Written by Bruce Shwedick © Reptile Discovery Programs
World Trade in Crocodilians: an Update

John Caldwell

Data are presented showing that global trade in crocodilian skins peaked at just over 1.3 million in both 2000 and 2001 but fell back to 1.1 million in 2002. Exports of caiman from Colombia peaked in 2000 and their decline the following year was replaced by a massive increase in exports of American alligator. Trade in both declined in 2002, although caiman appears to have been more seriously affected. Exports of Nile crocodiles increased steadily during the late 1990s with steady or increased production in Madagascar, South Africa, Zambia and Zimbabwe. Exports from other African countries show a general decrease. Exports of *Crocodylus novaeguineae* from Indonesia have been increasing steadily while those from Papua New Guinea appear stable. Estuarine crocodile exports from Australia peaked in 2000 and appear to have declined slightly since while exports from Indonesia and Papua New Guinea appear to be stable. Of the other crocodile species, *C. johnstoni* has not been traded since 1996, there are low levels of exports of Morelet’s crocodile from Mexico and a few thousand skins of *C. siamensis* are exported annually from Thailand. Trade in wild-caught caiman from Venezuela has declined steadily to under 20,000 yearly while exports of Yacaré from Bolivia, Brazil and Paraguay have been increasing steadily since 1999.
Major Issues Affecting Sustainable Trade of Crocodilians

Don Ashley (Chair)
Ashley & Associates, 3621 Belfast Drive, Tallahassee, FL 32309, USA (jdalligator@aol.com)

Twenty-six CSG members from 12 countries participated in a trade workshop to identify major issues affecting the sustainable trade of crocodilians. Ten CSG Steering Committee members attended, including all three officers of the Trade Committee.

The consensus was trade workshops were useful during CSG meetings, provided an opportunity to review and discuss major trade issues and engaged a wider cross-section of CSG interests involved with sustainable trade. More interest in sustainable trade issues has evolved since the Singapore CSG meeting and the Gainesville trade workshop with clear support in Darwin for more frequent interactions on trade issues that should include industry updates, inquiries to clarify timely issues, general trade information on market trends and more venues for enhancing the business and conservation benefits of sustainable trade. A series of Sustainable Trade Forums is recommended.

The rhetorical question: “Would world trade in crocodilians have been restored without the conservation benefits of sustainable use?” was generally agreed as “no”, at least not at the near historical peak levels of classics and increasing supplies of caiman. The important point is profits are enjoyed because of conservation benefits to crocodilian sustainable use and a responsibility to enhance conservation is inherent to the economics of sustainable trade. Since the best conservation engages and benefits local people, the emphasis on community-based conservation that benefits people and wildlife should be a priority.

The workshop group felt the major issues should be stated simply and the focus be on achievable results. The major issues are generally grouped in four categories: CITES, CSG, Range States and General:

1. CITES
   A) Compliance
   The issues of complying with the pre-conditions of downlistings as well as annual reports, infractions, illegal trade and inadequate enforcement are urgent priorities. As stated originally in Singapore, CSG must insure its own house is in order if we expect wider acceptance of sustainable use as a conservation strategy. The clear standard for all crocodilian trade must be it is legal, sustainable and verifiable.
   B) Personal Effects Exemption
   The harmonization of CITES Range states to allow unrestricted import and export of up to four legal, non-commercial crocodilian products is very important to enhance trade. The USA in fact will accept up to 8 personal effects products, the EU is adopting the CITES standard of 4 products. Japan will implement the same and China will propose in Bangkok that “harmonization” is expected of CITES Parties unless they notify the Secretariat. Addition of new species to the Personal Effects list (currently crocodilians, caviar, rainsticks and queen conch) are expected to be dried seahorses, coral and perhaps other marine products. The standard for all species listed under the Personal Effects exemptions is that the trade is legal, sustainable and verifiable.
   C) Trade Fair Permits (Carnets for product samples)
   The continuing effort of CITES and range states to simplify and streamline permit requests is important to trade.
   D) Source Code Amendments
   The USA proposal to redefine CITES source codes was a concern to the trade workshop group and immediate clarification will be requested through the Chair.
2. CSG

A) Economic Analysis (McGregor Reports)

Concern by some trade group members was expressed concerning this Report. While the overall Report was judged as good, the usefulness to the trade remains a question to some. On the other hand, the original goal of economic analysis projects was to monitor trade data compiled through the IACTS Report and initiate case studies to review issues that could impact conservation benefits. The only economist in attendance at the workshop suggested the information collected for economic review should be data that could “change management decisions” and that strategic or trend data was important to ongoing economic analysis. The decision was to await review of the newly completed draft of Phase Two of the project coordinated by TRAFFIC and drafted by McGregor before recommending a course of action to the CSG.

B) Captive Breeding

The issues of captive breeding and its relationship to conservation benefits merits continued monitoring and analysis. A CITES review is in order.

C) Live trade in crocodilians out of native ranges for commercial farming

This issue merits immediate action by CSG, particularly with *C. siamensis* and live exports to China from Cambodia, Vietnam and other critically endangered populations. The illegal capture of wild specimens for live trade must stop.

D) Trade Representation

The CSG trade group has been under represented from Latin America and more representation from the primary Range States of Colombia, Venezuela, Brazil, Argentina, Mexico and others is needed. Six representatives attended the Darwin trade workshop from South America and participated in the discussions.

3. RANGE STATES

A) USA

Concerns with the Endangered Species Act (ESA) and its potential impact on restored trade of some species (ie *C. latirostris* from Argentina or captive breeding restrictions) needs to be clarified. In addition, difficulties with exports of legal *C. porosus* from Thailand to US needs to be addressed. The Chair will provide an update on these issues. Efforts by Louisiana and CSG to initiate a repeal of the unenforceable California law prohibiting sales of crocodilian products should continue.

B) European Union

Slow import procedures, particularly in Italy and perhaps other countries must be addressed. Permit processing times up to four weeks are not acceptable to business and does not enhance sustainable use. The issues of tagging and retagging also needs clarification.

C) Mexico and Central America

Concerns with the sustainable use of *C. moreletti, C. acutus* and *Caiman crocodilus* require review, particularly in Mexico, Panama, Honduras and Guatemala. The impact of the USA (ESA) needs to be addressed.

4. GENERAL

A) Airport Displays

Continued effort to remove negative or misleading airport displays should continue. In addition opportunities to provide better conservation education to the public on sustainable use should tell a more balanced story about the value of crocodilians to people and wildlife.
B) Trade and Market Information

While the trade data from IACTS derived from CITES Annual Reports is essential, the report is two years dated (2004 report compiles data through 2002). More current trade information is important, particularly to range states without direct access to current market trends.

C) Directory of Farming and Ranching Operations

An updated directory of farming and ranching operations would be useful and UNEP-WCMC is willing to undertake it once funding is secured.

D) Authenticity of Trade

The relationship of scientists to traders is sometimes skeptical of commitments to conservation benefits. Credibility must improve to foster better cooperation in telling the conservation success story of crocodilians with benefits to people and wildlife through sustainable use.

The six most urgent recommendations were to address:

1) Live trade of critically endangered *C. siamensis* and captive breeding issues.
2) Compliance issues with CITES and Range States.
3) Maintain high standards for CITES personal Effects exemptions.
4) Slow import procedures of some European Union countries.
6) Airport and other negative public displays that mislead people about crocodilian products and conservation benefits of sustainable use.

In summary, the three primary conclusions of the trade workshop were to initiate some trade forums between the two-year CSG meetings, improve credibility of traders and explore ways to enhance community-based conservation that benefits people and wildlife.
CrocPLAN: A Genetic Improvement Program for Saltwater Crocodiles

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Abstract

By implementing an improvement program based on reproductive performance, juvenile growth and juvenile survival, superior juveniles will be selected as future breeding animals to increase the profitability of crocodile farms. It was, therefore, the aim of this study to create a plan for a practical genetic improvement program at a commercial crocodile farm (Janamba Croc Farm), thereby establishing an industry-wide genetic improvement program to be called CrocPLAN. Data were collected from Janamba Croc Farm and analysed to obtain relevant genetic and phenotypic parameters (heritability, repeatability and correlation) for breeding objectives and selection criteria. Relative economic weights were estimated and combined with estimated crocodile breeding values (CBVs) into a crocodile economic selection index (SCESI). Each SCESI value was expressed as a dollar ($) deviation from the herd average. Using the breeding pairs from Janamba, the highest-ranked pair had a SCESI value of +$4748, whereas the lowest-ranked pair had a SCESI of -$5257. The response to selection was predicted to be $324 increase in profit per breeding pair per annum. This result reinforces the potential for implementing CrocPLAN on saltwater crocodile farms in Australia. It also illustrates the potential for similar selection programs to be implemented using other crocodilians.

Introduction

To date, research in crocodilian industries has concentrated on improving management, for example in relation to nutrition and housing, to optimise production efficiency. No research has yet been conducted into the possibility of genetic improvement in captive breeding populations. The aim of a genetic improvement program is to improve the total economic value of the herd, and consequently maximise farm profit, for a given set of inputs. Identifying and breeding from pairs, or preferably individuals, that are genetically superior will increase the average genetic merit of the herd and aid in improving farm profitability.

Isberg et al. (2003) defined breeding objectives for the Australian crocodile industry. They included skin grade, number of hatchlings per female per year, survival rate, food conversion efficiency, age at slaughter and potential skin “quality” traits (scale row number and regularity, shape and thickness). Subsequently, Isberg et al. (2004) presented results from genetic analyses of these breeding objectives with the exception of the skin grade and food conversion efficiency breeding objectives. A summary of these results are presented in this paper. Resultant crocodile breeding values (CBVs) have been combined with estimated economic values into a crocodile economic selection index (SCESI) for candidate selection. The application of CrocPLAN, using Janamba Croc Farm as a model, is also presented.

Methods and Materials

All data (reproduction, production and survival) were collected on the Janamba Croc Farm (Middle Point, Northern Territory) using information from 30 known breeding pairs between 1994 and 2002 (Isberg et al. 2004). Restricted maximum likelihood (REML) procedures were used to obtain the required (co)variance components for estimating the relevant parameters (repeatability, heritability, genetic and phenotypic correlations) for each breeding objective and relevant selection criteria. A Cox’s proportional hazards model was used for the survival analysis. Only repeatability and phenotypic correlation could be estimated for the reproductive data due to the unknown pedigree structure. Heritability and genetic and phenotypic correlations were estimated for the breeding objectives age at slaughter and scale row number, whilst heritability only was estimated for juvenile survival. Data were not available for food conversion efficiency or the other skin-quality traits. In addition, estimated crocodile breeding values (CBVs) for
each pair were obtained.

Economic values for each breeding objective were estimated by Gray (2003), and were also presented in Isberg et al. (2004). The economic values were estimated on a ‘per breeding pair’ basis using a Cobb-Douglas type production function.

**Results and Discussion**

**Number of hatchlings per female per year**

The reproduction breeding objective investigated was the number of hatchlings produced per female per year (NoHatch). Possible selection criteria also included in the analysis were initial clutch size, number of viable eggs, hatchability, average hatching snout-vent length and time of nesting. Only repeatability could be estimated since no pedigree structure was available. All repeatability estimates were high, ranging from 0.24 (hatchability) to 0.68 (initial clutch size and time of nesting). Phenotypic correlations between the traits ranged from negligible (0.03) to high (0.86). All traits were kept in the multivariate analysis for the estimation of CBVs for NoHatch shown in Figure 1.

The CBVs shown in Figure 1 range between -8.75 hatchlings (B20) and 15.09 hatchlings (UB03), a difference of 23.84 hatchlings per female per year. These CBVs are expressed as deviations from the average herd CBV. Specifically, mating of a pair of offspring from parents both with a CBV of 15.09 like the pair UB03 will produce 15.09 hatchlings per annum greater than a pair whose parents have average breeding value, whilst progeny from a pair like B20 will have a reproductive performance of 8.75 hatchlings less than the herd average.

![Graph showing CBVs for number of hatchlings per year](image)

*Figure 1. Pair CBVs (± SE) for the reproduction breeding objective, number of hatchlings produced per clutch per year (NoHatch).*

**Age at slaughter**

The age when an animal is slaughtered directly influences the cost of production on crocodile farms. An investigation of this breeding objective, age at slaughter, and possible selection criteria including measurements taken at hatching and inventory (average age ~ 9 months) showed heritability estimates to be high. Heritability for age at slaughter was 0.40 (SE 0.10), whilst for hatching snout-vent length, it was 0.60 (SE 0.15). The genetic (-0.81) and phenotypic (-0.82) correlations between slaughter ages and inventory head length were high, whereas the correlation estimates between hatching snout-vent length and the other traits were either low and/or unreliable due to large standard errors. The resulting CBVs (± SE) for slaughter age are shown in Figure 2.

The range of CBVs shown in Figure 2 is between -158 days (B16) and 144 days (B01), with a difference of 302 days. These results indicate that future offspring from pair B16 will be predicted to reach slaughter size 158 days before the herd average, whilst offspring from pair B01 take an additional 144 days to reach the marketable size.
Figure 2. Pair CBVs (± SE) for the breeding objective, age at slaughter (days).

Juvenile survival

The number of juveniles that reach slaughter size from each clutch directly influences farm income. This trait was investigated using a Cox’s proportional hazard analysis. The heritability estimate for log juvenile crocodile survival time was 0.15 (SE 0.04). The log hazard pair estimates are shown in Figure 3a. However, since the average age at slaughter is three years, CBVs were calculated based on a juvenile surviving to 1095 days (or three years). These CBVs are presenting in Figure 3b.

Figure 3. A) Log hazard pair estimates (± SE) of juvenile survival produced using the Cox’s proportional hazards model. B) Pair CBVs (± SE) for juvenile survival (%) at 1095 days (or three years).
UB10 had the lowest log hazard estimate of -0.57 (antilog estimate ($e^{-0.57}$) = 0.57), whilst B01 had the highest estimate of 0.74 (antilog estimate = 2.09). This means that a juvenile from a clutch produced by UB10 has a higher chance of surviving to slaughter than a juvenile produced by the pair B01. More specifically, if we denote $S_i(t)$ as the baseline survival function, that is the probability that an individual survives to age $t$, averaged across the population, then the survival function for offspring of UB10 will be $[S_i(t)]^{0.57}$ (increased survival) whereas those from B01 will have a survival function of $[S_i(t)]^{2.09}$ (reduced survival). So in general, the survival function for offspring of a particular pair will be $[S_i(t)]^R$, where $R$ is the hazard ratio for a particular pair, being the antilog of the BLUP estimate on the log hazard scale. A further description is given in Isberg et al. (2004).

Since the hazard of mortality changes with time, it was decided that the most appropriate time to approximate breeding values was at day 1095 (or three years) since this was the average age at slaughter (Isberg et al. 2004). Juvenile survival CBVs were then expressed as a percentage difference in survival to 1095 days, relative to the population average. Thus, from the CBVs (Fig. 3b), offspring from pair UB10 have a 20.3% reduced risk of mortality compared to the herd average, whilst offspring from B01 have a 23.5% greater risk of dying before cull age.

**Number of scale rows**

The price received for an individual crocodile skin is currently determined by i) its width, and ii) its grade (determined by the number and severity of blemishes). Additional skin-quality traits have been identified by Manolis et al. (2000) that could, in the future, become important when marketing skins. Possible quality traits include: number of scale rows, regularity of scale pattern, and skin thickness. Currently, there is no premium received for any of these traits. Only data on the number of scale rows were collected. The heritability estimate using data from Janamba Croc Farm was 0.37. The CBVs ($\pm$ SE) for number of scale rows are shown in Figure 4. The range of CBVs was between 0.92 rows (UB13) and -1.20 rows (B12).

![Figure 4. Pair CBVs ($\pm$ SE) for number of scale rows.](image)

**Economic values**

Economic values for unit improvements in each breeding objective are presented in Table 1. An economic value could not be obtained for the number of scale rows since there is currently no premium price received for a greater number of scale rows on a belly skin.

**The crocodile economic selection index (SCESI)**

The aggregate breeding value for profitability is: $H = v_1BV_1 + v_2BV_2 + \ldots + v_mBV_m$

where $v_i$ = the economic value for the $i$th breeding objective, $BV_i$ = the true breeding value for the $i$th breeding objective, and $m = \text{the total number of breeding objectives in the selection index}$. Candidates are selected after ranking based on an estimate of their aggregate breeding value, $H$, which is calculated as the crocodile economic
Table 1. Economic values for crocodile breeding objectives. “Abb.” is the abbreviated term for the respective breeding objective.

<table>
<thead>
<tr>
<th>Breeding objective</th>
<th>Abb.</th>
<th>Increment</th>
<th>Economic value ($AUD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of hatchlings per year</td>
<td>NoHatch</td>
<td>Increase by one hatchling per year</td>
<td>41.95</td>
</tr>
<tr>
<td>Age at slaughter</td>
<td>CullAge</td>
<td>Increase time to reach slaughter size by one week</td>
<td>-25.68</td>
</tr>
<tr>
<td>Juvenile survival</td>
<td>Surv</td>
<td>Increase survival by 1%</td>
<td>52.37</td>
</tr>
<tr>
<td>Number of scale rows</td>
<td>SR</td>
<td>Increase by one row</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The selection index ($CESI$)

$$CESI = \nu_{NoHatch} CBV_{NoHatch} + \nu_{CullAge} CBV_{CullAge} + \nu_{Surv} CBV_{Surv} + \nu_{SR} CBV_{SR}$$

After substituting the economic values from Table 1, the $CESI$ becomes

$$CESI = 41.95(CBV_{NoHatch}) - 25.68(CBV_{CullAge}) + 52.37(CBV_{Surv}) + 0(CBV_{SR})$$

A $CESI$ value for each breeding pair was estimated and is shown graphically in Figure 5. Each pair is expressed as a dollar ($) deviation from the pair average. Pair B16 has the largest $CESI$ value (+$4748), whilst B01 has the lowest value (-$5257). Note that because covariances between the component CBVs could not be determined, it was not possible to determine standard errors for these $CESIs$.

![Figure 5. Crocodile economic selection index ($CESI$) values for each breeding pair at Janamba Croc Farm used in this study. The CESI value is expressed as a dollar ($) deviation from the herd average, expressed on a per annum basis.](image)

**Recommendations for implementing CrocPLAN**

Isberg et al. (2004) provided recommendations for implementing CrocPLAN using Janamba Croc Farm as a model. Briefly, the selection of replacement breeder animals will occur when the animals reach slaughter size (approximately 2.8 years). Juveniles will be selected using their own $CESI$ value, using individual performance records integrated into an index with records from relatives. Ten per cent of adult breeding pairs will be replaced each year, with selection intensities ($i$) of 2.88 and 2.05, for males and females respectively. Generation interval was estimated to be
13 years for both males and females, using the following assumptions: sexual maturity will occur at eight years of age for both males and females (Elsey et al. 1993); replacement rate is 10%; and, the oldest six pairs are replaced each year (that is, each animal breeds for ten years after sexual maturity).

Using these parameters, the response to selection was predicted to be a $324 increase in profit per annum per breeding pair, assuming no genetic and phenotypic correlation amongst breeding objectives. This result, in conjunction with the large variation in CBVs reinforces the potential for implementing a genetic improvement program (CrocPLAN) on Australian crocodile farms.

A recommendation for maximising genetic variation is the industry-wide adoption of CrocPLAN allowing between-farm (or across-herd) selection of replacement animals. With a functional crocodile economic selection index, $\text{CESI}$-values can be obtained at any time, allowing across-herd trade of genetically superior (fertile) eggs, hatchlings, juveniles, and adults. The occasional inclusion of wild-harvested animals may also provide additional variability. Additionally, if the level of genetic variation is consistent between crocodilian species, these results provide evidence that genetic selection programs may also provide a method of improving farm profitability in these industries.

**Literature**


Outbreaks of Mycoplasmosis in Farmed Nile Crocodiles in South Africa

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Abstract

Since July 2002 several severe outbreaks of mycoplasmosis with polyarthritis and pericarditis have occurred on South African crocodile farms. The affected crocodiles became unable to move and had to be slaughtered. A Mycoplasma sp. isolated from the lesions was different from M. crocodyli previously known from outbreaks in Zimbabwe. In more recent outbreaks of polyarthritis in farmed Nile crocodile hatchlings and juveniles M. crocodyli was isolated. The affected hatchlings had been imported from Kenya. The epidemiology of the outbreaks still needs to be investigated further.

Introduction

Outbreaks of mycoplasmosis are associated mainly with polyarthritis and occasionally with pericarditis as well. Such outbreaks are known to have occurred in American alligators Alligator mississippiensis and in Nile crocodiles Crocodylus niloticus (Mohan et al. 1996; Clippinger et al. 2000) and two species of crocodilian mycoplasmas have been described: Mycoplasma alligatoris (Brown et al. 2001) and Mycoplasma crocodyli (Kirchhoff et al. 1997). In June 2002 a severe outbreak of polyarthritis occurred in juvenile farmed crocodiles on a farm in the Limpopo Province of South Africa and this was followed by further outbreaks on other crocodile farms. This paper reports on the investigations into these outbreaks.

Materials and Methods

Juvenile Nile crocodiles from several crocodile farms in South Africa suffering from outbreaks of polyarthritis were killed humanely and dissected either before or after skinning. Whole legs affected by arthritis and pericardial sacs containing the heart were cut out and taken to the laboratory for Mycoplasma isolation. The legs and pericardial sac were dissected aseptically and swabs taken from the joints and the pericardial fluid. These were plated onto Columbia blood agar (Oxoid, Basingstoke, England) containing 5% horse blood, Hayflicks mycoplasma (Hayflick 1965) and Chalquest (Chalquest 1962) agars and incubated in 5% CO₂ at 37°C and in air at 22°C. Both of the agars contained 10 mg ampicillin to inhibit Gram-positive bacteria. Small colonies (<1mm diameter) with a so-called “fried egg” appearance were purified and proven to be mycoplasmas by repeated subculture onto Hayflick’s agar without antibiotics. Basic biochemical characterization was also done.

Results

Between December 2002 and April 2004 crocodiles from nine farms were examined. Clinically most of the crocodiles had swollen leg joints and were unable to move. The swollen joints were filled either with excessive quantities of turbid fluid or with dry fibrinous exudate and were surrounded by edematous tissue. Some of the crocodiles also had an exudative pericarditis. Lung lesions were not seen. In some cases the pharyngeal tonsils were found to be swollen.

Mycoplasmas were isolated from specimens from five of the nine farms (Table 1). The Mycoplasma isolates showed several different features. One group of mycoplasmas showed all the characteristics of M. crocodyli while the most notable feature of the earlier mycoplasmas cultured was their ability to only grow at 22°C and not at 37°C. They differed from M. alligatoris by being able to hydrolyze arginine and from M. crocodyli by being able to hydrolyze arginine and not growing at 37°C.

The brief histories of the disease on the nine farms are as follows:

Farm 1: High incidence of polyarthritis in 2-year-old crocodiles in one pen where water from a river with wild crocodiles had been used. The other pens received borehole water.
Table 1. Pattern of *Mycoplasma* isolations from farmed Nile crocodiles in South Africa. *Preferred temperature at which the mycoplasmas were cultured. The mycoplasmas that grew at 37°C also grew at 22°C, whereas those that grew at 22°C did not grow at temperatures above 25°C.*

<table>
<thead>
<tr>
<th>Date submitted</th>
<th>Farm</th>
<th>Laboratory Number</th>
<th>Result (Temperature*)</th>
<th>Site</th>
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<td>B85/03</td>
<td>+ (22°C)</td>
<td>Joint</td>
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<td>-</td>
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<tr>
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<td>B442/03</td>
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<tr>
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<td>-</td>
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<td></td>
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<td>-</td>
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<td>3</td>
<td>B317/04</td>
<td>+ (37°C)</td>
<td>Joints</td>
</tr>
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</table>

**Farm 2:** High incidence of polyarthritis in 2-year-old crocodiles, probably triggered by temperature stress. The outbreak started in July 2002, while the senior author was overseas. It was first investigated in September of the same year after his return but mycoplasma cultures were undertaken only later, in January 2003.

**Farm 3:** High incidence of polyarthritis in two- and three-year-old crocodiles, probably first triggered by temperature stress. This farm had purchased crocodiles from several sources.

**Farm 4:** Hatchlings with pericarditis and peritonitis later found to have been caused by Adenovirus and salmonellosis.

**Farm 5:** Mortality in 3-year-old crocodiles with pericarditis later found to have been caused by salmonellosis.

**Farm 6:** High incidence of polyarthritis and pericarditis in hatchlings which had been imported from Kenya. The outbreak started after the hatchlings had been purchased from the original importer and transported by road for ± 1500 km, triggered by transport stress.

**Farm 7:** Polyarthritis and pericarditis in hatchlings imported from Kenya.

**Farm 8:** High incidence of polyarthritis in one group of 3-year-old crocodiles. There may have been a connection with farm 3. In spite of negative culture results the farm is believed to be infected. This will have to be confirmed by serological testing.

**Farm 9:** Mortality in 3-year-old crocodiles later diagnosed as stress septicaemia. Only one of the examined animals had arthritis.

**Discussion**

*Mycoplasma* species were not cultured from all suspect cases. Even in confirmed cases not every joint or pericardial sac submitted yielded an isolate. Although there may have been other unidentified causes of this disease, it is more likely that since culturing is a relatively insensitive method that these were false negative results. Mycoplasmas are sensitive to overgrowth by putrefactive bacteria and it was found that in spite of using aseptic sampling methods many joints had a mixed growth of walled bacteria which grow more rapidly than mycoplasmas and were not inhibited by the penicillin in the media. Tetracycline therapy of affected animals will inhibit most mycoplasmas. The causative mycoplasmas may also have been eliminated by the host’s immune system by the time crocodiles with chronic disease were slaughtered.
All of the outbreaks appeared to have been triggered by stress - preceding stressful events or conditions. As the crocodiles became immobilized and unable to feed, they had to be slaughtered in an attempt to harvest their skins and thus to save at least some value. Particularly on farms 2 and 3 the losses were quite catastrophic.

There had been two outbreaks of polyarthritis in crocodiles in preceding years which at the time had been interpreted as stress-induced septicaemia. Those outbreaks, however, were very limited in extent whereas the more recent ones, the subjects of this paper, appeared to be grouped or linked. Another difference is that in the present outbreaks group treatment with tetracycline after the removal of clinical cases appears to be suppressing the infection for a limited time only, approximately two months, and then new cases appear, more clinically affected crocodiles have to be slaughtered and more antibiotic treatment has to be administered.

Two species of *Mycoplasma* have been isolated from the outbreaks, first a new species yet to be described and subsequently *M. crocodyli*. While the epidemiology of the outbreaks still is confused, it appears that the new species may be of local origin, from a local population of wild crocodiles, whereas *M. crocodyli* was at least in one case brought in with the importation of hatchlings from another country.

Mycoplasmosis is thought to be transmitted via the water with the mycoplasmas originating from either the oral cavities or faeces of carrier crocodiles. There appears to be a silent carrier stage, while outbreaks of clinical disease appear to be triggered by stressful events or conditions. Antibacterial treatment, mainly with tetracycline, did lead to an improvement of clinically ill crocodiles. However, it suppressed further appearance of new cases, but only for a limited period after which waves of new cases tended to appear. Extreme care should be taken to prevent spreading the infection from pen to pen and when considering the purchase of stock from a farm of unknown disease status.

**Conclusion**

More work needs to be done to clarify the epidemiology of the recent outbreaks and to develop diagnostic tools, in particular serological tests, which could be used to monitor imported crocodiles or even those traded between farms.

**Acknowledgements**

This paper is dedicated to the memory of Prof. K. Mohan, the discoverer of *Mycoplasma crocodyli*, who passed away in 2003.

**Literature**


Ultrasound as a Tool to Evaluate Reproductive Structures of Female  
_Caiman crocodilus fuscus_ in Closed Cycle Conditions

Iván D. Palacios R.¹ and Alberto Beltrán F.²

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² Equina reproduction Management Adviser; Colombia (cyberagro_equine@hotmail.com)

Abstract

To select reproductive groups of crocodilians in farms, ultrasound is a tool that allows us to evaluate reproductive structures of females. Between December 2002 and February 2003, reproductive animals at three farms located in Atlántico, Colombia, were classified. During the period when courting and mating begin for _C. c. fuscus_, gravid females are not normally found. Of 8435 females (mean TL of 136.2 cm, mean weight 8.5 kg), 3590 were evaluated with ultrasound on both flanks. We diagnosed: 3170 “empty” females; 320 with vitellogenic follicles in the ovary to ova in the oviduct (32 mm); 73 with ova of different sizes and calcified eggs (32 to 72 mm); and, 27 with eggs in the abdominal cavity (32 to 66 mm). The transfer mechanism of the eggs from the oviduct to the abdominal cavity is unknown, where they stick to the intestine to be reabsorbed. According to what we observed in 15 females that were sacrificed to confirm the diagnosis, we examined the oviducts macroscopically and passed a catheter inside without finding evidence of any ruptures, also we analyzed egg samples, oviducts and abdominal liquids to isolate microorganisms, all of which were reported as negative.

Para seleccionar grupos reproductores en granjas de crocodilidos el ultrasono es una herramienta, que permite evaluar estructuras reproductivas de las hembras. Entre diciembre 2002 y febrero 2003, se clasificaron los grupos de reproductores en tres granjas ubicadas en el departamento de Atlántico, Colombia; época donde comienza el cortejo y apareamiento para _C. c. fuscus_, normalmente, nunca deben encontrarse hembras ovadas. De 8435 hembras totales, se evaluaron por ultrasonido en ambos flancos 3590, con 136.2 cm (LT) promedio y 8.5 kg (W). Se diagnosticaron 3170 hembras vacías; 320 presentaron desde folículos vitelogénicos en ovario, hasta óvulos en oviducto 32 mm; 73 hembras con óvulos de diferentes tamaños y huevos calcificados desde 32 mm hasta 72 mm; 27 tenían huevos en cavidad abdominal desde 35 mm hasta 66 mm. Se desconoce el mecanismo de traspaso de huevos desde el oviducto a cavidad abdominal, donde se adhieren al intestino para ser reabsorbidos, de acuerdo a lo observado en parte de 15 hembras sacrificadas para confirmar diagnósticos, se examinaron los oviductos macroscópicamente y se pasó un catéter por dentro sin hallar evidencia de rupturas, también se analizaron muestras de huevos, oviductos y líquidos abdominales para aislar microorganismos, siendo negativo el reporte del laboratorio.

Introduction

The success of the majority of the animal production system is based on the selection of the reproducers, Being this a managing practice that is normally used. To accomplish this it has been very important the identification of determinate anatomic and physiological characteristics of the individuals that lead to establish efficient biological standards, to be able to accomplish the optimization of these production systems.

Nowadays we have implemented technologies that allow us predict, diagnose and correct critical points of the processes already mentioned. Case of many species of the domestic fauna, in which to monitor the estrus cycle, detect pathologies, determine pregnancy, establish development state during the gestation and detect anomalies or malformations in the reproductive structures, the ultrasound technique is used. Ones the specimen fulfills the protocol where the pathologies are discarded, we evaluate the uterus and the increasing of the follicular through ultrasound and the professional decides the hour of artificial insemination of the females to obtain high quality genetic breeding.

The breeding of crocodilians in closed cycle, like any other industry of livestock production, must adjust to the use of new technologies that allow the increasing of the efficiency to meet the goals of production.

Materials and Methods

A ultronography was done to 3590 females of the _C. c. fuscus_ species coming from three farms (DEL CARIBE
COLOMBIANO, SAN FRANSICO e INVERSIONES SALAZAR DIAZGRANADOS) located in the “Departamento del Atlántico, Colombia”.

For this procedure we used: special gel for ultrasounds, Pie Medical equipment, lineal transducer of 5Mhz., and basic equipment for the procedure.

Each animal was ultra sounded in the left and right flank and we used special gel for the ultrasound to improve the image quality.

Each animal previous to the ultrasound was marked, weighed, and measured. The females have a double marking system; a general one that consists of an amputation of the first dorsal crest of the tail, an the other one is an individual marking with a numbered plastic band in the base of the tail. For the statistic analysis we used the SPSS 9.0. program. The variables included were:

1. Ultrasound date
2. Specimen identification
3. Length
4. Weight
5. Left and right flank

The characteristics found in the flanks were the following:

* Empty: The animal that didn’t present any particular internal characteristics when viewed by the ultrasound machine.
* Gemma in formation: These are defined as structures like small black circles generally located in the ovary level like a cluster of grapes.
* Gemma: They are black round circles, that were observed generally a long side the flank, we found them in different sizes or very similar inside the animal.

In case of finding different sizes we measured the gemmas that size was more abundant, we established an average and it was given a rank of calcification. The gemmas were classified in the following way.

Gemma under 10 mm
Gemma 10-20 mm
Gemma 21-30 mm
Gemma 31-40 mm
Gemma over 40 mm

Masses: These structures were presented with shape of a gemma but in the ultrasound they were observed in color gray, its size was variable and in many cases very difficult to diagnose. These masses also were classified by size in the following way:

Masses like so
Masses under 10 mm
Masses 10-20 mm
Masses over 20 mm

Masses and Gemmas: Likewise some specimens showed in their flanks mixed masses and gemmas and they were classified in this category.

Eggs: In some females we could appreciate eggs perfectly delimitated and with shell formation in the majority of the cases. The sizes like the gemmas that varied inside the animal in the position of the egg or by being in different grades of formation. In these cases we averaged the size presented with more frequency and it was categorized in the following ranks:

Eggs under 40 mm
Eggs 40-50 mm
Eggs 51-60 mm
Eggs over 60 mm
Eggs without shell: In this rank we classified the females that presented eggs of great size without evidence of a shell.
Gemas, Eggs and Masses: Some females showed in their flank 3 types of structures and they were classified in this
group.

Eggs in apparent abdominal cavity: In our discoveries we found that some females out of the laying period presented
one or many eggs, generally observed in either one of the flanks and located in the abdominal cavity. It called our
attention and some specimens were sacrificed to corroborate our diagnostic.

These eggs were found like we expected out of the oviduct, additionally we evaluated the oviduct to try to find the
way out to the abdominal cavity passing through a flexible pipette for horse insemination and we didn’t observe in
any of the cases rupture of the oviducts wall or scar, that would allow us assurance that the reason of this so called
exit was a breach of the oviduct tissue. For us this characteristic is still a mystery, we couldn’t find any mechanic
explanation for the localization of these eggs in the abdominal cavity, but we could find how they were reabsorbed.

The process begins with the extension of the intestine, through the small fimbrias and catches the egg and hinge to it.
There we think the re-absorption begins, with time the shell gets weak. By mechanic action, fights between animals
or manipulation of de man, the liquid of the egg is spilled in the abdomen absorbing it directly, the rest of the egg’s
structures are absorbed reducing themselves to small masses found in the intestinal walls.

As something curious I add, a female diagnosed with an abdominal egg died 6 months later of the diagnostic and it
still persisted in the abdominal cavity.

Eggs in apparent re-absorption: Here we classified the animals that showed eggs in the abdominal cavity, but with
the particular characteristic that the ultrasound viewed deformations, not round or oval.

Liquids in the abdominal cavity: In some cases we observed in the flanks of some specimens the presence of liquids,
these are seen in the ultrasound as black stains. Probably in some cases specially at the beginning of the job and due
to inexperience, the observed liquids were coming from the stomach of the babilla (C. c. fuscus) when these weren’t
submitted to a fasting.

Fat presence: This fat could be observed at the level of the flank in previous or posterior localization, generally when
it was present it didn’t let the ultrasound penetrate at it made any diagnostic impossible.

Characteristics: This variable included all those particular phenotypic aspects of the species, this would help us in
some cases to recognize corporal conditions, mutilations or abnormalities that would permit us recognize even more
the animal or change in the corporal condition to relate it with the reproductive state.

Results

Descriptive statistics

With the use of the transducer of e Mhz. It was impossible to observe from the belly or from the back any structure
or particular characteristics due to the presence of the osteodermus that don’t allow the penetration of sound. The
average of ultrasounds were 142 females per day. The speed of the diagnostic depended on the disposability of the
animals in the tanks., the size of the animals and the experience of operators. Each animal was measured, weighed
previously to the ultrasound diagnostic. Registering the data of length and weight, the minimum and maximum sizes,
which average analysis and standard deviation are presented in Table 1.

In Table 2 the weight and the length are related to obtain information that allows us predict in three farms, with the
data of the length the approximated weight of each female. The females under 128 cm in their majority were selected
as replacements of a group of reproducers in three farms in which we also found reproductive activity. Each animal
was ultrasounded in its left and right flank, in some of them were found different types of structures, those animals in
which wasn’t observed any particularity were diagnosed as empty. The results shows us that the 88.3% of the monitored
animals didn’t present any type of structure that allow us assure that for those dates when the ultrasounds were done
that the females were presenting some type of ovary or reproductive activity (Table 3).
Table 1. Ranges, averages and standard deviations of the length and weight of 3580 female *C.c. fuscus*.

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<th>Parameter</th>
<th>N</th>
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<th>Maximum</th>
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<td>18.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
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<td>4.0</td>
<td>27.0</td>
<td>8.5</td>
<td>4.64</td>
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</table>

Table 2. Standards deviations (SD) for the length and weight of 3580 female *C.c. fuscus*.

<table>
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<tr>
<th>Length (cm)</th>
<th>Weight (kg)</th>
<th>N</th>
<th>SD</th>
<th>Length (cm)</th>
<th>Weight (kg)</th>
<th>N</th>
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<td>0.346</td>
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<td>1.713</td>
<td>186.0</td>
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<td>3.535</td>
</tr>
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</table>

Conclusions

The industry of caimans breeding has to adopt diagnostic and production systems completely updated, to detect unfertile specimens with reproductive pathologies. These animals take space, consume food and hand craft, and they’ll stay in the breeding place for long periods of time with out being really productive.

Acknowledgements

We specially thanks the croc farms: From the DEL CARIBE COLOMBIANO, SAN FRANCISCO, INVERSIONES SALAZAR DIAZGRANADOS, located in the Atlantico department Colombia for the unconditional cooperation for the development of this investigation. Thanks to croc farm REPTICOSTA for you’re support and Miguel Rodriguez for his comments.

Literature


Table 3. Reproductive structures in the left oviduct of female *C. c. fuscus* in three farms on the Caribbean coast of Colombia.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percentage</th>
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<tbody>
<tr>
<td>Empty</td>
<td>1143</td>
<td>88.9</td>
<td>88.9</td>
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<tr>
<td>Gemmas in formation</td>
<td>4</td>
<td>0.3</td>
<td>89.3</td>
</tr>
<tr>
<td>Gemmas &gt;10 mm</td>
<td>21</td>
<td>1.6</td>
<td>90.9</td>
</tr>
<tr>
<td>Gemmas 10-20 mm</td>
<td>55</td>
<td>4.3</td>
<td>95.2</td>
</tr>
<tr>
<td>Gemmas 21-30 mm</td>
<td>11</td>
<td>0.9</td>
<td>96.0</td>
</tr>
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<td>Gemmas and Masses</td>
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<td>96.1</td>
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<td>Masses</td>
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<td>96.2</td>
</tr>
<tr>
<td>Masses &gt;10 mm</td>
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<td>96.3</td>
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<td>Masses 10-20 mm</td>
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<td>96.7</td>
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<td>Masses &lt;20 mm</td>
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<td>Gemmas and shelled eggs</td>
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<td>0.1</td>
<td>96.9</td>
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<td>Eggs 40-50 mm</td>
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<td>0.1</td>
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<td>Eggs 51-60 mm</td>
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<td>0.3</td>
<td>98.3</td>
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<tr>
<td>Eggs Aparent abdominal cavity</td>
<td>3</td>
<td>0.2</td>
<td>98.5</td>
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<tr>
<td>Eggs abdominal cavity</td>
<td>1</td>
<td>0.1</td>
<td>98.6</td>
</tr>
<tr>
<td>Fluids Abdominal cavity</td>
<td>1</td>
<td>0.1</td>
<td>98.7</td>
</tr>
<tr>
<td>Flank fat</td>
<td>7</td>
<td>0.5</td>
<td>99.2</td>
</tr>
<tr>
<td>Gemmas 11-20 mm and Masses</td>
<td>1</td>
<td>0.1</td>
<td>99.3</td>
</tr>
<tr>
<td>Gemmas 10-20 mm &amp; Masses 10-20 mm</td>
<td>2</td>
<td>0.2</td>
<td>99.5</td>
</tr>
<tr>
<td>Gemmas 21-30 mm &amp; Masses 11-20 mm</td>
<td>2</td>
<td>0.2</td>
<td>99.6</td>
</tr>
<tr>
<td>Masses &lt;20 mm and Abdominal. Fluid</td>
<td>1</td>
<td>0.1</td>
<td>99.7</td>
</tr>
<tr>
<td>Eggs without shells 40-50 mm</td>
<td>1</td>
<td>0.1</td>
<td>99.8</td>
</tr>
<tr>
<td>Eggs Aparent Reabsorption 50-60 mm</td>
<td>2</td>
<td>0.2</td>
<td>99.9</td>
</tr>
<tr>
<td>Gemmas 10-20 mm &amp; Masses 10-20 mm &amp; Eggs 40-50 mm</td>
<td>1</td>
<td>0.1</td>
<td>100.0</td>
</tr>
</tbody>
</table>


Development of Manufactured Feeds for *Crocodylus porosus*

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Abstract

Potential exists to meet the nutrient requirements for the growth and production of *Crocodile porosus* using manufactured semi-moist feeds, thus presenting an opportunity to reduce overall production costs and improve the efficiency of feeding. Research completed to date has demonstrated that juvenile crocodiles can achieve growth rates approaching 16 g/d with feed conversion ratios of 3:1 when fed semi-moist pellets (420 g/kg crude protein; 50 g/kg crude fat; 630 g/kg dry matter) at a rate of 3% of liveweight per day. Manufactured diets do not require the inclusion of fresh meat co-products (kangaroo mince, beef mince, chicken heads, etc.) to achieve adequate intakes, and attractants appear to have little influence on feeding intensity or total feed intake. A staged introduction of manufactured feeds is required to ensure newly hatched crocodiles are successfully weaned onto manufactured feeds as their primary source of nutrients, but once weaned, no difference in growth or feeding efficiency is observed between feeding every 3, 4 or 5 days. Further research will investigate improved weaning procedures, ingredient characterisation, feeding delivery strategies, feed production methods, and nutrient requirements with a view to reducing the proportion of production costs attributable to feed.

Introduction

Commercial crocodile production in Australia relies primarily on combinations of fresh meat for the supply of nutrients to all production phases. Not only is fresh meat unlikely to represent an optimal supply of nutrients for efficient crocodile growth, but supply, storage and handling can be difficult and costly. In contrast, the composition of manufactured feeds can be manipulated to match diet specifications to the nutrient requirements of the crocodile for a particular production phase, manufactured feeds can be formulated to reduce the content of fresh meat thus improving shelf life and reducing the need for refrigerated storage, and they are generally easy to handle. In addition, the nutrient density of manufactured feeds is often greater than fresh meat and hence the cost per nutrient supplied in every kilogram of manufactured feed is usually less than via fresh meat.

When defining the most appropriate approach for the development of manufactured feeds for crocodiles, it is important to maintain a focus on the primary nutritional drivers of profitability in any intensive animal production system (Fig. 1). By maintaining this focus, it becomes clear that the primary nutritional challenges for *Crocodylus porosus*, where development of manufactured feeds is still in its infancy, include:

- Identification of the most suitable diet form taking in to account acceptance by crocodiles in various production phases, feeding habits, digestive anatomy and physiology, and the shelf-life and handling characteristics of the feed and the most efficient means of manufacturing the feed;
- Selection of the most appropriate ingredients for inclusion in manufactured feeds;
- Matching diet specifications to the nutrient requirements of crocodiles in various phases of production;
- Initiation of feeding and the weaning of juvenile crocodiles onto manufactured diets as their primary food source;
- Identification that influence feed intake of manufactured feeds by crocodiles and the most appropriate feeding strategies.

The aim of this paper is to describe the attributes of manufactured feeds and feeding strategies developed for *Crocodylus porosus* and results of an extensive research program that underpins this development. Overall, we are seeking to develop manufactured feeds that are:
Profit = (Revenue - Costs of production) x volume

Feed costs
Feed cost ($/kg)
Ingredient supply
Diet specifications
Manufacturing costs
Transport costs
Storage costs

Non-feed costs
Feed conversion efficiency
Feed intake
Variation in feed intake and FCE
Feed utilization

Figure 1. Primary nutritional drivers of profitability in intensive animal production systems.

- Acceptable to crocodiles;
- Cost-effective;
- Capable of promoting efficient production;
- Optimal in terms of final product quality;
- Easy to manufacture, store and handle.

**Diet Form**

Based on research undertaken previously in Zimbabwe and local experience, a semi-moist pellet (ie 25% moisture) was deemed to be the most appropriate initial diet form for manufactured crocodile feeds in Australia. Jansen-Van Vuuren (1993) reported that dry diets were poorly accepted by crocodiles, but acceptance was improved when moist pasta-like products were offered. As more experience is gained with feeding manufactured feeds to crocodiles, it is possible that the need for a semi-moist pellet will be reduced and that dry pellets could have application with specific production phases. This was certainly the experience of the salmon industry worldwide that now relies totally on low moisture, high protein, high fat extruded feeds, but started as an industry feeding fresh bait fish and semi-moist feeds (Fig. 2).

**Salmon Aquaculture**

![Diagram showing diet form from 1971 to 2001](image)

Figure 2. Schematic representation of chronological development of manufactured feeds in the salmon industry.

As well as acceptance, diet form must be matched to the digestive anatomy and physiology and the feeding habits of the target animal. Crocodiles are generally opportunistic feeders and can go for long periods without food with frequency of feeding influenced by body size and environmental temperatures. In addition, crocodiles do not extensively chew their food, have a highly acidic and mechanically active stomach environment and comparatively short intestines and colon. As a consequence, the diet form needs to be such that it can be maintained in the stomach environment for a period of time ensuring a constant flow of nutrients over this period to the intestine, but as there is limited chewing, it cannot be so well bound that it will not break down in the stomach.
The current semi-moist pellet used for crocodiles in Australia is produced with wheat gluten as the binder. A significant amount of trial and error has resulted in definition of the optimum balance between wheat gluten, oil and water so that pellet binding is optimal. Pellet sizes vary depending on the age of crocodiles being fed, ranging from a mince during the weaning period to pellets exceeding 5 cm in diameter for adult breeding crocodiles. The semi-moist pellets produced are generally sinking, but potential exists to produce floating pellets, but this may be at the expense of water stability in the first instance.

Semi-moist pellets are produced using a modified mixer/mincer with a range of tube die attachments (Fig. 3). A gearbox allows the auger speed to be varied, so that the amount of mechanical energy imparted on the feed can be controlled. Ideally, if the temperature of the mix can reach approximately 52°C through friction, the semi-moist pellet binding will be optimal.

![Figure 3. Modified mixer/mincer with pipe die used to produce semi-moist pellets for crocodiles.](image)

**Ingredient Selection**

Ingredients used in manufactured diets for crocodiles must match the capacity of the crocodile to digest these components as well as being acceptable. While diets consumed by crocodiles in the wild are some guide to potential ingredients in manufactured feed, this is generally more likely to reflect the feed that is available rather than the most appropriate ingredients for use in the supply of nutrients in an intensive production system.

Crocodiles have a high capacity to digest protein from both animal and vegetable sources (Coulson and Hernandez 1983; Staton and Vernon 1991; Manolis 1993), and fats (Manolis 1993). It also appears that crocodiles have some capacity to utilise carbohydrates as a source of dietary energy (Staton et al. 1990b). As a consequence, a wide range of feed ingredients can be utilised in manufactured crocodile feeds, resulting in significant flexibility in formulations, and potential to closely match diet specifications to the nutrient requirements of the crocodiles.

While we have a basic understanding of the types of food constituents that can be digested by crocodiles, further refinement of manufactured feeds will be achieved through a better understanding of the enzymic and microbiological profiles in the gut, and how manufactured feeds can influence these factors. For example, while some enzymes have been identified (including pepsin, intestinal protease, trypsin, chymotrypsin, carboxypeptidase, aminopeptidase and a-amylase) their activity and relative proportions have not been identified. Digestive enzymes, whether of microbial or endogenous origin are the key to understanding digestive processes in the intestinal tract. However, not only is the total digestive profile important, it is also essential to understand the regional localisation of specific digestive enzymes so that the structure of feed pellets can be matched with digestive capabilities. In order to maximise the digestibility and absorption of nutrients, we need to understand which digestive enzymes have the greatest activities, where they are located and whether they change in level with changes in feed.

In addition to enzyme activities and profiles, microbial populations also play an important role in the efficiency of digestion and manufactured feeds composition and form. Microorganisms play an important role in digestive processes in most terrestrial species, and there is good evidence that microorganisms also exist in the digestive tract of aquatic species and reptiles. However, it is not clear what role these bacteria play. They could play a passive role in restricting
the establishment of significant numbers of pathogenic bacteria in the gut, or a more active role by promoting or enhancing digestion of the normal diet. When crocodiles are fed a manufactured diet containing components not normally found in the wild, the action of microbial populations may be essential in achieving optimal digestion and growth response. Integration of the microbial and enzyme components of the farmed crocodilian gut could provide useful information about the capability of crocodiles to digest manufactured feeds, and help in the structural and compositional design of a feed pellet.

Manufactured diets for crocodiles that have been used to produce acceptable growth rates in crocodiles consist primarily of:

- Proteins including wheat gluten, meat and bone meal, feather meal, blood meal, poultry meal and fish meal;
- Water;
- Oils or tallow;
- Vitamins and minerals;
- Preservatives and anti-microbials such as potassium sorbate, phosphoric acid and propylene glycol to manipulate water activity and confer increased shelf life;
- Anti-oxidants and mycotoxin binders.

While fresh meat is used as a basal diet in many crocodile production systems, it is not necessary to include it in manufactured diets to achieve acceptable intakes. Fresh meat is not currently used as a ingredient in manufactured diets in Australia and this does not effect the efficacy of the resulting diet. In addition, it appears that crocodiles do not have distinct preferences for particular ingredients in manufactured diets. Research undertaken by the Queensland Department of Primary Industries in Townsville compared the influence of fresh meat content (0 or 50%), fat level (10 or 15%), fat type (chicken tallow or canola oil) and an attractant (0 or added chicken flavour). All combinations of these factors were tested (Table 1) through a total of 16 different diets, using paired preference tests to reveal no significant preference for any combination in crocodiles of different sizes.

One characteristic of crocodile nutrition in the wild is the fact that they are known to consume a significant proportion of indigestible material and to retain proportions of this in the gut as gastroliths. This is similar to the consumption of shell grit by poultry to enhance the action of the gizzard. Previous research undertaken in Australia had demonstrated that diets with increasing levels of kaolin (a fine clay used in the production of porcelain) as an indigestible filler and decreasing levels of fat promoted superior performance in growing crocodiles (Fig. 4). It was hypothesized that the kaolin may be acting as a gastrolith and could be an important addition to manufactured feeds. Subsequent research however, demonstrated that addition of dietary kaolin has no influence on crocodile performance, nor do other clays such as bentonite (Fig. 5).

Table 1. Diet combinations used to test preference for fresh meat, fat level, fat type and attractant in manufactured semi-moist pellets.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Fat Content (%)</th>
<th>Fresh Meat (%)</th>
<th>Fat type</th>
<th>Attractant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>Chicken tallow</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>0</td>
<td>Chicken tallow</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>25</td>
<td>Chicken tallow</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>25</td>
<td>Chicken tallow</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>0</td>
<td>Canola oil</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>0</td>
<td>Canola oil</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>25</td>
<td>Canola oil</td>
<td>No</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
<td>25</td>
<td>Canola oil</td>
<td>No</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>0</td>
<td>Chicken tallow</td>
<td>Chicken flavour</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
<td>0</td>
<td>Chicken tallow</td>
<td>Chicken flavour</td>
</tr>
<tr>
<td>11</td>
<td>10</td>
<td>25</td>
<td>Chicken tallow</td>
<td>Chicken flavour</td>
</tr>
<tr>
<td>12</td>
<td>15</td>
<td>25</td>
<td>Chicken tallow</td>
<td>Chicken flavour</td>
</tr>
<tr>
<td>13</td>
<td>10</td>
<td>0</td>
<td>Canola oil</td>
<td>Chicken flavour</td>
</tr>
<tr>
<td>14</td>
<td>15</td>
<td>0</td>
<td>Canola oil</td>
<td>Chicken flavour</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
<td>25</td>
<td>Canola oil</td>
<td>Chicken flavour</td>
</tr>
<tr>
<td>16</td>
<td>15</td>
<td>25</td>
<td>Canola oil</td>
<td>Chicken flavour</td>
</tr>
</tbody>
</table>
Diet Specifications

There is limited information available on the nutrient requirements of crocodiles. Studies comparing the performance of crocodiles fed different forms of fresh meat clearly demonstrate that farmed crocodiles can respond to differences in nutrient intake, but they have done little to define the actual requirements of specific nutrients. Garnett (1985) made some progress in the assessment of fatty acid requirements showing that saturated fatty acids were apparently digested less efficiently by *C. porosus* than longer chain, unsaturated fatty acids and that C20:5 (eicosapentaenoic acid, EPA) and C22:6 (docosahexaenoic acid, DHA) are essential in diets for these crocodiles. Staton et al. (1990a) suggested that a dietary source of arachidonic acid may also be required for maximum growth of alligators (*Alligator mississippiensis*). Staton et al. (1990b) went further and estimated optimum digestible energy: dietary protein ratios for young alligators to be 1.96-2.60 kJ/g protein which was similar to the requirements of other aquatic ecosytems of equal size.

Despite some basic information on the nutrient requirements of crocodiles, there are a large number of factors that influence our capacity to accurate define diet specifications. First and foremost is the fact that individual crocodiles farmed in groups have a large variation in daily intake and crocodiles also have a high capacity to vary their metabolic rate. In addition, it has been shown that environmental temperature can have a significant influence of the rate of intake and the feed conversion efficiency. As a consequence, definition of generic nutrient requirement information for crocodiles will be difficult and the need for highly specified diets is diminished. Instead, diet specifications based on broad parameters such as crude protein, crude fat and digestible energy are likely to be sufficient.

The composition of the first manufactured diets produced in Australia were based on available literature (eg Staton and Vernon 1991) and local experience, and resembled the following:
<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter content:</td>
<td>60%</td>
</tr>
<tr>
<td>Crude protein content (as fed)</td>
<td>35-40%</td>
</tr>
<tr>
<td>Crude fat content (as fed)</td>
<td>16%</td>
</tr>
<tr>
<td>Fresh product:</td>
<td>20-50%</td>
</tr>
<tr>
<td>Binders:</td>
<td>Nil</td>
</tr>
<tr>
<td>Cost:</td>
<td>$1.00-$1.50/kg</td>
</tr>
</tbody>
</table>

Subsequent research, such as that examining dietary fat content (Figure 4), and growth studies has resulted in a significant revision of these specifications for growing crocodiles, with diet composition now reflecting the following:

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter content:</td>
<td>63%</td>
</tr>
<tr>
<td>Crude protein content (as fed)</td>
<td>42%</td>
</tr>
<tr>
<td>Crude fat content (as fed)</td>
<td>5%</td>
</tr>
<tr>
<td>Fresh product:</td>
<td>0%</td>
</tr>
<tr>
<td>Binders:</td>
<td>0%</td>
</tr>
<tr>
<td>Cost:</td>
<td>$0.70-$0.80/kg</td>
</tr>
<tr>
<td>Other additives:</td>
<td>Shell grit</td>
</tr>
<tr>
<td></td>
<td>Mycotoxin binders, acidifiers, Vitamin D and Fe supplements</td>
</tr>
</tbody>
</table>

**Feeding Initiation**

Manolis (1993) suggested that one of the most important steps in the development of manufactured feeds involved ensuring rapid initiation of feeding. Unless feeding initiation is completed rapidly, long-term performance of the crocodiles can be compromised. Manolis et al. (1989) also demonstrated that within the first month of life, C. porosus hatchlings showed clutch-specific preferences for certain foods, and in general, there was an avoidance of “smelly” foods. The primary drivers of initial preference are poorly understood, but it appears that weaning management rather than particular feeds has the greatest impact on the rate of acceptance and feeding initiation.

Research undertaken by the Queensland Department of Primary Industries has assessed the use of a wide range of attractants for juvenile crocodiles. Some of the attractants assessed as part of a structured initiation trial include:

- Fresh meat;
- Chicken head digest;
- Fresh blood;
- Liver digest;
- A range of proprietary digests and attractants;
- A variety of oil and meat combinations.

These experiments revealed a high level of variability in response, and all demonstrated minimal “attractive properties”. Responses to these attractants was so poor that the experiment had to be prematurely terminated. In the absence of attractants, it appears that the best approach to ensuring a rapid initiation of feeding on manufactured feeds is via “staged weaning”. This process involved the gradual replacement of fresh meat with manufactured pellets. Staged weaning processes currently under investigation are aimed at reducing the time required to progress from fresh meat to 100% semi-moist pellets and resemble the following over a 6 week period:

- 90% meat : 10% pellets       7 days
- 80% meat : 20% pellets       7 days
- 70% meat : 30% pellets       7 days
- 60% meat : 40% pellets       7 days
- 50% meat : 50% pellets       7 days
- 100% manufactured pellets   7 days

**Feeding Frequency**

Crocodiles are opportunistic feeders and as a consequence, their digestive systems and metabolism may be unsuited to frequent feeding. This is further supported by general observations of daily feed intake of farmed crocodiles (Fig. 6). It can be seen that feed intake drops after each large feed suggesting that daily feeding may not be required.
Initial research has shown that there is significant improvement in feed conversion efficiency of crocodiles are not fed daily. Subsequent research using fifteen individually caged animals balanced across five clutches undertaken by the Queensland Department of Primary Industries examined feeding frequencies of 3, 4 or 5 days. It was demonstrated that feeding every five days had no negative influence on final body weight, and that there were numeric improvements in feed conversion efficiency (Fig. 7). Further research is required to examine the effects of infrequent feeding on carcase quality.

Overall Feeding Management

While significant progress has been made in the development of manufactured feeds for crocodiles in Australia, it is important to remember that the diet itself is only half of the equation. Using the “salmon model”, successful feeding of manufactured diets to crocodiles is going to depend equally on the feeding management. It is unlikely that a suitable manufactured diet will be developed that promotes acceptable levels of intake, growth and feed conversion in the absence of appropriate management.

As diet development progresses, additional factors that need to be considered include the impact of manufactured diet use in crocodile health and overall production hygiene, the capacity of manufactured feeds to manipulate body composition and overall product quality, and the role of different diets for different crocodile production phases.
Conclusions

In summary, crocodile nutrition research conducted to date has resulted in the development of manufactured diets with no fresh product needed that will support growth of crocodiles at an acceptable rate. A research program is now needed to capitalize on these initial investigation with a view to reducing the nutritional costs of producing crocodiles.

Literature


The Crocodilian Model in Current Developmental and Evolutionary Studies

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Abstract

Living crocodilians are the only present day descendants of basal archosaurs. Because of their archaic appearance and their Triassic origin, they have been predicted to be biologically more primitive than other modern reptiles. Crocodilians, however, possess many advanced anatomical, physiological and behavioral patterns. These well illustrate the evolutionary potential of the Archosauria, a group which has produced the most diversified and competitive vertebrates in evolutionary history: actively flying feathered creatures, warm-blooded reptiles, and animals with parental care. The Crocodylia have undergone incomplete adaptation to an aquatic life style with only minor alterations in their morphology. Conservative uniform morphology is typical also for the other living archosaurs, birds. Once they evolved the power of flight, they did not change the aerodynamic adaptations of their body, even when becoming flightless. The crocodilian and avian model (CAM) thus represents an unique case for the reconstruction of evolutionary novelties in the morphology of extinct non-avian dinosaurs, which are phylogenetically bracketed with recent archosaurs. The unique role of the crocodilian morphotype in the CAM is apparent, and more detailed crocodilian developmental mechanisms and regulatory gene expression patterns, comparable to those in the chick model, are needed. In relation to this need, the dynamics and migratory pathways of the cephalic neural crest cells of the crocodilian embryo are described for the first time.

Introduction

Living crocodilians and birds are the only survivors of the highly diversified Mesozoic archosaurs, which passed through the selective mass extinction at the Cretaceous/Tertiary boundary. The crocodilians thus represent a model for a primitive archosaur morphotype, while the birds reflect an opposite, highly modified, archosaur morphotype. Both morphotypes differ from each other in several important features, which correspond with the possession of highly variable locomotor behaviors, and which are among the major evolutionary novelties in vertebrates. However, these neotypic structures evolved in non-avian archosaur ancestors, among theropod dinosaurs, which are phylogenetically bracketed with recent archosaurs. The fact that the crocodilians and birds are the two most-proximal living outgroups of the non-avian theropods allows us to apply the Extant Phylogenetic Bracket Approach, not only for functional reconstruction and interpretation of the fossil soft tissue patterns (Witmer 1995), but challenge us to reconstruct a developmental scenario of different molecular signalling pathways amongst others. These signalling pathways produce homologous but differently adapted structures in both crocodilians and birds, such as neotypic integumental structures (Widelitz \textit{et al.} 2003; Kundrát 2004), craniofacial transformation, including loss of the teeth, and the inclusion of digit reduction patterns (Kundrát \textit{et al.} 2002).

Detailed comparisons of developmental mechanisms and programs in crocodilian and avian model system (CAM) would permit the elucidation of how evolution has worked through developmental mechanisms. Application of new molecular techniques combined with experimental surgical techniques on the crocodilian-avian chimaeric system may represent a way forward in answering some of these questions. To effect this, we need to define signalling molecular pathways, establish \textit{Hox} gene expression patterns, as well as study transcriptional regulation at the genomic level in the crocodilian model. Studies focusing on the molecular evolution of crocodilians (eg Janke and Arnason 1997; Dessauer \textit{et al.} 2002) creates the base on which to define the crocodilian embryo as a unique model for a universal component of a CAM experimental system for investigating relations between developmental mechanisms and evolutionary morphogenetic pathways.

Because of the complex behavior of the cephalic neural crest cell populations, which include intricate cell-cell and cell-environment interactions involved in molecular signalling pathways, as well as the potential evolutionary significance of the interspecies differences in migratory cell populations (Kulesa \textit{et al.} 2004), staining patterns of the cephalic neural crest migratory routes in crocodilian embryos were obtained with HNK-1 marker, and are described below by developmental day-stages.
Material and Methods

Crocodilian eggs (*Crocodylus niloticus*) were obtained in the La Ferme aux Crocodiles (Pierrelatte, France) during March and May 2003. Clutches were collected from nesting areas and incubated at 28-31°C in a mixture of vermiculite and sand. Embryos were retrieved by methods of Webb and Manolis (1987) and fixed to get a representative pattern. In the case of this study, embryos were collected each day within period of 1 through 11 days after egg-laying. Embryos were fixed and refixed again within 24 hours with two kinds of fixatives, each for a different procedure (see below): 4% paraformaldehyde in 0.1 M phosphate-buffered saline (PFA/PBS) with diethyl pyrocarbonate, and Bouin’s fixative. These embryos of *Crocodylus niloticus* were compared with embryonic stages of *Alligator mississippiensis* according to the scheme of Ferguson (1985).

Whole-mount immunostaining

After fixation with PFA/PBS the embryos were kept at 4°C. Then embryos were dehydrated in graded series of methanol solutions and stored at -20°C. After treatment with Dent’s fixative and MeOH (diluted 4/1), in order to block endogenous peroxidase activities, the embryos were washed in Tris-HCl-buffered saline-0.01% Triton X/100/ dimethyl sulfoxide (TST/DMSO) and then blocked with 5% non-fat dried milk in TST/DMSO (TST/M/DMSO). The monoclonal antibody, HNK-1 (Leu-7, CD 57, Becton Dickinson, San Jose, CA) was used to label early migration of the cephalic neural crest cells, as well as their neurogenic subpopulations. The primary antibody was diluted 1/50 in TST/M/DMSO containing 0.1% sodium azide, and applied to the embryos for 3 days at room temperature. After washing with TS1/3T/DMSO, secondary antibody, HRP-anti mouse IgM (ZYMED Lab. Inc.) diluted 1/200 in TS1/3T/M/DMSO, was applied to the embryos for 1 day. After final washing in TST/DMSO, the embryos were preincubated with 3,3’-diaminobenzidine (25mg/ml DAB;distilled water) in TST/DMSO (diluted 1/100) for 1 h. Then the embryos were allowed to react with hydrogen peroxide 0.01% (v/v) hydrogen peroxide at 0°C. The reaction was stopped by several washings in TST/DMSO.

Immunostaining on sectioned specimens

Specimens fixed in Bouin’s at 4°C were embedded in paraffin and sectioned at 7 to 10μm. They were deparaffinized and treated with MeOH with 1% (v/v) hydrogen peroxide for 30 minutes at room temperature, followed by washing in TS1/3T/DMSO. Anti-HNK-1 mAb was used to label both the migrating cephalic neural crest cells and the developing peripheral nervous system on the paraffin-sectioned specimens. Primary Ab was diluted 1/50 in TS1/3T/M/DMSO and applied to the sections for 1h at room temperature. After washing in TS1/3T/DMSO, the secondary Ab IgM was diluted 1/200 in TS1/3T/M/DMSO and applied on the sections for 1 h. Then the samples were finally washed in TS1/3T/DMSO, and preincubated using a kit: DAB/Metal Concentrate/Stable Peroxide Substrate Buffer [Pierce]. After the peroxidase reaction, the sections were counter-stained with hematoxylin.

HNK-1 (Leu 7 antigen, CD 57) was raised originally as a membrane fraction of the human T cell line (Abo and Balch 1981). This is a membrane antigen, expressed on human natural killer cells and some other lymphoid cells (Lainer *et al.* 1986). It is also present on approximately 15-20% of normal peripheral blood mononuclear cells as well as on subsets of NK lymphocytes and T lymphocytes (Fitzgerald-Bocarsly *et al.* 1989). The HNK-1 epitope is demonstrated to be the sulfated trisaccharide, which is shared with glycolipids and glycoproteins, acting as an adhesive. The expression of this carbohydrate epitope is observed in rhombomeres, in subpopulations of the cephalic neural crest cells since their earliest emigration from the neural tube folds, as well as temporally and spatially regulated in development of the nervous system (data shown here).

Despite it not being a pan-specific marker for neural crest cells in all vertebrates, positive HNK-1 immunoreactivity, visualizing the neural crest migration routes, has been demonstrated in many vertebrate species: lampreys (Hirata *et al.* 1997; Morikawa *et al.* 2001; *Pteromyzon marinus* - Kundrát, unpubl. data), skate (*Raja erinacea* - Kundrát unpubl.data), teleost fish (Sadagiani and Vielkind 1990; Hirata *et al.* 1997), frog (Olsson *et al.* 2002), turtles (Hou and Takeuchi 1994; Clark *et al.* 2001; *Pelodiscus sinensis* - Kundrát, unpubl. data), chick, quail (Bronner-Fraser 1986; Newgreen *et al.* 1990; Heath *et al.* 1992; *Struthio camelus* - Kundrát, unpubl. data), rat (Érickson *et al.* 1989). Negative HNK-1 immureactivity was reported for opossum by Vaglia and Smith (2003)

Using immunohistochemistry on whole mount embryos and sectioned material, I observed the localization and expression of the HNK-1 epitope in crocodilian embryos at different developmental stages. Based on HNK-1 expression patterns, I can present the first description of migration and colonization patterns of the neural crest cells in crocodilians, namely in embryos of *Crocodylus niloticus*. 368
Cephalic Neural Crest Cells Migratory Routes in the Crocodilian Embryo

Using immunohistochemistry, the localization and expression of the HNK-1 epitope in crocodilian embryos at successive developmental stages, from day 1 to day 11 were observed. Because the Leu 7 antigen labels on migrating neural crest, the HNK-1 visualization technique now provides us with the first view of migratory routes and events that occur during cephalic neural crest emigration from the dorsal part of the neural tube to frontonasal and branchial region in *Crocodilus niloticus*. Staining patterns obtained with HNK-1 marker are described below by day-by-day stage, beginning with the first appearance of the opaque patch on the eggshell, and continuing to beyond the time when cells have dispersed from the migratory streams. Each account describes the most characteristic features of the embryos of the corresponding stage, based on the extension of the neural crest cells in the head region.

The results from the crocodilian embryos demonstrate that HNK-1 epitope is expressed widely in the cephalic neural crest cells, and that the distribution of the HNK-1 positive molecules show signalling specificity in differentiation of the crest cells into skeletogenous and neurogenous subpopulations. They are the components of the peripheral nervous system wholly or partly derived from the neural crest which maintain HNK-1 immunoreactivity for a longer period in roots and ganglia of the cephalic peripheral nerves. This early staging of the crocodilian development based on neural crest patterns, offers a new base for experimental embryology and study of the developmental mechanisms in the crocodilian model using molecular techniques.

**DAY 1 (after egg laying)**

*Crocodilus niloticus* - Stage A; <22 somites (Figs. 1A-G)

[= Stage 1 (day 1) of *Alligator mississippiensis*, Ferguson 1985]

The embryo described here represents the earliest collected developmental stage and is documented by only one specimen. Emerging cephalic neural crest cells (CNC-cells) constitute three well known principal migratory streams: mandibular, hyoid and branchial (Figs. 1A,B). However an additional stream, never reported in a vertebrate before, has been also recognized. This extra stream emerges from the forebrain with a subpopulation migrating forward along the midline (called here the rostral stream; Figs. 1C and 1D), and a paired subpopulation which spreads over a dorsal part of the optic placode (named here premandibular streams; Figs. 1C and 1E). The latter is unusual feature in the stereotyped vertebrate CNN-cells migratory patterning, and as hypothesized here may refer to the development of the massive prolonged craniofacial region in the crocodilians.

The premandibular CNC-cells migrate latero-ventrally and join the anterior extension of the mandibular CNC-cells at the posterior margin of the optic placode. It is pointed out here, that giving the name ‘premandibular’ to this stream does not mean confirming evidence for existence of a premandibular branchial segment as hypothesized by Bjerring (1977) and Jarvik (1980). Anymmetric pattern of the fusion itself may result from a short period for the emergence of the premandibular streams, which are not completely synchronized in time. When fused with mandibular CNC-cells, as seen on the left side of the embryo, the premandibular stream remains well recognized within the fused mass, because their HNK-1 staining is much more intense, even in the following stage B. It is a question whether the crocodilian premandibular CNC stream is a homologue or an analogue of the frontonasal crest cells identified, for example in the opossum (Vaglia and Smith 2003) or in the cat shark (Kuratani and Horigome 2000). An interpretation of the premandibular and mandibular streams as components of a single ancestral CNC stream, extended from the prosencephalon to the anterior rhombencephalon, may be present based on the fact that both streams are interconnected via intensively HNK-1 stained neural plate borders emitting dispersed CNC-cells on both sides (Fig. 1C).

An antero-posterior gradient in the ventro-lateral migratory extension of the mandibular, hyoid and branchial streams is apparent. The mandibular stream, emerging from the caudal mesencephalon to the border between rhombomere 2 and 3, populates the entire proximodistal extent of the first branchial arch. It also expands ventrally to meet its counterpart, anteriorly as well as posteriorly to the stomodeum.

The hyoid CNC-cells emigrate from rhombomere 4 and populate the upper part of the second branchial arch. Restricted areas of HNK-1, showing positive immunoreactivity, are found on both sides of rhombomere 3 (Figs. 1A and 1B), and show reduced emergence of the CNC-cells from this rhombomere, which may contribute to the both mandibular and hyoid stream.

The branchial CNC-cells are exclusively derived from rhombomere 6, although a contribution from rhombomere 5, in form of a chain of cells, can be seen (Fig. 1F). These cephalic neural crest cells emerge to form the broad, sheet-
like branchial stream, which initially comprises two parallel cell masses. Below the origin site of the branchial CNC, the population suddenly splits into two separate streams (Fig. 1G), the first and second branchial stream, which did not yet reach branchial region. The second, more massive, branchial stream migrates posteriorly.

**DAY 2 (after egg laying)**

*Crocodylus niloticus* - Stage B; <22 somites [Figs. 2A-F]
[= Stage 2 (day 2) of Alligator mississippiensis, Ferguson 1985]

The craniofacial region of the embryonic head is flexed at 45° to the antero-posterior axis of the body (Fig. 2A). The rostral stream, as well as neural plate borders related to prosencephalon, are not detectable by HNK-1 staining anymore (Fig. 2B). However, HNK-1 positive neural plate borders, related to anterior mesencephalon, still produce chains of CNC-cells on both sides. Premandibular streams are fused completely with the supraocclusal projection of the anterior extension of the mandibular stream. They are recognizable as longitudinal intensively stained patches over antero-dorsal margin of the expanding eye.

The mandibular stream undergoes differentiation in both anterior (the supraocclusal and subocclusal projections) and posterior (the maxillo-mandibular projection) extensions. The trigeminal placode is seen as the large randomly HNK-1 stained area lateral to the caudal mesencephalon (Fig. 2B). In Stage B, the area immediately below rhombomere 3, shows HNK-1 immunoreactivity (Figs. 2C and 2F). Based on my observations it seems that this staining refers to the CNC-cells derived from both the mandibular and hyoid streams than being generated by rhombomere 3. Similar projections or very thin anastomoses are infrequently found in Stage E.

The hyoid stream proceeds further into the branchial arch and expands distally. It is derived not only from rhombomere 4, but also a small contribution from the anterior part of rhombomere 5 is visible now (Fig. 2D).

The common branchial stream has divided into two different streams, both initially contacting the branchial region (Figs. A.C). Although rhombomere 6 represents the main source for the both branchial streams, small contributions of rhombomere 5 and the rhombomeric plate (for definition see below - Stage 5), to the first and second branchial streams, respectively are seen (Figs. 2E and 2F). The first branchial stream is remarkably branched, while the second branchial stream is a rectangular mass of HNK-1 positive cells populating an area immediatelly below the rhombomeric plate. The second branchial stream extends posteriorly around the first somite, especially in postero-ventral direction. The rhombomeric plate contributes more to the proximal part of the differentiating ganglionic crest of the future accessorio-vagal nerve than to the second branchial stream itself. The ganglionic crest contacts the second branchial stream. This connection is very thin at this stage.

**DAY 3 (after egg laying)**

*Crocodylus niloticus* - Stage C; 22 somites [Figs. 3A-E]
[= Stage 2 (day 2) of Alligator mississippiensis, Ferguson 1985]

Stage C may correspond to the most conservative developmental stage among vertebrates, called ‘pharyngula’. Four distinct CNC streams populate the branchial region. From anterior to posterior: they are the mandibular (= trigeminal), hyoid (= acustico-facial), first branchial (glossopharyngeal) and second branchial (accessorio-vagal) stream (Figs. 3A and 3B).

The premandibular streams cannot be distinguished by the intensity of HNK-1 staining from the supraocclusal projection of the mandibular stream. The cells of the premandibular streams extend more rostrally around the optic placode and populate a broad fronto-nasal area (Fig. 3C). The unpaired residual HNK-1 positive area, of the anterior mesencephalic neural plae border, may be seen in some specimens.

Dorsally within the mandibular stream, a more HNK-1 positive area, destined to become the trigeminal ganglion, appears. The trigeminal placode is substantially expanded and covers the largest area in this stage. The subocclusal projection points ventrally. The maxillo-mandibular projection bends posteriorly close to the upper part of the first branchial cleft. At the most distal point of this projection, the mandibular stream joins the hyoid stream below the first branchial cleft (Figs. 3A and 3B). The hyoid stream spreads posteriorly around the ventral margin of the otic invagination.
The first and second branchial streams populate the branchial area by this stage. The streams are well separated by
the HNK-1 free area above and around the intermediate branchial groove. Although both still interconnected dorsally,
the second branchial stream seems to be derived now from the posterior part of rhombomere 6 (Figs. 3D and 3E).
The ganglionic crest of the developing accessorio-vagal nerve is confluent with the second branchial stream, and the
latter now begins to populate the region postero-ventral to the anteriormost somite.

**DAY 4 (after egg laying)**

_Crocodylus niloticus - Stage D: 29 somites [Figs. 4A-D]_

(= Stage 3 (day 3) of _Alligator mississippiensis_, Ferguson 1985)

Several remarkable changes in the morphology of the embryonic head characterize Stage D: the rostral part of the
head is prolonged and bent more posteriorly, the mesencephalon begins to expand, the otic placode is inflated and its
external opening starts to close, while the branchial region is completely populated by the CNC-cells (Fig. 4A).

By this stage the population of the premandibular CNC-cells has substantially lost HNK-1 immunoreactivity and
becomes an unrecognizable part of the whole lightly stained frontonasal region. The supraocular projection of the
mandibular stream differentiates into individual filaments of the ophthalmic branch of the trigeminal nerve. Half of
way to the trigeminal ganglion, which is well emarginated dorso-posteriorly, the supraocular branch is connected to
the trigeminal placode. The maxillo-mandibular projection of the mandibular stream is flexed at the right angles now
(Fig. 4B), separating the maxillary from the mandibular region, within the one neural crest subpopulation of the
mandibular stream. Circular arrangements of the mandibular CNC-cells distinguish it from the maxillary CNC-cells
(Fig. 4C).

The acustico-facial ganglion differentiates from the proximal end of the hyoid stream. CNC-cells of the hyoid
stream are generated only from the posterior part of rhombomere 4 (Fig. 4D). The hyoid stream expends between
the ganglion and the first branchial cleft and makes temporary interconnection with the neighbouring first branchial
stream around the ventral margin of the otocyst (Figs. 4A and 4B). Distally, the hyoid stream tapers and the HNK-1
signal becomes fainter. Because of the expansion of the otocyst in a posterior direction, the first branchial stream
emerges now from the posterior part of rhombomere 6, and the cells of the second branchial stream are derived from
the rhombomeric plate at this stage (Fig. 4D). Both branchial streams are fused after their separate emergence, and
continue as separate populations of the CNC-cells. However, dorsal to the branchial cleft, a new connection develops,
the glossopharyngeal-accessorio-vagal anastomosis (Figs. 4A and 4B). The second branchial stream extensively
populates the area below the first three somites.

**DAY 5 + DAY 6 (after egg laying)**

_Crocodylus niloticus - Stage E: 37 somites [Figs. 5A-E]_

(= Stage 5 (day 5) of _Alligator mississippiensis_, Ferguson 1985)

Since stage E, HNK-1 staining becomes widespread in the primordia of cranial and spinal nerves as well as in the
trigeminal placode, while it gradually decreases in the skeletogenous CNC-cell populations in the frontonasal and
branchial regions (Figs. 5A,B). This selective process of HNK-1 immunoreactivity begins with day 5 and continue
day through 6 (Fig. 5C), with inconspicuous addition of new somites developed by day 5. The stage E thus represents
a deceleration in somite increase, during which initial differentiation of the peripheral nervous system (PNS) is
established. The embryos of this stage are typified by a small opening in the otocyst (Figs. 5A-C).

Distribution of HNK-1 positive molecules shows that neurogenic subpopulation of the mandibular stream are
transformed at this stage into the trigeminal ganglion, with a ventrally projected primordium of the proximal part of
the maxillo-mandibular branch of the trigeminal nerve, as well as the anteriorly projected ophthalmic branch, which
remains connected with the trigeminal placode. The trigeminal ganglion has now moved into a more posterior position
between rhombomere 2 and 3 (Figs. 5D,E). In the hyoid stream, as well as in both branchial streams, only neurogenic
CNC subpopulation above the branchial clefts is transformed into ganglionic primordia of the PNS, and the hyoid
stream is transformed into the acustico-facial ganglion. The branchial streams transform into the glossopharyngeo-
accessorio-vagal ganglionic complex. In the branchial area in the region of the clefts, the neurogenous and
skeletogenous CNC-cells are still mixed, although staining is much more intense in the former.

Based on HNK-1 immunoreactivity inside the rhombencephalic division of the neural tube, six discrete rhombomeres
are visible (Figs. 5D,E). Behind rhombomere 6, lies the paired, longitudinal, posteriorly tapering rhombencephalon HNK-1 positive area, called here the rhombomeric plate (Figs. 5D and 5E). The rhombomeric plate shows HNK-1 expression at the anterior end, as well as along its dorsal and ventral margin. These anterior HNK-1 expression patterns may be the antecedents of the rhombomere 7; however, this theoretical seventh segments are not separated by an HNK-1 free area from the rest of the rhombomeric plate.

**DAY 7 (after egg laying)**

*Crocodylus niloticus* - Stage F; 43 somites [Figs. 6A,B]  
[= Stage 6 (day 6) of *Alligator mississippiensis*, Ferguson 1985]

This stage is characterized by HNK-1 staining of the nasal placode and the development of well emargined ganglia of the cephalic peripheral nervous system (Fig. 6A). The trigeminal placode still connects the opthalmic branch of the trigeminal nerve. HNK-1 expression is strong within proximal parts of all three cephalic neural crest strems, but is almost absent from distal parts. Differentiation of the acustico-facial, glossopharyngeal and accessorio-vagal nerves grows into the dorsal part of the branchial region. HNK-1 immunoreactivity within rhombomere is more intense ventrally (Fig. 6B).

**DAY 8 (after egg laying)**

*Crocodylus niloticus* - Stage G; 51 somites [Figs. 6C,D]  
[= Stage 7 (day 7) of *Alligator mississippiensis*, Ferguson 1985]

By the beginning of this stage, the trigeminal placode ceases to exist. HNK-1 marker still labels endotelial cells, the peripheral nervous system (Fig. 6C), and in later stages also temporary epibranchial placodes (Fig. 6D).

**Conclusions**

1. The results of immunohistochemistry show that HNK-1-immunoreactivity is distributed extensively in different tissues, and the intensity of immunoreaction varies with the development stages in crocodilian embryos.
2. HNK-1 immunoreactivity provides convinient and reliable marker for emerging cephalic neural crest cells migration in *Crocodylus niloticus*. HNK-1 recognizes a subpopulation of neural crest cells and crest derivatives, as well as neurogenic placodes, conductive tissue of the heart, and endotelial cells. The otic vesicle is also labelled with HNK-1.
3. Earliest emigration of the cephalic neural crest cells may appear by the time of the egg-laying.
4. Emerging cephalic neural crest cells coalesce into principal migratory streams at the time when the embryo attaches itself to the innermost surface of the shell membrane immediately below the opaque patch.
5. Besides the mandibular, hyoid, first and second branchial cephalic neural crest stream, a new migratory pathway, never described in other vertebrates before, organised from the caudal prosencephalon, is present in the crocodilian embryo. This is hypothesized that such a development might have mediated new modifications, by affecting adjacent tissues with new neural crest interactions, which resulted in a series of evolutionary novelties in development of the craniofacial region in crocodiles. The new population is named here the 'premandibular stream'. However, it does not provide any evidence for the premandibular branchial segment.
6. The cephalic neural crest cells populate the craniofacial and branchial region in four days. Stage C (day 3) may exhibit the most conservative vertebrate developmental stage called the 'pharyngula' (Kuratani et al. 2000).
7. The limited migration of the cephalic neural crest cells in areas adjacent to rhombomere 3 and 5, suggests that exclusion zones are not absolutely inhibitory. Rhombomere 3 shows a restricted HNK-1 immunoreactivity in Stage A. The rhombomere 5 shows the most intense HNK-1 staining among the rhombomeres and contributes to both the hyoid, and especially to the first branchial stream.
8. Small numbers of migrating cells are frequently observed diverting in the direction of neighboring streams. The hyoid stream makes ventrally contact with the maxillo-mandibular projection of the mandibular stream in Stage C (day 3).
9. Only 6 discrete rhombomeric units and the rhombomeric plate, are recognized, based on the HNK-1 immunoreactivity inside the rhombencephalon. The intense HNK-1 stained area in the anterior part of the rhombomeric plate may evoke presence of rhombomere 7, however it is not separated by a HNK-1 free area. These observations differ from those of Pritz (1999), who recognized eight rhombomeres in the embryonic development of *Alligator mississippiensis*.
10. The cephalic neural crest streams, transforming to the equivalent cranial nerves, shift caudally: the trigeminal...
nerve from the position of rhombomere 2 to new position between rhombomere 2 and 3; the acustico-facial nerve is gradually restricted to the posterior part of rhombomere 4, similarly, the glossoopharyngeal nerve becomes restricted to the posteriormost part of rhombomere 6; the vagus nerve is derived from rhombomere 6, but shifts later, completely, to the anterior level of the rhombomeric plate.

11. First filaments appear in the mandibular stream, in a primordium of the ophthalmic branch of the trigeminal nerve, in day 4.

12. HNK-1 is no longer an effective marker for skeletogenous subpopulation of the cephalic neural crest cells after stage F (day 7). Thereafter, individual neural crest cells begin to disperse among other cephalic cell types, and cannot be followed reliably.

Acknowledgements

I am grateful to Mr. L. Faugeirol and Dr. J. Yves-Sire for giving me permission to collect the embryos of Crocodylus niloticus in La Ferme aux Crocodiles during nesting season 2003. I am also grateful to Dr. J. Perran Ross and Dr. F. Huchzermeyer for giving supportive recommendations for collecting crocodilian embryos. Sincere gratitude is extended to Dr. S. Martin for his generous supply, valuable discussions and assistance during the collecting procedure, as well as to both Dr. S. Martin and Mr. V. Lancelle for their very risky assistance with getting eggs from the nesting area. I thank Dr. A. R. Cruickshank for reading the manuscript, his valuable comments and language improvements. This work was supported by grants from the Grant Agency of the Academy of Sciences of the Czech Republic [KJB6111301], the Grant Agency of the Charles University in Prague (Czech Republic) [122/2003-B BIO-P_F], and NATO Fellowship Programme, Dr. J. Lachman [13/2003-Czech Republic], as well as by Prof. S. Kuratani (Center for Developmental Biology, RIKEN, Kobe, Japan) and Prof. A. C. Burke (Wesleyan University, Middletown, USA).

Literature


Figure 1. Cephalic neural crest emigration in *Crocodylus niloticus*, Stage A - Day 1 (after egg laying); HNK-1 immunostaining. Abbreviations: a, anastomosis; af, acustico-facial ganglion; bs, branchial stream; e, eye; ep, epibranchial placode; gc, ganglionic crest of the accessory-vagal nerve; hs, hyoid stream; mes, mesencephalon; mmp, maxillo-mandibular projection; ms, mandibular stream; ng, nodose ganglion; nsp, neurogenous subpopulation; ofp, olfactory placode; opp, optic placode; otc, otocyst; otp, otic placode; pro, prosencephalon; ps, premandibular stream; rho, rhombencephalon; rp, rhombomeric plate; rs, rostral stream; r1-6, rhombomeres; s, somite; sbp, suboccular projection; sop, supraocular projection; ssp, skeletogenous subpopulation; tg, trigeminal ganglion; tp, trigeminal placode; 1bs, first branchial stream; 2bs, second branchial stream; V1, ophthalmic branch of the trigeminal nerve; V2,3, maxillo-mandibular branch of the trigeminal nerve; VII-VIII, acustico-facial nerve; IX, glossopharyngeal nerve; X-XI, accessorio-vagal nerve; IX-XI, glossopharyngeo-accessorio-vagal ganglionic complex; XII, hypoglossal nerve.
Figure 2. Cephalic neural crest emigration in *Crocodylus niloticus*, Stage B - Day 2 (after egg laying); HNK-1 immunostaining. For abbreviations see Figure 1.
Figure 3. Cephalic neural crest emigration in *Crocodylus niloticus*, Stage C - Day 3 (after egg laying); HNK-1 immunostaining. For abbreviations see Figure 1.
Figure 4. Cephalic neural crest emigration in *Crocodylus niloticus*, Stage D - Day 4 (after egg laying); HNK-1 immunostaining. For abbreviations see Figure 1.
Figure 5. Cephalic neural crest emigration in *Crocodylus niloticus*, Stage E - Day 5 [A,B,D], Day 6 [C,E] (after egg laying); HNK-1 immunostaining. For abbreviations see Figure 1.
Figure 6. Cephalic neural crest emigration in *Crocodile niloticus*, Stage F - Day 7 [A,B]; Stage G - Day 8 [C]; Day 11 [D] (after egg laying); HNK-1 immunostaining. For abbreviations see Figure 1.
Distribution of Mercury in the American Alligator (*Alligator mississippiensis*), and Mercury Concentrations in the Species Across its Range


Two studies were conducted to examine mercury concentrations in the American alligator. The first was conducted on alligators from the Rockefeller Wildlife Refuge (RWR), Louisiana, to determine how mercury is distributed among body organ/tissue compartments. Samples from body organ/tissue compartments were tested for mercury (Hg) and stable isotope (¹³C and ¹⁵N) signatures. Relationships between body organ/tissue compartments and non-invasive samples were examined to determine whether concentrations in non-invasive samples could be used to monitor populations non-lethally. Mercury concentrations in all organ/tissue compartments were correlated with each other, body size, and ¹⁵N signatures. Mercury was highest in the blood, followed by kidney and liver. Because mercury concentrations from non-lethal samples were correlated with those of the internal tissues, non-lethal sampling methods may be a viable method of indexing mercury in body tissues. The second study involved examining tail muscle and liver samples from wild alligators from the southeast to determine if mercury concentrations varied geographically in the species. The highest Hg concentrations were found in alligators from Glynn County, Georgia and southeast Alabama, while the lowest were found in the alligators from the RWR and the alligator farm. Differences among locations suggested that alligators could be used as biomonitors of mercury in the locations they inhabit.

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A Primary Study on Metal Elements of Chinese Alligator (*Alligator sinensis*) Eggs of the Changxing Population

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Metal concentration especially the heavy ones in eggs affects the development of young alligators. In order to know the living conditions of the Chinese alligators in Changxing, we surveyed the metal concentration in their eggs. Eight metal elements: magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd) and chromium (Cr) are investigated in different parts (eggshell, shell membrane and yolk) of fertilized and unfertilized eggs of Chinese alligators of Changxing population, by the Inductively Coupled Plasma Atomic Emission Spectrometry (ICP–AES). Metal concentrations exhibited distinct concentration orders for the eight elements in different parts of both types of eggs. Furthermore, the different parts of the egg showed dissimilar metal accumulation levels. In addition, the distribution and accumulation of Cu, Zn, Pb and Cd were compared in the corresponding parts of unfertilized eggs of Chinese alligators of Changxing and Anhui populations, and found that: the Changxing population showed much lower heavy metal accumulations.
Influence of Pesticides, Micronutrients, and Fatty Acids on Hatch Rates of Wild, Florida Alligator Eggs

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American alligator (Alligator mississippiensis) egg viability (the probability of an egg hatching) has been variable among Florida lakes. Lakes Apopka, Griffin, Jesup, Hancock, Monroe, George, and Okeechobee have exhibited chronically depressed egg viability since monitoring began in the 1980s. Further, Lakes Apopka and Griffin have experienced acute declines in egg viability during the last 20 years, followed by recoveries. We examined the relation of egg viability with nest and clutch characteristics to see if natural factors were associated with depressed egg viability. No obvious associations were detected between nest material and egg viability. Clutch size from areas with depressed egg viability is greater than high viability areas and may be associated with nutrient levels. Lakes with chronically depressed egg viability have been associated with agricultural effluents. Therefore, we examined the association of egg viability with organochlorine (OC) compounds and nutrient levels on two areas with chronically low egg viability (Lake Apopka and Lake Griffin) and two areas with high egg viability (Lake Orange-Lochloosa and Lake Woodruff National Wildlife Refuge). We found concentrations of OC compounds, DDE and toxaphene, to be significantly greater on Lake Apopka egg yolks than in yolks from lakes Griffin, Orange-Lochloosa, and Woodruff, but we could not detect a significant linear association between egg viability and these compounds. We did detect an indication of a threshold effect - eggs with concentrations of DDE or toxaphene ≥1 ppm had a lower probability of hatching than those with concentrations <1.0 ppm. We also examined the association of egg viability with vitamins A and E, which are important in early development of embryos. Vitamin A concentrations in egg yolks did not differ significantly, but Vitamin A concentrations were lower on Lakes Apopka and Griffin relative to reference lakes.

Ecotoxicology of Crocodiles in Central America


Over the last 30 years, numerous studies have documented exposure of wild crocodilians to environmental contaminants, particularly organochlorine (OC) pesticides and metals. Recent evidence of population declines and reproductive impairment in American alligators (Alligator mississippiensis) inhabiting contaminated wetlands in Florida, USA has increased concerns over the effects of these chemicals on other crocodilian populations living in contaminated habitats. In Central America, habitat loss and direct persecution by humans are the greatest conservation concerns for Morelet’s (Crocodylus moreletii) and American (C. acutus) crocodiles; however, exposure to environmental contaminants may present a subtle yet significant long-term threat to populations in this region and warrants greater attention. We recently reported OCs and mercury in C. moreletii and C. acutus eggs from Belize. In this paper, we present new data on contaminants detected in crocodile tissues from Belize as well as results of a study examining biological effects of contaminant exposure on wild C. moreletii. In addition, we also present the first report of contaminants in C. acutus in Costa Rica. Finally, we identify data gaps and provide recommendations for future ecotoxicological studies on Central American crocodilians.
NMR Studies of Water Transport and Metabolism in Crocodile Erythrocytes

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Vertebrate blood is a chemically and physically complex fluid that serves largely a transport function. About 20% of the volume of crocodilian blood is contained within red blood cells (RBCs). Blood is metabolically active with each RBC consuming energy to maintain a transmembrane ionic disequilibrium and to maintain its shape via an energy-consuming cytoskeleton. Both aspects support the role of the RBC as a gas transporter. The cell membrane contains many membrane transporters that facilitate solute transport across it. There are also cytoskeletal proteins associated with the anion transporter band 3, and in RBCs from many species a water transporter, aquaporin. There are some fundamental differences in the physiology and biochemistry of crocodilian RBCs compared with their mammalian counterparts; these are linked to the regulation of oxygen affinity by haemoglobin that have led us to investigate the biochemistry and water transport in actively metabolising RBCs using the non-destructive technique of pulsed nuclear magnetic resonance (NMR) spectroscopy. In most vertebrates organic phosphates are the key regulators of the affinity of O2 for haemoglobin. In crocodiles HCO3− ions fulfil this role (Grigg et al. 1999). There is an intimate connection between metabolic activity and oxygen affinity and in the case of the HCO3− it is formed directly from CO2 as oxygen is consumed in the cell, while for organic phosphates in mammals there is complex metabolic control involving many chemical species (Mulquiney et al. 1999). On the other hand, the transport of HCO3− through crocodilian RBC membranes appears to be fundamentally similar to that in humans (Jensen et al. 1998).

1H, 13C and 31P NMR spectra were acquired from suspensions of Crocodylus porosus RBCs. The time courses of metabolism by crocodile RBCs yielded high-resolution spectra and identified the fact that carbon monoxide causes a marked decline in metabolic rate. Like in humans both glucose and inosine are substrates for crocodile RBCs. We also measured the water transport rates in crocodile RBCs using an NMR Mn-doping method. High quality data were obtained for a range of temperatures. Thus, an Arrhenius analysis revealed a temperature dependence of the exchange rate that is like that found with birds; it implies a lack of specific aquaporin exchange pathways in the RBC membrane. Water diffusion in and around crocodile RBCs was studied using q-space analysis based on pulsed field gradient spin-echo (PGSE) NMR spectroscopy. The q-space plots reflected a larger size distribution in the crocodile RBCs than human RBCs confirming optical microscopy measurements.

Literature


Diving Behaviour of Freshwater Crocodiles (*Crocodylus johnstoni*) in the Wild: Correlations with Heart Rate and Body Temperature

Craig E. Franklin¹, Frank Seebacher and Mark Read

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The aim of this study was to describe the diving behaviour of the freshwater crocodile *Crocodylus johnstoni* in the wild, and to assess the relationships between diving, body temperature and heart rate. We captured freshwater crocodiles from a permanent waterhole (approx. 150 m x 20 m, with a maximum water depth of 3.5 m) at Lakefield National Park, Queensland, Australia, during July 2003. Time-depth recorders, temperature sensitive radio transmitters, and heart rate transmitters were deployed on six *C. johnstoni* (4.0-26.5 kg), and data were obtained from five animals. Crocodiles showed the greatest diving activity in the morning (6:00-12:00), and were least active at night, remaining at the water surface. Surprisingly, activity pattern was asynchronous with thermoregulation and activity was correlated to light rather than to body temperature. Nonetheless, crocodiles thermoregulated, and showed a typical heart rate hysteresis pattern (heart rate during heating greater than heart rate during cooling) in response to heating and cooling. Additionally, dive length decreased with increasing body temperature. Maximum diving length was 119.6 min, but the greatest proportion of diving time was spent on relatively short (<45 min) and shallow (<0.4 m) dives. A bradycardia was observed during diving, although heart rate during submergence was only 12% lower than when animals were at the surface.

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Movements of *Crocodile porosus* in the Kimberley Region of Western Australia: Integrating Genetic and Radio-Tracking Data

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VHF radio tags were attached to 16 estuarine crocodiles, which were tracked between October 2001 and May 2003. During the same period, 123 tissue samples were collected from three Kimberley river systems spanning a broad geographical range. Genetic diversity was similar in all three populations examined and inbreeding coefficients indicated there was only moderate differentiation among populations (\(F_{ST} = 0.08\)). However, differences in allele frequencies among populations were highly significant. Furthermore, assignment tests designated 80% of individuals to their population of origin and identified only five individuals (4%) as first generation migrants. Radio-tracking data corroborated genetic data, which indicated *Crocodile porosus* shows strong site fidelity. Furthermore, male and female crocodiles showed distinctly different patterns of movement. Females occupied a small core area (15 ± 7 ha) on the main channel of the Ord River during the dry season and moved distances of up to 62 km to nesting habitat during the wet season. Males moved considerable distances along the Ord River throughout the year. Rates of male movement appeared to be bi-modally distributed and did not significantly differ between three size classes. There were significant seasonal differences in rates of male movement, with the highest mean rates occurring during the summer wet season (4.0 ± 5.4 km/d).
Life History of *Caiman yacare* in the Brazilian Pantanal

Marcos Coutinho¹, Zilca Campos², Gordon Grigg³ and Hamish McCallum³

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The understanding of population dynamics requires knowledge about age-dependent schedules of birth and death, together with their relationship to population rate of increase, age and size at maturity and reproductive performance. These parameters are, therefore, major components of the biological background required for development of wildlife conservation and management strategies. In this paper we present some of the data obtained from a long-term study of caiman (*Caiman yacare*) life history in the Pantanal Wetland, Brazil. Firstly, we focused on feeding and body condition and how they change during ontogeny and in response to seasonal changes in the environment. This was followed by an analysis of reproductive biology, with the main goal of integrating physiological and demographic data to further extend the understanding of the relationships between gonad activity, body condition and environmental variables. Next, a quantitative assessment of caiman growth was made, based on cross-sectional and longitudinal sampling. Finally, patterns in size and sex-specific growth rates were described and an attempt made to determine the ways in which individual growth relates to the environment and life history traits. The results provide important insights into the ecology of caimans, and also the evolution of crocodylian life histories

Movements of Adult-Sized Estuarine Crocodiles (*Crocodylus porosus*) Tracked by Satellite Telemetry

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We report preliminary results from a study of movement by mature *C. porosus* using satellite telemetry. Determining the movement patterns of any cryptic wild animal is always difficult, but when the animal is also shy, semi-aquatic and potentially dangerous to capture and manipulate, it becomes particularly challenging. Movement patterns of estuarine crocodiles (*C. porosus*) could not be studied by direct observation, even if individuals could be recognised. Some data has been gained successfully from crocodiles and alligators by conventional radio telemetry, but the observer or the receiving equipment needs to be close to the subject and there is too much potential for intrusion to modify the behaviour of these naturally shy and wary animals. Broad-scale, long-distance movements have been recorded using mark-recapture techniques, but this technique provides no information on movements between captures. The use of satellite telemetry avoids most of these difficulties because location data can be gained remotely, without the observer needing to be nearby, several times a day and for months at a time.

This paper summarises the results of a pilot study of six adult-sized estuarine crocodiles (1 female, 2.65 m TL; 5 males, 3.14 to 4.93 m TL) fitted with satellite transmitters, a world first for this species. The satellite transmitters provided high quality position locations for periods ranging from five weeks to more than nine months, allowing movement patterns and home ranges to be determined. Highlights of the preliminary data include observations of regular use of the adjacent ocean by four of the six animals and apparent homing behaviour by a translocated *C. porosus*.
The Influence of Weather Conditions on Caiman Night-counts

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Abstract

Although often assumed as imprecise and inaccurate, most surveys on crocodilians’ populations are based on night counts. At the present study, two observers conducted 52 night counts of broad-snouted caimans (Caiman latirostris) in a 12-month period at the facilities of the Caiman Project of the University of São Paulo in Piracicaba, State of São Paulo, Brazil (22°42.557’ S, 47°38.246’ W). Besides possible individual observers’ bias we evaluated the influence of the following weather variables on the precision and accuracy of night counts: air and water temperature, rain, wind, and moonlight (phase and visibility). Night-counts can be precise, highly correlated with real population size, and reliable in long-term studies even with different observers. Weather conditions such as rain, wind, and ambient temperature did not influence night-counts in the controlled conditions of the present study. Moonlight and caiman body-size influenced the number of animals counted (the darker the better, and the smaller the animal the more accurate the counting). Future studies on the influence of aquatic vegetation on the efficiency of night counts are urged.

Introduction

Although species are internationally recognized as the legal unity of conservation (Hemley 1994; Moulton and Sanderson 1997), populations are possibly the most adequate unities of management (Caughley and Gunn 1996). According to Caughley (1977), wildlife management should have one of the following goals: raise a population that has been depleted, control a population that is too dense, harvest a population for a continuous yield, or leave it alone but with an eye on it. The last applies to populations that do not fit into any of the former categories. The first is usually the main goal of conservation programs, the second is usually the main goal of wildlife control programs, and the third is the main goal of harvest programs. However, to diagnose the population status and its best management option among the four above it is necessary to have a good idea about its abundance in both space and time (Caughley and Sinclair 1994).

Estimating wildlife abundance is a sampling procedure which usually requires scientific approach and statistical methodology involving replication in space and time or at least in one of them depending on what kind of diagnostics is intended to be made (Krebs 1989; Skalski and Robson 1992). Ecological censuses generally involve one or some of the following goals: describing the interest of sites, estimating population size, monitoring population changes, determining the habitat requirements of a species, determining why species have declined, monitoring habitat management, and monitoring population dynamics (Sutherland 1996).

The following techniques have been developed for surveying crocodilians: interviews and opportune personal observations, surveys from artifacts, daylight ground counts, daylight surveys from aircraft, and night counts (Magussen 1982; Mourão et al. 1994). Night counts are usually done from a moving boat with the aid of a spotlight. The reflective tapetum of the crocodilian’s eyes glows red in a spotlight and can be seen at a considerable distance (Chabreck 1966).

Although night-counts are reasonably assumed to be an inaccurate abundance index (Abercrombie 1995; Abercrombie and Verdade 1995), they may be relatively precise (ie with a low standard error) when replicated (Bayliss 1987). For these reasons night counts have been extensively used in surveying and monitoring crocodilians populations (Messel et al. 1980; Brazaitis et al. 1988; Messel and Vorlicek 1989a, 1989b, 1989c; Thorbjarnarson and Hernández 1992; Velasco and Ayarzagüena 1995; Mourão and Campos 1995).

The following information can be reasonably taken from crocodilians night counts: population age/size structure, population sex ratio, and distribution of habitats in the area surveyed (Magussen 1982, 1993, 1995; Magnusson and Mourão 1997). Those are the basic variables for the establishment of mathematical models of population fluctuation (Nichols 1987; Abercrombie and Verdade 1995; Johnson 1996).
Environmental factors, such as ambient temperature, wind speed, luminosity, vegetation and others can influence the number of animals counted at night (Bayliss 1987). However, since it is virtually impossible to know the real populations of crocodilians in the wild, experimental design has been rarely used to determine the efficiency of the method (Larriera et al. 1992; Pacheco 1996). This is the main goal of the present study.

Materials and Methods

Fifty-two night counts of broad-snouted caimans were conducted from May 1996 to May 1997 at the facilities of the Caiman Project of the University of São Paulo in Piracicaba, State of São Paulo, Brazil (22°42.557’ S, 47°38.246’ W). The night counts were conducted by two observers from 2130 to 2230 h on a weekly basis.

The animals were divided into five separate pens (16 x 4 m) of young (SVL < 50cm) and four pens (12 x 10 m) of adults (SVL ≥60 cm) (Table 1). Each young- and adult-pen contained a cemented pool (12 x 2 m x 75 cm deep and 9 x 6 m x 100 cm deep, respectively). Young-pens were placed in line, as well as the adult-pens, but the two facility groups were located approximately 250 m far from each other. All enclosures were located on fenced areas with restricted visitation and no electric light. The disposition and number of caimans per enclosure remained constant during the period of study (Table 1).

<table>
<thead>
<tr>
<th>Enclosure</th>
<th>No. of Animals</th>
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<tbody>
<tr>
<td>J1</td>
<td>20</td>
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<tr>
<td>J2</td>
<td>16</td>
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<td>J3</td>
<td>34</td>
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<td>J4</td>
<td>31</td>
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<td>J5</td>
<td>10</td>
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<td>AR1</td>
<td>4</td>
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<td>AR2</td>
<td>5</td>
</tr>
<tr>
<td>AR3</td>
<td>6</td>
</tr>
<tr>
<td>AR4</td>
<td>6</td>
</tr>
</tbody>
</table>

During night-counts, observers approached quietly and separately and stayed out of the pens focusing the animals with a 12 V 15,000 c.p. sealed-beam spotlight (as described by Woodward and Marion (1978)) at an approximate distance of 10 to 20 m from the animals. Batteries were fully charged upon initiation of each session. Observers counted individually and secretively the animals by the reflection of the spotlight in their eyes. The animals were introduced to the pens at least six months before the beginning of the present study and were previously habituated to the presence of the observers.

Besides possible individual observers’ bias we evaluated the influence of the following weather variables on the precision and accuracy of night counts: air and water temperature, rain, wind, and moonlight (phase and visibility). Temperature was measured with a bulb thermometer (1°C precision). Rain and wind were treated as “nominal scale” variables (Freund and Wilson 1992) with the following levels: absent, low, moderate, and strong.

In order to compare observers precision we used correlation analysis (Sokal and Rholf 1995). In order to establish statistical relationships between observers counts and real populations we used regression equations (Brown and Rothery 1993). In order to evaluate the influence of weather conditions on the efficiency of night-counts we used analysis of covariance (ANCOVA) (Zar 1996) having the weather conditions as covariates. Statistical analyses were run in Minitab for Windows 13 (Minitab 2000).

Results

There was a high correlation between observers (P<0.000, r= 0.995). There was also a high correlation between observers and real population (P<0.000, r= 0.995) and no significant variation between observers along the study period (ANCOVA, P= 0.677).
The following linear models could be established between observers’ night-counts and real populations (N= real population, Nc= night-count):

\[ N = 2.02711 + 1.09778N_c \quad (P<0.000, \quad r^2 = 0.919 \text{ for Observer 1}) \]

\[ N = 2.99757 + 1.07920N_c \quad (P<0.000, \quad r^2 = 0.920 \text{ for Observer 2}) \]

Neither air temperature (11°C min., 31°C max.) nor water temperature (12°C min., 30°C max.) influenced night-counts (ANCOVA: \( P=0.681 \) to 0.772; ANCOVA: \( P=0.762 \) to 0.853, respectively). Similarly, neither rain (ANCOVA, \( P=0.391 \)) nor wind speed (ANCOVA, \( P=0.875 \)) significantly influenced night-counts.

On the other hand, moon phases influenced night-counts (ANCOVA, \( P<0.000 \)). The Analysis of Mean (ANOM) (Ott 1983; Ramig 1983) showed the following results: New (a) \( \geq \) First quarter (ab) \( \geq \) Second quarter (bc) \( \geq \) Full (c), with different letters meaning different results at 95% confidence level.

Moon presence/absence influenced night-counts (ANCOVA: \( P=0.032 \); ANOM: Absent>Present). Body-size influenced night-counts (ANCOVA: \( P=0.003 \); ANOM: Young>Adult).

**Discussion**

In controlled situations such as the present study night counts can be highly correlated with real population (ie accurate). In addition, night counts from distinct observers can be highly correlated (ie precise), and consistent along time (ie reliable). However, the present study does not take into account the influence of floating vegetation which can significantly affect animals detectability. There was no aquatic plant at the pools during the present study. Vegetation can affect night-counts because they can physically prevent observers of detecting the animals. Since vegetation can drastically change both in time and space even in small scale during monitoring programs this factor should be experimentally tested in future studies.

Surprisingly, at the present study we found different patterns than previous studies involving caimans and other crocodilians. A positive correlation between the number of animals counted and the maximum air temperature of the day was found for non-hatchlings *Alligator mississippiensis* (Woodward and Marion 1978), *Crocodylus niloticus* (Hutton *et al.* 1989), *Caiman latirostris* (Larriera *et al.* 1992), and *Melanosuchus niger* (Pacheco 1996). Small crocodilians seem to thermoregulate differently from the adults being active at lower temperatures (Diefenbach 1975a, 1975b). However, at the present study neither air nor water temperature at the moment of the counting significantly affected the number of animals sighted. The temperature range during the present study (from 11 to 31°C and from 12 to 30°C for air and water, respectively) quite likely covers the normal ambient temperatures the species experience in the wild in São Paulo State, Brazil. Therefore, the captive environment has not dramatically affected this variable.

On the other hand, there is a strong relationship between temperature and feeding behavior in heterotherms such as crocodilians (Lang 1987; Diefenbach 1988; Verdade *et al.* 1992), in a way that animals need to attain certain thermal (ie metabolic) levels in order to favor prey apprehension, ingestion, and digestion. Considering that feeding behavior is drastically modified in captivity - where basically all food is furnished “for free” at roughly regular intervals - thermoregulatory behavior can possibly explain why ambient temperature did not affect night counts, contrary to the pattern found in the wild in other studies.

Wind speed was the environmental variable that had the greatest effect on *Melanosuchus niger* night counts (Pacheco 1996) either because of its association (ie negative correlation) with ambient temperature or because crocodilians actively avoid the wave action caused by strong winds (Mazzotti 1989). However, at the present study the occurrence of wind did not affect the number of animals counted. A possible explanation for this is that there was no significant wave action due to the wind because of the small area of the pools and the possible windbreak action of the fences.

The cloud cover had a consistent negative effect on *Melanosuchus niger* counts either because of its possible association with wind speed (Pacheco 1996) and by extension with ambient temperature or because of possible disorientation of animals (as described by Murphy (1981) for juvenile alligators under full cloud cover). However, at the present study cloud cover and the occurrence of rain did not significantly affect night counts. A possible reason for this is its possible association with ambient temperature, not found correlated with night counts at the present study as described above.
Surprisingly Larriera et al. (1992) did not find any significant correlation between moonlight and night counts of Caiman latirostris. The most developed sense organ of crocodilians seems to be the vision (Bellairs 1971). Moonlight quite likely increases animals detectability by the observers. However, it also possibly improves observers detectability by the animals which usually results in their retreat or diving which in its turn makes them no longer visible (Bayliss 1987). This agrees with the pattern found at the present study where both moon phase and presence consistently affected the number of animals counted, decreasing from new to full moon. The evident association between moon phase and luminosity is reinforced at the present study by the consistent relationship between moon visibility (ie presence or absence) and the number of animals counted, significantly higher when moon is not visible than otherwise.

The efficiency of night counts at the present study was also influenced by caimans body size similarly to previous studies (Giles and Childs 1949; Woodward and Marion 1978; Pacheco 1996). Young individuals were more detectable than adults possibly because adults tend to be more wary (Webb and Messel 1977; Hutton et al. 1987; Pacheco 1993; Verdade et al. 2002).

Rarely - to say the least - wild populations of crocodilians can be monitored under controlled situations such as the present study. However, the experimental manipulation of environmental variables in order to better understand how they influence night counts of crocodilians in the “real world” is desirable. It is virtually impossible to assess the real number of individuals from a wild population of caimans or crocodiles, which is necessary to determine the local accuracy - not only precision - of the method and validate populational fluctuation models. This is usually only feasible under controlled experiments.

Conclusions

Night-counts can be precise and highly correlated with real population size. Linear models can be established between observers’ night-counts and real population size. Night-counts are reliable in long-term studies even with different observers. The accuracy and precision of night-counts can be affected by the moonlight (the darker the better) as well as by animals’ body size (the smaller the animal the more accurate the counting). However, weather conditions such as rain, wind, and ambient temperature can be surprisingly irrelevant. Future studies on the influence of aquatic vegetation on the efficiency of night counts are urged.

Acknowledgements

This study has been partially supported by Fundação de Amparo à Pesquisa do Estado de São Paulo - FAPESP (Processes Nos. 00/01495-3 and 04/0188-0). Katia Ferraz helped reviewing the manuscript. Denis Sinisgali (in memoria) helped with the fieldwork.

Literature


Anatomical Correlates Associated with the Bracing System of Extant Crocodilians: addressing the Locomotor Inadequacies of the Indian Gharial

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All extant crocodilians brace their bodies against mechanical loading and during movement in a similar manner. This type of bracing mechanism is referred to as the ‘eusuchian-type bracing system’. Differences in the configuration of the paravertebral shield and the length of the lateral epaxial muscles in the cranial half of the tail between *Gavialis gangeticus* and other extant crocodilians correlate with the former’s apparent inability to high-walk at large sizes (> approx. 50 kg). These characteristics probably also preclude any capacity for galloping. A further correlation exists between: the configuration of the dorsal cervical muscles; the equivalence in height of the neural arches on the vertebrae in the trunk; tail base and caudal-most portion of the neck; the continuity between the nuchal and dorsal osteoderms in *Gavialis gangeticus*; and the inability of large, adult individuals of this species to flex the head ventrally against the neck to the degree observed in other taxa.

These differences mean that the operational repertoire associated with the bracing system of *G. gangeticus* is less diverse than that of other extant crocodilians. For this reason, it is proposed that two distinct forms should be recognised within the eusuchian-type bracing system: the *Gavialis*-form and the *Crocodylus/Alligator*-form.

The Mysterious Crocodylid Integumentary Sense Organs: What Are They For?

Kate Jackson

In all crocodylids and gavialids, a single dark dot is present on each of the ventral scales. Alligatorids lack this structure. Morphological study has shown this structure to be a sensory organ, similar in morphology to the mechanosensory “touch papillae” that are present on the facial scales of all crocodilians. Here I describe experiments completed and experiments in progress to test the possible function of these integumentary sense organs (ISOs). In particular I explore the possibility that they may be osmoreceptors, used for distinguishing hypersomotic seawater from fresh water, similar to many other anatomical and physiological specialisations that make crocodylids better able to tolerate estuarine conditions than alligatorids.
Status of the American Alligator (*Alligator mississippiensis*) in Southern Florida, USA and its Role in Measuring Restoration Success in the Everglades

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Abstract

The American alligator (*Alligator mississippiensis*) was abundant throughout the pre-drainage Everglades of Southern Florida, USA. Development and water management practices have reduced the spatial extent and changed the hydropatterns of these habitats. As a result of these activities, alligator populations have decreased. Currently, restoration of hydrologic pattern and ecological function is beginning in the Everglades. Due to the alligator’s ecological importance and sensitivity to hydrology, salinity, habitat and system productivity, the species was chosen as an indicator of restoration success. A number of biological attributes (relative density, relative body condition, nesting effort, and nesting success) can be measured, standard methods for monitoring have been developed, and historical information exists for alligator populations in the Everglades. These attributes can be used as success criteria at different spatial and temporal scales and to construct ecological models used for predicting restoration effects.

Introduction

The American alligator once occupied all wetland habitats in south Florida, from sinkholes and ponds in pinelands to mangrove estuaries during periods of freshwater discharge (Craighead 1968; Simmons and Ogden 1998). Development and water management practices have reduced the spatial extent and changed the hydropatterns of these habitats (Fig. 1; Mazzotti and Brandt 1994). Less freshwater moves through the tributaries into the mangrove zone resulting in higher salinities and the filling in of creeks (Craighead 1971). In the marl prairies, the historic 6-9 month hydroperiod has been replaced by a hydroperiod of 3 months or less. In addition, water levels may drop 2 feet below the ground surface during the dry season. Because of these habitat changes, alligators are now less numerous in these habitats (Mazzotti and Brandt 1994).

Abundance, distribution, nesting success, and condition of the species are all expected to change in response to planned restoration of the Everglades. Alligator relative abundance is expected to increase as hydrologic conditions improve in overdrained marshes and freshwater tributaries. As canals are removed, densities of alligators in adjacent marshes and occupancy of alligator holes is expected to increase. As hydroperiods and depths approach more natural patterns, alligator nesting success, growth, and condition are all expected to increase in areas where they are currently lower than historic values.

In south Florida alone there are over 1000 miles of canals and nearly 700 miles of levees. These structures, initiated in the late 1800s, were initially designed to drain the Everglades and make it “usable.” Later they became important for flood control and now they serve a third purpose of delivering water to urban and agricultural areas. During the 1970s and 1980s concern was raised that this extensive network of canals was having a negative impact on the environment and that the Everglades was, in fact, dying (Mazzotti 1999). In 1992, Congress authorized a study to reevaluate the network of canals and develop a plan to restore the hydrology of the Everglades. The result was a 7.8 billion dollar plan, the Comprehensive Everglades Restoration Plan (CERP; US Army Corps of Engineers 1999), that includes over 68 projects ranging from removing canals to creating alternative water storage areas both above and below ground. The goals of the plan include increasing the spatial extent of natural areas, enhancing the quality
of existing natural areas, and improving the abundance and diversity of native plants and animals (US Army Corps of Engineers 1999).

In addition to their economic and ecological importance, the American alligator was selected as an indicator of restoration success because it is sensitive to hydrology, salinity, habitat and system productivity, all factors that are expected to change with the completion of CERP. In addition, there are a number of biological attributes that can be used as success criteria at different spatial and temporal scales, and there are standard methods for monitoring of alligators and their nests. Also, existing data for population densities, alligator condition and nesting ecology in some areas can provide baseline data for assessing changes and developing modeling tools (Jacobsen and Kushlan 1989; Kushlan and Jacobsen 1990; Dalrymple 1996a, 1996b; Barr 1997).

Several restoration performance measures (or targets) for the South Florida alligator population have been identified, including relative abundance, occupancy rates of alligator holes, nest success, and body condition. In the following discussion, we will outline the baseline conditions of the above restoration performance measures and suggest the role of monitoring alligator success during Everglades restoration.

Abundance and Distribution

Although we will never know accurately past numbers of alligators in the Everglades, the pattern of population changes is clear. Alligators were very abundant at the turn of the century. Hunting and wetland drainage caused alligator populations to decline through the 1930s. Coincident with statewide controls on alligator harvests, populations
began to increase in to the 1950s, only to crash dramatically in the 1960s. Some poaching was occurring at this time but water management was the primary reason for this second decline.

Changes in land use and land cover resulting from water management also have affected alligator populations. Some locations that were alligator habitat have been converted to agricultural and residential development (Simmons and Ogden 1998). Other locations have not been developed, but are so over-drained that alligators only occur in permanent water bodies such as canals or ponds, or during periods of extremely high water. As Everglades restoration targets restoring the hydrology of these habitats, the reoccurrence of alligators in those areas will be an excellent indicator of success.

Salinity is a limiting factor for the distribution and abundance of reptiles in estuaries (Dunson and Mazzotti 1989). Freshwater flow into estuaries directly affects the location of alligators, as most alligators are found in areas of lowest salinity (Mazzotti 1983). The relationship of seasonal freshwater flow to the distribution and abundance of alligators in Everglades estuaries was noted by Craighead (1968), Brown (1993) and Simmons and Ogden (1998). Restoring a productive freshwater (oligohaline) zone with alligators of all size classes to Everglades estuaries would be a sign of successful restoration.

**Alligator Holes**

The Everglades alligator is an ecosystem engineer that physically influences the floral and faunal characteristics of the Everglades landscape through the construction and maintenance of small ponds (alligator holes) and associated underground caves (Craighead 1968). Alligator holes are excavated from the muck and peat that make up the Everglades soil, often down to the limestone bed. These depressions provide an aquatic refuge for alligators and other aquatic organisms, nest sites for other reptiles, and colonization sites for plants during frequent drying events in the Everglades (Craighead 1968; Kushlan 1972; Kushlan 1974; Loftus and Eklund 1994). Prior to drainage, alligators and alligator holes were abundant in the Everglades. Alligator hole occupancy was believed to be close to 100%, sometimes with several alligators occupying one hole (often a female with young).

Many holes were filled in with the development of areas to the east of Everglades National Park (Simmons and Ogden 1998). Those that were not destroyed experienced altered hydroperiods as a result of drainage. As early as the 1920s and 1930s, alligator hunters noted the drying out of alligator holes within some habitats. Occupancy of alligator holes in these fringe habitats is believed to have continued to decrease with continued hydrologic alterations that lead to the drying of alligator holes, especially in drought years (Craighead 1968).

The distribution and occupancy of alligator holes has been identified as a performance measure for restoration. As important as aquatic refugia are imagined to be, their ecology has remained an almost completely unstudied phenomena. This gap in information is becoming critical for making ecosystem restoration decisions.

**Nesting**

Current water management practices have resulted in a high and unpredictable rate of alligator nest flooding. Historically, maximum summer (nesting season) water levels were correlated with water levels in early summer when alligators were nesting. Alligators used the early summer water levels to determine nest placement and egg cavity height. In many areas, this natural predictability has been lost (Kushlan and Jacobsen 1990) and has resulted in mortality of eggs due to flooding.

While the historical record of alligator nest monitoring is not as extensive as that for population density or alligator hole occupancy rates, we do have information that flooding rates have increased due to water management practices (Kushlan and Jacobsen 1990) and that nest densities are extremely low in overdrained wetlands (Fleming 1991). Modified hydrologic conditions during restoration might be expected to decrease losses due to flooding, stabilize nesting effort in the long hydroperiod wetlands, and increase nesting effort and success of alligators in the aforementioned edge habitats. However, expansion of current monitoring is essential for assessment of restoration success.

**Body Condition**

The Everglades is a naturally oligotrophic system. Alligators in Everglades National Park weigh less than alligators of the same length from other parts of their range (Jacobsen and Kushlan 1989; Dalrymple 1996a; Barr 1997), do not
get as large, and take longer to reach sexual maturity (Kushlan and Jacobsen 1990; Dalrymple 1996a). Changes in hydropatterns further contribute to the harshness of the south Florida environment. Jacobsen and Kushlan’s (1989) model for growth in the Everglades of southern Florida predicted that alligators would reach a mere 1.26 metres in 10 years and requiring at least 18 years to reach sexual maturity. Dalrymple (1996b) analyzed the length to weight relationship of alligators in Shark Slough, Everglades National Park using a condition factor analysis and found that the Shark Slough alligators showed a slight reduction in mass as length increased. In addition, alligators tended to be in better condition during the dry months when food was concentrated and more available. Barr (1997) used a similar analysis on alligators in another portion of Shark Slough in ENP and showed that in very wet dry seasons alligators do not show this increase in condition, further supporting the influence that hydrology has on alligator condition. Our more recent analysis of alligator condition throughout the Everglades suggests that Everglades alligators exhibit lower body condition than populations in South Carolina and north Florida (Zweig 2002). It is currently suspected that the reason for this poor condition is a combination of low food availability due to hydrologic factors and high metabolic costs due to warm temperatures (Jacobsen and Kushlan 1989; Mazzotti and Brandt 1994; Dalrymple 1996a; Barr 1997; Percival et al. 2000).

Measures of body condition can provide a measure of restoration success through an examination of alligators throughout their range in the Everglades. Condition has been linked to reproductive success and long-term survival of alligators. Further, condition can be viewed as a measure of the quality and accessibility of prey species and provide a linkage to lower trophic levels and their success during restoration. Monitoring of condition in both newly restored habitats and in existing population centers is critical to an understanding of the effects of restoration.

**Modeling**

Everglades hydrologic patterns that result from the distribution, volume, and timing of water flow are major driving forces controlling the trophic dynamics of these systems. Hydrologic restoration alternatives are now being developed and proposed in response to the many decades of adverse water management practices that have impacted the Everglades with altered and intense drought and flooding events. Predicting and comparing the future effects of alternative hydrologic restoration scenarios on the biotic components of these systems is necessary. These forecasts can be accomplished only by ecological modeling. Several modeling efforts are underway including ATLSS (Across-Trophic Level System Simulation, 1999), Wildlife Suitability Indices and hydrology (SFWMD), and several others predicting hydrologic measures, water quality, and vegetation responses to restoration. Through the development of alligator population simulation models (see www.atlss.org) based on empirical data, we can evaluate restoration alternatives and assess restoration performance measures. By applying these models, we can provide information for making decisions on those alternatives that result in biotic characteristics that approximate historical conditions.

**Conclusions**

Future work on alligators in the Greater Everglades Ecosystem should focus on addressing the uncertainties identified while developing the components for the ecological models. Included in those are questions related to breeding female size, juvenile dispersal, and spatial and temporal variation in alligator distribution and abundance throughout the Everglades. Until recently, the only monitoring of alligators in Everglades National Park has been surveys for nests. Nesting surveys and limited nightlight surveys also have been conducted by the Florida Fish and Wildlife Conservation Commission in and near canals in the central Everglades as part of their public hunt and ranching programs. Though nest surveys provide important information and should be continued, it is not expected that changes in nesting in response to restoration will be measurable for 10 years, the time necessary for dispersing juveniles to become nesting animals. Evaluating the relative distribution, abundance, and demography of alligators using night light counts and condition analysis allows for a more rapid assessment of the impacts of CERP projects on target systems. We have recently begun developing an alligator survey network to collect the baseline population and demographic information necessary to evaluate restoration success on a 3 to 5 year time frame.

In this discussion, we have summarized what we know about alligators in the Greater Everglades Ecosystem. Baseline data are needed now to provide post restoration feedback to the policy making process. Using a combination of historic data and implementation of new monitoring programs, we will be better able to follow how alligators respond to restoration efforts. Night light surveys are a well-established, cost effective method for gathering the required information on abundance, distribution, and size class distribution (Bayliss 1987; Woodward and Moore 1990). Alligator hole distribution, densities, and occupancy rates have been monitored using a combination of mapping and survey (Mazzotti et al. 1999). Aerial nesting surveys have been used widely to monitor nest densities and distribution (Rice et al. 1999). Body condition indices have been used to monitor alligator population in several studies, and
methods for more accurate comparisons between and among populations are being developed (Barr 1997; Dalrymple 1996a, 1996b; Rice et al. 2001). Ecological models used in evaluating restoration alternatives are constantly being refined and developed (ATLSS 1999). The methods required to monitor and predict alligator population responses to restoration of the Everglades exist, and in many cases are in place. Careful development of a monitoring and modeling program for an indicator of restoration success, such as the alligator, will insure that uncertainties and surprises about the system are incorporated during the adaptive process of Everglades restoration.

**Literature**


Captive Breeding and Reproductive Biology of the Indian Gharial
*Gavialis gangeticus* (Gmelin)

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Abstract

*Gavialis gangeticus* females attain sexual maturity when they are close to 3 m and males when they are 3.5 m and above. The nesting season is during summer occurring between March and May and the maximum number of nests were laid between the 16th to 20th April. Mean clutch size was 24.53 ± 12.32 (range 2-44) and percentage of fertile eggs within a clutch averaged 75.31 ± 32.6% (range 0-100). Egg length averaged 85.89 mm (range of means 69.85-111.7 mm), width averaged 55.32 mm (range 45.8-63.6) and weight averaged 155.81 g (range 86.9-230). Total clutch weight averaged 3013.50 ± 1480.70 g (range 311.6-5640.0). Total clutch weight highly correlated with clutch size than with mean egg weight. Significant variation in clutch size and percentage of viable eggs within a nest was evident between nesting seasons in the 13 years of breeding. Age and clutch size were found to be highly correlated and total clutch weight is strongly correlated with mean clutch size. As in all other crocodilian species *G. gangeticus* has temperature-dependent sex determination (TSD) and the TSD pattern is female-male-female. Fertile eggs incubated at set constant temperatures from 29-31.5°C produced only females and at 32°C 89% were males. At 33 and 33.5°C, 20% and 15% males were produced, respectively. Incubation period averaged 70 days for eggs incubated at 31°C, which was is 1.20 times higher than eggs from 29°C and 1.17 times longer than 33°C (Lang and Andrews 1994).

Introduction

*Gavialis gangeticus* is endemic to the Indian sub-continent, occurring in India and Nepal, with Pakistan, Bhutan and Bangladesh having a few scattered individuals. Adults tend to inhabit slow flowing portions of large rivers at their bends and confluences, while smaller animals prefer sheltered backwaters (Singh 1978; Whitaker and Basu 1982). The GOI/FAO/UNDP Indian Gharial Project saved this species from the brink of extinction, when in the early 1970s they numbered less than a 100. Through major conservation efforts since 1974, the Indian gharial was brought back to safe numbers by the 1000s in several locations through out its range in India. Currently there are threats of extinction to some of the populations due to pressures on habitats and inadequate recruitment within populations (Whitaker and Andrews 2003; Ross 2003).


In the present study we examine trends in Gavialis reproductive biology in captivity from 1989 to 2002, save for 1997 in which no data was recorded. In addition to nest dynamics, ages at onset of sexual maturity, the age factors influence on clutch size and fertility, and mating and egg laying season, ambient temperature’s effects relative to the same, temperature-dependent sex determination and relationships between morphometrics of eggs and hatchlings.
Materials and Methods

The Madras Crocodile Bank Trust/Centre for Herpetology (MCBT) is a non-profit charitable Trust, and has been involved in reptile breeding, conservation and research since its inception in 1976. MCBT is situated at 12°50'N, 80°10' E, 45 km south of Chennai city, along the Bay of Bengal. The facility receives an annual average rainfall of 1.2 m, occurring primarily during two seasons southwest monsoon (June-July) and the northeast monsoon (October-December). The annual mean temperature is 28°C and ranges from 20°C during December and January to 38°C in May and June.

The *Gavialis gangeticus* breeding enclosure is located at the lower end of the facility and at almost 1.5 m above sea level. Substratum of the enclosure is predominantly large grained sand, in addition to leaf litter. The enclosure contains a natural aquifer, within which depth varies from 1.5 to 2.5 m seasonally. The enclosure is irregular, roughly ovoid-rectangular in shape, measuring 42 m in length and 25 m in width. The aquifer, measuring 30 m long and 8 m wide, is at the base of gradually sloping banks. The bank on the northern side of the enclosure is almost 4 m above water level and only the upper reaches of this bank is used as a colonial-nesting bank. The banks on all sides of the enclosure are landscaped with trees and screwpine. In addition to the gharial, the enclosure pond contains, fish and freshwater turtle species comprising *Melanochelys trijuga trijuga*, *Aspideretes gangeticus*, *Lissemys punctata* and *Kachuga kachuga*.

The study animals 10 females and three males were acquired between 1974 and 1982 and two juvenile females in 1986. Of these a male at 1.3 m TBL and a female at 0.82 m TBL, originated from the wild, probably the lower eastern reaches of the River Ganga in Uttar Pradesh. Eight females and two males hatched from wild eggs These eggs acquired from the Kukrail Breeding Centre had been collected from the Chambal River in Uttar Pradesh. These females on arrival were in the age group of 2-6 years, the two females in the two years age group measured 1.2 and 1.3 m (TBL). The two females in the four and five year age group measured 1.45 and 2.47 m (TBL). The six large females in the six years age group measured 2.2-2.6 m and averaged 2.4 m (TBL). Two other captive-bred F1 females were acquired in 1986 from Nandankanam Biological Park in Orissa and these measured a little over 1 m (TBL). These were housed in separate enclosures till 1991 and then were included with the rest of the breeding groups. Upon arrival, animals were sexed, measured and designated individual code numbers by clipping a combination of scutes on the single and double caudal whorls. Until March 1995 the entire breeding group were held in the study enclosure. During March 1995, one of the males lost half of his upper jaw in male-male combat and was transferred to another enclosure. A second male died in June 1997 following capture, perhaps due to post-capture fatigue as discussed by Seymour *et al.* (1987). In January 1999 and December 1998 two females were transferred out of the study enclosure.

For the duration of the nesting season, *G. gangeticus* females were observed from 1900-0630 h. Eggs were collected from nests within 0-3 days by marking the upper surface of the egg to maintain orientation throughout handling and incubation. Nest parameters recorded were distance from nest to edge of pond, height above pond, nest cavity width and depth. Temperatures at different depths of each layer of eggs were also recorded. Measurements of animals were recorded by marking off, with a long stick, the snout and tail tips in the sand while females and males bashed. The animals were then chased away into the pond and two ends were measured with a tape measure.

In a lab each egg was assigned individual clutch and egg numbers and then candled against a light to determine fertility by the presence or absence of the sub-embryonic fluid as discussed by Webb and Manolis (1987). Eggs were measured to the nearest ± 0.1 mm length and width with KWD type dial vernier calipers, and weighed to the nearest ± 0.1 g with an ACCULAB 226 digital weighing scale. Fertile eggs were either incubated in artificial nests buried in areas exposed or protected from sunlight (n= 26 nests), or incubated at various set constant temperatures (n= 20 nests) as previously described by Lang *et al.* (1989) and Lang and Andrews (1994). Of the 49 nests laid between 1989 and 2002 (1997 excluded), 44 of these (89.8%) have known laying dates and of 38 (77.6%) have known female IDs. Some nests that were not located at the time of nesting were ultimately discovered as females defended nest sites. In circumstances where oviposition date was unknown and a nest was discovered, band width of fertile eggs was recorded.

**Egg incubation:** Eggs were buried between 35-40 cm beneath the sand surface in an outdoor incubation facility, either as a whole clutch, or after halving the clutch in which case one half was exposed to sun and one half to shade. Temperature of each individual egg group was monitored with thermistor probes (YSI 400 series), digital thermometer, and the accuracy of absolute temperature measurements was 0.1°C. Temperatures were recorded either two times a day, at 0800 and 1600 h, or three times a day at 0600, 1200 and 1700 h.
To demonstrate that incubation temperature determines sex, eggs were incubated in an insulated lab with an air-conditioner as discussed by Lang and Andrews (1994). The incubators were custom designed foam box incubators set at constant temperatures maintained within ± 0.1°C of the set. Eggs were assigned to different incubators at different constant temperatures, mainly 29, 30, 31, 31.5, 32, 33 and 33.5°C.

**Hatchlings:** Hatchlings that resulted from both artificial nests and constant temperature incubation trials were coded and measured within 24 hours of hatching. Measurements recorded were standard total body length (TBL), snout to vent (SVL) and weight (wt).

**Results**

**Sexual maturity**

At MCBT first nesting occurred when a 10-year-old female laid eggs during April 1989, this female was measured on the following day, while she was basking and was 3.2 m TBL. Two other females nested during the same season and measured 2.8 and 3 m TBL (Andrews 1989 b). During the same season the three males were also measured and they ranged from 3, 3.5 and 3.8 m TBL. During the 1989 breeding season courtship and mating was observed and, only the two largest males were observed courting and mating.

**Trial nests and temporal distribution of nests within the egg laying season**

In all years, the first indication that nesting was imminent was the tracks of females around the nesting area (20 m x 10 m rough rectangle on the north bank) and by trial nests. Some females prior to nesting make trial nest holes probably trying to find optimum nesting sites. Trial nests were made on the same night of actual oviposition and

![Figure 1. Spatial distribution of 44 *G. gangericus* nests during 1989-2002.](image)
maximum number of days before oviposition was seven days. Depths of trial nests varied between 10 and 36 cm. Nesting dates for the 44 nests (89.8% of the total) for which egg laying dates were known ranged from 10th March to 7th May. The maximum numbers of nests (n= 7) were laid between the 16th to 20th April (Fig: 1).

Clutch size, fertility and egg characteristics

Clutch size and clutch fertility were compared between the first laid clutch and last observed clutch. Significant difference in clutch size (Paired t-test, t= 2.91, df= 6) and fertility (t= 3.38, df= 6) between the first and last observed nest was evident. Mean clutch size (MCS) (n= 49) was 24.53 ± 12.32 (range 2-44). Percentage of viable eggs within a clutch (n= 49) averaged 75.31 ± 32.6% (range 0-100). Egg dimensions, given as the means of individual clutch means, were: length (n= 26 clutches) 85.89 ± 5.44 mm (range of means 69.85-111.7 mm); width (n= 26 clutches) 55.32 ± 3.51 mm (range 45.8-63.6 mm); and weight (n= 24 clutches) 155.81 ± 25.14 g (range 86.9-230 g). Total clutch weight (TCW) (n= 21) averaged 3013.50 ± 1480.70 g (range 311.6-5640.0 g). TCW correlated more highly

![Figure 2. Relationship between age and clutch size in G. gangeticus (Age= 11.67 + 0.27CS ± 3.79; n = 37, r²= 0.39).](image2)

![Figure 3. Relationship between total clutch weight and clutch size in G. gangeticus (TCW= -125.17 + 157.82CS ± 545.78; n= 23, r²= 0.86).](image3)
with clutch size (Product Moment Correlation, n= 23 nests, r= 0.93) than with mean egg weight (r= 0.37, n= 23 nests). Age and clutch size were found to be highly correlated (Fig. 2). TCW is strongly correlated with MCS, and may be predicted from the formula as shown on Figure 3.

Reproductive effort

For the first six years of nesting (1989-1994), three males were present in the breeding enclosure; clutch size (CS) averaged 19.44 ± 7.0 eggs, viability averaged 50.42 ± 38.17%, and average number of females nesting per year was 3.16 ± 1.60 (n= 18 clutches for X CS & %Via, n= 19 clutches for X number of females nesting/year). Between 1995 and 1996, two males were present in enclosure and CS averaged 25.92 ± 11.07 eggs, viability averaged 84.69 ± 17.23%, and average number of females nesting per year was 6 ± 0.0 (n= 12 clutches). For the four years between 1998 and 2002, when only one male was in enclosure 13, CS averaged 32.88, average viability was 91.64% and average number of females nesting per year was 2.4 (n= 16 clutches for X CS and %Via, n= 12 clutches for X number of females nesting/year). Measured as a combination of average clutch size, number of clutches produced during the 13 years the animals were studied, and average fertility per clutch, reproductive effort of the eight females observed nesting are given in Table 1. The highest number of nests produced over the years by a female was eight clutches and the lowest was a single clutch - this female was very old and finally died trying to lay eggs and after she extruded her oviducts (Andrews and Whitaker 1988). We could not identify factors affecting variation in the number of clutches produced by individual females and social hierarchy and too much of male-male interactions could have influenced this.

Table 1. Summary of ages, clutch sizes and fertility (expressed as % of fertile eggs) of nesting female G. gangeticus. (*= one clutch excluded from C.S. and fertility summary).

<table>
<thead>
<tr>
<th>ID</th>
<th>Mean Age (First to last clutch)</th>
<th>Age Range (1989-2002)</th>
<th>No. of Clutches</th>
<th>Mean CS</th>
<th>CS Range</th>
<th>SD (Clutch)</th>
<th>Mean % Via.</th>
<th>% Via. Range</th>
<th>SD % Via.</th>
<th>Total Eggs Prod.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22.1</td>
<td>18-26</td>
<td>7</td>
<td>35.9</td>
<td>15-44</td>
<td>10.09</td>
<td>81.49</td>
<td>0-100</td>
<td>36.34</td>
<td>251</td>
</tr>
<tr>
<td>2</td>
<td>20.5</td>
<td>17-26</td>
<td>4</td>
<td>32.3</td>
<td>28-37</td>
<td>3.77</td>
<td>92.5</td>
<td>85.7-100</td>
<td>6.04</td>
<td>129</td>
</tr>
<tr>
<td>3*</td>
<td>21.43</td>
<td>16-29</td>
<td>7</td>
<td>17.16</td>
<td>11.26</td>
<td>6.05</td>
<td>84.8</td>
<td>56.3-100</td>
<td>17.99</td>
<td>108</td>
</tr>
<tr>
<td>7</td>
<td>20.5</td>
<td>17-26</td>
<td>4</td>
<td>28.3</td>
<td>26-33</td>
<td>3.2</td>
<td>76.2</td>
<td>48.0-92.3</td>
<td>19.96</td>
<td>113</td>
</tr>
<tr>
<td>9</td>
<td>19.8</td>
<td>16-24</td>
<td>5</td>
<td>31.2</td>
<td>22-36</td>
<td>5.76</td>
<td>82.6</td>
<td>22.7-100</td>
<td>33.6</td>
<td>156</td>
</tr>
<tr>
<td>10</td>
<td>13.5</td>
<td>12-15</td>
<td>2</td>
<td>24</td>
<td>19-29</td>
<td>7.07</td>
<td>84.3</td>
<td>78.9-89.7</td>
<td>7.64</td>
<td>48</td>
</tr>
<tr>
<td>12</td>
<td>14.75</td>
<td>10-22</td>
<td>8</td>
<td>21</td>
<td>2-42</td>
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<td>109</td>
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<td>-</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>33.3</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
</tbody>
</table>

The number of eggs produced in the course of the 13 years is highly correlated to the number of clutches (Table 1), (Product Moment Correlation, n= 8, r= 0.81), average clutch size (n= 8, r= 0.76), average nesting age (n= 8, r= 0.73), but weakly related with the percentage of fertile eggs within a clutch (n= 8, r= 0.49). Significant variation in clutch size (ANOVA; F= 2.41, N= 45) and percentage of fertile eggs within a nest (ANOVA; F= 4.60, N= 45) was evident between nesting seasons in the 13 years of breeding.

Re-nesting intervals and sequence of laying

Re-nesting intervals of seven females is presented in Table 2. As mentioned previously, it must be noted that there is a margin of error as not all nests had females identified with them. Sequence of laying, that is the order in which a said female laid her eggs in relation to the other seven females, was ranked for all the females analysed; Female 12 (n= 8 nests) frequency averaged 1.25 ± 0.46 (range 1-2), female 3 (n= 7) averaged 2.57 ± 0.79 (range 2-4), female 9 (n= 5) averaged 2.60 ± 1.14 (range 1-4), female 01 (n= 7) averaged 2.43 ± 0.79 (range 2-4), female 7 (n= 4) averaged 4.0 ± 0.82 (range 3-5), female 2 (n= 4) averaged 3.5 ± 2.89 (range 1-6), while female 10 (n= 2) averaged 2.0 ± 1.41 (range 1-3)
Table 2. Re-nesting intervals (years) of 7 female *G. gangeticus*.

<table>
<thead>
<tr>
<th>ID</th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>N5</th>
<th>N6</th>
<th>N7</th>
<th>N8</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>G1-89</td>
<td>1 G1-90</td>
<td>1 G1-91</td>
<td>1 G2-92</td>
<td>1 G1-93</td>
<td>1 G1-94</td>
<td>6 G1-00</td>
<td>1 G2-01</td>
</tr>
<tr>
<td>3</td>
<td>G2-89</td>
<td>1 G2-90</td>
<td>1 G2-91</td>
<td>2 G3-93</td>
<td>3 G2-96</td>
<td>4 G3-00</td>
<td>2 G4-02</td>
<td>- -</td>
</tr>
<tr>
<td>9</td>
<td>G2-93</td>
<td>2 G3-95</td>
<td>1 G4-96</td>
<td>3 G1-99</td>
<td>2 G3-01</td>
<td>- - -</td>
<td>- - -</td>
<td>- -</td>
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<tr>
<td>1</td>
<td>G2-94</td>
<td>1 G2-95</td>
<td>1 G3-96</td>
<td>3 G2-99</td>
<td>1 G2-00</td>
<td>1 G4-01</td>
<td>1 G2-02</td>
<td>- -</td>
</tr>
<tr>
<td>7</td>
<td>G4-93</td>
<td>2 G4-95</td>
<td>1 G5-96</td>
<td>6 G3-02</td>
<td>- - -</td>
<td>- - -</td>
<td>- - -</td>
<td>- -</td>
</tr>
<tr>
<td>2</td>
<td>G6-93</td>
<td>2 G1-95</td>
<td>1 G6-96</td>
<td>6 G1-02</td>
<td>- - -</td>
<td>- - -</td>
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<tr>
<td>10</td>
<td>G3-89</td>
<td>3 G1-92</td>
<td>- - -</td>
<td>- - -</td>
<td>- - -</td>
<td>- - -</td>
<td>- - -</td>
<td>- -</td>
</tr>
</tbody>
</table>

Mean - 1.71 - 1 - 3.5 - 2 - 2 - 3 - 1 -  
SD ± - 0.76 - 0 - 2.07 - 0.82 - 1.73 - 2.65 - 0 -  
Range - 1-3 - 1 - 1-6 - 1-3 - 1-4 - 1-6 - 1 -

Figure 4. Temperature profile of natural nest (G2-91; exposed to sun); 45 of 59 incubation days recorded. Incubation period = 59 days; X at 0800 h = 32.84 ± 1.18°C (range 31.7-34.7°C); X at 1600 h = 32.74 ± 1.12°C (range 30.4-34.6°C); Pooled X = 32.79 ± 1.15°C (range 30.4-34.7°C).

Artificial nest temperatures

Incubation temperatures remained relatively constant throughout the incubation period, drops and peaks occurred when rainfall occurred and nests dried out again respectively (Fig. 4). Rainfall effectively lowered nest temperature within eight hours. The incubation period ranged between March-July, the latter trimester coinciding with the south-west monsoon. Pooled temperatures averaged 31.41 ± 0.79°C, range 30.43-32.79°C (n= 6) for treatments at sunny locations, and averaged 30.70 ± 1.22, range 29.43-32.32°C (n= 5) for treatments at shaded locations.

Hatchlings from artificial nests

Hatchlings from nests located in sunny and shady locations collectively pooled and measured within a day of hatching, had the following dimensions; mean TBL 35.52 ± 1.30, ranging between 33.8-37.45 cm (n= 185), mean SVL 17.27 ± 0.73, range 16.13-18.50 cm (n= 185) and mean weight of 104.02 ± 14.19, range 75.5-124.05 g (n= 151). No significant difference was found in the TBL (ANOVA, F ratio= 0.0056; N= 19), SVL (ANOVA, F ratio= 0.0; N= 19), and wt. (ANOVA, F ratio= 0.55; N= 15) was observed between clutches exposed to sunlight, and shaded clutches. Hatchling morphometrics were found to be highly correlated to each other, regression equations are presented in Table 3.

Temperature-dependent sex determination

Lang and Andrews (1994) have previously discussed temperature-dependent sex determination for this species. As in all other crocodilian species *G. gangeticus* has TSD and the pattern is female-male-female. Fertile eggs incubated at set constant temperatures from 29-31.5°C produced only females and at 32°C 89% males were produced. At 33 and 33.5°C resulted in 20% and 15% males respectively. Incubation period averaged 70 days for eggs incubated at 31°C, which was 1.20 times higher than eggs from 29°C and 1.17 times longer than 33°C.
Table 3. Natural nests (“sunny” and “shady” hatchlings pooled); Correlation coefficients and linear regression equations for predicting hatching parameters from each other. 151 hatchlings from nine clutches analysed for all wt. related equations, while n= 185 hatchlings from 11 clutches analysed for non-wt. related equations; for equations 1-6, values calculated from average of the average; for Hwt/Ewt equation 7, n= 100 hatchlings, direct correlation between parameters; hatchlings resulted from eggs laid by five different females in addition to two nests of unknown origin. (SEE= standard error of the estimate).

<table>
<thead>
<tr>
<th>Equation</th>
<th>Formula</th>
<th>SEE</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TBL = 5.99 + 1.71SVL</td>
<td>0.13</td>
<td>0.92</td>
</tr>
<tr>
<td>2</td>
<td>SVL = -1.56 + 0.53TBL</td>
<td>0.06</td>
<td>0.92</td>
</tr>
<tr>
<td>3</td>
<td>HWt = -2.35.18 + 9.62TBL</td>
<td>54.26</td>
<td>0.71</td>
</tr>
<tr>
<td>4</td>
<td>TBL = 27.56 + 0.07HWt</td>
<td>0.60</td>
<td>0.71</td>
</tr>
<tr>
<td>5</td>
<td>HWt = -223.21 + 19.17SVL</td>
<td>59.91</td>
<td>0.69</td>
</tr>
<tr>
<td>6</td>
<td>SVL = 13.33 + 0.036HWt</td>
<td>0.11</td>
<td>0.69</td>
</tr>
<tr>
<td>7</td>
<td>HWt = 17.937 + 0.525Ewt</td>
<td>6.17</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Discussion

Sexual maturity

Size and age at the onset of sexual maturity for several species has been previously discussed to an extent. McCann (1940) and Joanen and McCann (1975) have established that sexual maturity is size, not age, dependent. Bustard and Singh (1981) have reported for *C. palustris*. McCann (1940), Whirworth (1971), Joanen and McCann (1975) and Nichols and Chabreck (1980) have reported the onset of sexual maturity for *A. mississippiensis*. Andrews (1986, 1989a, 1989b, 2000) has reported for *C. palustris*, *C. simensis*, *C. niloticus*, *Caimin crocodilus crocodilus*, *C. moreletti* and *G. gangeticus*. Hornaday (1885) first reported a female *G. gangeticus* that he had shot measuring 2.7 m and had 15 developing eggs. Another 2.97 m long female shot in the Sutlej River had 56 eggs (Parshad 1914). Whitaker and Basu (1982) have reported that the minimum breeding size of females as 2.6 m TBL, and Biswas *et al.* (1977) reported that males attain sexual maturity when they are over 3 m. Acharjiyo *et al.* (1990) confirmed that females attained sexual maturity when they are close to 3 m TBL and when they are 8.5-9 years old in captivity. Bustard and Maharana (1982) reported 3-3.17 m TBL for *G. gangeticus* females and Maharana (2001) reported that females in captivity (n= 7) attained sexual maturity when they reached 3 m and from 10-17 years of age.

At MCBT first nesting occurred when a female 3.2 m TBL and 10 years laid eggs. Two other females nested during the same season and these two females measured 2.8 m (17 years) and 3 m (11.8 years) (Andrews 1989b). During the same season the three males were also measured and they ranged from 3.35 and 3.8 m TBL, and were aged 9.6, 12.6 and 18.6 years of age. During the 1989 breeding season courtship and mating were observed and only the largest males was observed courting and mating.

Of the three males in the breeding group, the largest male’s ghara development has been reported (Whitaker and Whitaker 1989); the snout looked like a female’s snout until 1982, when the first protuberance became obvious. Ghara growth proceeded steadily with a definite back folding tendency which eventually covered the nostrils in 1988. This male’s ghara was first evident at 11 years of age, and covered the nostrils by 18.6 years (in 1989). Coincidentally, nesting occurred for the first time in the same year. Biswas *et al.* (1977) noted that a male at Nandankanan Biological Park, Orissa, could be distinguished from females at the age of 12.5 years on the basis of the development of the ghara.

Temporal distribution of nests within the egg laying season

Nesting coincided with the period of minimal rainfall, and increasing ambient temperatures, a trend parallel to that observed in *C. palustris* at the same study site (Lang *et al.* 1989). Span of the nesting season (accumulative range)
varied from 57 days at lower latitudes (MCBT) to 22 days at higher latitudes such as the Narayani River in Nepal (Bustard 1980). Maximum deposition of clutches at MCBT occurred between the 16th and 20th April (51.9% of the total) (Table 4). In the Narayani River, Nepal, nesting occurred during 1-5 April (42.4% of the total) (Bustard 1980a). Rao (1988) reported 51.5% between 26-30 March at Baroli in the National Chambal Sanctuary, Madhya Pradesh.

Table 4. Average temperatures during courtship and egg-laying seasons of *Gavialis gangeticus* (excluding 1997).

<table>
<thead>
<tr>
<th>Year</th>
<th>Courtship and mating season (December-February)</th>
<th>Egg laying season (March-May)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Max.</td>
<td>Mean Min.</td>
</tr>
<tr>
<td>1989</td>
<td>29.13</td>
<td>21.25</td>
</tr>
<tr>
<td>1990</td>
<td>29.23</td>
<td>22.62</td>
</tr>
<tr>
<td>1991</td>
<td>32.60</td>
<td>23.05</td>
</tr>
<tr>
<td>1992</td>
<td>29.01</td>
<td>22.57</td>
</tr>
<tr>
<td>1993</td>
<td>29.24</td>
<td>22.67</td>
</tr>
<tr>
<td>1994</td>
<td>29.06</td>
<td>23.79</td>
</tr>
<tr>
<td>1995</td>
<td>31.90</td>
<td>21.12</td>
</tr>
<tr>
<td>1996</td>
<td>31.03</td>
<td>21.77</td>
</tr>
<tr>
<td>1998</td>
<td>31.19</td>
<td>23.51</td>
</tr>
<tr>
<td>1999</td>
<td>29.91</td>
<td>22.11</td>
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<tr>
<td>2000</td>
<td>30.49</td>
<td>22.29</td>
</tr>
<tr>
<td>2001</td>
<td>32.41</td>
<td>21.47</td>
</tr>
<tr>
<td>2002</td>
<td>32.36</td>
<td>21.95</td>
</tr>
<tr>
<td>Average</td>
<td>30.58</td>
<td>22.32</td>
</tr>
<tr>
<td>SD</td>
<td>1.41</td>
<td>0.83</td>
</tr>
<tr>
<td>Range</td>
<td>29.01-32.60</td>
<td>21.12-23.79</td>
</tr>
</tbody>
</table>

Clutch size and egg characteristics

Clutch size averaged 25.9 (n= 49 nests) for the entire study period, however when calculated for the last four years the clutch size averaged 32.9. Rao and Singh (1993) reported 38 eggs as the average for 12 nests at the Baroli communal nesting site in the National Chambal Sanctuary. Hussain (1999) reported 36.52 eggs for 124 nests in the National Chambal Sanctuary and this is from the largest sample size. Maharana (2001) reported 32.6 (n= 69 clutches) ranging 2-57 in captivity at the Nandanankan Biological Park. In the current study, *G. gangeticus* clutch size (CS) gradually decreased from 39 eggs in the 1-5 March timeframe to the 26-30 March timeframe (Mean CS= 22.8 eggs). It then escalated in the 1-5 April timeframe (Mean CS= 38.25 eggs), then showed a general gradual decrease till the 26-30 April timeframe (Mean CS= 15.33 eggs), and finally a second escalation in the 1-5 April timeframe (X CS= 28 eggs). Thus, there is a trend of decreasing clutch size through the oviposition period, and this in turn indicates that larger females lay clutches first in a given nesting season. This trend is confounded by the varying number of clutches for each time frame under consideration. Webb et al. (1983) noted that in *C. johnstoni*, larger clutches tend to be laid first in a given nesting season. At variance to our observations is that provided by Hall (1991), with respect to *C. novaeguinae* where clutch size was found to remain nearly constant throughout the oviposition period.

Egg morphometrics from the current study are similar to that reported from previous studies. In our study, egg length averaged 85.89 mm (range 69.85-111.7), egg width averaged 55.32 mm (range 45.8-63.6) and weight averaged 155.8 g (range 146.9-230). Rao (1988) recorded dimensions of eggs for 60 nests and egg length averaged 86 mm (range 77-94), width averaged 61.3 mm (range 59-64), and weight averaged 185.5 g (range 145-210). Srivastava (1981) recorded egg dimensions for 15 nests laid over four consecutive years, egg length averaged 84.8 mm (range 71.5-88.7), width averaged 59.5 mm (range 50.3-64.5), and weight averaged 145.2 g (range 102-185). Maharana (2001) reported egg weights from 69 clutches laid in captivity and mean clutch weight was 155 g (range 105-195).

Acknowledgements

Most is due to Jeff Lang for initiating this program at MCBT and for his continued encouragement over the many years of the project and after. We also thank the staff of the Madras Crocodile Bank/Centre for Herpetology for their
assistance at every stage. Grahame Webb and Rom Whitaker provided valuable comments and reviewed an earlier draft of this manuscript. We are grateful to the Trustees of the Madras Crocodile Bank Trust/Centre for Herpetology for their continued support and encouragement. Last but not least, we are indebted to Seema Mundoli for her patience in reviewing this manuscript three times and for all her editorial help.

**Literature**


Conservation Genetics of Chinese Alligator, *Alligator sinensis*

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Chinese alligator is one of the most endangered species among 23 species of crocodiles. Only single population, of no more than 200 individuals, remains in the wild at Xuanzhou, Anhui Province in China. To save this species, captive propagation programs were established, which consist of 2 captive subpopulations at Xuanzhou and Changxing breeding farms. The first crocodile farm, The Anhui Research Center of Chinese Alligator Reproduction (ARCCAR), is the largest captive subpopulation of this alligator, was set up at Xuanzhou, Anhui Province in 1979. 212 alligators came from wild as foundation stock for ARCCAR, and subsequently raised in a natural pond, where the survivors (about 60-70 individuals) remain today. From then on, about 9000 individuals including first (F₁) and second filial generation (F₂) were bred in ARCCAR.

A major concern among conservation biologists is loss of genetic diversity in small or captive populations through genetic drift and inbreeding. Because of their restricted population size, inbreeding is virtually unavoidable in captive populations (Pray et al. 1994). The molecular approach has been proved an increasingly valuable tool in the identification of animal genetic variation. Genetic markers, such as Random Amplified Polymorphic DNA (RAPD), mitochondrial control region sequences and microsatellites, have been applied to assess genetic structure of Chinese alligator captive population. The results show that very low genetic variation was revealed in captive population of Chinese alligator. Especially, only one haplotype of control region sequence was found in Chinese alligator population. Recently, we continued to analyze the mitochondrial control region sequences variation using the enlarged samples of Chinese alligator. Total 2 variable loci were found in the control region sequences in skull samples from history population. But also, no sequence variation was detected in captive population. In another study, a pair of degenerate primers was used to amplify polymorphic segments of MHC class II genes from the genomic DNA of *Alligator sinensis*. Ten different nucleotide sequences, which were divided into two groups (A, B), were obtained from cloning and sequencing. There were 38 variable sites among ten nucleotide sequences, and 23 variable sites among amino acid sequences. So, we think that, the loss of genetic variation may not occur in the whole genome of Chinese alligator, the high polymorphism of some functional genes, such as MHC in *A. sinensis*, was of great benefit to genetic conservation in the captive population of Chinese alligator.
Crocodilian Genome Projects: Status and Resources

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²Department of Biological Sciences, University of South Carolina, Columbia, SC 29208, USA

Many new tools to analyze the genetics of crocodilians are being developed. Standard genetic tools to identify individuals, family groups, populations, and species are now reasonably advanced. In addition to these more traditional tools, additional approaches are advancing rapidly. The number of genes described from crocodilians will go from a few dozen in 2003 to thousands within the next year. The vast majority of the new data will be from American alligators (*Alligator mississippiensis*). American alligators will also be included in a Reptilian Genome Project proposal to the U.S. National Human Genome Research Institute. Leveraging the data from American alligators and other new comparative genomic data sets will present new opportunities for both applied and basic research of crocodilians. Specific information about the DNA tools now available, PowerPoint slides used for this presentation, abstracts of research presented at the 2nd International Crocodilian DNA Workshop, as well as a variety of additional resources are available from the Crocodilian DNA Information Repository (http://www.uga.edu/srel/CrocDNA/CrocDNAindex.htm).

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Crocodilian Gene Hunting with Expressed Sequence Tags (ESTs)

Nancy A. Schable¹, Travis C. Glenn¹² and Roger H. Sawyer²

¹University of Georgia, Savannah River Ecology Laboratory, Georgia, USA;
²University of South Carolina, USA (schable@srel.edu)

Increasing our knowledge about genome organization and expressed genes for the American alligator (*Alligator mississippiensis*) will provide important information about the basic biology of crocodilians, enhance captive propagation success, and increase the commercial value for this species. Developing an Expressed Sequence Tag (EST) library is the most direct and efficient way to examine the type and number of active genes that are expressed in a particular tissue. We are currently developing EST libraries for brain, liver, kidney, skin, ovary, testes, embryonic tissues, as well as “whole animal” for the American alligator. We will present information about how these libraries are constructed, how they can be used, and how other researchers can access the libraries, clones, and information generated. Several newly discovered American alligator genes will be revealed along with a brief discussion of the significant research that may result from their identification.
Captive Animals with Known Pedigrees Are Needed for Genetic Maps of Crocodylians

Cris Hagen¹ and Travis C. Glenn¹,²

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²Department of Biological Sciences, University of South Carolina, Columbia SC 29208, USA (Travis.Glenn@sc.edu)

Genetic maps are an important resource for biologists with interests ranging from evolution to production agriculture. Unfortunately, no genetic maps exist for crocodilians. We are interested in developing genetic linkage maps for American alligators (Alligator mississippiensis), as well as other crocodilians. To accomplish this, our immediate goal is to obtain the necessary blood samples from captive crocodylians with known pedigrees. In general, samples from families with 3 generations (ie grandparents, parents, and offspring) are desirable. Family groups with large numbers of offspring as well as those from interspecific crosses (eg golden crocodiles) are particularly valuable. We welcome information from anyone with knowledge of or access to such samples.

Stochastic Simulation Model of the Population Dynamics of the Caiman yacare in the Brazilian Pantanal

Marcos Coutinho, Milani Chaloupka and Zilca Campos

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A heuristic simulation model was developed to foster a better understanding of the complex nature of caiman population dynamics in the southern Pantanal wetlands. The model was based on systems of finite difference equations linked with demographic rates characterized by nonlinear, feedback and stochastic properties. The model is age- and sex-structured with significant environmental stochasticity included through the relationship between female breeding likelihood and mean maximum water level in the wetlands. Water level fluctuates significantly from year to year and is a major environmental function which also displays long periods of low water levels, resulting in complex nonlinear population dynamics. Demographic stochasticity was included in the model by sampling vital rates such as age-specific survival probabilities from normal probability distribution functions reflecting the estimated measurement error. The model was used to analyse the behaviour of the population and to support risk evaluation of each of following management strategies: a) Egg harvesting: presently, this is the only legal possibility of exploiting natural populations of caimans in the Pantanal, even though the infrastructure and logistic support required to rear the hatchlings is unavailable in the large majority of the farms within the wetlands; b) Harvesting individuals five to nine years of age (50 to 90 cm SVL); c) Harvesting individuals >10 years of age (>90 cm SVL): scenarios b and c are likely to be economically feasible given that only a low infrastructure and small capital investments are required. It is important to assess the biological feasibility of these approaches. However, changes in the Brazilian federal environmental legislation would be necessary before they could be implemented, given that commercial use of wildlife by hunting is presently prohibited; d) Headstarting and harvest age classes five to nine and/or >10 years: headstarting the population with hatchlings and harvesting young-adults and/or adults are management activities which require relatively low investments and are technically possible to be implemented, despite the lack of infrastructure and logistic support that prevails in most farms in the Pantanal.
Evidence for Long-Distance Migration by Wild American Alligators

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²Graduate School of Public Health, San Diego State University, San Diego, California 92128, USA

As part of an ongoing study on growth and sexual maturation of the American alligator on Rockefeller Refuge, 3004 specimens ranging in total length from 28 to 361 cm were captured from June 2001 through January 2004. Each animal was tagged, measured, the sex recorded and released at the site of capture. A large number of these marked animals were recaptured outside the refuge at the annual alligator hunts during the month of September. Of the recaptures identified, 69 were males, 22 females and six of undetermined sex. From each recaptured alligator, total body length and number of days since initial capture were recorded, and minimum distance from initial capture site estimated. From these preliminary data we calculated growth rate and plotted minimum distance moved. The number of days between first capture and ultimate capture ranged from 29 to 1151 days. To calculate growth rate we used only the days between April 1 and September 30. Males grew significantly faster than females (3.55 ± 0.15 vs. 1.94 ± 0.23 cm/growing month). Distance from initial capture site to final capture site ranged from 0.33 to 90.17 km. Three alligators moved more than 30 km, seven alligators moved between 20 and 30 km and 19 moved between 10 and 20 km. There was no significant bias in the compass direction moved. These results greatly extend previous estimates of long-distance movement by alligators and demonstrate that both sub-adult and sexually mature animals move considerable distances. Suggested reasons for such dispersal will be discussed.

Characterization of the Innate Immune System of the American Alligator
(Alligator mississippiensis)

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Recent studies in our laboratory have shown that serum of the American alligator exhibits potent and broad-acting antibacterial properties. In addition, alligator serum exhibits strong amoebacidal properties. The antimicrobial character of the serum has been attributed to the innate immune system of the alligator. The innate immune system is the first line of defense against infection. The serum complement protein system comprises an important component of innate immunity. We have identified one alligator complement protein component and characterized much of the biochemistry of the complement system, including kinetic analyses, thermal dependence, and the role of Mg²⁺ and Ca²⁺. Other studies have focused on the role of leukocytes in innate immunity. We have described the antifungal effects of crude granulocyte extracts. In addition, we have measured complement-mediated opsonization and phagocytosis of bacteria and the generation of oxidative bursts by alligator granulocytes using advanced flow cytometric techniques. This presentation will focus on an overview of our recent and current studies on the innate immune system of the American alligator.
Isolation and Identification of Microorganisms in the Eggs of Caiman crocodilus fuscus from Three Farms on the Atlantic Coast of Colombia

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¹ Wildlife Management Adviser, Colombia (crocofauna@hotmail.com);
² Estudent M.V.Z. Universidad San Martín, Barranquilla, Colombia

Abstract

During the incubation process of the crocdylias, embryonary mortality occurs due to different effects, one of them being contamination by microorganisms. Our sample material came from three farms that carry out industrial zoobreeding programs in a closed cycle with the C. c. fuscus species, located on the Colombian atlantic coast (from the Colombian Caribbean, San Francisco and Colombian Crocodilia) and have automated incubation systems and calibrated at 32°C and 99% of relative humidity. In order to evaluate this situation 29 eggs (shell, inside) were analysed, three water samples, four samples composed by vegetal material, three samples composed by vermiculita. Microorganisms were is dated and identified, from these. The most frequent bacterial on shells were Pseudomonas spp., Klebsiella pneumoniae. Fungi were only found on shells and less than bacteria, Trichophyton rubru and Aspergillus fumigatus being the most frequent. The latter microorganisms were also found on vermiculita samples and vegetal material from nests, the latter presumably being the contaminating origin. It is fundamental to carry out disinfection techniques for eggs and incubation equipment.

Introduction

In the closed cycle production systems of Caiman crocodilus fuscus the incubation process places a fundamental role for the productive success of the system, therefore, embryonary mortality occurred during this process, may affect the production. For such effect and in order to find causes that may by corrected through the implementation of and adequate handling, the Colombian Caribbean, San Francisco and Colombian Crocodilia farms collaborated with the logistic and economic support to carry out this investigation.

In these farms, the maximum length observed for males is 225 cm (88.58”) and the females reach up to 185 cm (72.83”). The females of largest size normally lay a big number of eggs and of great size, which makes the newborn be equally big.

For the area of study (Caribbean zone of Colombian), the mating occurs after the first symptoms of courtship starting at the end of January which last until the end of June. The nests are constructed by the female piling vegetation material, an event that starts in the first week of April and ends by the middle of August. Hatching occurs after an average of 72 days of incubation at a temperature of 32°C and 99% relative humidity, starting by the middle of June and ending during the first week of November. In these three farms the physical characteristics of the eggs of C. c fuscus have been found to be: weight that can vary from 29 to 69 g, length from 5 to 6.4 cm and width of 3.1 to 4.1 cm.

The shell of these eggs is hard and calcified stuck to a fibrous membrane. The calcified portion of the shell is rough and contain groups of fine pores that may not be seen by the human eye. The pores are vital for gaseous interchange and are also structure that permit maintaining hydration balance of the egg according to the level of humidity that surrounds it.

Microorganisms can also go through these pores the same way and affect the immune system of the eggs and cause the mortality of the embryo because of this. The incubation systems used in these three farms are electronic, reason why they have the necessary equipment to offer the conditions that permit maintaining a constant temperature during the whole incubation process.

Objectives

The main objectives was to identify the types of bacteria and fungi present in C. c. fuscus eggs and the materials involved in their incubation.
Materials and Methods

Basic laboratory equipment was used for the sample taking as for their analysis, each one of them well sterilized. The egg samples were taken from three farms, inside the group of incubated nest, having as a selection criterion, visual characteristics such as fungi presence, unfertile eggs and fertile eggs.

Procedure

Initially, through ultrasound, females were detected that presented sonogram characteristics such as presence of structures compatible with eggs, eggs in abdominal cavity and females with no eggs. From these samples were taken of ovaries, oviducts, follicles and eggs found in oviduct as in abdominal cavity, to be analysed in laboratory which determined the absence of microorganisms in the different samples.

There are proceeded to take the egg samples, identifying the nest, taking these with gloves and depositing them in sterile bags, the same with the vermiculite, vegetative material, from the nest and water samples, to be transported this way to the laboratory.

Where it proceeded to analyse the external and internal material of the egg following the corresponding protocol to do the planting using Agar blood as a cultivation means and EMB for anaerobiosis (non-oxygen) at 37°C for 24 hours and the means for fungi at laboratory room temperature from 8 to 10 days.

Samples

29 eggs were used, analysing the shell and the inner content, 4 samples of compound vegetative material, three of water and three of compound vermiculite, this means a total of 39 samples were analysed.

Global Analysis of Samples

Samples were taken from 19 lakes of reproducers of a total 30, that exist on the three farms, which corresponds to a 63.3%.

For the global analysis of samples the number of isolations was established of each type of bacteria and kinds of fungi, in each one of the three farms and its percent relation.

Results

Bacteria

Fifteen (15) different types of bacteria were detected on the shell and 13 in the inner part. Among the isolated bacteria on the shell and the inner part of the eggs, the most common ones were: Pseudomonas, Klebsiella pneumoniae and Enterobacter agglomerans.

Fungi

Five different kinds of fungi were identified on the shell, and interestingly they weren’t found in the inner part of the eggs. The fungi that was isolated in a greater number of times was Trichophyton rubrum and Aspergillus fumigatus, each one 16 times.

Discussion

When making a comparison between the samples taken and the bacteria and fungi detected in each one of them, we can notice that a high relationship exists between the most isolated microorganisms in eggs, with the ones found in vegetation material. The bacteria and fungi that were isolated in this procedure, coincide greatly with the ones reported by Mayer (1998).

Births and Deaths Per Farm

The rate of embryonic mortality and the percentage of hatchings were calculated using only the viable eggs taken
from the nests used for this evaluation - broken eggs were not taken into account. In the case of farm one, we used eggs from 11 nests, in which embryonic mortality was 73.5%, and the hatching rate was 26.5%; the newborn mortality rate was 11%.

In the case of farm 3, the embryonic mortality in the nest was 47% (hatching rate of 53%), and the newborn mortality rate was 1.7%. In farm two, embryonic mortality was 55% (hatch rate of 45%), with a newborn mortality rate of 34%. The average embryonic mortality rate for all incubated eggs in the three farms was 16.3% (hatching success of 83.7%).

This comparison could reflect that the bacteria and fungi in the eggs and the environment that surrounds them, influence notably so that the eggs don’t culminate in a successful birth.

We have to take into a account that the initial samples of eggs were taken under specific circumstances like: infertility, microscopic presence of fungi and normal eggs. This is why these percentages are valid for the total sampling done for this study, which isn’t a totally real situation for each one on the farms at a global level, nevertheless it those reflect the high embryonic and newborn mortality caused by these microorganisms, which is a warning to take measures to better this situation.

Conclusions

The isolated bacteria and fungi are microorganisms natural to the environment in which the samples were and because of the conditions the C. c. fuscus eggs were incubated in, such as a 99% relative humidity and 32°C temperature, made the environment good for the growth of these microorganisms. Specially for the fungi, which managed to grow to such a point the manifested microscopically so well as it they were in an environment of enriched plantation special for them, like the ones in the laboratory are.

The eggs and the newborn have their own defence mechanisms, which are able to fight a certain number of microorganisms nevertheless when the number of these microorganisms is such bigger, they overcome the defences of the eggs and newborn managing to cause embrionary mortality, the newborn deaths and postbirth sicknesses.

The presence of bacteria in the inner content of the eggs, reflected that some of then had the chance to penetrate the shell causing damages nevertheless the possibility that some were the result of contamination isn’t discarted eventhough the measure taken to prevent the contamination in the planting in the laboratory.

About the fungi, these weren’t isolated from the inner content of the eggs, which makes us presume they didn’t manage to penetrate the shell, these doesn’t mean they don’t cause harm, due to the data of obtained, we observed that in the nests where microscopic growth took place, was where a 100% of embryonic mortality of the nesting was present. These fungi are presumed to act two ways: one is that when forming an extense longer over the surface of the egg, the manage to stop the normal gas exchange between the egg and the external environment, causing the embryonic mortality this way; or that the fungi can generate toxins and these penetrate the shell, can be the ones causing the embryonic mortality, surely these are only suppositions and to confirm them, they must be studied specifically and with the means for it.

Suggestions

To be able to diminish the microbial load on the fertile eggs for incubation and in general in all equipment and incubation infrastructure, its advisable to practice disinfection techniques on these.

Acknowledgements

We specially thanks the croc farms: From the DEL CARIBE COLOMBIANO, SAN FRANCISCO, CROCODILIA COLOMBIANA, located in the Atlanticco department Colombia for the unconditional cooperation for the development of this investigation. Thanks to croc farm REPTICOSTA for their support, and Miguel Rodriguez for his comments.

Literature


Using Bioelectrical Impedance Analysis (BIA) to Determine the Body Condition of Farmed Estuarine Crocodiles

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Bioelectrical Impedance Analysis (BIA) technology has been used to assess the body composition of humans in nutritional-related studies for over 30 years. BIA is safe, rapid, accurate, non-invasive, portable and inexpensive. It works on the principal that the body is essentially composed of two compartments: a lean compartment that contains all the water and conducting electrolytes, and a fat compartment that contains little water and is non-conducting. In this study, a low-frequency, fixed current was passed through the body and a value for impedance (Z) is calculated. This value, combined with the crocodile’s length and weight, allowed the calculation of the animal’s total body water (TBW). However, BIA does not measure actual fat levels in the body and instead uses TBW, which is a good estimate of lean body mass. The BIA spectrometer was calibrated for use with crocodiles using twenty crocodiles that ranged in age and size. An independent measurement of TBW using tritiated water, combined with impedance measurements, the animal’s length and weight and carcass analysis, was used to develop a prediction formula that was then programmed into the BIA spectrometer. BIA could be an effective tool in developing manufactured feed for crocodiles by assessing the condition of animals trialling different feeds, since this technology is capable of measuring changes in body condition of individuals or groups of animals over time.

Development of Electrical Stunning Equipment for Farmed Crocodiles

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The development of electrical stunning equipment to capture farmed estuarine crocodiles has occurred over the last five years. The equipment was developed to address two primary considerations, the safety and well-being of farm workers and the welfare of the crocodile. Initially the equipment comprised of two units, one unit that operated off mains power, the other a portable unit in the form of a belt pack. The stunning wand was made from PVC piping which had a rubber belt running through the middle of the wand, which allowed the crocodiles to be dragged out of the water once they had been stunned. The equipment has been refined over time with the original operating units being replaced with a backpack unit housed in a clear Perspex box. This unit is fully waterproof and will float if dropped into water. Crocodiles easily damaged the original wands during capture. In an attempt to remedy this, wands have been manufactured from stainless steel pipe. A junction box at the top of the wand delivers power via two 3/16 shrink-wrapped stainless steel rods connected to electrodes at the head of the stunning wand. A push button switch supplies power to the equipment.
CrocProfit

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²Agency for Food and Fibre Sciences, Department of Primary Industries and Fisheries, PO Box 1085, Townsville, QLD 4810, Australia (steve.peucker@dpi.qld.gov.au)

CrocProfit is a complete information package for crocodile farmers and potential investors. The CD also contains reference material and a comprehensive list of contacts for related State Governments and industry associations for any questions or assistance that you may require.

In conjunction with the reference material, the farm model provided allows you to evaluate the economics of crocodile farming, using your own input parameters, before any investment or construction occurs.

The model covers all aspects of farming in a comprehensive fashion. The model is based upon the cost-benefit analysis technique. Cost-benefit analysis is a conceptual framework for the economic evaluation of projects, in this case, crocodile farming projects. This approach differs from financial appraisal in that it considers all gains and losses. The basic premise of cost-benefit analysis is to assist you to make a decision in regard to the allocation of resources. In particular, CrocProfit helps you to make decisions about whether or not to invest in crocodile farming.

Existing farmers can also use CrocProfit. Once the data is entered into the model a farmer can use the computer version of his farm to determine the impact of different management decisions. For example, the farmer may wish to know how introducing new diets will effect annual production and profitability.

The model is easy to operate. It is simply a matter of entering data into the input cells of the model you have selected. It is better to be as accurate as possible with data entry in order to get the best possible results.

Risk analysis is also included to ensure that all possible economic outcomes are considered. The model provides a static figure on the summary page (annual return). When probabilities (uncertainty) are added to production and price the range of economic outcomes are delivered (cumulative probability distribution). Investors or potential farmers must accept that they can receive a wide range of returns (including negative ones).

Once all the data is entered into the model you can view the summary statistics for the farm. All the statistics used are explained in the model itself. Basically, the farm is run over a 20-year period. The output includes the expected annual returns, when the farm is paid off and the interest rate at which you can borrow funds to invest in the project. The summary statistics will also provide a break down of costs on a per animal basis.

The models are set up in Microsoft Excel as a spreadsheet. All the sheets contained in the model are labelled for easy reference and there are buttons in the menu for easy movement between sections.

The basic premise for the operation of the model is that there are two types of cells; the “data entry cell” and the “data secured cell”. The yellow cells represent data entry cells that allow you to enter data. The red cells are locked because they contain calculated answers.

CrocProfit is available from DPIF at a cost of $AU220 (GST inclusive) by phoning the DPI Call Centre on 13 25 23 (local call within Queensland) or 1800 816 541 (within Australia) or +61 7 3239 3163 (overseas), email “books@dpi.qld.gov.au” or go to the DPI website www.dpi.qld.gov.au.
A Parentage Determination Kit for Saltwater Crocodiles

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Fifteen microsatellite loci were evaluated in farmed saltwater crocodiles for use in parentage testing. One marker (C391) could not be amplified. For the remaining fourteen, the number of alleles per locus ranged from 2 to 16, and the observed heterozygosities ranged from 0.219 to 0.875. The cumulative exclusion probability for all fourteen loci was 0.9988. The eleven loci that showed the greatest level of polymorphism were used for parentage testing with an exclusion probability of 0.9980. Using these eleven markers on 107 juveniles from 16 known-breeding pairs, a 5.6% pedigree error rate was detected. This level of pedigree error, if consistent, could have an impact on the accuracy of genetic parameter and breeding value estimation. The usefulness of these markers was also evaluated for assigning parentage in situations where maternity and/or paternity may not be known. In these situations, a 2% error in parentage assignment was predicted. It is therefore recommended that more microsatellite markers be used in these situations. The use of these microsatellite markers will broaden the scope of a breeding program allowing progeny to be tested from adults maintained in large breeding lagoons for selection as future breeding animals.

Developing Crocodilian Education in Public Schools

Harold E. Nugent

Paynes Prairie Preserve, State Park and Lower Suwannee and Cedar Keys, National Wildlife Refuges, 6406 NW 36th Terrace, Gainesville, Florida 32653, USA

The overriding purpose of this poster presentation is to help presenters increase public school students' understanding and appreciation of crocodilians by making effective classroom presentations. This poster consists of two panels presenting an overview of the following concepts: The first panel presents the process by which three entities: the local, the scientific, and the school communities can collaborate in constructing and presenting meaningful environmental education. The Local Community with its special needs determines the content and approach. The Crocodile Specialist Group provides the scientific knowledge. The State Department of Education contributes the appropriate standards, objectives, and curriculum format. Venn diagrams illustrate how the Interpretive Approach and the Cognitive Approach can be integrated using the student’s four Learning Styles. The second panel presents examples of twelve intellectual strategies as they are applied to the study of crocodilians. These strategies are basic to effective writing, critical thinking, and problem solving. Each strategy on the poster is accompanied with a crocodilian photo illustrating its use. A number of handouts and resource bibliographies will be available as well as model environmental curriculum guides from successful programs found in Refuges and Parks around the U.S. and Cuba.
Improved Quality of Australian Crocodile Skins (*C. porosus*)

Stephen C. Hawkins and Chi P. Huynh
CSIRO Textile and Fibre Technology

Crocodile skins can be fairly accurately graded at all stages of processing, hence faults such as brown spot and scarring that impact upon the final leather value result in a large reduction in the raw skin value. Faults arise from poor husbandry, butchering and preservation. The opportunity for improvement in skin quality ceases at the point of slaughter so husbandry should aim to have quality peaking at that point. Animals with skins that are less than first grade should be assessed for their potential and retained, if suitable, until first grade is achieved. Competent butchering and effective preservation will then ensure maximum return.

Faults due to poor preservation are very common within the industry, resulting in scale slip, grain damage and loss of strength. Salt alone is not sufficient to protect skins for an extended period of time from bacteria, including red heat, and fungi. As an aid to determining the significance of faults seen on the live animal, marks and damage that are observable on the raw skin have been photographed and tracked through to finished leather. It has been found that some apparently minor brown spot infections can cause major pitting of the leather grain, whilst severe scale erosion may not affect the finished leather. Partially regrown scales often appear as crescents (double scaling’) on the leather, and faint scars may also show up very clearly.

This project, to improve the quality of Australian Saltwater Crocodile (*Crocodylus porosus*) skins is jointly supported by CSIRO and RIRDC (Rural Industries Research and Development Corporation), in collaboration with Koorana Crocodile Farm, Rockhampton, Queensland.
Persistent Organic Pollutants in Eggs of the Saltwater Crocodile from Tropical Australia: a Preliminary Survey

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Abstract

Nonviable eggs (n= 23) of the Saltwater Crocodile (Crocodylus porosus) were collected from three sites across the tropics of Northern Australia and analysed for persistent organic pollutants (POPs) over the 2002 to 2004 summer breeding seasons. The p,p-DDT metabolite p,p-DDE was found to be the most prevalent contaminant for all sites. Residues of p,p-DDE in eggs collected from Queensland nests ranged from a mean of 45 ppb for Proserpine River (n= 2) to 156 ppb for the Fitzroy River (n= 6), while residues in Northern Territory eggs had a mean of 31 ppb (n= 6). All eggs analysed (from all sites) had detectable residues of p,p-DDE. A number of eggs was also contaminated by other persistent pollutants at trace levels. The survey was conducted to gain an understanding of the bioaccumulation of POPs in several Australian coastal ecosystems and compliments similar recent studies for the Central American region where comparable concentrations were detected in crocodilian eggs. The results will provide information for wild crocodile management issues concerned with toxicology and infer that the species is a valuable long-term indicator of ecosystem health and contaminant exposure. Suggestions for future Australian work are given.

Introduction

Persistent organic pollutants (POPs) are those chemicals that are resistant to degradation in the environment under ambient conditions and bioaccumulate in food chains via their solubility in the lipids of organisms. In addition, many are capable of long-range transport due to their vapor pressure and partitioning characteristics. Concerns over the global distribution of POPs has led to recent studies aimed at bioaccumulation of PCBs and organochlorines (OCs) in particular (Kalantzi et al. 2001; Smith 1999). The discovery and widespread application of the long-lived OC pesticides such as DDT, Dieldrin, Aldrin, and persistent non-organochlorine compounds such as Endosulfan has been of great benefit to agriculture and public health. However, the particular properties of these materials such as their persistence, and their fat solubility which contribute, in part, to their utility has lead to them being almost universally distributed throughout the ecosphere.

Recent work on bioaccumulation in top level predators suggest that some of these materials have pseudo endocrine activities in alligators (Guillette et al. 1995, 2000; Lind et al. 2004). Much of this work relies, in part, on specimens taken from Lake Apopka in Florida, USA. This Lake was highly contaminated in 1980 by a chemical spill of dicofol, DDT and sulphuric acid (Matter et al. 1998) and the question arises whether comparable levels of OC contamination and bioaccumulation occur in other environments, and if species other than the American alligator (Alligator mississippiensis) are subject to the same effects. Alligators, with crocodiles, caimans, and gharials, make up the crocodilians. They all share the same characteristics of being long-lived top-level predators in tropical and semitropical aquatic systems and are frequently highly territorial.

Many species of crocodilians seem to be undergoing a population decline worldwide, though this may merely reflect habitat destruction or increased hunting pressures rather than a widespread impact of endocrine disrupting chemicals. Morelet’s crocodile (C. moreletti) occurring in Belize, Guatemala, and Mexico is considered to be an endangered species by the IUCN - World Conservation Union and is listed on Appendix I of CITES. Using crocodile eggs collected from two lagoons in northern Belize, Wu et al. (2000a) showed that Morelet’s Crocodiles in these two
environments had been exposed to organochlorine compounds and that such an “exposure may represent a health threat to populations of crocodiles in central America”. In a closely related examination of eggs from Morelet’s Crocodile (C. moreletii) and the American Crocodile (C. acutus) from southern Belize and the coastal zones of Belize respectively, Wu et al. (2000b) demonstrated the presence of p,p-DDE, a degradation product of DDT as well as DDT and p,p-DDD another metabolite of DDT.

In contrast, in Australia, where the non-traditional hunting pressure on the Saltwater Crocodile (C. porosus) has been removed, the population has rebounded, and they can at times constitute a nuisance species that has to be relocated from areas where the potential for fatal human-crocodile contact (for the humans) exists. Worldwide there have been at least 6 investigations into the occurrence of organochlorines in the flesh of various crocodilians (Best 1973a, 1973b; Vermeer et al. 1974; Wheeler et al. 1977; Matthiesen et al. 1982; Delany et al. 1988; Phelps et al. 1989) and more limited investigations of the organochlorine content in crocodile eggs (Wessels et al. 1980; Phelps et al. 1986; Heinz et al. 1991; Skaare et al. 1991; Wu et al. 2000a, 200b).

The only measurements on OCs in both Freshwater and Saltwater Crocodile eggs from Australia (Best 1973) predate the prohibition on the widespread use of DDT which was phased out for general use around the early 1980s. We report on persistent organic pollutants in wild and farmed crocodile eggs collected in Queensland and the Northern Territory of Australia in order to contribute to the knowledge base for these chemicals in crocodilians in the southern hemisphere. In addition, we point to the advantages of using nonviable C. porosus eggs as a convenient, low impact and reliable method of assessing bioaccumulation of POPs in the environment.

Materials and Methods

Egg Collection

Nonviable C. porosus eggs were collected during 2002, 2003 and 2004 from 3 sites across tropical Australia. Not all sites were sampled in all years, farmed eggs from Crocodylus Park in the Northern Territory and Koorana Crocodile Farm in Queensland were only sampled during 2002. Collection sites are shown in Figure 1.

![Map of Australia showing collection locations](image.jpg)

Figure 1. Collection locations of nonviable C. porosus eggs during 2002-2004 survey.
Location 1 included collections from Melacca Swamp (mostly fresh - near coast) and from the Adelaide River system (tidal). The Adelaide system has an approximate area of 4400 km² and the major land use is cattle grazing with limited areas of agriculture. The Proserpine River location (tidal) has a drainage area of around 550 km² with grazing in the upper catchment and sugar cane cultivation in the lower reaches.

The Fitzroy River location consists of a series of large water holes in the fresh water system around 100 km upstream of tidal influences, it has a catchment area of around 142,600 km² and has grazing as the main land use with substantial dry land and irrigated agriculture.

The Fitzroy River in Queensland is considered the southern breeding limit for *C. porosus*. All the above sites are listed in the Department of Environment and Heritage directory of Important Wetlands in Australia. Eggs were labeled, frozen, packaged and transported (chilled) to the Queensland Health Scientific Services laboratories in Brisbane, Queensland, for analysis a range of persistent and non-persistent pollutants.

**Extraction and Analysis of Egg Residues**

Analysis of shell-free wet egg contents were performed at the National Association of Testing Authorities Australia (NATA) certified laboratories of Queensland Health Scientific Services in Brisbane via quality assured procedures. The laboratory regularly conducts analyses for contaminant residues in food products including hen eggs as part of an ongoing Australian standards program. Basically, the contents of an egg were blended and approximately 5 g taken for analysis and accurately weighed, results are calculated on a wet basis. The sub-sample was mixed with anhydrous sodium sulphate until a free flowing powder was obtained. Extraction was via acetone solvent. Finally, Gel Permeation Chromatography (GPC) and Florisil cleanup steps followed by Gas Chromatography/Mass Spectrometry (GC/MS) were used for determination of contaminant types and amounts. The analysis covered a wide spectrum of common environmental contaminants with 184 chemical species including OCs, OP’s, and other insecticides, herbicides, fungicides (i.e. common pesticides) included. In addition, some eggs (2003 collections) were screened for the following PCB congeners (confined to those commonly associated with Arachlor residues) IUPAC 1, 5, 18, 28, 31, 52, 44, 66, 101, 87, 110, 118, 151, 149, 153, 141, 138, 183, 180, 170, 194 and 206. A similar and more in-depth description of the methodology for the isolation of organochlorine and organophosphorus residues from hen eggs (Schenck and Donoghue 2000) can be readily applied to crocodile eggs. Eggs were not analysed for heavy metals or dioxins.

**Results**

A total of 23 eggs from both captive and wild Saltwater Crocodiles (*C. porosus*) were examined. Organochlorine residues were found in all eggs (Table 1). The concentrations of DDE ranged from 2 to 350 ppb and the highest concentrations were in the eggs from the freshwater reach of the Fitzroy River upstream of Rockhampton, Queensland. DDE concentrations in eggs taken from captive animals were at the lower end of the range and were comparable to the lower concentrations seen in the Northern Territory wild samples from the Adelaide River and Melacca Swamp in 2003. The concentrations of DDD another metabolite of DDT, and of DDT itself were always lower than the DDE concentrations in the same egg. Analysis of nest material (Proserpine Site 2003) showed nil concentrations (by our methods) of DDT metabolites thus providing confidence that the eggs had not been contaminated by nest material (Canas and Anderson 2002) and that the measured concentrations in the eggs reflected the maternal body burden of DDE and were not an artefact. A comparison of mean concentrations of DDE found in eggs from the three locations is shown in Figure 2.

Concentrations of Heptachlor epoxide and Dieldrin were always less than 10 ppb (Table 1). Numerous PCB congeners were detected in the various samples though they seemed to be heterogeneous with respect to their content of the various congeners. That is, there was no constant ratio between the different congeners suggesting that there must be, at least several different sources each with its own characteristic mixture of congeners. Tri-n-butyl phosphate was detected in the Northern Territory samples together with DEET. This is the active ingredient of various insect repellent products and suggests that the whole area has been contaminated by this widely used material.

**Discussion**

Our results show a wide range of DDE concentrations in the eggs of the Saltwater Crocodile collected in a range of habitats in Queensland and the Northern Territory, Australia. The average concentration (56 ppb; standard deviation 97 ppb) does not differ significantly from the average value (68 ppb; 86 ppb) for the most extensive other set of data
covering both the American Alligator and Morelet’s Crocodile in Belize (Wu et al. 2000b). The range of concentrations was virtually identical in the two cases. DDT concentrations were always much less than DDE concentrations in the same eggs when DDT could be detected. This suggests that the primary route for DDE contamination of Saltwater Crocodile eggs in Australia is via maternal consumption of DDE contaminated prey rather than by ingestion of prey which is primarily contaminated by DDT, and this is subsequently metabolised within the mother to DDE. The DDE in the environment arises from bacterial and other metabolism of DDT released some time in the past and the results imply that there are few if any actual fresh DDT releases. The highest concentrations of DDE were found in eggs

Table 1. Persistent pollutant residues detected in *C. porosus* eggs. NA= not analysed for contaminant; ND= not detected; Trace = below level of reporting (5 ppb) but detected; RP= results pending.

<table>
<thead>
<tr>
<th>Location - site - Date</th>
<th>Contaminant residues in <em>C. porosus</em> eggs expressed as ppb</th>
<th>PCB congeners</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DDT  DDD  DDE  Heptachlor  Epoxide  tri n-butylphosphate  Dieldrin  DEET</td>
<td></td>
</tr>
<tr>
<td>Northern Territory (2002)</td>
<td>ND  ND  Trace  ND  ND  ND  ND  ND</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Captive</td>
<td>ND  ND  Trace  ND  ND  ND  ND</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Wild</td>
<td>ND  ND  Trace  ND  ND  ND  ND</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Northern Territory (2003)</td>
<td>ND  ND  ND  ND  ND  ND  ND  ND</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Adelaide River nest 1</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Adelaide River nest 2</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Adelaide River nest 3</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
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<tr>
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<td>ND  ND  ND  ND  ND  ND  ND</td>
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<td>Melacca swamp nest 1</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Melacca swamp nest 2</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Melacca swamp nest 3</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Queensland</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Proserpine River (2003)</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Nest 1a</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Nest 1b</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Nest material</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Fitzroy River</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Kooraia Farm (2002)</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Fitzroy nest 1 (2003)a</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Fitzroy nest 1 (2003)b</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Fitzroy nest 2 (2003)a</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Fitzroy nest 2 (2003)b</td>
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<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Fitzroy nest 1 (2004)</td>
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<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
<tr>
<td>Fitzroy nest 2 (2004)</td>
<td>ND  ND  Trace  ND  ND  ND  Trace</td>
<td>ND  ND  ND  ND  ND  ND  ND</td>
</tr>
</tbody>
</table>

Figure 2. Mean DDE concentration in eggs by collection location.
from the Fitzroy River system downstream of several irrigated agricultural areas, the DDE was most likely transported attached to soil particles from these areas.

There appears to be a high correlation of DDE concentration in eggs sampled from the same nest. Further work to verify this may lead to some confidence in sampling a single egg from an individual nest leading to more efficient survey strategies in the future.

A survey of the global distribution of POPs (Smith 1999) found that Australian butter (n= 9 samples) had a DDE concentration of around 12 ppb. In a similar study into DDT in human breast milk Kalantzis et al. (2001) found that whole breast milk from Australia (n= 14) had around 42 ppb DDE. Both studies suggest that long range atmospheric transportation of DDT and DDE could be involved in the concentration found in milk fat. Long range transport and deposition from other countries where DDT is still in use may be a source for DDE in river sediments via fluvial concentration in large catchments similar to the Fitzroy basin.

Therefore there may be two separate sources for DDE contamination in *C. porosus* eggs, a supply from historical use in the catchment via agriculture and grazing, and another via aerial deposition originating from other countries. We suggest that further work is required concerning contaminants in nonviable crocodile eggs in tropical Australia. A more general sampling approach aimed at assessing levels over the entire range for *C. porosus* and *C. johnstoni* (freshwater crocodile) in Australia will provide valuable information on the bioaccumulation of persistent organic pollutants in the environment. It would also be useful to develop an international strategy for sampling various crocodilian eggs on a global scale using common protocols. This would enable comparisons to be made between geographically isolated populations in regard to persistent pollutant exposure and bioaccumulation. The information gained in such an exercise may be important for crocodilian conservation in the future and for ecotoxicology in general.

**Acknowledgements**

We gratefully acknowledge the assistance of Queensland National Parks and Wildlife officers in Rockhampton and Shute Harbour in securing the various permits required for the collection of eggs. We would also like to thank the staff of Queensland Health Scientific Services Laboratories in Brisbane for their assistance and professional service.

**Literature**


Population Status and Future Management of *Crocodylus niloticus* (Nile Crocodile) at Lake Sibaya, South Africa

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Introduction

The Greater St Lucia Wetland Park (GSLWP) is one of the most important areas in South Africa for the conservation of *Crocodylus niloticus*. The largest freshwater system within the GSLWP, Lake Sibaya, hosts the second largest crocodile population in the Park. Research from the late 1950s suggested that crocodiles were abundant at Lake Sibaya; yet only 67 were counted during the first aerial survey in 1985. Subsequent aerial surveys indicated an increase in the population during the following five years, with some 107 crocodiles counted in 1990. Concerns over the current population status, breeding component and future of crocodiles at Lake Sibaya, led to aerial and spotlight counts, nesting surveys and the identification of potential breeding areas from February 2003 to January 2004.

Study Area

Lake Sibaya, South Africa’s largest freshwater lake is located between Kosi Bay and the St Lucia estuary, on the seaward margin of the low-lying Moçambique Coastal Plain (refer to Figure 1). It also forms part of the Greater St Lucia Wetland Park, South Africa’s first World Heritage Site. The area is a transitional zone between a tropical and sub-tropical climate, forming the southernmost limit for a number of tropical species, resulting in an area rich in biological diversity.

Methodology

- Literature review of crocodilian survey and monitoring techniques
- Aerial surveys (microlight)
- Spotlight surveys (boat and foot)
- Nesting surveys for the 2002/3 and 2003/4 breeding seasons
- Identification of potential nesting areas

Results

Figure 2 indicates the aerial (1985-2003) and spotlight (2003) counts for the total number of crocodiles counted at Lake Sibaya and surrounding wetlands. The combination of clear water with sparingly vegetated and exposed shorelines, favours aerial surveys for large parts of the lake, although most of the channels with dense reed beds are subjected to high levels of visibility bias if only surveyed from the air. This is reflected in the spotlight counts, which resulted in a 72% increase in the density of crocodiles (excluding hatchlings), as well as a better representation of smaller size classes. Please note that during the following years no surveys were conducted: 1989, 1991, 1992, 1994-2002.

Figure 3 indicates the decrease in the population at Lake Sibaya is accompanied by an apparent decrease in breeding success. During the 1970 nest survey, 30 crocodile nests were found. This decreased to three nests found during the 2002/3 survey and not a single nest was found during the 2003/4 survey. Please note that during the following years no surveys were conducted: 1972-1975, 1977-1985 and 1992-2002.

Figure 4 illustrates the spatial distribution of 36 crocodiles counted during the aerial survey, 65 counted during the spotlight surveys, three nests found during the 2002/3 survey (no nest were found during the 2003/4 survey) and potential nesting areas in the Lake Sibaya system. Due to the low number of crocodiles and their uneven distribution in the Lake Sibaya system, all surveys were “total surveys”, covering the total 137.3 km shoreline.
Figure 1. The Greater St Lucia Wetland Park. The Greater St Lucia Wetland Park, South Africa’s first World Heritage Site, is situated in the province of KwaZulu Natal in the northeastern corner of South Africa. The Park consists of five distinct ecosystems and Lake St Lucia is also the most southern breeding population of Nile crocodiles in the world.

Discussion

The population appears to have declined significantly during the past decade with only 36 crocodiles counted during the 2003 aerial survey. The spotlight counts (65 crocodiles) reflects a 72% increase in density and reflects the importance of having a combined survey approach, since accuracy, and not precision, was the key objective of the survey. A
Figure 2. Aerial (1985-2003) and spotlight counts (2003) at Lake Sibaya.

Figure 3. Nesting surveys (1974-2004) at Lake Sibaya.

correction factor of 1.72 was calculated for future aerial surveys, based on the spotlight counts. Using Magnusson et al. (1977) double-count technique for two independent counts (in this case aerial and spotlight), the population is estimated to be 112 crocodiles with a variance of 22.49 and standard error of 4.47.

It seems like the decrease in breeding at Lake Sibaya could be a result of high levels of disturbance by subsistence fisherman and pressure from herds of drinking cattle at historical as well as potential nesting areas. Sixty-five potential nesting areas have been identified (refer to Figure 4) and evaluated in terms of their importance both from a species (Nile Crocodile) and community perspective. These areas will form part of an overall strategy to actively conserve some key breeding areas at Lake Sibaya.

Conclusions

Despite legal protection and World Heritage Site status, the population is clearly under threat as a result of poaching and increase disturbance of nesting areas. The survival of crocodiles at Lake Sibaya might only be possible through the establishment of a joint management partnership between the conservation agency and the local community where the protection of crocodiles and nesting areas will benefit the community. The alternative is the likely extinction of this top predator from the largest freshwater ecosystem in South Africa’s first World Heritage Site.
Figure 4. Spatial data (GPS) for aerial, spotlight and nest surveys at Lake Sibaya. The Lake Sibaya system is a unique independent microcosm with 18 fish, 22 frog, 8 reptile and 279 bird species recorded in the area. Numerous rare or threatened species occur in the lake system. Lake Sibaya was designated a Ramsar Wetland of International Importance in 1991 and although the area surrounding the lake is tribal land, the water surface was proclaimed a protected area in 1994 in terms of the KwaZulu Nature Conservation Act. In December 1999, the surface area of the lake was included in the formation of the Greater St Lucia Wetland Park, Word Heritage Site.

Literature


Effects of Two Different Incubation Media on Hatching Success, Body Mass and Length in *Caiman latirostris*

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Since 1990, Proyecto Yacaré (MAGIC/MUPCN) has been developing new technologies and improving/adapting old ones to reduce production costs for the ranching programs in South America. Previous works evaluated growth rates of *Caiman latirostris*, the effect of time collection on hatching success, depredation and temperature effects on incubation, but there is no information about incubation media for the species. In this experiment we tested the effects of two incubation media, vermiculite and grass (‘nesting material’), on hatching success and hatching size. We collected nine nests (350 eggs) from natural *C. latirostris* populations in Santa Fe, Argentina, soon after oviposition. In Proyecto Yacaré facilities, each nest was divided in two groups and each one received one of two incubation treatments (vermiculite or nesting material). We found no difference in hatching success among the treatments (0.89 for vermiculite and 0.87 for nesting material). We observed, but did not measure, that incubation with vermiculite tended to be longer, and that hatchlings from this treatment had more unabsorbed abdominal yolk, in all nests used in the experiment. Hatchlings from nesting material treatment were bigger than vermiculite treatment in length, but we found no differences between treatments in body mass. As we found similar hatching success in both treatments (but possibly overestimated in vermiculite), a larger size of hatchlings (which could enhance survivorship as was reported in lizards and turtles) and lower cost, nesting material is the recommended incubation media. Future investigations should address how incubation media might modify hatching performance.

Desde 1990, e Proyecto Yacaré (MAGIC/MUPCN) está desarrollando nuevas técnicas y mejorando o adaptando otras para reducir los costos de los programas de ranching en Sur América. Trabajos previos evaluaron tasas de crecimiento, el efecto del momento de cosecha en el éxito de eclosión, la predación y el efecto de la temperatura en la incubación, pero no hay información sobre los medios de incubación para *Caiman latirostris*. En este experimento analizamos el efecto de dos medios de incubación, vermiculita y pasto en el éxito de eclosión y el tamaño de los neonatos. Cosechamos nueve nidos (350 huevos) de poblaciones naturales de *C. latirostris* en Santa Fe, Argentina luego de la postura. En las instalaciones del proyecto yacare, cada nido fue dividido en dos grupos y a cada uno se le asignó un tratamiento de incubación (vermiculita o pasto). No encontramos diferencias en el éxito de eclosión entre los tratamientos (0,89 en vermiculita y 0,87 en pasto). Observamos, pero no medimos, que la incubación con vermiculita fue más larga, y que los pichones de este tratamiento tenían más yema sin absorber en todos los nidos. Los pichones del tratamiento de pasto fueron más largos pero del mismo peso. Debido a que encontramos un éxito de eclosión similar entre ambos tratamientos (pero posiblemente sobre estimado para la vermiculita), un tamaño mayor de los pichones (que puede mejorar la supervivencia tal cual se reportó para lagartos y tortugas) y el menor costo, el pasto es el medio de incubación recomendado. Próximas investigaciones deberían estudiar como puede modificar el medio de incubación el crecimiento y la supervivencia de los neonatos.
Size of *Caiman latirostris* Eggs and Hatchling Body Size Coming from Three Different Environments in Santa Fe, Argentina

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It is known that *Caiman latirostris* (n.v. broad snouted caiman) has a great capacity to make use of different environments for nesting; but females could select microhabitats, potentially affecting hatchlings sex ratios. The factors that would lead females to make that selection are unknown. Regarding this aspect, it was proposed as the objective of this work to evaluate the reproductive parameters related to egg size and hatchling size in three different environments (forest, floating vegetation and savannah) in Santa Fe Province (working area includes San Cristóbal and San Javier Districts). Eggs were harvested during the 2001-02 season and incubated until hatching in the Proyecto Yacaré incubator. Based on our results, we discarded that all reproductive variables be different among the environments. Only egg width and hatchling SVL (both related to female body size) were different among environments. Hatchling body mass in the three environments was always better associated to egg volume than to length. Finally, we could infer that floating vegetation is the environment that has the best performance.

Según trabajos previos, *Caiman latirostris* (n.v. yacaré overo) posee una gran capacidad para utilizar diversos ambientes para nidificar. Recientemente se ha planteado la hipótesis que las hembras de *Caiman latirostris* podrían seleccionar los micro-hábitats, afectando potencialmente la proporción de sexos de los pichones; pero los factores que conducirían a las hembras a dicha selección son desconocidos. En este aspecto; nuestro trabajo tuvo como objetivo específico evaluar parámetros reproductivos relacionados al tamaño de los huevos y tamaño de los pichones de yacaré overo en tres ambientes (sabana, embalsado y bosque) de la provincia de Santa Fe. Los nidos recolectados para tal fin provienen de áreas de muestreo relevadas por el equipo del Proyecto Yacaré en los departamentos de San Javier y San Cristóbal, durante la temporada 2001-02. A partir de los resultados obtenidos, se descarta que todas las variables reproductivas de esta especie sean diferentes entre los ambientes, ya que de todas las ellas, solamente el ancho de los huevos y la longitud desde el hocico hasta la cloaca en los pichones (ambas variables asociadas al tamaño de la hembra), registraron diferencias entre los mismos, demostrando un efecto del ambiente sobre dichas variables. Por otra parte, en los tres ambientes el peso de los pichones estuvo siempre mejor asociado al volumen de los huevos que la longitud. Finalmente, de acuerdo a los resultados, el embalsado resultó ser el ambiente de mejor performance.

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Food Conversion Rates of *Caiman latirostris* Reared at Two Different Temperatures

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Temperature and diet have influence over growth of caimans and crocodilians. Animals maintained at higher temperatures obtained a greater growth and increase of the real food consumption. The objective of this work is to evaluate the efficiency of food conversion in *Caiman latirostris* at two different temperatures: 29°C and 33°C. In the experiment we used 68 animals from four different nests, of two month of age, bred in captivity. All the treatments were kept under similar conditions of captivity, but temperature. We found differences in body mass and total length between groups, being bigger those maintained at higher temperature. The greater growth of animals raised at 33°C was probably due to the relationship between increasing temperature and its consequently reduction of time to process the food, promoting repeated food ingestions. Also, we found a more efficient nutritional conversion rate in animals kept at 33°C. Lang (1987) reported that the increase of temperature did not increase the amount of energy extracted from food. Nevertheless, that is a possible explication of our results.
Gender Discrimination in Hatchling Broad-Snouted Caiman
(*Caiman latirostris*): an Alternative Technique

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Broad-snouted caiman (*Caiman latirostris*) hatchlings present a consistent sexual dimorphism in their cranial form not only size. Hatchling males present smaller cranium than females. Using multivariate statistical analyses it is possible to discriminate sex in broad-snouted caiman hatchlings by their cranial form with a relatively high efficiency. Sex discrimination of crocodilian hatchlings might possibly be improved by experimental manipulation of both genetic and phenotypic variables such as incubation environment and genealogy.

Los neonatos de yacaré overo (*Caiman latirostris*) presentan dimorfismo sexual en la forma del cráneo y en su tamaño. Con el uso de técnicas multivariadas es posible discriminar el sexo de los pichones de yacaré overo, basado en su forma craneal con una aceptable eficiencia. Los pichones macho tienen un cráneo menor que las hembras. La discriminiación sexual de los pichones de cocodrilos podría mejorarse por la manipulación experimental de variables genéticas y fenotípicas tales como el ambiente de incubación y la genealogía.

The Effect of Three Different Experimental Salinity Levels on *Caiman latirostris* Growth

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In this experiment we evaluated the effect of three different salinity levels (0, 7 and 20 ppt marine salt) on the growth of 36 *Caiman latirostris* hatchlings from three different nests, over a period of 52 days. All treatments were kept under similar conditions of captivity, except for salinity.

We found differences in food consumption, growth, fitness and survivorship between treatments. At 20 ppt salinity, no food was taken by the animals, there was no growth and mortality rate was 33%. At 7 ppt survivorship was 100%, and bodyweight was similar to the animals kept at 0 ppt, but the fitness and the morphology of the animals was affected because they have showed evidence of subcutaneous oedema.
Growth of *Caiman latirostris* Reared at Three Different Stocking Densities

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In this study we have evaluated the effects produced by stocking density over growth of juveniles *Caiman latirostris*. Thirty-six captive-reared juvenile caimans were used in the experiment. They were randomly assigned to three different treatments consisting on stocking densities of 0.12, 0.06 and 0.04 m²/individual that were maintained in environmentally controlled chambers for 3 months. The juveniles were weighed and measured at the beginning and at the end of the experiment to determine the increase in growth for each group. The results showed that caimans maintained at the lower and intermediate stocking densities gained more weight and showed a greater increase in total length than those of the higher stocking density group. The results obtained indicated that crowding of juvenile caimans inhibits optimum growth. These data agree with results found in similar studies for other crocodilians.
Population Genetic Analysis of *Caiman latirostris* in Santa Fe Province, Argentina, by RAPD

Patricia Amavetz and P. Rosso

Abstract

*Caiman latirostris* is a species scarcely studied to genetic level in our country, which is essential to complement strategies for management and conservation. In the present paper the preliminary results of a population analysis performed in Santa Fe province are described. Random Amplified Polymorphic DNA markers (RAPD) are used in order to determine variability and genetic structure of 3 distant wild populations. Genomic DNA isolation of 31 individuals were performed by a method that does not require the use of proteinase K, cheaper and effective in its results.

At the moment, 20 primers were tested, out of which 8 have been selected for analysis. All samples of DNA have been amplified with these primers, and amplification products from one population were analyzed on agarose gels. Registered results show that all primers examined produced different RAPD fragment patterns and could find no differences between banding patterns of individuals of the same population.

Introduction

Wild populations of Santa Fe Province of *Caiman latirostris* (broad-snouted caiman) are subjects of management of the Proyecto Yacare (MAGIC-MUPCN) program, whose object is the sustainable use of this species, together with its habitat conservation. Since 1997, the *Caiman latirostris* population of Santa Fe is listed in Appendix II of CITES due to an obvious numeric recovery, for which the regulated trade is allowed (Larriera 1998), and is turned into an important species at both national and international levels.

Particularly in crocodilians (Forstner and Forstner 2002), molecular methods apportioned valuable data about reproductive mechanisms, gene flow, population effective size, geographic distribution, and genetic variability measures, essential to complement management strategies. More important molecular studies in crocodilians implicate proteins analysis (Gartside et al. 1976; Lawson et al. 1989), DNA mitochondrial (Densmore and White 1991; Janke and Arnason 1997; Glenn et al. 2002; Ray and Densmore 2002 ), and microsatellites in wild populations (Davis et al. 2000, 2001, 2002; Glenn et al. 1998, 2002), existing limited antecedents of the application of the technique chosen for the present work (Glenn et al. 1998; Wu et al. 2002, in genus *Alligator*).

Population genetic studies in broad snouted caiman using microsatellites (Verdade et al. 2002; Zacoloto et al. 2002) have started in Brazil, but in our country we do not have data about variability neither about structure in wild populations of *Caiman latirostris* due to the little previous work at the genetic level. One of them is a comparative analysis of the karyotypic structure between *Caiman latirostris* and *C. yacare*. Results indicate similarities between them, with a diploid number of 42 chromosomes, with equal karyotypic structure and two microchromosomes. Both lack sexual chromosomes and show very similar C and NOR banding patterns (Amavetz et al. 2000, 2002, 2003). Due to the remarkable similarities found, added to the absence of data in relation to their population structure, the present study intends to gather some data about the genetic structure of wild populations of *Caiman latirostris* in our country.

In addition, an alternative technique for DNA isolation is described, that implies lower costs and a higher biosecurity in relation to traditional methods, equally achieving a considerable concentration of DNA for further analysis by RAPD.

Materials and Methods

Sixty samples were processed. They were taken from 31 individuals of *Caiman latirostris* (19 females and 12 males)
coming from of 3 distant populations of Santa Fe province: San Justo State (S 30° 43’ 587’’, W 60° 17’ 458’’), San Cristóbal State (S 29° 42’ 844’’, W 60° 50’ 404’’) and San Javier State (S 30° 03’ 341’’, W 59° 58’ 746’’).

Entire blood samples are used, obtained by puncture of intern jugular vein at the level of the cervical vertebrae (Tourn et al. 1993) with EDTA as anticoagulant. The technique used for DNA isolation (modified by Murray and Thompson 1980) consisting in the following steps: Suspend 500 mL entire blood in 3 mL TE (10 mM Tris-HCl, pH 7.5, 10mM Na₂EDTA 2 H₂O). Wash 3 times. Eliminate the last wash’s supernatant. Add extraction solution (CTAB-NaCl-Mercaptoethanol-EDTA-Tris HCl). Homogenize and then carry to thermostatized bath to 60°C for 3 or 4 hours. Wash 3 times in chloroform. Precipitate the last supernatant with isopropyl alcohol. Eliminate the alcohol by means to vaporization. Hydrate in 1 mL sterile double distilled water.

A set of 20 decamer primers from Promega - (N° Cat B050-10 and B051-10) were tested in this study. Then 8 primers were selected taking into account which of them showed a band mean number (between 5 and 10 bands). The samples of all individuals of three populations were amplified with these primers (Table 1).

<table>
<thead>
<tr>
<th>Selected Primers Codes</th>
<th>Sequence (5’ to 3’)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>CCC AAG GTC C</td>
</tr>
<tr>
<td>A02</td>
<td>GGT GCG GGA A</td>
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<td>A03</td>
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<td>TGC CAT CAG T</td>
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<tr>
<td>B05</td>
<td>GCG CTC ACG C</td>
</tr>
<tr>
<td>B07</td>
<td>AGA TCG AGC C</td>
</tr>
</tbody>
</table>

Amplification reactions are carried out in a final volume of 25 mL with 10 mM Tris-HCl, pH 8.3, 50 mM KCl, 2.5 mM MgCl₂, 0.01 per cent Gelatin, 200 pM de dATP, dTTP, dGTP and dCTP, 5 pmoles of 10-base primer, 1.25 unit Taq DNA polimerase (Promega, Biotec.) and 50 ng genomic DNA. A negative control containing all reagents except genomic DNA was included in each reaction.

DNA amplification was performed in a thermal cycler (PTC-100 Peltier Thermal Cycler) with a cycle program the 45 cycles of 2 min to 94°C, 1 min to 36°C and 2 min to 72°C, with a final extension to 72°C to 10 min. Approximately 15 mL of amplification products were separated on 2% agarose gels in TBE buffer (0.89 M Tris, 0.89 M boric acid and 0.11 M EDTA, pH 8.3). Gels were stained with ethidium bromide and photographed under UV light.

RAPD markers are dominants and their presence or absence in them is analyzed (Lynch and Milligan 1994). Genetic distances will be calculated following different measures (Nei and Li 1985; Lynch 1991; Bardakci and Skibinski 1994).

**Preliminary Results**

After processing of 60 samples, genomic DNA was extracted with a mean concentration of 1.84 mg/mL and a mean purity of 1.667 (l260.0/l280.0). DNAs extract were obtained in a native, not degraded, of high molecular weight form, as the presence of band unique in a electrophoresis in agarose gels shows (Fig. 1).

In relation to band analysis, at the moment, registered results are preliminary and refer only to one population. All the primers examined produced different RAPD fragment patterns. The number of fragments generated per primer varied between five and 12. Generated bands are between 500 and 1200 bp indicate with 100 bp ladder. Electrophoresis on agarose gels of amplified products with 8 primers shows no differences between the banding patterns of the individuals of the same population (Fig. 2).
Discussion

The technique used for DNA isolation by CTAB has shown good results in relation to the requirements of DNA concentration for further analysis by RAPD, although the purity was not high.

For a higher purity DNA isolation precipitate again with phenol the extracts obtained allowing that material to be used for other specific analysis.

In relation to RAPD analysis, preliminary results , at the moment, allow us to assume low levels of polymorphism with low per cent of heterozygosity, in agreement with previous studies using other methods, except microsatellites (Gartside et al. 1976; Lawson et al. 1989; Densmore and White 1991; Dessauer et al. 2002). That fact was explained by bottle necks that were experimented by crocodile species, together with big size and longevity, add to the low sensivity of this technique to detect polymorphism.

After registering results of last samples, it will amplify all samples with others primers to expand series.

Acknowledgements

This study is supported by the Proyecto Nº 102, Programa Nº 14 CAI+D 2002, Universidad Nacional del Litoral and Proyecto Yacaré (MAGIC-MUPCN), Santa Fe, Argentina. The authors thank other members of Proyecto Yacaré, especially Dr. C. Piña, for their comments and suggestions. The authors are also grateful to G. Poletta and L. Lucero for their help with processing of samples.

Literature


Caiman latirostris and Caiman yacare Population Surveys in Formosa Province, Argentina

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Abstract

Caiman latirostris and Caiman yacare are two crocodilians species that inhabit Formosa Province, Argentina. These first two surveys are attempt to determine spatial distribution, relative abundance and population size of both species. These studies were carried out during spring of 2002 and 2003. Night counts showed that caiman’s populations have important densities for C. latirostris and C. yacare in this province. These surveys have covered a big part of the available habitat and these indicate that populations of caimans in Formosa appear to be adequate to sustain management programs based on ranching.

Introduction

Broad-snouted caiman (Caiman latirostris) and yacare caiman (Caiman yacare) are the two crocodilians species that inhabit Argentina, and they can be easily differentiated based on cranial and nuchals structures, among others (Medem 1983). The two species are sympatric over a large part of their distribution in Argentina, but because of their more southern and more western dispersion, broad-snouted caiman appears in an allopatic way in a bigger area. Occasionally, when the two species are seen together, the broad-snouted caiman would stop occupying certain environments trying to find others (Micucci and Waller 1995); however, they are used to find themselves sharing the same bodies of water (Micucci and Waller 1995; Siroski 2003). This suggests that ecological preferences are not absolute but incidental.

Caiman latirostris prefers densely vegetated environments of difficult access and usually basks in floating vegetation, while Caiman yacare generally appears in environments free of floating vegetation and normally basks on beaches or coasts (Medem 1983). The presence of Caiman latirostris in the superior riverbanks of Iguazú River (Fabri 1998) is significant due to its the great flow.

The eastern limit for broad-snouted caiman distribution is the Atlantic Ocean, and the western limit is the Mountain range of the Andes (Medem 1983). In Argentina, broad-snouted caiman inhabits Jujuy, Salta, Formosa, Santiago del Estero, Entre Ríos, Santa Fe, Corrientes, Chaco and Misiones Provinces (Yanosky 1990); while Caiman yacare inhabits the same provinces except for Salta, Jujuy and Entre Ríos.

Although our country is the southern limit of dispersion for the two species. C. latirostris reaches a bigger latitude 32°SL (Freiber and Carvalho 1965) while C. yacare reaches 30-31°SL (Medem 1983), many specimen have been seen in bigger latitudes due to extraordinary situations (Micucci and Waller 1995).

There is no record of commercial use of caimans in Argentina from the end of the 1980s to the beginning of the 1990s. There was a differential use between both species of caimans, due to the biggest ossification in the osteoderms that the Caiman yacare possesses, the most looked for one was the broad-snouted caiman because of its greater economic value.

The diversity and extension of habitats that caimans take up in this province makes it very difficult to estimate an amount that represents the whole of populations. In these cases, it is convenient to estimate the abundance or relative density, for what it is necessary to choose work places that are representative and recurring for the different areas.

The objective of this work was to evaluate the population status, distribution and structure of sizes of Caiman gender in the Province of Formosa, Argentina.
Biogeographical Characterization

The province of Formosa occupies a part the Chaco eco-region. This eco-region is characterized to have a vast semi-arid plain that covers around 1,200,000 km² of South America, of which about 800,000 km² belong to the Argentina and the rest is distributed among Bolivia and Paraguay. This province is characterized by the prevalence of subtropical thorny forests, humid and semi-arid savannah, being very rich in wildlife, mainly in the northwest portion where the anthropic intervention is scarce. In spite of their semi-arid conditions, the abundance of wetlands stands out with a diversity in their origins as well as in their physical and biological characteristics caused by the variability in rains year after year. It also presents a gradient for north-south temperature (the annual average varies between 19°C and 24°C, with maximum of up to 49°C), and one east-west for the rain (450 to 1200 mm). The availability of habitats during the dry season varies significantly year after year, depending on the duration of the drought (Coutinho et al. 1995). This is of ecological importance since the aquatic habitats during the drought can affect the dynamics of wildlife population, particularly caiman populations.

The province of Formosa finds in the climatic factor a great advantage for the establishment of caiman populations. This is due chiefly to the short duration and intensity of cold months. Consecutively, *Caiman yacare* possesses a small capacity to adapt to the lowest temperatures, contrary to *Caiman latirostris*.

Methodology

A description of crocodilians population’s abundance and distribution is generally the first step in this study, and it often establishes the basic information for conservation and management programs. (Bayliss 1987).

The crocodilians abundance estimate is based on density indexes, for example, the number of specimen seen per km or hectare. The importance of monitoring is to very well define the conditions with as many data as possible. Sampling places were characterized *in situ* regarding the diverse data, for example: physiognomy, dimensions, vegetable covering, type of banks and representativeness relating to other environments, inside the same bio-region, etc.

In each monitoring, different variables were registered, like: time of beginning and finalization, temperature of the air and water at the same time, cloud, wind and accessibility. Temperature was measured with a mercury bulb thermometer, which ranges from 0 to 50°C and a 0.5°C precision. For each studied place, indexes of relative abundance were calculated dividing the number of caimans observed by the total covered distance during the observation expressed in km.

Structure of sizes was estimated, in most of the cases, at 5 m maximum distance of each caiman. Classification of sizes was: Class I: <40 cm, Class II: 40-120 cm, Class III: 120-180 cm, and Class IV: >180 cm. In the cases where the distance was not enough to assure the classification, (EO) eyes only was reported.

Results

From 4 November to 10 November 2002 and from 1 November to 7 November 2003 reports on *Caiman latirostris* and *Caiman yacare* populations were carried out in different places of the province of Formosa. The work evaluated distribution, relative densities and structures of monitored populations. The results are shown in the table on the following page.

Discussion

During the last 20 years there has been a very important change in the relationship between conservation, exploitation and the trade. Initially, trade was seen as a problem in conservation, however, these days it seems more a solution to the conservation problem.

A pre-requisite to fulfill the successful management of wildlife is to know the relative densities or tendencies of populations (Rhodes and Wilkinson 1994). There is not much precedent about the population situation of the caiman’s species in the Province of Formosa, except for the first exhaustive study carried out by Siroski (2003); that is why this type of work carried out annually constitutes a fundamental database for the handling of conservation and exploitation.
<table>
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<th>Locality</th>
<th>Distance Covered (km)</th>
<th>Species</th>
<th>Class I</th>
<th>Class II</th>
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<th>Class IV</th>
<th>EO</th>
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<td>12</td>
<td>1</td>
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<td>9</td>
<td>-</td>
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</table>

* In the sampling places where the presence of both species was observed, relative density was not reported for each species, since animals considered as EO cannot be assigned to none of them. Relative density was not informed either in the sampling places where just one species was observed, even though eggs from the two species were afterwards harvested.

In places where *Caiman latiostris* is predominant, *Caiman yacare* was not observed, however, in other places both were observed but *Caiman yacare* was predominant. This observations show that this kind of environment is not the preferred one by this species, but it confirms the flexibility of *Caiman latiostris* to tolerate a bigger diversity of environments.

**Conclusions**

These are the first methodical studies of caiman populations in the province of Formosa, carried out with the standard methodology of the Crocodile Specialist Group of the World Union for Conservation (CSG/SSC/IUCN), which makes it repetitive and demonstrable.

In Colonia Monte Lindo, animals of both species were observed but *C.latiostris* nests were not harvested. However, in Bañado La Estrella and Colonia El Olvido, both species were observed; and in the nesting season nests from both species were harvested. Bearing this in mind, it is clear that *Caiman latiostris* has not disappeared from none the areas that historically occupies in its distribution. Furthermore, the densities found in monitored places, thoroughly surmount the habitual average values for the species in this country. The places that broad-snouted caiman prefers to inhabit usually constitute a permanent obstacle for its study (Larriera 1992)

In environments where *Caiman latiostris* was observed, *Caiman yacaré* was not, where *C. yacare* prevailed, *C. latiostris* could be also observed. According to the data of the eggs of the 2003 and 2004 harvest, it can be established that they share nesting habitat in some places. Disturbance factors for yacare populations in the studied areas are related to habitat loss in favor of agricultural production and some isolated deaths, generally owing to hunting for survival or elimination by accident, unawareness, or fear. There is no record of commercial hunting with the purpose of using neither its skin nor its meat.
The present work was useful not only to update the knowledge of the species in the region, but also, to verify the striking interest of local residents in the utilization of the resource in a sustainable way.

In the Province of Formosa, populations of the gender *Caiman* are in a very good condition, what is shown, as well in population counts as in the increased number of nests during the 2003 and 2004 harvests.

Finally, the educational aspects of work mechanics in the face of a flawed reality in local economies make us suppose that future economic retribution for the detection of yacare nests, will constitute a significant stimulus for the appraisal of ecosystems starting from its sustainable use in the province of Formosa.

**Acknowledgements**

To Cesar Pérez and Oscar Ramón Candia, for their very good and constant willingness to team up. To the vet. Juan Carlos Orozco, Director of Fauna and Parks of the Province of Formosa for his open support. To “Caimanes de Formosa SRL” corporation and the Fac. de Cs. y Tec., UADER, for financing these studies and to the vet. Alejandro Larriera for his critical review of this document and to the whole Projecto Yacaré (MAGIC-MUPCN agreement).

**Literature**


“Pancuronium Bromide” - an Immobilising Agent for Crocodiles

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Abstract

Flaxedil (gallamine triethiodide) was used extensively by crocodile farms and wildlife managers for the immobilisation of Saltwater Crocodiles (Crocodylus porosus). However, as it became increasingly difficult to obtain and the cost became prohibitive, alternative immobilising agents were sought. Preliminary testing suggested that Pavulon (pancuronium bromide) could be a potential replacement for Flaxedil. Extensive experimentation with juvenile C. porosus allowed dosage rates for Pavulon to be quantified. Dosage rates for immobilisation for 6-10 h, for large crocodiles (>2.9 m total length), were extrapolated from limited data, and continue to be tested. Nonetheless, Pavulon has proven to be a cheap, reliable immobilising agent for C. porosus.

Introduction

Crocodile management and research have benefited greatly from the use of injectable immobilising agents. Not only do these contribute to “safety” for handlers, they reduce stress, and risk of injury or death to the animals. A variety of drugs have been used for crocodilians, the effect of each drug on a particular species being somewhat unique in terms of dose rates, degree of immobilisation and recovery rates.

Flaxedil (gallamine triethiodide) has been the main immobilising agent used in Australia for Saltwater Crocodiles for over 30 years. It recently became unavailable in Australia, which motivated the search for an alternative agent. Pavulon (pancuronium bromide) is a closely-related drug widely used in human medicine, and preliminary testing by WMI indicated that it could be a suitable alternative. More extensive testing was then undertaken to derive dosage rates for Saltwater Crocodiles. A range of dosage rates was tested against a number of variables, including: size of crocodile, sex, bodyweight, body temperature, and degree of exercise. From this we determined induction time, duration of immobilisation, recovery time, and upper lethal dose. The physiological effects of the drug were examined, and we also tested the effectiveness of the antidote, neostigmine methylsulphate.

Both Flaxedil and Pavulon are non-depolarising neuromuscular blocking agents - they impair nerve impulses to the striated muscles, rendering the animal helpless and unable to move until the drug has been metabolised. Paralysis tends to be specific to striated muscle, leaving vital functions such as ventilation and heart function relatively unaffected except at high dose rates.

Methods

Crocodiles in three size classes: juveniles (2.4-5.1 kg; <1.2 m TL), sub-adults (5.1-40 kg; 1.2-2.3 m TL) and adults (>40 kg; >2.3 m TL) were used in this study, although most testing was confined to juveniles. Dosage rates for larger animals were extrapolated from the results obtained for juveniles, and then tested on a limited sample of large crocodiles.

Pavulon’s performance was evaluated through a number of experiments, including recording the time for specific responses to disappear and reappear as a measure of the level of immobilisation, assessing the influence of key variables (eg bodyweight, body temperature, exercise, sex) to understand the dynamics of immobilisation, physiological effects, and exploring upper lethal limits.
Results

Induction time: The time from injection to immobilisation (induction time) decreased with increasing dose (Fig. 1). Minimum effective dose was 0.019 mg/kg. Induction time does not decrease significantly at dose rates above 0.025 mg/kg due to limits on diffusion rate from muscle to bloodstream. The average induction time within the size range tested was 21.8 minutes.

![Figure 1](image1.png)

Figure 1. Relationship between dose rate and induction time for 34 *C. porosus* immobilised with Pavulon. Line shows significant linear regression ($r^2=0.23$, $P<0.005$).

Duration of immobilisation: Duration of immobilisation increased at higher dose rates (Fig. 2), although both exercise and body temperature also influenced duration. Crocodiles remained immobilised for longer when exhausted prior to immobilisation, but recovered faster at higher body temperatures because the drug metabolises more rapidly.

![Figure 2](image2.png)

Figure 2. Relationship between dose rate and duration of immobilisation for 36 *C. porosus* immobilised with Pavulon. Closed circles = animals not exercised (N= 29); open circles = animals exercised (N= 7).
Duration of immobilisation can be predicted from induction time (Fig. 3) - crocodiles that take longer to become immobilised tend to recover more rapidly. However, once recovery had started (ie some reflexes were regained), the time taken for full recovery of all reflexes was not influenced by dose rate, sex, body weight or induction time.

![Graph](image)

**Figure 3.** Relationship between dose rate and induction time for 36 *C. porosus* immobilised with Pavulon.

**Antidote:** Neostigmine methylsulphate was found to be highly effective at reversing the effects of Pavulon. Recovery time was significantly reduced (<5 minutes) in all animals following injection of >0.02 mg/kg neostigmine (Fig. 4).

![Graph](image)

**Figure 4.** Relationship between neostigmine dose rate and recovery time for 10 *C. porosus* previous immobilised with 0.034 mg/kg Pavulon. Solid triangles = neostigmine dose >0.02 mg/kg (N= 6); crosses = neostigmine dose £0.02 mg/kg (N= 3); crossed box = no neostigmine.

**Lethal dosage rates:** Dosage rates greater than 0.4 mg/kg (>20 times minimum effective dose rate) proved lethal in non-exercised crocs. Dosage rates of 0.2 mg/kg were lethal in crocodiles exercised to exhaustion and in crocodiles with higher body temperatures. Even in non-exercised crocodiles, dosage rates greater than 0.2 mg/kg (>10 times minimum effective dose) could lead to respiratory distress and death unless administered with the antidote. Neostigmine
can prevent mortality if administered early, but is ineffective at restoring muscular movements at high dosage rates (>0.14 mg/kg). Very rapid induction time (<10 minutes) indicates a potentially lethal dose.

Physiological effects: The physiological effects appear to be a 10% increase in heart rate (tachycardia; Fig. 5) and a 66% decrease in respiration rate (hypoventilation; Fig. 6) between injection and complete immobilisation. Tachycardia was not observed using Flaxedil, and appeared to be independent of the stress response to handling. Hypoventilation was greater than that observed using Flaxedil (66% instead of 50%).

![Figure 5](image5.png)

**Figure 5.** Apparent physiological effect of 0.034 mg/kg Pavulon on heart rate of juvenile *C. porosus* with body temperature standardised at 32.8°C.

![Figure 6](image6.png)

**Figure 6.** Apparent physiological effect of 0.034 mg/kg Pavulon on respiration rate of juvenile *C. porosus*.

**Larger crocodiles:** To test dose rates extrapolated for larger crocodiles, the predicted effects of a normal dose were compared with actual effects in 10 large *C. porosus* (12.1-240.5 kg BWt). There was a significant difference between the predicted and actual effects - induction time, immobilisation duration and recovery times were all higher than predicted from smaller crocodiles. Minimum effective dose was also predicted to be lower than 0.02 mg/kg. These effects are consistent with crocodiles of higher bodyweight taking longer to metabolise the drug.
Conclusions

These results indicate that Pavulon is an effective immobilisation agent, and a suitable replacement for Flaxedil. The effective dose rate is relatively low, and there is a considerable safety margin before lethal levels are reached. There are relatively clear indicators if dose rates are excessively high, and unless extreme there is a possibility for administering neostigmine - an effective antidote, particularly at normal dose rates. There appeared to be a change in dynamics of immobilisation between smaller and larger crocodiles, the latter’s higher bodyweight and lower metabolism of the drug meaning that smaller dose rates relative to body size are required. Based on the results, provisional dosage rates of Pavulon for wild Saltwater Crocodiles were derived (Table 1). However, caution should be exercised with large crocodiles, as the dosage rates were derived from limited data.

Table 1. Provisional dosage rates of Pavulon (4 mg/2 ml) for wild *Crocodilus porosus*. Dosage rates in shaded area are extrapolations, and should be used with caution. Line beneath “total length of 2.9 m” denotes a change in dose rate. Concentration of neostigmine methylsulphate is 2.5 mg/ml.

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<th>TL (m)</th>
<th>BWt (kg)</th>
<th>Partial Immobilisation (ml)</th>
<th>Immobilisation 3-6 h (ml)</th>
<th>Immobilisation 6-10 h (ml)</th>
<th>Neostigmine (ml)</th>
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Study and Conservation of Black Caiman (*Melanosuchus niger*) in French Guiana: a 4-years Record

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**Introduction**

Formerly considered as “endangered”, the status of the Black Caiman (*Melanosuchus niger*) has been reevaluated recently on the basis of ecological monitoring (eg da Silveira and Thorbjarnarson 1999), and the species is now considered as “vulnerable”. Nevertheless, this status remains closely dependant to conservation program at the populations levels (Hilton-Taylor 2000). The monitoring of the French Guianan population was initiated in the late 1999 (Blanc and de Thoisy 2001; de Thoisy *et al.* 2001, 2002). Since the population was formerly supposed to be restricted to the Kaw Swamps area (but see de Thoisy and Auffret 2003), primary aims of the program funded by the Kaw Swamps Nature Reserve and the French Ministry of Ecology, were:

- to assess the status of the population, using both field surveys and molecular markers;
- to identify areas of major importance for the species;
- to gather new data on ecology and biology; and,
- to propose recommendations for a better management of habitat and species conservation.

**Area of Study and Methods**

The Kaw Swamp Nature Reserve (04°25-04°50 N, 52°00-52°15 W) comprises several habitats for caimans, including swamps, flooded forests, and mangroves. These areas are facing different levels of anthropic pressure.

The core area of the reserve: the Angélique Swamp

Due to its inaccessibility, this 80 sq. km flooded herbaceous swamp remained in a rather pristine state. Five surveys were realized in several permanent ponds.

The Kaw River

This 70 km-long river crosses the reserve. Its upper part is dominated by a herbaceous habitat, the lower part crosses a gallery forest, and, closer to the sea, a mangrove. A small village is located on the edges of the river. Caimans were extensively hunted during decades, until the complete protection of the species by Ministerial Decree in 1986. To date poaching still occurs, although at a low scale. The area is exploited by unmanaged tourism, cattle ranching, and fishing. Count surveys were undertaken monthly since 4 years; as far as possible animals were marked for capture/recapture (C/R) purposes, as well as for the genetic study.

Approuague Estuary

This mangrove habitat has been identified as a important nesting site. The area was chosen for study of the growth and dispersal of youngs using C/R method. Also, a genetic approach was developed, using 2 distinct molecular markers: nuclear microsatellite DNA, and mitochondrial cytochrome-b in collaboration with Izeni Farias from the University of Manaus.

**Results**

**Abundances on the Kaw River**

Three species are present: the Dwarf Caiman *Paleosuchus palpebrosus*, the Black Caiman *Melanosuchus niger*, and the spectacled caiman *Caiman crocodilus*. A fourth species, the smooth-fronted caiman *P. trigonatus*, is recorded in forest tributaries, but not in the main river course.
The abundance of the Dwarf caiman ranged from 2.8 to 5.6 individuals per 10 km. Whatever the season and the water level, the Dwarf caiman was more present in the gallery forest area, where 67 to 100% of monthly sightings were recorded.

The kilometric index of both Black and Spectacled caimans are shown on Figure 1. The decrease of the abundance of the Black caiman is significant since 4 years, and the increase of the Spectacled caiman could be an ecological response to this feature (Herron 1991, 1994). Additionally to very low KIs, Black caimans on the river were only young animals; alternatively the size structure recorded in the Angélique Swamps reflects a healthy population. Also, hatchlings and nesting activities were not recorded on the Kaw River. Nevertheless, large animals, although still poorly represented, were recorded at a higher occurrence during the last year of survey, and may be considered as an encouraging feature (Fig. 2). The Black caiman marks a significant preference for forest habitats (40% of records located in the gallery forest area, 18% in the mangrove area, vs. 42% in savannas); the Spectacled caiman used preferably the savanna area (94% of sightings).

![Figure 1](image1.png)

**Figure 1.** Evolution of monthly kilometric index (KI) of Black caiman *Melanosuchus niger* and Spectacled caiman *Caiman crocodilus* on the Kaw River, Kaw Swamps Nature Reserve, French Guiana. Period 2000-2003.

![Figure 2](image2.png)

**Figure 2.** Sizes structure of Black caimans on the Kaw Nature Reserve, French Guiana. Period 2000-2003.
Growth

Data are very preliminar; only 10 C/R events were recorded, the difference of total lenghts between the 2 captures, for each C/R (with 1 to 11 months between the 2 events), are shown on Figure 3. Mean increase ranges from 1 to 3.5 cm/month, and is significantly higher in youg animals. To date, no animal marked in one of the three areas: Angélique Swamp, Kaw River, and Approuague, were recaptured in another.

![Graph showing growth rates](image)

Figure 3. Growth rate of *Melanosuchus niger* in French Guiana.

Genetic diversity

Analysis of both nuclear and mitochondrial DNA suggested a high genetic diversity and a significant recovering potential (Farias *et al*. 2004; de Thoisy and Lavergne 2004). Nuclear markers suggested that gene flows are important between Angélique and Kaw River. On the other hand, animals from the Approuague would be related to breeders from Pointe Béhague, another large swamp inaccessible area located in the East of the river, close to the brazilian boundary (de Thoisy and Lavergne 2004).

Conclusions

A large population of Black caiman is still present in French Guiana, due to the remoteness of large swamps. Although the population is severley depleted in bordering areas, a recovering potential is expected, but a strict management of the area is fully necessary, and is not yet sufficient. Considering together surveys and genetic data, we can suggest that:

(i) at the population scale, the high diversity and the absence of significant probability of consaguinity means an overall satisfactory status, with the evidence of gene flows between pristine areas (ie the Angélique Swamp), that may act as sources, and depleted areas; and,

(ii) on the Kaw River, the continuous decrease has to worry the reserve managers, and may be explained, at least in part, by insufficient management: overfrequation, inadequate behaviors of visitors and tourism operators, and maintenance of a silent poaching pressure.

Forthcoming actions will include VHF telemetry and extension of the genetic survey towards animals located outside the reserve, and as far as possible with the Brazilian population of Cabo Orange.

Literature


Blood Parasites of *Crocodylus siamensis* in Thailand

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Abstract

Blood samples of 383 captive freshwater crocodiles, *Crocodylus siamensis*, from three different parts of Thailand, central-eastern (n= 231), northeastern (n= 38) and southern parts (n= 114) were examined. Blood smears, whole blood, white cells and red cells were prepared, stained with Wright stain, and microscopically examined. To evaluate the relation between hematological values and blood parasite infection, 128 whole blood samples were identified for the packed red cell volume (PCV), differential of white blood cell (WBC) count and thrombocyte count per 100 WBC. Standardized questionnaires, concerning the diets and management practices, were collected and evaluated for their association with parasitological prevalence. The results show no parasite in crocodile blood (prevalence rate= 0%). The hematological values (mean ± SD) were as follows: PCV 28.90 ± 2.90%, heterophil 77.52 ± 3.70%, eosinophil 1.30 ± 0.90%, basophil 1.09 ± 0.78%, lymphocyte 18.55 ± 3.39%, monocyte 1.46 ± 1.03%, and 117.25 ± 19.76 thrombocytes per 100 WBC. These values were not significantly different between sexes. However, some hematological values of crocodiles from farms that changed water once a week were significantly (P<0.05) lower than those from farms that changed water once a month. These results should prove safety in crocodile blood consumption.

Introduction

Freshwater crocodiles, *Crocodylus siamensis*, are endemic in Thailand. At present, they are commercially important. Thus they are more frequently found in captivity than in the wild. Recently, crocodile production is increased because of the progress in the farming technology. Crocodile skin is the principal product for annually exporting in the exotic leather trading. Besides, crocodile by-products such as meat, fat, bile, and penises are increasing important in adding values of captive crocodiles. The crocodile byproducts are influential in some farming areas and are conveniently classified into two categories, curios/novelty items and ingredients for medicines and other products (Hutton and Webb 1993; Huchzermeyer 2003). Crocodile blood, one of the by-products, is traditionally consumed for preventing and curing allergy and asthma.

Crocodiles may be infected by a number of blood-inhabiting protozoa and nematode worms transmitted by haematophagous arthropods. Protozoan parasites included haemoparasida in the genera *Hepatozoon*, and *Pregnaria* (Siddall 1995; Smith 1996; Lainson 1995), and haemoflagellates in the genus *Trypanosoma* (Hoare 1931; Lainson 1977). Nematode worms in the family Filaridae occur in many crocodile species (Huchzermeyer 2003). Blood-inhabiting parasites of crocodiles are of particular interest because a high incidence of parasitic infections lowers productivity leading to important economic losses. Some blood parasites are zoonoses, transmitted between humans and animals.

The prevalence of blood parasites and parasitic species of zoonotic importance in *C. siamensis* has never been reported in Thailand. To ensure safety in crocodile blood consumption, the prevalence of the parasites in crocodile blood was observed. The relationships between hematological values and parasite infections were also investigated.

Materials and Methods

Sample size and study area: The sample size was calculated following the formula described by Thrusfield (1995). The total samples (n= 383) consisted of crocodiles from three parts of Thailand, central-eastern (n= 231 from 7 Provinces, 33 samples/Province), northeastern (n= 38 from 2 Provinces, 19 samples/Province) and southern parts (n= 114 from 6 Provinces, 19 samples/Province).
**Designed questionnaires and collection:** The questionnaires were designed concerning the diets and management practices. The data in each questionnaire were collected by personally communicating with crocodile farm owners or via mail. They were analyzed and evaluated for their association with parasitological prevalence.

**Subjects and sample collection:** Crocodiles, 2 to 3-year-old, were caught from the captive farms and transferred for slaughtering at Sriracha Crocodile Farm, Chonburi, during April 2003 and March 2004. Their weight, thorax length, and total length, from head to tail, were measured. Blood samples (5 ml) were collected from the post-occipital venous sinuses with sterile-technique. The samples were kept in tubes containing ethylene diamine tetraacetic acid (EDTA). The pack red cell volume (PCV) was prepared and determined according to the standard microcentrifugation method. The blood samples were used to produce three types of blood smear namely, whole blood, white cell and red cell smear. To make the whole blood smear, approximately 5 μl of blood was smeared on a microscope slide. The remaining blood was centrifuged at 3000 rpm for 10 min. Afterwards, blood was divided into two layers, the upper white blood cell (WBC) with thrombocyte and the lower red blood cell (RBC). Each portion was then used to prepare the white and red cell smears. All blood smeared slides were individually labeled, air-dried, fixed in 100% methanol for 15 sec, and stained with Wright stain (Dip-Quick®, Clinical Diagnostics, Ltd., Part, Bangkok, Thailand).

**Smear examination:** To identify parasite species, all blood smears were examined at 1000x magnification under oil immersion. The crocodiles were classified as negative for the absence of parasites and as positive for the presence of various parasite types. The prevalence of infection was defined as the percentage of infected individuals in a sample. In addition, the whole blood smears were checked for the differential WBC counts and the number of thrombocyte per 100 WBC at 1000x magnification.

**Statistical analyses:** The prevalence of blood parasites in freshwater crocodiles was calculated as a percentage of crocodile infected. Group differences were assessed by ANOVA.

**Results**

The sizes of crocodiles collected from different parts of Thailand are summarized in Table 1, together with the prevalence of blood parasites. The captive-bred crocodiles, 2-3 years-old, were 189.54 ± 10.48 cm in length and weighed 28.23 ± 5.25 kg. Their thorax length averaged 56.01 ± 4.62 cm. However, parasites were not detected in all types of blood smears, 383 specimens.

![Table 1](image)

**Table 1. Prevalence of blood parasites in freshwater crocodiles (Crocodylus siamensis) from three parts of Thailand.**

<table>
<thead>
<tr>
<th>Part/Province</th>
<th>Length (cm)</th>
<th>Weight (kg)</th>
<th>Thorax length (cm)</th>
<th>No.</th>
<th>WbB*</th>
<th>WBC*</th>
<th>RBC*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Central-Eastern</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bangkok</td>
<td>194.21±8.42*</td>
<td>30.98±3.97</td>
<td>58.58±3.32</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ayuthaya</td>
<td>190.81±15.62</td>
<td>26.94±7.18</td>
<td>55.30±5.98</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Samut Prakan</td>
<td>195.67±17.61</td>
<td>32.30±10.86</td>
<td>57.95±8.82</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nakhon Pathom</td>
<td>185.61±10.67</td>
<td>26.42±4.99</td>
<td>56.27±4.96</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Trat</td>
<td>197.30±7.92</td>
<td>34.90±2.91</td>
<td>59.42±3.95</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rayong</td>
<td>193.25±11.93</td>
<td>28.75±5.28</td>
<td>56.58±4.72</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chanthaburi</td>
<td>185.76±6.78</td>
<td>27.85±3.65</td>
<td>56.12±3.82</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Northeastern</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loc1</td>
<td>183.89±7.87</td>
<td>24.33±4.07</td>
<td>53.63±4.27</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nakhon Phanom</td>
<td>175.21±11.06</td>
<td>22.01±4.69</td>
<td>53.79±3.95</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Southern</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petchaburi</td>
<td>197.21±9.37</td>
<td>27.34±4.75</td>
<td>55.84±4.09</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chumphon</td>
<td>200.20±8.44</td>
<td>32.69±5.34</td>
<td>58.05±4.84</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ranong</td>
<td>197.68±14.20</td>
<td>33.28±8.23</td>
<td>58.32±5.39</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Surat Thani</td>
<td>176.50±10.02</td>
<td>23.40±4.53</td>
<td>52.74±4.16</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Songkhla</td>
<td>173.95±7.08</td>
<td>21.82±2.89</td>
<td>51.21±3.44</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Phatthalung</td>
<td>195.89±10.18</td>
<td>30.45±5.38</td>
<td>56.35±3.98</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>189.54±10.48</td>
<td>28.23±5.25</td>
<td>56.01±4.62</td>
<td>383</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*WbB: whole blood; RBC: red blood cell; WBC: white blood cell
The hematological values in relation to parasitic infection could not be evaluated because there were no parasites in the crocodile blood. However, the hematological values, PCV, differential WBC count and the number of thrombocytes per 100 WBC, of 128 samples from 6 Provinces were analyzed.

The hematological values of male and female crocodiles from different parts of Thailand are presented in Tables 2 and 3, respectively. These values were not significantly different between sexes (P > 0.05). The type of water changes significantly affected male hematological values, PCV, %heterophil, %eosinophil and %lymphocyte (Table 4). Similar results were observed in females (Table 5). The frequency of water changes significantly influenced %monocyte in female. On the contrary, the regularity of water changes did not affect %monocyte in male.

Table 2. Hematological values of male freshwater crocodiles (Crocodylus siamensis) from three parts of Thailand.

<table>
<thead>
<tr>
<th>Hematological tests</th>
<th>Hematological values (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Central-Eastern (n = 25)</td>
</tr>
<tr>
<td>PCV (%)</td>
<td>28.20 ± 3.06</td>
</tr>
<tr>
<td>Differential count (%)</td>
<td></td>
</tr>
<tr>
<td>Heterophil</td>
<td>75.52 ± 3.33</td>
</tr>
<tr>
<td>Eosinophil</td>
<td>1.72 ± 1.12</td>
</tr>
<tr>
<td>Basophil</td>
<td>0.68 ± 0.48</td>
</tr>
<tr>
<td>Lymphocyte</td>
<td>20.78 ± 3.00</td>
</tr>
<tr>
<td>Monocyte</td>
<td>1.30 ± 0.91</td>
</tr>
<tr>
<td>Thrombocytes/ 100 WBC</td>
<td>112.52 ± 26.02</td>
</tr>
</tbody>
</table>

n: number of analyzed samples, PCV: pack red cell volume, WBC: white blood cell.

Table 3. Hematological values of female freshwater crocodiles (Crocodylus siamensis) from three parts of Thailand.

<table>
<thead>
<tr>
<th>Hematological tests</th>
<th>Hematological values (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Central-Eastern (n = 8)</td>
</tr>
<tr>
<td>PCV (%)</td>
<td>27.38 ± 2.10</td>
</tr>
<tr>
<td>Differential count (%)</td>
<td></td>
</tr>
<tr>
<td>Heterophil</td>
<td>75.00 ± 3.76</td>
</tr>
<tr>
<td>Eosinophil</td>
<td>1.69 ± 1.07</td>
</tr>
<tr>
<td>Basophil</td>
<td>0.56 ± 0.32</td>
</tr>
<tr>
<td>Lymphocyte</td>
<td>21.25 ± 2.82</td>
</tr>
<tr>
<td>Monocyte</td>
<td>1.50 ± 1.22</td>
</tr>
<tr>
<td>Thrombocytes/ 100 WBC</td>
<td>107.81 ± 7.54</td>
</tr>
</tbody>
</table>

n: number of analyzed samples, PCV: pack red cell volume, WBC: white blood cell.

Table 4. Effect of the types of water change on hematological values of male freshwater crocodiles (Crocodylus siamensis).

<table>
<thead>
<tr>
<th>Hematological tests</th>
<th>Hematological values (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Once a week</td>
</tr>
<tr>
<td>PCV (%)</td>
<td>27.69 ± 2.91&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Differential count (%)</td>
<td></td>
</tr>
<tr>
<td>Heterophil</td>
<td>73.72 ± 3.63&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Eosinophil</td>
<td>1.52 ± 1.15&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Basophil</td>
<td>1.49 ± 1.33&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lymphocyte</td>
<td>22.46 ± 3.70&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Monocyte</td>
<td>1.23 ± 0.87&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Thrombocytes/ 100 WBC</td>
<td>106.40 ± 27.18&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values with different superscripts in the same column, are different (ANOVA; P ≤ 0.05). PCV: pack red cell volume, WBC: white blood cell.
Table 5. Effect of the types of water change on hematological values of female freshwater crocodiles (Crocodylus siamensis).

<table>
<thead>
<tr>
<th>Hematological tests</th>
<th>Hematological values (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Types of water change</td>
</tr>
<tr>
<td></td>
<td>Once a week</td>
</tr>
<tr>
<td>PCV (%)</td>
<td>28.00 ± 1.94a</td>
</tr>
<tr>
<td>Differential count (%)</td>
<td></td>
</tr>
<tr>
<td>Heterophil</td>
<td>75.76 ± 3.86a</td>
</tr>
<tr>
<td>Eosinophil</td>
<td>1.89 ± 1.22a</td>
</tr>
<tr>
<td>Basophil</td>
<td>1.03 ± 0.84a</td>
</tr>
<tr>
<td>Lymphocyte</td>
<td>20.29 ± 2.80a</td>
</tr>
<tr>
<td>Monocyte</td>
<td>1.00 ± 0.93a</td>
</tr>
<tr>
<td>Thrombocytes/ 100 WBC</td>
<td>121.53 ± 26.13a</td>
</tr>
</tbody>
</table>

Values with different superscripts in the same column, are different (ANOVA; P≤ 0.05), PCV: pack red cell volume, WBC: white blood cell.

The questionnaire data revealed that crocodiles were usually individually maintained in a single pen with smooth concrete ground. They were fed with chicken skeleton (94%), fish (38%) and pork remains (6%) every other day (87%). Sources of water supply were from artesian well (56%), piped water (25%), pond (19%) and other natural water sources (6%). The water was regularly changed once a week (63%) rather than once a month (19%).

Discussion

Our study examined captive or farmed crocodiles from 15 Provinces in three parts of Thailand. Most crocodile farms (60%) were concentrated in the central-eastern areas. The others were scattered in the southern (30%) and northeastern (10%) parts of Thailand. The crocodiles from these farms were delivered to Sriracha Crocodile Farm located in Chonburi Province, in the eastern part of Thailand. This farm is a center for crocodile trading and slaughter. Moreover, Sriracha Farm owner advises the smaller operations in transfer technology of crocodile husbandry.

According to the questionnaires the crocodiles were kept singly in a pen with smooth concrete ground. They were fed mainly with chicken skeleton every other day. The source of water was mostly from artesian well water (56%). The water was changed predominantly once a week (63%).

In general, parasitic infections in crocodiles are acquired by eating or drinking contaminated food or water. The crocodiles may also be infected through direct contact with soil or water containing parasitic eggs or larvae, or by being bitten by infectious insects. Temperature, food and pen design were the main factors influencing the occurrence of many diseases in farmed crocodiles (Buenviaje et al. 1994).

Our results showed no parasites in the crocodile blood. This may due to good farming condition and valid management. The infection rate also depended upon the crocodile physiological status. Some hematological values of crocodiles were significantly influenced by the regularity of water change indicating the association between the management practice and the crocodile physiological status.

The crocodile blood is one of interesting by-products. It is traditionally consumed for medicinal purpose. However, little information is available on its safety for human consumer. The blood is usually processed by freeze drying or lyophilizing. This process does not harmfully affect active substances in blood but it cannot destroy many pathogens. These viable pathogens may pass to consumer and cause serious health problems. For example food contaminated with common parasites, Giardia and Strongyloides species can cause zoonosis. Thus food safety is gaining increase attention.

The results in this study, the prevalence of blood parasites in captive or farmed crocodiles, serve as mark information that is important in improving husbandry management and assuring safety in consuming crocodile blood.
Literature


Intestinal Parasites of Freshwater Crocodiles, *Crocodylus siamensis*, in Thailand

Win Chaeychomsri¹, Jindawan Siruntawineti¹, Boongeua Vajarasathira¹, Komsun Komljindakul¹, Tawatchai Ong-aat² and Yosapong Temsiripong²,³

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Abstract

The prevalence of intestinal parasites in farmed juvenile crocodiles, *Crocodylus siamensis*, was compared with that of adults in breeding pens. Faecal samples of 383 juveniles were gathered from three parts of Thailand, central-eastern, northeastern and southern parts. Thirty faecal specimens of adult crocodiles were also taken from Sriracha Crocodile Farm. They were examined for parasitic infection by direct smear and Modified Kato thick technique. Standardized questionnaires, dealing with the diets and management practices, were collected and evaluated for their association with parasitological prevalence. The overall prevalence of coccidian parasites in juveniles was 3.13% (12/383). The highest prevalence of coccidian infection, 5.26% (2/383), was observed in north-northeastern part of Thailand. The prevalent rates of 3.51 (4/114) and 2.60% (6/231) were observed in southern and in central-eastern part of Thailand, respectively. In contrast, 23.33% (7/30) coccidian infection was found in adult crocodiles. The difference in coccidian prevalence between juveniles and adults, relative to diets and management practices, was discussed.

Introduction

Freshwater crocodiles, *Crocodylus siamensis*, are promising economic animals in Thailand. The crocodile farming business is progressively growing. At present, there are over 500 crocodile farmers in Thailand. Approximately 30,000 juvenile crocodiles are available for marketing as classical crocodile leather and other by-products. Parasitic infection is one of the most important diseases affecting a wide range of animals including crocodiles. In livestock, both clinical and sub-clinical infections cause mortality, decrease growth rate and productivity and increase treatment cost leading to economic loss. Thus far there is no information on the nature and prevalence of intestinal parasitic infections in Thai crocodiles. Our study was therefore aimed to determine the prevalence of intestinal parasites in captive breeding crocodiles.

Materials and Methods

Sampling frame: Sample size was calculated using the formula n= 1.96² P (1-P)/d² according to Thrusfield (1995), with P= 0.5 and d= 0.05. As the prevalence of the parasites was unknown, each was assumed to be 50% where the maximum sample size is calculated. To meet a desired absolute precision of 5% and a 95% level of confidence, a sample size of at least 383 crocodiles was required. Samples were taken from both juvenile and adult crocodiles. The juveniles, 383, were from three parts of Thailand and the adults, 30, were from breeding pens, Sriracha Farm.

Sample preparation and examination: The direct smear method was used to detect trophozoites of amoebae and flagellates. Faecal specimens were placed in a small container and a drop of physiological saline was added for emulsification. Subsequently, two drops of the emulsified stool was placed on a slide and observed under the microscope. Iodine was used to stain parasitic eggs and cysts. The total area of the cover slip was scanned using 10x and 40x objectives. Trophozoite mobility and the presence of ingested red blood cells (RBCs) were observed to differentiate between *Entamoeba histolytica* and other amoebae. *Eimeria* species were identified based on the morphology of oocysts (shape, colour, form index, presence or absence of micropyle and its cap, presence or absence of residual, polar and stieda bodies) and time of sporulation (Coudert 1992; Eckert et al. 1995).

The Modified Kato thick smear technique was also used to estimate worm egg number in the fecal samples, especially of *Ascaris*, Opisthorchis, Trichuris, Hookworm, Schistosomes (Martin and Beaver 1968). Forty micrograms of faecal material was passed through a template onto a slide and covered with a cellophane cover slip soaked in 0.3% malachite
green. The slide was inverted against a smooth surface and pressed down gently until the sample spread uniformly over the whole cellophane cover slip. The slide was left 20-30 min before microscopic examination. Parasite ova were identified according to the species characteristics described in Soulsby (1982), Campbell (1988), Anderson (1992), Khalil et al. (1994), and Calnek (1997).

**Designed questionnaires and collection**: The questionnaires were designed according to the diets and management practices. The questionnaire data were collected by personally contacting with crocodile farm owner or via postage. The data were analyzed and evaluated for their association with parasitological prevalence.

**Calculation of overall prevalence**: To determine the overall prevalence of intestinal parasites in the sample population the number of positive faecal samples was divided by the total number of faecal samples collected.

**Results**

The general data of crocodiles was summarized in Table 1. The crocodiles were individually maintained in a single cage with smooth concrete floor. They were fed with chicken skeleton (94%), fish (38%) and pig remains (6%). The feeding interval was mainly every two days (87%). Water supply for caging was from artesian well (56%), piped water (25%), pond (19%) and other natural water sources (6%). Frequency of water change was once a week (63%) rather than once a month (19%).

| Table 1. General data of crocodile farms. *N = number from returned questionnaires. |
|------------------------------------------|----------|----------|
| Number of crocodiles | N* | % |
| Mean number of captive crocodiles per farm | 15/15 | 100 |
| (Range 30-1600 crocodiles) | | |
| Mean number of ranched crocodiles per farm | 2/15 | 13.33 |
| (Ranges 10-40 crocodiles) | | |
| Type of crocodile feed | | |
| Chicken skeleton | 15/16 | 93.75 |
| Fish | 1/16 | 6.25 |
| Pig remains | 6/16 | 37.50 |

The overall prevalence of crocodile infection with intestinal parasites was lower in juveniles (3.13%) than in adult crocodiles (23.33%). Only coccidian parasite was detected in faecal samples of both adult and juvenile crocodiles (Table 2). By using direct faecal smear technique, 3.13% (12/383) juvenile crocodiles were found positive for coccidian parasite. The highest prevalence of coccidian, 2/38 (5.26%), was in the Northeastern part of Thailand. The lower prevalent rates, 4/114 (3.51%) and 6/231 (2.6%), were in the southern and the central-eastern parts of Thailand, respectively. By using similar method, 23.33% (7/30) adult crocodiles were positive for coccidian parasite (Table 2). In contrast, protozoa and other intestinal parasites were not found by Modified Kato thick smear technique (Table 3).

| Table 2. Prevalence of intestinal parasites observed by direct faecal smear technique. |
|------------------------------------------|----------|----------|----------|----------|----------|----------|
| Faecal exam. | Adult Crocodile | Central-Eastern | Southern | Northeastern | Total |
| No. | + | % | No. | + | % | No. | + | % | No. | + | % |
| Coccidia | 30 | 7 | 23.33 | 231 | 6 | 2.60 | 114 | 4 | 3.51 | 38 | 2 | 5.26 |
| Other | 30 | 0 | 0 | 231 | 0 | 0 | 114 | 0 | 0 | 38 | 0 | 0 |

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Table 3. Prevalence of intestinal parasites observed by direct faecal smear technique and Modified Kato Thick smear technique.

<table>
<thead>
<tr>
<th>Faecal exam</th>
<th>Central-Eastern</th>
<th>Southern</th>
<th>Northeastern</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.  + %</td>
<td>No.  + %</td>
<td>No.  + %</td>
<td>No.  + %</td>
</tr>
<tr>
<td>Direct smear</td>
<td>132 0 0</td>
<td>57 0 0</td>
<td>38 0 0</td>
<td>227 0 0</td>
</tr>
<tr>
<td>Kato’s thick</td>
<td>132 0 0</td>
<td>57 0 0</td>
<td>38 0 0</td>
<td>227 0 0</td>
</tr>
</tbody>
</table>

Discussion

The parasitic prevalence in captive breeding crocodiles was very low. This may be the results of good farm management and hygienic measures, regular deworming and improved caging system. Usually, parasites are likely to buildup when animals are held in confinement without proper hygiene. The incidence of protozoan infections in farmed crocodiles indicated a need for prophylactic anti-protozoan therapy as a basic farm management. Such procedure will minimize the likelihood of in-house parasite buildup and improve safety in the colony staff, because these parasites are capable of infecting and causing disease in crocodiles.

Coccidiosis is the disease caused by coccidia when the host ingests many oocysts of a pathogenic strain. It is a frequent problem when raising large numbers of domesticated animals in a confined space (Fayer and Reid 1982). Poultry men, cattlemen, rabbit breeders, pigeon raisers, etc., are familiar with the mortality and morbidity effects of coccidiosis. Coccidiosis is probably not a problem in wild populations because the hosts are widely distributed. They are not confined to limited areas where the oocysts concentration can increase in the environment to the point that the hosts would ingest large numbers of oocysts. However, from the parasite’s point of view, distribution would be more difficult in the natural setting. This study suggests that adult crocodiles that spend much of their time in a flock are more likely to be infected with coccidia than juvenile crocodiles that spend their time in a single cage.

Clustering behavior fosters oocyst transmission because of the close proximity of infected crocodiles passing oocysts to potential new hosts. Oocysts, develop endogenously, are passed in the feces, and sporulate in the environment. Crocodiles become infected when they ingest the sporulated oocysts while feeding. Transmission of the parasite is facilitated by close contact with infected hosts who are actively passing oocysts in their feces. The results from questionnaires indicate that crocodiles were fed chicken skeleton (94%), fish (38%) and pig remains (6%). Their feeding habit was controlled by management program. They were fed every two days in the cage. The water supply was changed either once a week or once a month depending on the farm management. Thus the chance for the farmed crocodiles exposing to pathogenic agents or infective stage of parasites was very low. Although the transmission of coccidian parasites is well known, there are few reports of the prevalence of coccidian parasites in wild animal populations and no reports of the prevalence of coccidian in the farmed crocodiles in Thailand.

Habitat also influences the prevalence of coccidian in crocodile populations. Adult crocodiles, that were ground feeders, had higher prevalence of coccidian than juvenile crocodiles that were fed in the single concrete floor cages. Oocyst viability is dependent on moisture and oxygen (Brotherston 1948; Farr and Wehr 1949; Marquardt et al. 1960). Oocysts are very susceptible to desiccation and oxygen is required for sporulation and development to the infective stage. The soil in dens would be moist and conducive to oocysts survival and development. Wild crocodiles and the forest canopy would have more sunlight and higher temperatures that would enhance desiccation and reduce oocyst viability (Long 1959; Farr and Wehr 1949).

In conclusions, both adult and juvenile crocodiles harbored similar species of coccidian parasites. However, the prevalence of protozoan infections was higher in the adults than in the juveniles. These findings could not be easily explained based on conventional epidemiological criteria. Colony management, such as housing, sanitation and veterinary interventions such as a regular chemoprophylaxis against protozoa, was expected to be responsible for the lower level of coccidian infection in the juveniles. The lack of chemoprophylaxis against protozoa could have been responsible for the relatively higher prevalence in the captive breeding adults.

Literature


Efficacy of Siamese Crocodile (Crocodylus siamensis) Serum on Bacterial Growth Inhibition

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Abstract

Bactericidal efficacy of Thai freshwater crocodile (Crocodylus siamensis) serum was tested. Various serum concentrations, 100, 75, 50 and 25%, were mixed with Escherichia coli, Pseudomonas aeruginosa, Bacillus subtilis and Staphylococcus aureus, incubated at 37°C for 12 h. The samples, 100 ml, were collected at 0, 1, 3, 6, 9, and 12 h intervals. The crocodile serum, inoculated with E. coli and P. aeruginosa, showed bactericidal activity depending on incubation time and serum concentration. However, the serum, inoculated with B. subtilis and S. aureus, exhibited a time- and concentration-independent inhibition of bacterial growth. The bactericidal activity of crocodile serum was completely inhibited by preincubating the serum at 56°C for 30 min. The mechanism of antimicrobial activity may due to complement system and/or antimicrobial peptides presented in the crocodile serum.

Introduction

Crocodiles infrequently exhibit impairment health conditions due to infection. They often sustain serious injuries by rapidly healing and always without infection. Crocodilians have been known to live with opportunistic pathogenic bacteria with no physiological effects (Madsen et al. 1998). Their immune systems consist of two types of acquired and innate immune systems. The first line of defense of them against pathogens and parasites is of physical nature via their hard skin. However, once this barrier is passed, a complex interaction of innate humoral and cellular immune reactions is induced in both tissues and body fluid in circulatory system, which results in a fast elimination of microorganisms. High avidity binding of proteins to foreign material is a requisite of most humoral immunological recognition events (Dodds and Alex Law 1998).

Blood is a liquid tissue that has three major functions; as a transportation, for regulation, and protection. It holds specialized cells and chemicals that defend the body against diseases. As in other higher vertebrate, crocodilian also has chemicals involving in host defense mechanisms against infection. Discerning the nature of crocodile immunity, Siamese freshwater crocodile, C. siamensis, serum was evaluated for the efficacy of antimicrobials, and validated antimicrobial activity.

Materials and Methods

Crocodile samples: Samples were conducted on portions of Sriracha Crocodile Farm, Chonburi, Thailand. Crocodiles in 3 years age, at least 25 kg weight and 1.5-2.0 m length, were used. A blood sample, 5-10 ml, was collected from the anterior dorsal sinus, centrifuged and separated for serum. The serum was kept at -20°C until used.

Bacterial samples and cultures: Lyophilized bacterial strains were purchased from National Institute of Health (NIH, Thailand). The following ATCC-registered strains were used: Escherichia coli (25922), Pseudomonas aeruginosa (27853), Staphylococcus aureus (5638), and Bacillus subtilis (6633). Bacteria were preserved on nutrient agar slants at 4°C. The bacteria were inoculated in 4 ml of nutrient broth culture and incubated at 37°C overnight to raise log phase growth. Serial dilutions of the log-phase cultures were performed and plated on nutrient agar in 100 x 15 mm petri dishes. The dishes were incubated at 37°C for 18 h. Then, the cultures were determined for the colony-forming unit (CFU).

Optimized antibacterial assays: Each bacterial culture, E. coli, P. aerogenosa, B. subtilis and S. aureus, in log phase growth was prepared in 10-fold serial dilutions using sterile physiological saline. The samples were measured for optical densities using a spectrophotometer (Spectronic 20 Genesys, Spectronic Instruments, Inc., USA) at 600 nm. Fresh crocodile serum samples, 450 ml, were treated with 50 ml of bacterial cultures or a dilution containing different
amounts of bacteria. The samples were incubated at 37°C for 18 h. One hundred ml of a dilution of each sample was spread onto the surface of nutrient agar plates to determine the CFU. Samples were plated at three different dilutions to obtain plates with a quantity of colonies such to provide a reasonable estimate of bacterial density (30-300 CFU/plate).

**Antibacterial assays:** Fresh crocodile serum (F-CS), was diluted to 25, 50, 75 and 100% with physiological saline for variation of time and concentration dependent. Nine hundred ml samples containing various concentrations of crocodiles sera were inoculated with 100 ml of log phase culture of bacteria, approximately 1 x 10^7 cell/ml. The samples were incubated at 37°C for 0, 1, 3, 6, 9, and 12 h. One hundred ml of each sample was spread onto the surface of nutrient agar plates to determine the CFU.

**Inhibition of antibacterial activity:** The inhibition of antibacterial activity in crocodile serum was performed by serum incubation at 56°C 30 min. Then, the inactivated sera (I-CS) were diluted to 25, 50, 75 and 100% with physiological saline for variation of time and concentration in dependent. Nine hundred ml samples containing various concentrations of crocodile sera were inoculated with 100 ml of optimum concentration that previously performed. The samples were incubated at 37°C for 0, 1, 3, 6, 9, and 12 h. One hundred ml of each sample was spread onto the surface of nutrient agar plates to determine the bacterial CFU.

**Statistical analysis:** To obtain valid statistical evaluation of the results, all experiments were performed in triplicate. The percentage of relative growth for each bacterial strain was calculated.

**Results**

The dilution of bacteria in log phase growth provided optimal colony-number for manually counting exhibited 0.2 of optical density at 600 nm. In this study, we used 10^7 dilution of bacteria that showed 30-300 of viable cells on nutrient agar plate. The results showed that concentration, 50-100% of fresh crocodile serum (F-CS) particularly inhibited *E. coli* growth in 3 h of incubation (Fig. 1a). However, these gram-negative bacteria were incompletely inhibited when treated with in 25% F-CS. *Pseudomonas aeruginosa* growth was totally suppressed by all concentrations of F-CS approximately in 1 h of incubation (Fig. 1c). Concentration-dependent inhibition of the bacterial growth by F-CS was observed. Moreover, all concentrations of F-CS incompletely inhibited *S. aureus* and *B. subtilis* growth (Figs. 2a and 2c). These bacteria remarkably exhibited their colonies less than 150 after all period of incubations. In contrast, heat-inactivated crocodile serum at 56°C, 30 min (I-CS) fully obliterated the antimicrobial activities (Figs. 1b, 1d, 2b and 2d).

**Discussion**

The crocodile serum exhibited antimicrobial activity including in gram-negative and gram-positive bacteria. In this study, high efficacy in bactericidal activity was observed in gram-negative bacteria, *E. coli* and *P. aeruginosa* (Figs. 1a and 1c). The results revealed that the antibacterial capacity of F-CS in *E. coli* was higher than in *P. aeruginosa*. Both bacteria, as shown in Figures 1b and 1d, were inhibited depend on F-CS concentration and incubation time. The strengths of antibacterial activities against bacteria are probably related to bacterial membrane structure. In present study, gram-positive bacteria, *S. aureus* and *B. subtilis*, cultured with crocodile serum exhibited fluctuating relative growth (Figs. 2a and 2c), however, their relative growth were not over than 150%. Overall results implying that in the crocodile serum may have antimicrobial factors responsible for defense microbial invaders. Firstly, we hypothesized that the antimicrobial factors in serum were including proteins in complement system and antimicrobial peptides.

During the past few years, studies on the components of an immediate immune response against infectious microorganism or innate immune system have established the contribution of antimicrobial peptides (AMPs). AMPs are polypeptides of fewer than 100 amino acids, found in host defense settings, and exhibiting antimicrobial activity at physiologic ambient conditions and peptide concentrations. They are expressed in many tissues, polymorphonuclear leukocytes, macrophages and mucosal epithelial cells (Brogden *et al.* 2003). AMPs neutralizes bacteria by interacting specifically with their cell membranes (Lehrer and Ganz 1999). Previously, saltwater crocodile, *Crocodylus niloticus*, has been exhibited antibacterial activities of lung and adrenal tissues (Shaharabany *et al.* 1999).

Complement is a necessity part of the innate immune system and contains about 35 soluble and membrane-bound proteins. The complement system performs a major role in killing and neutralizing microorganisms. These events are mediated by activation of the lytic pathway and by opsonization. Complement proteins are expressed and circulated as inactive precursor proteins that can be activated in a very precise and highly coordinated fashion (Campbell *et al.*
Figure 1. Relative growth of gram-negative bacteria (*E. coli* and *P. aeruginosa*) after treated with fresh and heat-inactivated *C. siamensis* sera.

Figure 2. Relative growth of gram-positive (*S. aureus* and *B. subtilis*) after treated with fresh and heat-inactivated *C. siamensis* sera.
The complement cascade can be initiated by three distinct mechanisms, an antibody-dependent classical pathway, an antibody-independent alternative pathway and lectin pathway (Fujita 2002). Several investigators have reported the existence of an active serum complement system in a variety of reptilian species (Koppenheffer 1987). For example, Koppenheffer (1986) has evidenced the presence of both classical and alternative pathways in turtle serum. In reptiles, the complement system has been studied almost exclusively in the cobra (Sunyer and Lambris 1998). Moreover, Kuo and coworkers (2000) characterized the complement-mediated killing of the Lyme disease spirochete (Borrelia burgdorferi) in the western fence lizard.

Using classical human serum complement inactivation conditions (incubation at 56°C, 30 min), we found antibacterial activities obliteration in the treated crocodile serum (Figs. 1 and 2). With evidences that the major sources of AMPs are in various tissues, as described above, and concerning our data, bacterial growth inhibition of the crocodile blood serum should correspond to serum complement system. Recently, Merchant et al. (2003) have presented antibacterial properties of serum from the American alligator (Alligator mississippiensis) and suggested an active serum complement system. We have done a preliminary study of a sheep red blood cell hemolytic assay, CH50, for the function of crocodile complement system. Its results also supported the finding in this study. However, to our knowledge, a detailed functional description of Thai freshwater crocodile complement has not been published to date. Further studies will have to be performed to find more detail in crocodile complements and AMPs.

**Literature**


Amoebacidal Effects of Serum from the American Alligator
(Alligator mississippiensis)

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Treatment of axenic Naegleria gruberi cultures with alligator serum resulted in time-dependent amoebacidal activity, with measurable activity at 5 min and maximal activity occurring at 20 min. The amoebacidal activity was concentration-dependent, with measurable activity at 25% serum, while treatment of amoebas with undiluted serum resulted in only 16% survival. The efficiency was dependent on the concentration of amoebas, with higher survival rates at high amoeba densities and lower survival at low amoeba densities. The amoeba-killing effects of alligator serum were observed to be broad in spectrum, as the serum was effective against three strains of Naegleria species tested. In addition, alligator serum was effective against four Acanthamoeba strains, which have been reported to be resistant to human serum complement-mediated lysis. The amoebacidal effects of alligator serum were shown to be temperature-dependent, with optimal activity at 15-30°C and a decrease in activity below 15°C and above 30°C. The amoebacidal activity of alligator serum was heat labile and protease sensitive, indicating the proteinaceous nature of the activity, and was also inhibited by EDTA, which indicated a requirement for divalent metal ions. These characteristics strongly suggest that the amoebacidal properties of alligator serum are due to complement activity.
GIS-based Habitat Suitability Analysis of Saltwater Crocodiles
(Crocodylus porosus) in the Northern Territory

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Abstract

A habitat suitability model for saltwater crocodiles (Crocodylus porosus) in north-west coastal regions of the Northern Territory was constructed using GIS techniques. The requirements of saltwater crocodiles for nesting, feeding and access to open water, as defined by a review of the literature, were linked to surrogates mapped at 1:250,000 in coverages assembled in a Geographic Information System (GIS). GIS layers were assigned a weighting based on assessments of the relative importance of each layer for defining suitable habitat. Intersections of the layers were used to assign a total “habitat suitability” score to all cells in the study area, derived from the sum of the weighted scores across all layers. The predicted habitat suitability map showed distinct areas with high habitat suitability, particularly in the lower floodplains of the region. The results of the habitat suitability were summarised on a catchment basis. The Mary River Catchment had the greatest proportion of highly suitable habitat (12%) followed by the Finnis/Reynolds River Catchment (8%) and the Adelaide River Catchment (6%) whilst the Darwin/Blackmore River catchment had the lowest proportion of suitable habitat (0%). A simple validation of the model (using data from the Parks and Wildlife Service of the Northern Territory) showed a relatively high correspondence between the habitat suitability prediction and the actual population data, with an overall accuracy of approximately 35%. This model was based on readily available but relatively broadly defined attributes mapped at coarse scales. We argue that, with refinement, GIS analyses may help inform management of crocodiles and their habitat in the Northern Territory and elsewhere.

Introduction

Geographical Information Systems (GIS) are much used in natural resource management as a powerful tool for managing spatial and temporal information (eg Bridgewater 1993; Stow 1993; Berry 2000). Applications to wildlife management have taken advantage of the opportunities to link GIS with environment models to investigate and model dynamic species-environment relationships (Ackakaya 1994; Koeln et al. 1996). One of the most common GIS applications is habitat suitability analysis and mapping. A habitat suitability map is defined as a map displaying the suitability of land or water as a habitat for specific wildlife species (Leeuw et al. 2002). Production of a habitat suitability map requires a predictive model with a set of environmental variables that define the resources required by the species. GIS combines spatial representations of these variables to create the predicted habitat suitability maps.

We applied GIS techniques to predict suitable habitat on catchment basis for Saltwater Crocodiles (Crocodylus porosus) in the Northern Territory of Australia. The objectives of the analysis were to: 1) model habitat suitability based on environmental attributes thought to influence crocodile distribution, 2) generate a habitat suitability map of crocodiles based on the habitat suitability derived from the model, and 3) examine the validity of the predicted habitat suitability by comparing it to actual crocodile density data.

Methods

Study Area

The study area is the north west coastal regions of the Northern Territory, covering the major river systems and floodplains between the Moyle River in the west and the Glyde River (Arafura Swamp) in the northeast coast of the Northern Territory. The total area of the study site is approximately 109,500 km².
Input Data

Five different input datasets were used in this study:

- GEODATA TOPO 250K SERIES 2 - Hydrography Theme
- GEODATA Australian Surface Water Management 2000 (SWMA 2000)
- GEODATA 9-Second Grid Digital Elevation Model (9 Second DEM)
- Wetland Vegetation Map in the NT
- Crocodile Population Data in the NT

All the GEODATA datasets were obtained from Geoscience Australia. The Wetland Vegetation Map in the NT and Crocodile Population Data in the NT were provided by the Parks and Wildlife Service of the NT and Wildlife Management International through the Key Centre for Tropical Wildlife Management.

Habitat Modelling

Requirements for suitable habitat were determined by a literature review and from expert opinion. To reflect various aspects of crocodile biology, the habitat criteria were defined in terms of accessibility to a waterbody, availability of food, and influence on successful breeding and nesting. Based on these criteria for rating habitat favourability, environmental variables to be incorporated in the model were derived from the available data (Table 1).

Each variable was divided into 3 classes based on the statistical distribution of the variable. These classes referred to Low, Medium and High values and were assigned suitability values of 1, 2 and 3, respectively. The variables were further multiplied by a weighting value based on their impact on habitat suitability. The weightings were calculated based on the variable’s relevance to the habitat criteria and their importance as determined by the literature review (eg suitability values of any variable related to permanent water were doubled) (Table 1).

After assigning the weighted habitat suitability value to each variable, the GIS layers were overlayed and the individual suitability values summed to calculate an overall habitat suitability score in the study area. The final habitat suitability scores were divided into three equal classes to represent low, medium and highly suitable areas.

Data validation of the results was performed to assess the accuracy of the model. The habitat suitability map was compared to actual crocodile population data in the NT provided by the PWCNT. An error matrix was constructed to see the fitness of the predictive model to the observed population data.

Results and Discussion

Overall habitat suitability

The output showed some distinct areas with high habitat suitability, particularly in the lower floodplains of the region (Figs. 1 and 2). In terms of habitat quality, the Mary River Catchment had the greatest proportion of high suitability habitat (12%), followed by the Finniss/Reynolds River Catchment (8%) and the Adelaide River Catchment (6%). The Darwin/Blackmore River catchment had the lowest proportion of high suitability (0%). Interestingly, the East Alligator River had the greatest proportion of habitat rated above zero suitability (59%) although the proportion of high suitability habitat was very low (0.3%).

Model validation

At the relatively crude level of our validation, the error matrix showed an overall accuracy of approximately 35% (Table 2). It should, however, be noted that, since most animal species are mobile and use different habitat types for different purposes at different times, a single assignment of habitat suitability represents a gross oversimplification (Leeuw et al. 2002). We conclude that the match between predicted habitat suitability and observation of variation in densities is sufficient to show the potential to rank habitat suitability at large spatial scales by application of GIS to readily available mapped information.

Limitations

It is important that the application of such approaches be matched to the management objectives. We regard this
Table 1. The variables, including different waterbody types and other environmental factors, used in the habitat suitability model, their relevance to different habitat requirements of *C. porosus* (indicated by !) and their final weighting value.

<table>
<thead>
<tr>
<th>Type</th>
<th>Variables</th>
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<tr>
<td></td>
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<td></td>
<td>Permanent – distance to individual stream</td>
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<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
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<td>Permanent fringed by mangrove – individual area</td>
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<td>Temporary fringed by freshwater floodplain – individual area</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Swamp</td>
<td>Swamp – individual area</td>
<td>!</td>
<td>!</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Swamp – total area per catchment</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Swamp – distance to individual swamp</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Lake</td>
<td>Permanent – individual area</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Permanent – total area per catchment</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Permanent – distance to individual permanent lake</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Temporary – individual area</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Temporary – total area per catchment</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Temporary – distance to individual temporary lake</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Tidal area</td>
<td>Tidal area – distance to permanent freshwater stream</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Freshwater floodplain</td>
<td>Freshwater – coastal or inland</td>
<td>!</td>
<td>!</td>
<td>!</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Freshwater – individual area</td>
<td>!</td>
<td>!</td>
<td>!</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Freshwater – total area per catchment</td>
<td>!</td>
<td>!</td>
<td>!</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Freshwater – ratio to length of permanent freshwater stream</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Freshwater – ratio to length of temporary freshwater stream</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Freshwater – ratio to number of permanent lake</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Freshwater – ratio to number of temporary lake</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Freshwater – ratio to number of swamp</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Freshwater – ratio to area of permanent lake</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Freshwater – ratio to area of temporary lake</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Freshwater – ratio to area of swamp</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Saline floodplain</td>
<td>Saline – individual area</td>
<td>!</td>
<td>!</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Saline – total area per catchment</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Saline – ratio to area of permanent freshwater stream</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Saline – ratio to number of permanent lake/billabong</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Saline – ratio to number of swamp</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Saline – ratio to area of permanent lake</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Saline – ratio to area of swamp</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Mangrove</td>
<td>Mangrove – individual area</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Mangrove – distance to permanent stream</td>
<td>!</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Vegetation – vegetated by melaleuca</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Elevation</td>
<td>Elevation – &lt; 15m</td>
<td>!</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
Figure 1. Map of overall habitat suitability

Figure 2. Area of each suitability class in each catchment.
Table 2. Error matrix of the predicted habitat suitability classes compared to the observed density classes. The values are shown as a percentage of the predicted recordings.

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>23</td>
</tr>
<tr>
<td>Medium</td>
<td>18</td>
</tr>
<tr>
<td>Low</td>
<td>16</td>
</tr>
<tr>
<td>N/A</td>
<td>6</td>
</tr>
</tbody>
</table>

study as no more than a “proof of concept” in its present form. Enhancement to permit predictions relevant to management (eg sites warranting special protection) will require identification of additional data sources, perhaps at finer spatial scales, relevant to habitat needs of estuarine crocodiles. Exploration of options and refinement of methods are presently under investigation.

Acknowledgements

We would like to thank Professor Grahame Webb and Charlie Manolis who gave us the opportunity to present this work at the 17th Working Meeting of the CSG. Yusuke Fukuda also appreciates the support of Asako Kobayashi.

Literature


Workplace Health and Safety Queensland - Guidelines for the Exhibition and Farming of Crocodiles

Ryan Anderson

(Ryan.Anderson@dir.qld.gov.au)

Workplace Health and Safety Queensland, a Division of the Queensland Department of Industrial Relations, is currently rewriting its guidelines for the crocodile industry. The guidelines relate to the exhibition and farming of crocodiles only and not to activities such as meat processing.

Workplace Health and Safety Queensland invites stakeholders to comment on a draft copy of the guidelines available at the poster stand. Through working with industry practical guidance material can be developed that will make the exhibition and farming of crocodiles a healthier and safer activity.

Officers from Workplace Health and Safety Queensland will be attending the stand. Please feel free to make enquiries regarding the guidelines, the process for review or any general workplace health and safety issues.

Temperature-sex Determination in the Broad-snouted Caiman
(Caiman latirostris)

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[CIP = Author for Correspondence]

The present study was carried out with the captive colony of Broad-snouted caiman (Caiman latirostris) at the Laborat\~{o}rio de Ecologia Animal/ESALQ/USP, in the summer of 2001. We collected eggs from two clutches within the first 24 hours after egg-laying and incubated them at temperatures of 28, 30, 32 and 34°C. The eggs were placed on plastic trays and covered with vermiculite, which was kept humid. Digital Thermolab® 6030 thermometers were attached to each incubator near the egg trays, and the temperature was registered every morning. The mean hatching success at 30°C was 70%, at 32°C was 79% and at 34°C was 65%, and at 28°C was nil. At temperatures of 30°C the sex ratio produced was 10% male and 90% female; at 32°C it was 46% male and 54% female; and, at 34°C the gender produced in both nests was 100% male.
Diet and Condition of American Alligators (*Alligator mississippiensis*)

in Three Central Florida Lakes

Amanda N. Rice

Everglades National Park SFNRC, 40001 SR 9336, Homestead, FL 33034, USA
(ama_n_rice@usgs.gov, anrzoo@aol.com)

Understanding the diet of crocodilians is important because diet affects condition, behavior, growth, and reproduction. In this study, I examined the diet and condition of adult American alligators (*Alligator mississippiensis*) in three central Florida lakes, Griffin, Apopka, and Woodruff. Alligators ate a variety of vertebrates and invertebrates, but vertebrates were more abundant and fish dominated alligator diets in the lakes. Species composition of fish varied among the lakes. The majority alligator diets from Lakes Apopka and Woodruff was fish, 90% and 84% respectively. Lake Apopka alligators consumed a significantly (*P* = 0.006) higher proportion of fish. Fish were 54% of Lake Griffin alligator diets and the infrequent occurrence of reptiles, mammals, birds, and amphibians often resulted in a large biomass.

Alligator condition (Fulton’s Condition Factor, K) was significantly (*P*<0.001) different among the lakes. Alligators from Lake Apopka had the highest condition, followed by those from Lake Griffin, and alligators from Lake Woodruff had the lowest condition. Composition of fish along with diversity and equitability of fish in alligator diets may have contributed to differences in condition among lakes. The observed diet and condition differences probably reflect both habitat differences and prey availability in these three lakes.
Cranial Morphometric Study of Chinese Alligators in Different Age Groups

Xue Hui¹ Wu Xiaobing¹, Jiang Hongxin², Ruan Xiangdong² and Nie Jishan³

¹College of Life Sciences, Anhui Normal University, Key Lab for Conservation and Utilization of Biological Resources in Anhui, Wuhu 241000; ²Department of Wildlife Conservation, SFA, Beijing 100091; ³Anhui Researching Center for Chinese Alligator Reproduction, Xuancheng 242000, China

Abstract

Morphology study is the most basic part of biology, while cranial morphology study is especially important for crocodilians. In this paper, 98 samples were taken from different age groups of Chinese alligator according to the measurements adapted from Iordansky (1973), 14 variables were achieved from each specimens. Meanwhile, 10 ratio variables were also introduced because the cranial morphology traits depend on some of these ratios. The ratio variables characterized the short and broad trait of head, as well as indicated that the orbital is rather large and broad. Most of the ratios of different age groups have statistical difference except relative length of mandibular symphysis (RLSS; p= 0.369), which indicated that there were distinctions between different phases ontogenetically. This study suggested that ratio variables vary regularly most of the time. It’s obviously useful to grasp those ratios and their variations among different age groups for alligator’s cranium and fossil identification, age-estimation, and wild investigation.

Introduction

Cranial morphology traits depend on some optimal ratio variables in crocodyliidae and cranial morphology research has been done on many species, such as Alligator mississippiensis, Crocodylus novaeguineae, and Caiman latirostris (Allstead et al. 1995; Hall et al. 1994; Verdade et al. 1998). Beside the visual observation, the pertinent datum is much more necessary for qualitative analysis of cranial shape, containing the traits of length, width and height, and comparison between interspecies, different geographical populations, and different age groups. Iordansky (1973) defined 14 measurement variables and 10 ratio variables to depict the configuration and appearance of the whole cranium. These variables were received by most of the researchers (Verdade et al. 1998; Cong et al. 1998). Measurement record about Chinese alligator (Alligator sinensis) had been seen in several papers (Zhu et al. 1957; Huang et al.; Cong et al. 1998). But small sample size and uncoincident measurement standards didn’t suit for comparison and analysis of cranial morphology.

Mook (1921) and Iordansky (1973) found that the cranial shape varied with the animals growing, and snout changes from acute to blunt, from narrow to broad, and from short to long; orbital shape and size vary at the same time; the cranial sculpturing become more and more. Chen (1985) did some primary research on the difference of cranium between the young and the old, while the few samples can’t draw a conclusion for them. In this paper, the cranial shape of different age groups was compared to explore the rule in the varying course.

Materials and Methods

The samples were taken from Anhui Researching Center for Chinese Alligator Reproduction (ARCCAR). There are five age group animals in the center, including eight-month-old, one-year-old (about 15 months), two-year-old (about 27 months), three-year-old (about 39 months) and four-year-old (more than 51 months), containing few five-year-old individuals, as the four-year-old group and the five-year-old group were bred together and unable to be identified in ARCCAR, the four-year-old is considered as matured). Fourteen head variables were taken for each alligator, in addition to total length (TL) and snout-vent length (SVL) (Table 1). Instruments needed are simple: a steel electronic digital caliper (0.01 mm precision, third decimal unconsidered) and a tape. The study began at the onset of the animals’ hibernation period to reduce the infection on the animals.

Before analyzing the data, normality and homogeneity were tested by Kolmogorov-Simirnov, Shapiro-wilk and
Table 1. Measurements (adapted from Iordansky 1973).

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Explanation</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCL</td>
<td>Dorsal cranial length: anterior tip of snout to posterior surface of occipital condyle</td>
<td>mm</td>
</tr>
<tr>
<td>CW</td>
<td>Cranial width: distance between the lateral surface of the mandibular condyles of the quadrates</td>
<td>mm</td>
</tr>
<tr>
<td>SL</td>
<td>Snout length: anterior tip of snout to anterior orbital border</td>
<td>mm</td>
</tr>
<tr>
<td>SW</td>
<td>Basal snout width: width across anterior orbital borders</td>
<td>mm</td>
</tr>
<tr>
<td>OL</td>
<td>Maximal orbital length</td>
<td>mm</td>
</tr>
<tr>
<td>OW</td>
<td>Maximal orbital width</td>
<td>mm</td>
</tr>
<tr>
<td>IOW</td>
<td>Minimal interorbital width</td>
<td>mm</td>
</tr>
<tr>
<td>LCR</td>
<td>Length of the postorbital cranial roof: orbital border to the posterolateral margin of the squamosal</td>
<td>mm</td>
</tr>
<tr>
<td>WN</td>
<td>Maximal width of external nares</td>
<td>mm</td>
</tr>
<tr>
<td>PXS</td>
<td>Length of palatal premaxillary symphysis</td>
<td>mm</td>
</tr>
<tr>
<td>ML</td>
<td>Mandible length</td>
<td>mm</td>
</tr>
<tr>
<td>LMS</td>
<td>Length of the mandibular symphysis</td>
<td>mm</td>
</tr>
<tr>
<td>WSR</td>
<td>Surangular width</td>
<td>mm</td>
</tr>
<tr>
<td>LM</td>
<td>Length of lower ramus</td>
<td>mm</td>
</tr>
</tbody>
</table>

Levene-test on them. After tested, some data was transformed to fit for the need of the analysis later. One-way ANOVA and Tukey’ HSD were used to test the difference significance and compare the correspondent data.

Results

Descriptive statistics for measurements of the head of each age group were shown in Table 2. Ten ratio variables were introduced (see Table 3) and the ratio were tested by One-way ANOVA and Tukey’ HSD to find the difference between age groups (see Table 4). The result indicates that most of the ratio variables exist difference between each group.

Analysis and Discussion

Ratios about cranium

In other species of Crocodylidae, there is a difference between two measurements - dorsal cranial length and axial length of cranium and axial length cranial (between the tip of the snout and the posterior margin of the occipital condyle) is longer usually, but the two measurements are very similar in Chinese alligator. So the dorsal cranial length (DCL) is regarded as cranial length approximately. Cranial length of 8-month old Chinese alligator is about (28.35 ± 0.19) of SVL, (13.53 ± 0.10) of TL, while the length of the 4-year old is about (22.75 ± 0.41) of SVL, (11.34 ± 0.07) of TL. The proportion in SVL becomes less and less gradually from 8-month to 4-year-old (F₄₉= 33.062, p<0.001). Thus it can be seen, the relative length of cranium takes on reverse ratio function relationship with age (see Fig. 1).

Usually cranial width index was used to express relative cranial width, which is the major factor to decide the cranial type, as well as directly reflect whether the cranium is broad or not. The high value of cranial width index embodies the short broad trait of cranium of Chinese alligator obviously. Cong et al. (1998) compared the Chinese alligator with other species, and found that the index of Chinese alligator was greater than most of other crocodilians. When testing RCW of 5 age phases of Chinese alligators, we found that the value of one-year and four-year individuals is relatively high; that of 8-month and three-year individuals was not high; and it is relatively low in the two-year individuals (see Fig. 1, RCW). The cranial width index of different age varies irregularity and the RCW has no linear correlation with age.

Ratios about snout

Snout also can be called rostrum, whose relative length determines the stretch of itself and effects on the cranial
Table 2. Descriptive statistics for head-size in Chinese Alligator. N= sample size; M= mean; CV= coefficient of variation; O.R.= observed value range.

<table>
<thead>
<tr>
<th></th>
<th>8 month (N= 18)</th>
<th>One year (N= 20)</th>
<th>Two year (N= 20)</th>
<th>Three year (N= 20)</th>
<th>Four year (N= 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>CV</td>
<td>O.R.</td>
<td>M</td>
<td>CV</td>
</tr>
<tr>
<td>DCL</td>
<td>39.74</td>
<td>0.033</td>
<td>37.96-43.60</td>
<td>52.21</td>
<td>0.054</td>
</tr>
<tr>
<td>CW</td>
<td>24.51</td>
<td>0.054</td>
<td>23.08-25.88</td>
<td>32.67</td>
<td>0.074</td>
</tr>
<tr>
<td>SL</td>
<td>16.72</td>
<td>0.086</td>
<td>11.86-19.00</td>
<td>24.37</td>
<td>0.069</td>
</tr>
<tr>
<td>SW</td>
<td>18.88</td>
<td>0.093</td>
<td>13.60-21.80</td>
<td>25.09</td>
<td>0.073</td>
</tr>
<tr>
<td>OL</td>
<td>12.85</td>
<td>0.038</td>
<td>12.16-13.62</td>
<td>15.49</td>
<td>0.054</td>
</tr>
<tr>
<td>OW</td>
<td>10.99</td>
<td>0.043</td>
<td>10.20-12.00</td>
<td>12.65</td>
<td>0.062</td>
</tr>
<tr>
<td>IOW</td>
<td>2.68</td>
<td>0.132</td>
<td>1.94-3.34</td>
<td>4.48</td>
<td>0.124</td>
</tr>
<tr>
<td>LCR</td>
<td>13.73</td>
<td>0.062</td>
<td>12.24-16.48</td>
<td>16.24</td>
<td>0.072</td>
</tr>
<tr>
<td>WN</td>
<td>6.70</td>
<td>0.029</td>
<td>6.28-7.00</td>
<td>8.48</td>
<td>0.080</td>
</tr>
<tr>
<td>PXS</td>
<td>8.07</td>
<td>0.081</td>
<td>6.56-8.84</td>
<td>11.02</td>
<td>0.074</td>
</tr>
<tr>
<td>ML</td>
<td>39.32</td>
<td>0.031</td>
<td>37.52-41.68</td>
<td>55.39</td>
<td>0.068</td>
</tr>
<tr>
<td>LMS</td>
<td>6.84</td>
<td>0.056</td>
<td>6.12-7.70</td>
<td>13.09</td>
<td>0.097</td>
</tr>
<tr>
<td>WSR</td>
<td>23.53</td>
<td>0.045</td>
<td>22.00-26.36</td>
<td>30.42</td>
<td>0.073</td>
</tr>
<tr>
<td>LM</td>
<td>22.70</td>
<td>0.060</td>
<td>20.54-25.62</td>
<td>39.22</td>
<td>0.070</td>
</tr>
</tbody>
</table>
Table 3. Head-size ratios (introduced from Iordansky 1973). Usually use the ratio as index form, meaning 100 times of the relative length.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCW</td>
<td>Relative cranial width: CW/DCL</td>
</tr>
<tr>
<td>RLST</td>
<td>Relative length of snout: SL/DCL</td>
</tr>
<tr>
<td>RWST</td>
<td>Relative width of snout: SW/SL</td>
</tr>
<tr>
<td>ROL</td>
<td>Relative orbital length: OL/DCL</td>
</tr>
<tr>
<td>ROW</td>
<td>Relative orbital width: OW/OL</td>
</tr>
<tr>
<td>RWI</td>
<td>Relative interorbital width: IOW/OL</td>
</tr>
<tr>
<td>RWN</td>
<td>Relative width of external nares: WN/(DCL-SL)</td>
</tr>
<tr>
<td>RPXS</td>
<td>Relative length of premaxillary symphysis: PXS/DCL</td>
</tr>
</tbody>
</table>
| RLSS         | Relative length of mandibular symphysis: L MS/ML |}

![Figure 1. The bars show the mean ratios about cranium of different age groups, Y scale axis refer to the ratio value.](image1)

![Figure 2. The bars show the mean ratios about snout of different age groups, Y scale axis refer to the ratio value.](image2)

length and shape of whole cranium. Figure 2 indicates that RLST become greater gradually and the values of different ages were documented to have significant difference by test. Obviously, the extension of snout increases step by step, at the same time the orbital location move backward relatively.

The width index of snout (100 times of RWST) is used to judge the extent of long or narrow, short or broad: ①<40 refers to elongate, ②>70 refers to broad, and ≥40, <70 refers to intermediate. Mean width indexes of snout of the young and the old are all about 100, even more than 100. The snout width index listed in this paper is greater than that with 88-83 (Cong, L.Y, 1998), which may be caused by the measurement difference between the living and the skeleton or other reasons. However, the Chinese alligator belong to broad type without any question. In the same type, index of Broaded-snouted Caiman (Caiman latirostris) is especially great, and even reaches near to 130 in some large individuals (Verdade 1998). RWST of 8-month-old individuals is the greatest among all objects measured, one-year secondly, the three- and four-year old have no significant difference with the two aforementioned, the two-year individuals is lowest. Without considering the two-year old, snout width index take on decreasing trend with the animals growing up.

**Ratios about the orbita**

The length of orbita is always greater than the width of orbita in crocodilians, the smaller the individual, the bigger the proportion of orbita in cranium, which presents as ROL and ROW decreases with the animals growing up in the
measurements, whereas RWI takes on increasing trend. As Figure 3 shows, RLST and RWST reduce gradually with growing. This indicates the proportion of orbita in cranium shows descending trend and the shape becomes narrow relatively. RWI is relatively low in the 8-month old; other age stages don’t differ significantly. Through comparison, values of RWST and RLST are greater than that of other species, nevertheless the RWI are lower than other ratios. These differences make up of the large and broad trait of orbita.

Other ratios

The relative length of premaxillary symphysis (RLSS) increases with the age increasing, that is to say, the proportion of premaxillary symphysis in cranium appears increasing trend and they grow relatively fast in contrast to whole cranium. The relative width of mandibular of 8-month individuals is the greatest, four-year-old individuals in the next place, one-year, three-year-old thirdly, the two-year-old is the lowest, whole trend take on “V” shape (see Table 4): the 8-month value is the greatest, then the ratio descends with growth, later rise again. No age differences were recognized in RLSS. RWN of different age groups differs significantly and takes on rapidly increasing tendency.

Conclusions

In taxonomy, Chinese alligator belongs to genus Alligator, Family Alligatoridae. High RCW and RWST values decide the outstanding morphology traits of them - broad cranium and broad snout. So, this species is classified as short-snouted type. The value of ROW is high relatively, and the orbita is relatively broad, when compared with other species. Some ratio variables (RLST, RPSX, RWN) take on increasing trend, some (ROL, RWST) take on descending trend, and several (RWM) takes on descending then increasing trend. Thus it can be seen, the whole ontogenetic trends of cranium in Chinese alligator take on: With age increasing, the trend of relative cranial width was not evident, probably the hatchlings and adults have great RCW value, while the middle ages have low value; The snout extend fast relatively, which make the snout turn narrow relatively; Both ROL and ROW reduce with individuals growing up, which reflect the relatively lessening of orbita against the age. In addition, both the length of premaxillary symphysis and width of nares increase rather rapidly, and the relative width of mandibular vary in V-shaped.

It is obviously useful to grasp those ratios and their variations of different age groups for alligator’s cranium and fossil identification. It also offered a feasible way to estimate the age of Chinese alligators. When identifying the cranium and fossil, the pertinent head-size variables and ratio variables can be used as standard to compare with the values of cranium and fossil being identified. Meantime, the regression equations between head-size variables and snout-vent length, the head-size variables, head ratio variables and age can predict the body length and age of the alligator met in wild.
Table 4. Head-ratio variables’ mean value and comparison between different age groups of Chinese alligator. One-way ANOVA to test the difference between different age groups (significance to 0.05 level), the result indicates except the relative length of mandibular symphysis (RLSS) all of other variables have significant difference. Means with different superscripts differ significantly _a>b>c>d._

<table>
<thead>
<tr>
<th>Age</th>
<th>RCW (M±SE)</th>
<th>RLST (M±SE)</th>
<th>RWST (M±SE)</th>
<th>ROL (M±SE)</th>
<th>ROW (M±SE)</th>
<th>RWI (M±SE)</th>
<th>RWN (M±SE)</th>
<th>RPXS (M±SE)</th>
<th>RLSS (M±SE)</th>
<th>RWM (M±SE)</th>
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</thead>
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<tr>
<td>8 m</td>
<td>0.6168±0.0031&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.4214±0.0095&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.1301±0.0131&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.3234±0.0027&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.8562±0.0089&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.2085±0.0058&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.2932±0.0056&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.2030±0.0034&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.1739±0.0022</td>
<td>0.5985±0.0052&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>0.5826±0.6356</td>
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<td>1.0356-1.2862</td>
<td>0.3060-0.3436</td>
<td>0.7944-0.9155</td>
<td>0.1588-0.2504</td>
<td>0.2073-0.3188</td>
<td>0.1702-0.2184</td>
<td>0.1592-0.1940</td>
<td>0.5366-0.6324</td>
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<td>1.0304±0.0121&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>0.8175±0.0113&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.2895±0.0080&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>0.2111±0.0025&lt;sup&gt;d&lt;/sup&gt;</td>
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Acknowledgements

We thank the Anhui Research Center for Chinese Alligator Reproduction for their gracious assistance in the data collection. This study was sponsored by National Natural Science Foundation of China (NSFC, No. 30270213), Natural Science Foundation of Anhui Province (No. 01043501), special funds for Anhui Young Leaders Fellowship Fund (04043049), the grants from National Forestry Administration and Conservation and Utilization of Important Biological Resources of Anhui Key Laboratories.

Literature


David H Wilken and Eric Langelet

Mainland Holdings Ltd, PO Box 196, Lae 411, Papua New Guinea
crocfarm@mainland.com.pg

Introduction - Background

Papua New Guinea’s two species of crocodiles, the Saltwater crocodile (*Crocodylus porosus*) and the New Guinea Freshwater crocodile (*Crocodylus n. novaguineae*) are not only an integral part of the traditional culture for the Sepik River people but, since the 1950s have also become a commercially valuable natural resource.

Because both species were extensively exploited for their skin and to a lesser extend their meat, the PNG Government in 1966 enacted the *Crocodyle Trade (Protection) Act* to regulate the crocodile industry. Monitoring mechanisms to ensure their long term survival and, consideration for the welfare of the rural population have also been introduced.

In the early 1980s, the introduction of ranching and farming schemes added even more incentives for village people to continue benefiting from their natural resources while also encouraging them to actively protect the environment.

To further enhance the impact of its crocodile management program, the Department of Environment and Conservation in 1985 introduced a selective harvest of wild crocodile eggs in the surveyed area of the Middle Sepik River. This activity is run conjointly with the aerial survey and is closely monitored by DEC wildlife rangers. Mainland Holdings Ltd (MH), the largest commercial farm in Papua New Guinea, is an integral part of this national conservation policy. The company’s ranching program largely contributes to the economic success of the wild harvest of juvenile crocodiles and crocodile eggs.

Eggs Harvest - 2002 and 2003

Over the years, the combination of regular awareness campaigns, the effective enforcement of the *Crocodyle Trade (Protection) Act* and various private commercial incentives have encouraged the steady recovery of both crocodile species in the Sepik.

Since 2000, the Sepik Wetlands Management Initiative, a local non-Government organization based in Ambunti, has also actively campaigned to strengthen the concept of “sustainable use of the wildlife” amongst the villagers. A Participatory Rural Appraisal has concluded that crocodiles still constituted a major source of incomes for the Middle Sepik communities but, also raised concerns about the long term sustainability of the nesting habitat.

Consequently, in March 2002, the DEC agreed to further increase the harvest program for the wild Saltwater crocodile eggs in the Middle Sepik, in return for habitat conservation. A total of 3542 fertile eggs from 62 nests were purchased in this first motorised canoe harvest.

Again, in February 2003, a team of two Mainland employees accompanied by a DEC wildlife ranger and local guides departed Ambunti in two groups to harvest saltwater crocodile nests. One team visited the areas from Kubkain to the mouth of the May River, while the other team concentrated its search from Kubkain down to Wagú Lakes.

During this time 138 nests and 8346 eggs were harvested. Later, some more nests were brought in by the landowners during the annual aerial nests survey conducted by the DEC. At third trip was organized to make cash payment for the eggs harvested. Unfortunately by that time most of the remaining nests had already hatched or were flooded.

In 2003, it was generally observed that most of the habitats had well regenerated since the widespread burning of the 1997 “El Niño” drought and, only one hook / trap was found. The landowners were found to be very enthusiastic with the concept and keen to protect the nesting areas while at the same time reaping a better financial benefit as compared to hunting juvenile crocodiles.
Financial perspective of eggs harvesting for the landowners

Average price paid by MH for a 2-year-old live crocodile (71-75 cm TL) = K50.00

Average price paid by a local crocodile buyer to the hunter (landowner) for the same crocodile = +/- K25.00

Net benefit earned by the resource owner

<table>
<thead>
<tr>
<th>Price paid per crocodile</th>
<th>K25.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunting costs (petrol, batteries, ...), freight, mortality losses</td>
<td>-K15.00</td>
</tr>
<tr>
<td>Net profit per crocodile =</td>
<td>K10.00</td>
</tr>
</tbody>
</table>

It is estimated by MH suppliers that the mortality of small crocodiles so caught could be as high as 50%. That is, 100 crocodiles supplied to MH = 200 wild crocodiles taken from the wild.

On the other hand, MH pays K7.00 per fertile egg. In 2003, the incubator hatchability reached 80%. That is, 100 hatchlings = 125 fertile eggs taken from the wild.

If we also take into account that only 4.1% of the eggs laid (with a 25% hatchability) in the wild will survive as juveniles (Webb and Manolis 1989), the ecological cost of small crocodile hunting versus egg harvesting is:

100 live crocs = 200 wild animals = 1242 fertile eggs
100 hatchlings = 125 fertile eggs.

These 1242 fertile eggs translate into no more than K3750 (200 animals removed from the wild - 25% mortality = 150 crocs sold to local buyer x K25.00 each) for the landowner, or a value of K3.02 per fertile egg, compared to K7.00 per fertile egg paid by MH! There is also a 10x “ecological” saving factor in harvesting fertile eggs versus live crocodiles.

It is therefore our belief that by giving the resource owners a much greater return from the assets, they will continue supporting the initiative of eggs harvesting and refrain from burning the nesting habitats.

Eggs Harvest - 2004

In February 2004, another Saltwater crocodile harvest was undertaken, at an earlier date to avoid the flooding of the river and to precede the peak hatching period, again with two teams.

It was decided not to harvest eggs in areas where the nesting habitats were still threatened or where villagers did not yet show much interest in preserving it. The villagers were informed of the harvesting dates and more actively searched for the nests. As a result, this year’s harvest yielded 12,756 eggs from 215 nests.

As in 2003, the accurate position of all the accessible nests by motorized and paddle canoes were recorded on a “Garmin etrex” handheld GPS.

Conclusions

It is believed that the economic incentive to protect the breeding stock and the habitat is having a very positive effect on the recovery of the crocodile population. Most of the swamps and scrolls visited showed healthy vegetation suitable as nesting habitat and quite a few nests were built by young females. The teams noticed that less nests had been “raided” for egg consumption.

It appears that the recent initiative by SWMI, in collaboration with DEC and MH, to increase the annual saltwater crocodile egg harvest in the Middle Sepik has been positively supported by the villagers. This year’s overwhelming participation by communities even exceeded our predictions.

From a conservation point of view, it must be emphasized that only the accessible nests, built on the fringes of the swamps were harvested. Those situated deep in the herbaceous swamps or a long distance from the villages were spared. Many landowners also chose to save some nests to hatch naturally. Because of the nature of the nesting
habitat and the harvesting technique, it was virtually impossible to quantify the proportion of nests left. Only a systematic aerial survey would enable an observer to scientifically determine the harvesting index.

**Literature**


Observations of the Effect of Toxic Blue Green Algae on Crocodiles

Vicki R. Lowing

6 Minnipa Drive, Hallett Cove 5158, SA, Australia (vicki@txc.net.au)

Introduction

An 8-year-old Australian Freshwater Crocodile (Crocodylus johnstoni), raised from a hatchling in a domestic environment near the township of Deniliquin, located in the Murray-Darling Basin Region, southwestern New South Wales, Australia, was observed to develop abnormal various signs and symptoms following exposure to water containing high blue green algal cell counts.

This area is predominately rice production, requiring high levels of irrigation with increasing usage of herbicides, pesticides and fertilizers (nutrient pollutants, particularly phosphates). Eutrophication is recognized as a critical factor in creating an algal bloom; as well as low flow of water (irrigation) and high summer temperatures. The environmental impact is one of increasing mixed strains of blue green algal cells in the local water supply.

Findings

During the period from December 2002 to April 2003, environmental daytime temperatures ranged from approximately

![High Algae Alert for Mulwala Canal](image)

Figure 1. High algae alert.
Medium Algae Alert for Mulwala Canal

Alert levels for blue green algae in the Mulwala Canal have been downgraded from a high alert to a medium alert level, coinciding with a fall in algae levels in the Murray River.

Murray Irrigation has reduced its alert level after extensive monitoring of all its main irrigation supply channels. Algae levels in the Mulwala Canal and main lateral channels were at a medium alert level when samples were taken on Monday and Tuesday this week.

Murray Irrigation’s environment manager Alex Marshall said “although algae levels appeared to have fallen, landholders should not use channel water for domestic supplies and should make contingency arrangements for alternative water supplies.”

“Blue green algae is potentially toxic and dangerous to human and animal health,” Mr Marshall said. “Water affected by blue green algae is not suitable for drinking or cooking and skin contact should be avoided. Boiling affected water will not make it safe to use. Drinking affected water may cause gastroenteritis and liver damage in humans. It is also known to cause stock illness or even death and dogs are particularly sensitive.”

Murray irrigation is closely monitoring the situation and will continue to inform shareholders about the occurrence of algae.

Landholders with stock are asked to be watchful for signs of blue green algae in their water supplies. Scums can form, varying in colour from pale green/brown to bright fluorescent green, and may appear paint-like or granular in texture. Under windy conditions, the scum can accumulate along leeward banks. Blooms of blue green algae often give off a characteristic musty odour. Only examination of a water sample under the microscope will confirm the presence of blue-green algae.

Symptoms of blue green algae affected stock include scours, disorientation or other illness.

Further information on blue green algae detection and treatment can be found by calling the DLWC hotline 1800 088 510 or at the following web site: www.murraybluegreenalgae.com.

Ends

For further information please contact:
Mr Warren Elsbury, Deputy General Manager 03 5881 9352, mobile 0429 819 351
Mr Alex Marshall, Environment Manager 03 5881 9331, mobile 0428 819 331

Figure 2. Medium algae alert.

30°C to 45°C, resulting in Medium to High Blue Green Algae Alert Warnings for the local water supply in this area (Figs. 1 and 2).

However, these alert warnings were only advertised in a limited way, thus exposing the crocodile to water heavily contaminated with blue green algal cells over long periods of time throughout the summer months. High counts of toxic blue green algal cells were also identified from water samples taken from the local water supply (Fig. 3 and 4).

The crocodile (a healthy and alert subject prior to exposure or submersion in water contaminated with high counts of toxic blue green algal cells), was observed to show the following signs and symptoms immediately afterwards:

- Change in skin colour (head and jaw) from a pale creamy colour to a dark grey, almost black in colour. On occasions, a distinctive, bright yellowish tinge colour was also observed;
- Dilated pupils and depressed respirations;
Vicki Lowing

From: "Penny Sloane" <pennys@murrayirrigation.com.au>
To: <vlowing@mcmedia.com.au>
Cc: "Chris Shaw" <chriss@murrayirrigation.com.au>
Sent: Wednesday, 4 February 2004 12:59 PM
Subject: BGA

Vicki

First last years results:
Sample date: 10 Feb 03
Description: Q722B dam
Results: anabaena 2370 cells/ml
    coelosphaerium present in large numbers (not counted)
    (Counted at MIL lab.)

Sample date: 29 Jan 03
Description: Mundiya 1 @ Q721
Results: coelosphaerium 26768 cells/ml
    (Counted at Water Environment Lab. Sydney)

Coelosphaerium is a species found in Australia of the same genus as those known to be toxic elsewhere. These were the only two samples in the entire MIL area to have coelosphaerium identified as present.

This years samples:
Sample date: 30 Jan 04
Description: Q722B dam water
Results: anabaena (mixed species) 12423 cells/ml
    Green algae and diatoms present
    (Counted at MIL lab.)

Figure 3. Results of water sample testing.

- Mouth ulcers;
- Increasing difficulty in mobilization including sliding on belly and dragging rear limbs, with loss of power in these limbs for a period of time; and,
- Circling, postural abnormalities, and disorientation for short periods of time (approximately 10 to 20 minutes), were also observed on many occasions.

Following observations of the above signs and symptoms, a recovery period lasting four to five days was then observed. During this period the crocodile remained out of water for the majority of the time, displaying acute lethargy and appearing very dark in colour. These signs and symptoms were also complicated by those of dehydration. Following this recovery period, the crocodile would once again appear healthy and active, until further exposure to water contaminated with high counts of toxic blue green algal cells.

Serum pathology was also attended on the crocodile following several exposures to the contaminated water and the results received indicated the following:- Decreasing blood glucose levels; elevated se.cadmium levels; anaemia; increased white cell count; basophilia, and heterophilia (interpreted as: ” may reflect sub-acute inflammation” ).

Conclusions

These observations were made over a four year period on the crocodile, on a one to one basis. A journal was also maintained over this period reflecting the health changes observed. It is considered that both the chronic and the acute exposure to the toxic blue green algal cells were responsible for these health changes. The health of the crocodile has appeared to have improved markedly since a recent move to another State and subsequent removal from further exposure to water contaminated with high counts of blue green algal cells.
Figure 4. Results of water sample testing.

Note: The above Blue Green Algae Alert Warnings and Results from water samples were not received until March 2003 and February 2004 respectively.
Relationship between Telomere Length and Body Length
in Alligator mississippiensis

Nicole Scott¹, M. Haussmann¹, C. Vleck¹, Phillip Trosclair² and Ruth Elsey²

¹Dept of EEOBiology, Iowa State University, Ames, IA USA; ²Louisiana Dept. of Wildlife and Fisheries, Grand Chenier, LA, USA

Free-living American alligators grow about 30 cm per year until they reach about 2 m. Then growth slows, so size is not an accurate estimator of age. Our goal was to determine whether telomere lengths in blood cells shorten with growth in a predictable manner. Telomeres are DNA sequences at the end of each chromosome that do not fully replicate at cell division in most animals; thus telomeres are usually shorter in older animals. We sampled erythrocyte DNA from wild-caught animals of different body lengths and from captive-reared yearlings. Telomere length was determined by separation of restriction-digested DNA by electrophoresis, followed by hybridization to P³²-labeled oligonucleotides specific for the telomere. Mean telomere length for each animal was determined by densitometry. We found no significant difference in telomere lengths over the range of animals sampled (~30-300 cm), although males tended to have longer telomeres than females. The mechanisms preserving telomere length in these long-lived animals are not known.

Thyroid Hormone Biology of Embryonic Saltwater Crocodiles
(Crocodylus porosus)

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Thyroid hormones (THs) are essential for vertebrate development. This study investigated three aspects of thyroid hormone biology during the development of embryonic saltwater crocodile. Free thyroxine (T₄) and free triiodothyronine (T₃) levels in blood gradually rose during the late stages of incubation (days 60, 68 and 75), and were maximal at hatching (day 80). These changes could have been brought about by an increase in T₄ release from the thyroid gland, and changes in the metabolism of THs by iodothyronine deiodinases. Specifically, we showed a decrease in hepatic T₃ to diiodothyronine (T₂) conversion by a low Km inner ring deiodinase, and an increase in T₃ to T₂ conversion by a high Km outer ring deiodinase. Thyroid hormone distribution proteins (THDPs) are required for distribution of THs. Albumin was present as a THDP in serum at all ages examined. A second THDP was identified as transthyretin and was detected in serum at days 60, 68, 75 of incubation, and at day-1 post-hatch, but not in serum from 6 month-old or adult crocodiles. Changes in TH serum levels, TH metabolism and the presence of a second THDP demonstrate the importance of THs during the late stages of embryonic development.
Pit Holes in Nile Crocodile Skins

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Abstract

Deep holes in skins of three-year-old farmed Nile crocodiles were dubbed “pit holes”. In histopathological sections they appeared to be branched and were lined by an intact epidermis. Earlier lesions from two-year-old animals were in similar form but the surrounding tissue contained remnants of inflammatory cells. The skins of one-year-old animals contained large cysts of a diameter equal to the thickness of the dermis. These cysts were surrounded by an intense inflammatory reaction and only partially lined by epidermis. Investigations into the cause of the pit holes continue.

Introduction

The skin diseases of crocodiles were reviewed by Huchzermeyer (2003). Small holes of unknown causes in American alligator skins were described by Haire (1997). These were dubbed “pix” and later found to be caused by erupting dermal granulomata from which the fungus Hortaea werneckii was isolated (Dickson et al. 2002).

A South African crocodile farmer had a number of skins downgraded because of small holes, “pit holes”, found prevalently in the ventrolateral region of affected Nile crocodile skins. At close examination these holes were visible also in the skin of live crocodiles before slaughter. This paper describes the preliminary findings of an investigation into the cause of the pit holes.

Materials and Methods

Samples were taken from the skins of slaughtered crocodiles as well as from selected younger age groups. These were fixed in 10% buffered formalin and after fixation processed for routine histological sectioning, stained with haematoxylin-eosin stain and examined using light microscopy.

Results

The histopathological examination of the skins from slaughtered crocodiles (three years old) showed deep holes lined with a healed epidermis and without any inflammatory reaction. Two-year-old crocodiles had similarly healed lesions but with some inflammatory and pigment cells in the dermis surrounding the lesion. The one-year-old crocodiles had active lesions consisting of deep cysts penetrating the whole dermis, empty or filled with debris and surrounded by an intense inflammatory reaction.

Discussion

The canals seen in the histopathological specimens from 2- and 3-year-old crocodiles are believed to be collapsed cysts seen in skin preparations of the youngest animals. Preliminary investigations appear to indicate that the pit holes are caused by an infectious agent and that the incidence of this condition is linked to poor hygiene, although bacterial and fungal cultures so far gave negative results. The incidence appears not to be limited to one farm only. It also appears that the condition has been seen before but veterinarians were not consulted. Investigations continue.

Literature


Economic Valuation of the Tarcoles River C. acutus Population
Using the Travel Costs Method

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The value of crocodiles as an incentive for ecotourism at the Río Grande de Tárcoles in Costa Rica was measured by using the travel cost method. By analyzing travel behavior, the study reveals that foreigners are willing to pay considerably for the experience of visiting the site to see crocodiles. The travel cost method takes into account the total expenses undergone by visitors and assumes that costs increase with the distance to the site and therefore the number of visitors decrease with increasing costs. The economic value of a natural resource is estimated according to people’s willingness to assume the cost of visiting a natural site. The present value of the Río Grande de Tárcoles’ crocodile population, based on tourism, is found to be 19.5 times in magnitude greater than the purchase price currently paid for the hides. Ecotourism then proves to be an important conservation strategy because it focuses on the sustainable use of natural resources by providing an income to local communities.

The Ecological Distribution of Crocodiles in South West Cameroon:
Threats and Conservation Potentials

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The ecological distribution of crocodiles from the rain forest of South West Cameroon was carried out between 2002 and 2003. Investigations indicate that three species of the African crocodile, Crocodylus niloticus, Crocodylus cataphractus and Osteolaemus tetraspis, still exist in southwest Cameroon. Evidence reveals the later has a scattered distribution all over the region in tributaries of larger rivers, swamps and water ponds. It appears to be abundant but threatened by bush meat trade. Five smoked specimens where observed from an individual in a bush meat market. Larger rivers harbour considerable populations of the Nile crocodile with seven sites identified. It is hunted for its flesh, skin and eggs (an individual found with 53 eggs) sold at high prices. C. cataphractus is the rarest in the region and no direct evidence was recorded. These observations suggest areas where efforts of conservation and management should be implemented.
Research on Habitat Selection by Wild Chinese Alligator (*Alligator sinensis*)

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Research on the habitat selection of wild Chinese Alligator was conducted from September 2002 to July 2003 at Natural Conservation Regions of Chinese Alligator in southern Anhui Province. We sampled 22 specimens in order to research habitat selection by Chinese alligator. Eight ecological factors in correlation to subsistence of alligator such as shelter condition of bank, island of water area, stabilization of water, pH value of water, snail abundance, soil texture, density of bamboo and vegetation type were selected according to data of investigation on the spot. We adopted the methods of resource selection functions and principal components to analyze habitat selection. The results show that the model of first and second Principal Component: Z₁ the first Principal Component, Z₁ = 1.312X₁ - 0.253X₂ - 0.268X₃ + 0.035X₄ - 0.149X₅ + 0.160X₆ - 0.070X₇ - 0.174X₈; Z₂ the second Principal Component, Z₂ = -0.127X₁ - 0.047X₂ - 0.092X₃ + 0.054X₄ + 1.138X₅ + 0.123X₆ + 0.145X₇ + 0.095X₈. The Logistic regression model is logist P = -2.451 + 2.612Z₁ + 1.434Z₂ + 1.564Z₅ + 0.941Z₇ - 1.044Z₅ + 1.408Z₆ + 1.423Z₇ - 0.039Z₈. The results suggested that shelter condition of bank influenced habitat selection significantly and the subordinate ecology factor was pH value of water, while the ecological factors (Island of water area and Vegetation type) influenced habitat selection slightly.

The Population Status of Rescued Chinese Alligators From Wild in Anhui Research Center for Chinese Alligator Reproduction

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We analysed 212 rescued Chinese alligators and 21 nests in the wild from 1980 to 1988. The rescued alligators were mainly distributed in Xintian, Yishan and Yangling (24.5, 14.6 and 12.7% respectively), and included hatchlings (8.5%), subadults (18.5%) and adults (73%). These alligators laid a mean of 3 nests with mean of 13 eggs per nest every year. After breeding for several years, 14 individuals (6 males, 8 females) produced by the rescued alligators were released into the wild. The rescued alligators were also bred as stock populations of present breeding populations in Anhui Research Center for Chinese Alligator Reproduction.
Spotlight Surveys of New Guinea Freshwater Crocodile (*Crocodylus novaegeuineae*) in Mid-Zone Memberamo River (Memberamo and Rouffaer River Systems), Papua Province, Indonesia

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Abstract

All available spotlight survey data for the New Guinea Freshwater Crocodile (*Crocodylus novaegeuineae*) in mid-zone Memberamo River, Papua Province, Indonesia, were analysed. Survey areas consist of four rivers (Memberamo Mati, Jaro, Baso and Soi) and 10 lakes (Sobaki, Kamika, Waropen, Kweri Satu, Kweri Dua, Apuse, Berneham Satu, Berneham Dua, Cabang Tiga Satu and Cabang Tiga Dua), surveyed at different times between 1987 and 2002.

Results from the Jaro River (1989-2002) indicated a significant increase in non-hatchling density over time. All other areas surveyed indicated stable non-hatchling densities over the periods of survey. The latest surveys (2001-2002) were affected by high water levels (flooding), which are likely to have reduced the sightability of crocodiles.

Trends in live crocodile and skin harvests appear to be driven by market forces and a moratorium (early 1990s), rather than any limitations of the crocodile resource. In general, the population of *C. novaegeuineae* in Mid-zone Memberamo River has been relatively stable, despite extensive harvesting.

Introduction

The people of Indonesia have historically used crocodiles for a variety of non-commercial purposes. In the past ten years, commercial collection from the wild has threatened the population status of Indonesian crocodiles. As pressure from the commercial hunting is continuous, the successful conservation of Indonesian crocodiles will depend on the constant monitoring of their populations. Papua is one of several provinces in Indonesia which historically accommodate unknown numbers of commercial crocodiles (Webb and Jenkins 1991).

Monitoring of the crocodile population in the Mid-zone Memberamo River (see Appendix 1 for the region) was conducted from 2000 to 2002, with spotlight surveys in Kamika Lake (Kaureh District) and Waropen, Kweri Satu, Kweri Dua, Apuse, Berneham Satu, Berneham Dua, Cabang Tiga Satu and Cabang Tiga Dua Lakes (Memberamo Hulu District). Additional surveys were undertaken in 2001-2002 in the Memberamo Mati, Jaro, Baso and Soi Rivers, and Sobaki Lake (Memberamo Hulu District), all of which had been surveyed previously by the FAO-HPHA Project. All of these areas are within the Memberamo and Rouffaer River systems. Interviews with local people and harvest data indicate that the dominant species is *Crocodylus novaegeuineae*.

This paper presents the most recent spotlight survey data (Table 1), and summarizes all spotlight data and population trends (total numbers and non-hatchlings) for *C. novaegeuineae* in Papua Province.

Methodology

1. Timing of Surveys

   Surveys in 2000-2002 were undertaken in September-December each year (Table 1).
Table 1. Dates of *C. novaeguineae* spotlight surveys in mid-zone Memberamo and Rouffaer River systems, 2000-2002.

<table>
<thead>
<tr>
<th>Year</th>
<th>Duration</th>
<th>Number of sites</th>
<th>Total length of survey</th>
<th>Conducted by</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>September 27-October 2</td>
<td>9 lakes</td>
<td>29.9 km</td>
<td>KSDA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td>2001</td>
<td>November 26-December 5</td>
<td>10 lakes, 4 rivers</td>
<td>162.5 km</td>
<td>LIPI-KSDA</td>
<td>Kurniati <em>et al.</em> (2001)</td>
</tr>
<tr>
<td>2002</td>
<td>December 13-23</td>
<td>10 lakes, 4 rivers</td>
<td>143 km</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
</tbody>
</table>

2. Spotlight Survey Technique

Crocodile densities (number of individuals per kilometre of river or lake) were assessed by spotlight surveys using the method described by Messel *et al.* (1981). Spotlight surveys do not calculate absolute abundance, but provided an index or relative density which allows changes in population size and structure to be quantified over time (Bayliss 1987; Messel *et al.* 1981). A halogen torch, powered by 6 DD batteries (7.2V, 0.85 amp) was used. When an eyeshine was detected, an attempt was made to approach the crocodile in order to estimate total length (TL; see 3. below).

Surveys typically started downstream and proceeded upstream in rivers or to the mouth of lakes, except in the Soi River. All distances were determined using 1:250,000 maps (between 2°00′00″S and 4°00′00″S to 138°00′00″E and 139°30′00″E) and a GPS. The speed of the boat and canoe were recorded by GPS. Prevailing weather conditions at the time of survey were also recorded.

3. Species

The species of crocodile surveyed, *C. novaeguineae*, is known locally as Buaya Air Tawar or Buaya Bob. Crocodiles were categorized as hatchling (H, <50 cm TL); juvenile (J, 50-150 cm TL), adult (A, >150 cm TL) and Eyes Only (EO).

4. Locality

Areas surveyed were within the Memberamo and Rouffaer River systems. Specifically, they comprised Memberamo Mati, Jaro, Baso and Soi Rivers, Sobaki, Waropen, Kweri Satu, Kweri Dua, Apuse, Bernekam Satu, Bernekam Dua, Cabang Tiga Satu, Cabang Tiga Dua Lakes (Memberamo Hulu District), and Kamika Lake (Kaureh District).

5. Vessels

Survey areas varied in length, so the type of boat used varied accordingly. In long distance areas (Memberamo Mati, Jaro, Baso and Soi Rivers, and Kamika, Bernekam Satu, Sobaki, Kweri Satu and Kweri Dua Lakes) a long boat powered by a 40 HP motor was used. In other areas (Cabang Tiga Satu, Cabang Tiga Dua, Apuse, Waropen and Bernekam Dua Lakes) a canoe was used.

6. Interviews with local people

Interviews with local people were conducted to confirm the species of crocodile being harvested in each river and lake surveyed.

7. Data analysis

Linear regression analysis was used to describe population trends (SPSS statistic analysis, version 9.0). Significant level of statistic analysis is p<0.05.
Harvest data for *C. novaeguineae* were provided by one company (CV Bintang Mas), for the period 1995 to 2002.

**Results**

Generally higher water levels were encountered during surveys in 2001 and 2002, which affected the extent of riverbank that could be seen clearly (Table 2). Spotlight survey results for all years are in Table 3. This includes previous survey results for Memberamo Mati River, Jaro River, Baso River, Soi River and Sobaki Lake, collected by the FAO-PHPA Project.

**Population Trends**

Population trends of each area were determined using linear regression analysis. As hatchling numbers can vary greatly from year to year, and mortality rates for this size/age class can be high, analyses were carried using all data (ie H, A, J), and using only non hatchlings (Figs. 1-14).

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Table 2. Weather conditions recorded during spotlight surveys of *C. novaeguineae* in the Memberamo and Rouffaer River systems, 1987-2002. Information for surveys carried out in 2000-2002 is more detailed. Surveys were carried out by FAO-PHPA, Division of Natural Resources and Conservation Papua I (KSDA) and the Indonesian Institute of Sciences (LIPI).

<table>
<thead>
<tr>
<th>No</th>
<th>River/Lake</th>
<th>Weather description</th>
<th>Personnel team</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Memberamo Mati River</td>
<td>Low water level, dark moon, clear sky.</td>
<td>FAO-PHPA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>1/10/87</td>
<td>Low water level, dark moon, clear sky.</td>
<td>FAO-PHPA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>20/2/88</td>
<td>Low water level, dark moon, clear sky.</td>
<td>FAO-PHPA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>3/10/89</td>
<td>Low water level, dark moon, clear sky.</td>
<td>FAO-PHPA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>1/10/90</td>
<td>Low water level, dark moon, clear sky.</td>
<td>KSDA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>12/10/92</td>
<td>Low water level, dark moon, clear sky.</td>
<td>KSDA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>26/11/01</td>
<td>High water level, but more than half of survey distance the river bank could be seen clearly, full moon, clear sky. Survey started 2105 h, finished 2215 h.</td>
<td>LIPI-KSDA</td>
<td>Kurniati <em>et al</em> (2001)</td>
</tr>
<tr>
<td></td>
<td>20/12/02</td>
<td>High water level, but all survey distance the river bank could be seen clearly, no moon, cloudy and dark sky. Survey started 1905 h, finished 2240 h.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td>No</td>
<td>River/Lake</td>
<td>Weather description</td>
<td>Personnel team</td>
<td>Reference</td>
</tr>
<tr>
<td>----</td>
<td>-------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
</tbody>
</table>
| 2  | Jaro River  | 24/9/89 Low water level, dark moon, clear sky.  
30/9/91 Low water level, dark moon, clear sky.  
29/11/01 High water level (flood), but more than half of survey distance the river bank could be seen clearly, 3/4 full moon, cloudy sky and shower. Survey started 2105 h, finished 2205 h.  
19/12/02 High water level, flooding, full moon, clear sky. Survey started 1915 h, finished 2250 h. | FAO-PHPA  
FAO-PHPA  
LIPI-KSDA | KSDA (2000)  
KSDA (2000)  
Kurniati et al (2001) |
| 3  | Baso River  | 30/9/89 Low water level, dark moon, heavy cloudy sky.  
4/8/91 Low water level, dark moon, clear sky.  
4/12/01 High water level (flood), but most of survey distance the river bank could be seen very clearly, strong water current, heavy cloudy sky, no moon shine. Survey started 1930 h, finished 2100 h.  
21/12/02 High water level, less than half of survey distance the river bank could be seen clearly, full moon, cloudy sky. Survey started 1930 h, finished 2305 h. | FAO-PHPA  
FAO-PHPA  
LIPI-KSDA | KSDA (2000)  
KSDA (2000)  
Kurniati et al (2001) |
| 4  | Soi River   | 26/4/89 High water level (flood), full moon, cloudy sky.  
18/7/91 High water level (flood), full moon, clear sky.  
5/12/01 High water level (flood), but most of survey distance the river bank could be seen clearly, dark sky, no moon shine, shower to heavy rain. Survey started 1825 h, finished 2005 h.  
22/12/02 High water level, less than half of survey distance the river bank could be seen clearly, full moon, cloudy sky. Survey started 1915 h, finished 2200 h. | FAO-PHPA  
FAO-PHPA  
LIPI-KSDA | KSDA (2000)  
KSDA (2000)  
Kurniati et al (2001) |
| 5  | Sobaki Lake | 26/9/89 Low water level, dark moon, cloudy sky.  
14/7/91 High water level (flood), dark moon, heavy cloudy sky. | FAO-PHPA  
FAO-PHPA | KSDA (2000)  
KSDA (2000) |
|    |             | 5/12/01 High water level, only about half of survey distance the river bank could be seen clearly, dark sky, no moon shine, shower. Survey started 2215 h, finished 2300 h. | LIPI-KSDA | Kurniati et al (2001) |
|    |             | 23/12/02 High water level, less than half of survey distance the river bank could be seen clearly, full moon, cloudy sky. Survey started 1900 h, finished 2115 h. | KSDA | KSDA (2002) |
| 6  | Kamika Lake | 27/9/00 Low water level, dark moon, clear sky.  
30/11/01 High water level (flood), about half of survey distance the lake bank could be seen clearly, full moon, cloudy sky. Survey started 2130 h, finished 0040 h. | KSDA  
LIPI-KSDA | KSDA (2000)  
Kurniati et al (2001) |
| 7  | Waropen Lake| 28/9/00 Low water level, dark moon, clear sky.  
30/11/01 High water level (flood), full moon, shower. Survey started 1930 h, finished 2000 h.  
15/12/02 High water level, flooding, half of survey distance the river bank could be seen clearly, half moon, cloudy and dark sky. Survey started 1905 h, finished 2220 h. | KSDA  
LIPI-KSDA | KSDA (2000)  
Kurniati et al (2001) |
<table>
<thead>
<tr>
<th>No</th>
<th>River/Lake</th>
<th>Weather description</th>
<th>Personnel</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Kweri Satu Lake</td>
<td>Low water level, dark moon, cloudy sky.</td>
<td>KSDA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>29/9/00</td>
<td>High water level (flood), full moon, clear sky.</td>
<td>LIPI-KSDA</td>
<td>Kurniati et al (2001)</td>
</tr>
<tr>
<td></td>
<td>29/11/01</td>
<td>Survey started 1900 h, finished 2200 h.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td></td>
<td>16/12/02</td>
<td>High water level, flooding, half of survey distance the river bank could be seen clearly, half moon, cloudy sky. Survey started 1900 h, finished 2140 h.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td>9</td>
<td>Kweri Dua Lake</td>
<td>Low water level, crescent moon, clear sky.</td>
<td>KSDA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>30/9/00</td>
<td>High water level (flood), full moon, shower.</td>
<td>LIPI-KSDA</td>
<td>Kurniati et al (2001)</td>
</tr>
<tr>
<td></td>
<td>1/12/01</td>
<td>Low water level, clear sky.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td></td>
<td>15/12/02</td>
<td>High water level, flooding, less than half of survey distance the river bank could be seen clearly, half moon, cloudy sky. Survey started 1900 h, finished 2120 h.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td>10</td>
<td>Apuse Lake</td>
<td>Low water level, dark moon, cloudy sky.</td>
<td>KSDA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>30/9/00</td>
<td>High water level (flood), full moon, clear sky.</td>
<td>LIPI-KSDA</td>
<td>Kurniati et al (2001)</td>
</tr>
<tr>
<td></td>
<td>2/12/01</td>
<td>Low water level, clear sky.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td></td>
<td>16/12/02</td>
<td>High water level, flooding, half of survey distance the river bank could be seen clearly, half moon, cloudy sky. Survey started 1900 h, finished 2140 h.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td>11</td>
<td>Berneka Satu Lake</td>
<td>Low water level, crescent moon, clear sky.</td>
<td>KSDA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>1/10/00</td>
<td>High water level (flood), but most of the survey distance the lake bank could be seen clearly, dark sky, no moon shine, cloudy sky. Survey started 1805 h, finished 2050 h.</td>
<td>LIPI-KSDA</td>
<td>Kurniati et al (2001)</td>
</tr>
<tr>
<td></td>
<td>2/12/01</td>
<td>Low water level, clear sky.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td></td>
<td>17/12/02</td>
<td>High water level, flooding, half of survey distance the river bank could be seen clearly, half moon, heavy cloudy sky. Survey started 1830 h, finished 2130 h.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td>12</td>
<td>Berneka Dua Lake</td>
<td>Low water level, dark moon, cloudy sky.</td>
<td>KSDA</td>
<td>KSDA (2000)</td>
</tr>
<tr>
<td></td>
<td>1/10/00</td>
<td>High water level (flood), full moon, cloudy sky.</td>
<td>LIPI-KSDA</td>
<td>Kurniati et al (2001)</td>
</tr>
<tr>
<td></td>
<td>1/12/01</td>
<td>Low water level, clear sky.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td></td>
<td>17/12/02</td>
<td>High water level, flooding, less than half of survey distance the river bank could be seen clearly, half moon, heavy cloudy sky. Survey started 1830 h, finished 2130 h.</td>
<td>KSDA</td>
<td>KSDA (2002)</td>
</tr>
<tr>
<td>13</td>
<td>Cabang Tiga Satu Lake</td>
<td>Low water level, dark moon, cloudy sky.</td>
<td>KSDA</td>
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Table 3. Spotlight counts of *C. novae-guineae* in the Memberamo and Rouffaer River systems. H= hatchling; J= Juvenile; A= adult; EO= eyes only.

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<th>Distance (km)</th>
<th>Sightings</th>
<th>Total Crocodiles Sighted</th>
<th>Total Density (N/km)</th>
<th>Non-hatching density (NH/km)</th>
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Memberamo Mati River

Data for the Memberamo Mati River span 14 years, from 1987 to 2001 (Table 3). Two spotlight surveys were carried out in 1990 (April, October) - the April (end of wet season) data were used in the analysis (Table 3). Since 1988 density (total and non-hatchlings) has been stable. Excluding the 1987 data, there was no significant relationship between density and time, for either total crocodile density (r² = 0.00, p = 0.99, n = 6; Fig. 1a) or non-hatchling density (r² = 0.11, p = 0.53, n = 6; Fig. 1b). Non-hatchling density decreased from a high of 10.0/km in 1987 to 2.0/km in 1988 (Table 3; Fig. 1b), and has stayed relatively stable since that time [mean = 2.18 NH/km (1988-2002)].

Figure 1a. Total density of *C. novaeguineae* sighted during spotlight surveys in the Memberamo Mati River, 1987-2002. Solid line indicates the non-significant trend between 1988 and 2002 (see text).

Figure 1b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in the Memberamo Mati River, 1987-2002. Solid line indicates the non-significant trend between 1988 and 2002 (see text).
Jaro River

Notwithstanding the limited number of surveys carried out in the Jaro River, there has been a significant increase in total crocodile density ($r^2 = 0.947, p = 0.027, n = 4$; Fig. 2a) and non-hatchling density ($r^2 = 0.959, p = 0.021, n = 4$; Fig. 2b) over time. The trends in the intervening period between surveys (10 years) are unknown. Certainly high densities have been recorded in both of the most recent surveys. Given the high water levels at the time of these surveys, the increase may actually be greater than recorded.

Figure 2a. Total density of *C. novaeguineae* sighted during spotlight surveys in the Jaro River, 1989-2002. Solid line indicates the significant linear regression trend (see text).

Figure 2b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in the Jaro River, 1989-2002. Solid line indicates the significant linear regression trend (see text).
Baso River

The four surveys undertaken in the Baso River span a 12-year period (1989-2001), and indicate that the density of *C. novaeguineae* is relatively low and stable. Non-hatchling and total crocodile densities in the Baso River have not changed significantly over time \( r^2 = 0.330, p = 0.425, n = 4 \) (Fig. 3a) and \( r^2 = 0.2, p = 0.553, n = 4 \) (Fig. 3b) respectively.

![Figure 3a](image)

Figure 3a. Total density of *C. novaeguineae* sighted during spotlight surveys in the Baso River, 1989-2002. Solid line indicates the non-significant trend (see text).

![Figure 3b](image)

Figure 3b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in the Baso River, 1989-2002. Solid line indicates the non-significant trend (see text).
Soi River

Data for Soi River span 12 years, from 1989 to 2001 (Table 3). Regression analysis indicated a significant relationship between total crocodile density and time ($r^2 = 0.992, p = 0.004, n = 4$; Fig. 4a), but not for non-hatchling density ($r^2 = 0.501, p = 0.292, n = 4$; Fig. 4b). Analysis of results from the Soi River are complicated by the first two surveys involving a very short section of the river (0.5 km), and the later surveys a much longer section (20 km). The results for non-hatchling density (Fig. 4b) are more relevant here, and they indicate no change over time. Future monitoring will establish long-term population trends for the river.

![Graph showing total density of C. novaeguineae over time.]

Figure 4a. Total density of *C. novaeguineae* sighted during spotlight surveys in the Soi River, 1989-2002. Solid line indicates the significant linear regression trend (see text).

![Graph showing non-hatchling density of C. novaeguineae over time.]

Figure 4b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in the Soi River, 1989-2002. Solid line indicates the non-significant trend (see text).
Sobaki River

There was no significant relationship between density and time for either total numbers ($r^2 = 0.004$, $p = 0.937$, $n = 4$; Fig. 5a) or non-hatchlings ($r^2 = 0.000$, $p = 0.996$, $n = 4$; Fig. 5b).

![Graph](image1.png)

Figure 5a. Total density of *C. novaeguineae* sighted during spotlight surveys in the Sobaki River, 1989-2002. Solid line indicates the non-significant trend (see text).

![Graph](image2.png)

Figure 5b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in the Sobaki River, 1989-2002. Solid line indicates the non-significant trend (see text).

Kamika Lake

Survey data for Kamika Lake are available for three recent consecutive years (2000-2002). They indicate that total and non-hatchling densities have remained somewhat high (mean= 13.0 NH/km) and stable over the 3-year period ($r^2 = 0.614$, $p = 0.427$, $n = 3$ and $r^2 = 0.582$, $p = 0.448$, $n = 3$ respectively).

Waropen Lake

There was no significant relationship between density and time for either total numbers ($r^2 = 0.530$; $p = 0.481$; $n = 3$)
or non-hatchlings ($r^2 = 0.988$, $p = 0.069$, $n = 3$). The trend in non-hatching density is positive, increasing from 6.4 NH/km to 17.5 NH/km (Table 3). Additional surveys are required to confirm whether this increase is indeed significant. The first two kilometres of survey distance contained a high density of *C. novaeguineae* (see Table 3), and increasing survey distance for Waropen Lake may reduce the overall density.

**Kweri Satu Lake**

Densities in Kweri Satu Lake have remained stable over the period 2000-2002 [total numbers ($r^2 = 0.196$, $p = 0.347$, $n = 3$), non-hatching ($r^2 = 0.985$, $p = 0.078$, $n = 3$)]. The trend is towards increasing densities, from 9.0 NH/km in 2000 to 12.3 NH/km in 2002 (Table 3).

**Kweri Dua Lake**

Densities in Kweri Dua Lake have remained stable over time [total numbers ($r^2 = 0.722$, $p = 0.353$, $n = 3$), non-hatching ($r^2 = 0.311$, $p = 0.624$, $n = 3$)]. Although the trend indicates decreasing densities, it is not significant.

**Apuse Lake**

Like Kweri Satu and Kweri Dua Lakes, data from Apuse Lake indicated no significant relationship between density and time for either total numbers ($r^2 = 0.227$, $p = 0.684$, $n = 3$) or non-hatchlings ($r^2 = 0.138$, $p = 0.757$, $n = 3$). Mean non-hatching density is 8.1 NH/km.

**Bernekam Satu Lake**

A relatively high density (40.0 NH/km) was recorded in 2000, but subsequent surveys have indicated much lower levels (Table 3). Kweri Satu and Kweri Dua also showed similar trends, although the decrease was not as evident as it is for Bernekam Satu Lake. Water levels were higher in 2001 and 2002 (Table 2), and surveys were undertaken by boat rather than canoe (Table 3). These factors, particularly high water levels, could be expected to lead to lower sight ability of crocodiles. Nonetheless, the limited indicate no significant relationship between density and time for total numbers ($r^2 = 0.695$, $p = 0.372$, $n = 3$) and non-hatchlings ($r^2 = 0.693$, $p = 0.374$, $n = 3$).

**Bernekam Dua Lake**

Regression analysis for Bernekam Dua Lake indicated no significant relationship between density and time for total numbers ($r^2 = 0.123$, $p = 0.772$, $n = 3$) and non-hatchlings ($r^2 = 0.052$, $p = 0.857$, $n = 3$). Densities of *C. novaeguineae* are relatively stable and high (mean = 8.6 NH/km) in this area.

**Cabang Tiga Satu Lake**

There was no significant relationship between density and time for either total numbers ($r^2 = 0.646$, $p = 0.406$, $n = 3$) or non-hatchlings ($r^2 = 0.601$, $p = 0.436$, $n = 3$). The results for this area, like others, indicate high densities in 2000 (20.33 N/km and 20 NH/km; Table 3) relative to 2001 (4.13 N/km and 3.27 NH/km; Table 3) and 2002 (6.13 N/km and 6.13 NH/km; Table 3). Again, conditions at the time of survey may be implicated in this trend.

**Cabang Tiga Dua Lake**

Results for Cabang Toga Dua were similar to those for cabung Tiga Satu Lake (see above). Densities have been stable over time [total numbers ($r^2 = 0.624$, $p = 0.420$, $n = 3$), non-hatchlings ($r^2 = 0.500$, $p = 0.500$, $n = 3$).

**Crocodile Harvest**

Harvest data from two of the three legal companies that purchase live crocodiles and skins from the Memberamo River were not available. However, the harvest data from CV Bintang Mas (one of these companies) (Table 4) can be used as an index of the *C. novaeguineae* population in the Memberamo River. The numbers of live crocodiles traded by CV Bintang Mas has decreased significantly between 1995 and 2002 ($r^2 = 0.76$, $p = 0.005$, $n = 8$; Fig. 6). The number of skins traded increased significantly between 1995 and 2001 ($r^2 = 0.70$, $p = 0.02$, $n = 7$; Fig. 7). This relationship reaches non-significance with the inclusion of the 2002 data (2440 skins; Table 4) ($r^2 = 0.36$, $p = 0.116$, $n = 8$).
Table 4. *Crocodylus novaeguineae* harvest data (live crocodiles and skins; 1995 to 2002) from mid-zone Memberamo River (Memberamo and Rouffaer River system), provided by CV Bintang Mas.

<table>
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</thead>
<tbody>
<tr>
<td>Live (&gt;60 cm TL)</td>
<td>6661</td>
<td>6076</td>
<td>4303</td>
<td>3519</td>
<td>273</td>
<td>1395</td>
<td>762</td>
<td>1804</td>
</tr>
<tr>
<td>Skin (30-51 cm belly width)</td>
<td>2234</td>
<td>1868</td>
<td>1762</td>
<td>2101</td>
<td>3998</td>
<td>3400</td>
<td>4379</td>
<td>2440</td>
</tr>
<tr>
<td>Live + skins</td>
<td>8895</td>
<td>7944</td>
<td>6065</td>
<td>5620</td>
<td>4271</td>
<td>4795</td>
<td>5141</td>
<td>4244</td>
</tr>
</tbody>
</table>

![Figure 6](image1.png)

Figure 6. Numbers of live *C. novaeguineae* purchased by Bintang Mas (see Table 4). Line indicates significant linear regression trend (see text).

![Figure 7](image2.png)

Figure 7. Numbers of *C. novaeguineae* skins purchased by Bintang Mas (see Table 4). The inclusion of 2002 data renders the trend non-significant (line) (see text).
Discussion

Survey results from 13 of the survey areas (Memberamo Mati River, Jaro River, Baso River, Sobaki Lake, Kamika Lake, Waropen Lake, Kweri Satu Lake, Kweri Dua Lake, Apuse Lake, Bernekam Satu Lake, Bernekam Dua Lake, Cabang Tiga Satu Lake, Cabang Tiga Dua Lake) indicated no significant trends between non-hatchling density of *C. novaeguineae* sighted, and time. For one area, the Soi River, there has been a significant increase in non-hatchling density (Fig. 4b).

High water levels (flooding) in 2001 and 2002 were not optimum for spotlight surveys, and most likely affected the sight ability of crocodiles (Messel *et al.* 1981). Trends in some areas (eg Bernekam Satu Lake, Cabang Tiga Satu Lake, Cabang Tiga Dua Lake), with high densities in 2000 followed by lower densities in 2001 and 2002, probably reflect the suboptimal conditions under which the latest surveys were carried out. Surveys in 2000 were carried out in the dry season (Table 2). Notwithstanding the effects of high water levels, population trends of *C. novaeguineae* in Mid-zone Memberamo River generally indicate stability from 2000 to 2002.

There has been an overall decrease in total harvest (live and skins) between 1995 and 1999, followed by a general increase after 1999 (Table 4). These trends are attributable to factors unrelated to the status of the crocodile resource. Specifically, the following factors need to be taken into account in assessing these harvest data:

- From 1994 and 1996, Indonesia had a moratorium in place, and the demand for live crocodiles for raising on farms, decreased.
- Demand for wild skins during the moratorium period also decreased, as many companies possessed stockpiles of skins purchased from Papua Province, which could not be sold.
- Between 1996 and 1999, the price of crocodile skins on the international market dropped, which did not encourage companies to sell accumulated skin stocks. It also discouraged live crocodile purchases.
- From 1999-2002, skin prices on the international market improved, and the demand for live crocodiles increased as a result.
- The drop in harvested skins purchased by CV Bintang Mas, from 4379 in 2001 to 2440 in 2002, was the result of an annual quota (2440 skins) imposed on the company by the Indonesian Ministry of Forestry.

Spotlight surveys are not always good indicators of population trends in heavily vegetated habitats (Montague 1983), and nest counts may perhaps be better indices of the population in heavily vegetated swamps associated with the Memberamo River, which are not conducive to spotlight survey (Hollands 1987). However, nest count surveys in Papua Province would require substantial financial resources, which simply cannot be afforded at this time. Monitoring through spotlight surveys still offers an index of the *C. novaeguineae* population in the Memberamo River, Papua Province, and will be the prime monitoring method for the wild population in the short-term.

Acknowledgements

We are grateful to the many people who supported this survey and were instrumental in its success. Many thanks to Mr. Gandhi Gan, Mr. Billy Gan, Mr. Raymon Gan, Mr. Andi Antariksa and Mr. Ibrahim Mile from CV Bintang Mas, and to Mrs. Ay Cu from The Indonesian Crocodile Farmers Association. The surveys were made possible by the outstanding contribution of Ir. B.G. Resubun [Head of Subdivision of Natural Resources Conservation Papua I (KSDA)] and his staff, Ir. Arijan Prasadjo, Ir. Nanang Hari Murdani, Mr. Oktavianus Howay, Mr. Alpianus Kilungga, Mr. Derek Makabory, Mr. Kristian Marande, Mr. Hasudungan Hutaeyn Mr. Nixon Nauw, Mr. Untung Ginting and Mr. Teguh Mujiarto.

Literature


Report on the Activities and Actual Situation of the Crocodylia in Mexico

Recompilation of information by Manuel I. Muñiz
(Credit to authors in Annex)

moreletii@mx.inter.net or moreletii@muniz@hotmail.com

Abstract

Decades have passed studying, investigating and producing articles related to caimans, *Caiman crocodilus chiapensis* (not yet confirmed as subspecies), American crocodiles, *Crocodylus acutus* and Morelet’s crocodiles, *Crocodylus moreletii* in our country, but little of these results are known outside Mexico. That’s why the main objective of this work is to let know in a synthesis the situation and activities done around the crocodilians that inhabit in Mexico. We can find in 16 of the 32 States in Mexico crocodilians. From Sinaloa to Chiapas along the Pacific coast; from Tamaulipas and San Luis Potosí all the way to the Peninsula of Yucatan and in inland at the central depression of Chiapas State.

The Mexican authority in charge of environment regulations is SEMARNAT, through the Wildlife General Direction (DGVS), CITES Administration; CONABIO CITES scientific; PROFEPA inspection; and INE.

All three species are protected by Mexican laws under the category Special Protection, which permits and allows sustainable use. Registered are 35 farms and more than 80 zoo and collections with crocodilians, 3 of them have CITES permits and 1 farm working with caimans, which doesn’t need to register with CITES for exports. Mexico has imported more than 250,000 hides of caiman and other crocodilians which are transformed and re-exported as finished products and sub-products to the rest of the world.

Introduction

Decades have passed studying, investigating and elaborating articles related with Caimans, American crocodiles and Morelet’s crocodile in our country, but little of these results are known outside Mexico. That’s why, the main object of this work is to let know in a synthesis the situation and activities done around the crocodilian that inhabit in Mexico. As is known, in Mexico live 3 of the 23 species of crocodilians (Ross 1998) that we actually can find in our world. The caiman, *Caiman crocodilus chiapensis* (not yet confirmed as subspecies); American crocodile, *Crocodylus acutus*; and Morelet’s crocodile, *Crocodylus moreletii*.

Mexican species, as with most crocodilians, are threatened because of the destruction, transformation, contamination and invasion of their habitat. In addition they are victims of hunting and illegal trade. With great effort between the communities, cooperatives, investigators, private investors, ONG, Government entities, academics and institutions had invert and minimize these threats. But still a lot of work has to be done to guarantee the recovery of the three crocodilian species in Mexico.

Because of their ecological value and keystone importance in their habitat, the Mexican crocodilians are considerate as charismatic and priority species, acquiring with this, a high priority for their conservation and protection.

From the 32 States of the Mexican Republic, in 16 of them, we can find crocodilians. From Sinaloa to Chiapas along the Pacific cost; from Tamaulipas and San Luis Potosí all the way to the Peninsula of Yucatan and in inland at the central depression of Chiapas State.

Also during the last four year Mexico has imported more than 250,000 hides of caiman and other crocodilians which transform and re-exports finish products and sub-products to the rest of the world.
En Español

Décadas han transcurrido estudiando, investigando y elaborando artículos en torno a los caimanes, a los cocodrilos de río y a los cocodrilos de pantano en nuestro país, pero poca de estos resultados se han dado a conocer a nivel internacional. Por ello, el objetivo principal de este trabajo es dar a conocer en síntesis la situación y actividades que se realizan en torno a los cocodrilianos que habitan en México.

Como se conoce en México existen 3 de las 23 especies de cocodrilianos (Ross 1998) que actualmente se pueden encontrar en el planeta. El caimán, Caiman sclerops chiapensis, el cocodrilo de río, Crocodylus acutus, y el cocodrilo de pantano, Crocodylus moreletii.

Como la mayoría de las especies de cocodrilianos las especies mexicanas se encuentran amenazadas por la destrucción, transformación, contaminación e invasión de su hábitat, además son víctimas de cacerías y comercio ilegales. Con grandes esfuerzo entre las comunidades, cooperativas, investigadores, iniciativa privada, organizaciones no gubernamentales, entidades gubernamentales, académicos, e instituciones se han vertido y minimizado algunas de estas amenazas. Sin embargo falta mucho más por realizar para garantizar la recuperación de las tres especies de cocodrilianos en México.

Por su valor ecológico y eslabón importante en su hábitat, los cocodrilianos son considerados en México como especies carismáticas y prioritarias. Adquiriendo con ello una mayor importancia para su conservación y protección.

De los 32 estados en la República mexicana, en 16 de estos, podemos encontrar cocodrilianos. Desde Sinaloa hasta Chiapas por toda la costa del pacífico, desde Tamaulipas, pasando por San Luis Potosí y toda la península de Yucatán y adentrándose hasta la depresión central del estado de Chiapas.

Además en los últimos cuatro años México a importado más de 250,000 pieles de caimán y otros cocodrilianos que transforma y re-exporta productos y subproductos terminados al resto del mundo.

**Situation with the Three Species of Mexican Crocodilians**

**Identification of the three species**

Even though, in other part of the distribution of these species, other authors mention some characteristic, here we’re going to describe and resemble the characteristics and the observation made by Mexican investigators and scientists.

**Caiman sclerops chiapensis**

Described by Bocourt, the Caiman sclerops chiapensis is now known as Caiman crocodilus fuscus because there’s not enough information and studies on the species and subspecies of caimans to validate this data. But Álvarez del Toro and Luis Sigler (2001), mentioned and described the subspecies. Medem (1962) analysed, suggested, classified and described the subspecies of caimans, mentioning the Caiman sclerops chiapensis. Also some DNA studies suggest that Caiman crocodilus fuscus and Caiman crocodilus chiapensis are in the same natural group (Ross 1998). Though, we’ve seen morphological differences between the Mexican caiman, (Caiman sclerops chiapensis or Caiman crocodilus chiapensis) and the morphological descriptions made by other authors for the Caiman crocodilus crocodilus and Caiman crocodilus fuscus.

**Sizes:** Adults’ maximum sizes registered, 2.50 m. Adults sizes 1.20 m minimum (females) up to 2.00 m or more (males). Hatchlings average sizes 22.5 cm. Minimum 18.5 cm, maximum 25.5 cm. Females lays an average of 30 eggs, maximum 37 eggs. (Lopez M, per.com.)

**Conformation:** Snout is short, triangular and round tip. Measuring between 1.2 to 1.5 times as long as broad at the level of the front corners of the eyes. A transverse bony ridge connects the anterior points of the orbits. On the upper eyelid presents a high point or tubercle. On the lower jaw presents two, three or more blotches.

**Scutellation:** The belly skin of caimans has osteoderms and without the integumentary sensory organs (ISO) (Richardson, Webb and Manolis 2002). Postoccipitals: One or two transversal row of 6 to 8 scales irregularly arranged. Nuchals: 4 to 5 transverse rows of 4 to 2 scales, continuous with the dorsal scales. Collar: A single row of enlarged scales on collar.
**Distribution:** The species, *Caiman crocodilus* could be found from the south Pacific coast of Mexico all the way to north of Argentina. The subspecies *Caiman sclerops chiapasius*, as described by Medem, is registered to the Tonala region, northwest coast of Chiapas, so we believed that the distribution of this subspecies could find from the south of Oaxaca state throw all the Pacific coast of Chiapas as high as 50 meter above sea level (Álvarez and Sigler 2001). Not knowing is the distribution of this subspecies goes on Central America. Some authors mention it all the way to Panama.

**Crocodylus acutus**

**Sizes:** Adults’ maximum sizes registered, 7.00 m (Brazaitis 1973). In Mexico, is the biggest of all three species, Alvarez del Toro (1974) measured one specimen with a total length of 6.25 m, and also Pérez Higareda and friends (1991) reported one specimen of the same sizes. Nowadays, it’s difficult to find specimens larger than 5 m. Adults sizes 2.10 m minimum (females) up to 5.00 m or more (males). Hatchlings average sizes 28 cm minimum 24 cm, maximum 31.5 cm. Females lays an average of 34 eggs, maximum 51 eggs. Eggs average sizes 7.69 cm (+4.2) x 4.69 (+1.6) cm (Valtierra 2001; Sigler et al. 2000)

**Conformation:** Skull and snout are slender and elongate, 1.8 to 2.5 times as long as broad at the level of the front corners of the eyes. Adults develop a hump on the snout anterior to the orbit. Iris is greenish and eyelid wrinkled.

**Scutellation:** The scutellation is highly irregular and variable among individuals. The dorsal scales are enlarge and high. Postoccipital: A single transversal row of 1 to 6 enlarged scales medially divided by soft skin. Nuchals: The nuchal rosette has 4 enlarged scales in a quadrant and 2 scales flanked by the sides. Variability in pattern is great among individuals.

**Distribution:** *Crocodylus acutus* is found from south Florida, United States, Northwest Pacific coast of Mexico all the way to Venezuela and Colombia. Also found in Cuba, Jamaica, Dominique Republic, Antilles, and almost in all small island and cay in the Caribbean Sea. In Mexico, could be found from the north Pacific coast as high as La Bojonea, north of El Fuerte River all the way to the Suchiate River at the border of Guatemala and Mexico, inhabiting all major costal mangroves, marshes, swamps, rivers, lagoons, and larger ponds (Ponce 2002; Valtierra 2001; Sigler 2000). Also reported in the coast, cay and small islands of Quintana Roo State in the Yucatan Peninsula. It hasn’t been confirm to inhabit the Gulf of Mexico specially at Tabasco and Campeche States (Carballar J., 2002). There’s a particular isolated population of *Crocodylus acutus* living in the Grijalva River between massive high hydroelectric damps and high mountains, the Sierra Madre cordillera, in the middle of Chiapas State (Sigler 1998, 2000, 2002).

**Crocodylus moreletii**

**Sizes:** Adults’ maximum sizes registered, 3.50 m. Adults sizes 1.30 m minimum (females) up to 3.10 m or more (males). Hatchlings average size of 26.2 cm, minimum 20 cm. maximum 31.5 cm. Females lay an average of 35 eggs, maximum 50 eggs. Eggs average 6.8 cm x 4.3 cm (Muñiz 2000).

**Conformation:** Snout short, massive and wide, not more than 1.5 times as long as broad at the level of the front corners of the eyes.

**Scutellation:** The belly skin of Morelet’s crocodile is highly prized because it has few osteoderms (Richardson, Webb and Manolis 2002). Presents inclusions on tail and on ventral skin. Postoccipital: a single transversal row of 4 to 6 scales divided by smooth skin. Nuchals: Presents a nuchal rosette with one row of 4 scales and another row with 2 scales.

**Distribution:** Occurs on the Atlantic side in the Gulf of Mexico from centre as high as Laguna Madre, 42° 30’ latitude north in Tamaulipas State down throw Veracruz, San Luis Potosí, Oaxaca and Tabasco to Campeche, Yucatan and Quintana Roo in the Peninsula of Yucatan (Hinojosa 2001; Bautista 1999; Dominguez 2003; Figueroa et al. 2000; Gómez 2002; Pani 1999; Pérez 2002; Merediz 1999; Cedeño 2002). Inland as far as in the Huasteca Potosina at San Luis Potosi State in the north and in the south occurs in the northwest and northeast of Chiapas State, El Caracol lagoon, El Aguacate lagoon; Lacanja river and River Lacantú at Montes Azules biosphere reserve, Usumacinta river (the border between Guatemala and Mexico) up to 800 m above sea level. (Martinez 2001; Sigler et al. 2001; Sigler 2002). Also occurs in Belize and north of Guatemala (Platt 1997; Castañeda 2001).
Status of the Three Species

National and international list, laws and conventions that affects and controls Mexican crocodilians.

- NOM-059-ECOL-2001: is the official norm that identifies the species and population that are in risk of wild flora and fauna in the Mexican Republic. Based on a list that corresponded to the risk, the criteria of inclusion, of exclusion and changes of categories. See Categories in chapter of legislation.


- IUCN (International Union for the Conservation of Nature and Natural Resources) - The World Conservation Union Red List.

- ESA: Endanger Species Act, United States law.

- CSG: Crocodile Specialist Group, Species Survival Commission, IUCN.

_Caiman sclerops chiapasius_: Considered as _Caiman crocodilus fuscus._
CITES: Appendix II
IUCN 1996: Not listed.
ESA: Not listed
Threats: Habitat loss and illegal hunting.

_Crocodylus acutus_
CITES: Appendix I
ESA: Listed
Threats: Habitat loss and illegal hunting

_Crocodylus moreletii_
CITES: Appendix I and Special permits for 3 farms. Num. 501, 502 and 503
IUCN 1996: Listed.
ESA: Listed
Threats: Habitat loss and illegal hunting

Responsible Government Agencies, Legislation and Internal Control System

Management and Scientific Authorities:

Secretaría del Medio Ambiente y Recursos Naturales, (SEMARNAT) is the Secretary of Environment and Natural Resources in charge of everything related with the environment and our natural resources.

CITES Management Authority: Dirección General de Vida Silvestre, SAGP, SEMARNAT, (DGVS); is the general direction of Wildlife Service.
Address: Av. Revolución no.- 1475, Colonia Tlacopac, México D.F.

CITES Scientific Authority: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) is the National Commission for the Knowledge and use of the Biodiversity.
**Inspection, Control and Supervision**

Procuraduría Federal para la Protección del Medio Ambiente (PROFEPA,) is the Federal Attorney’s offices for environmental protection, is in charge of verifying the environmental legislation compliance, regarding natural resources and wildlife usage. In accordance, PROFEPA carries out a national inspection programme, which includes inspection of foreign trade of specimens, products and sub-products. It has inspection offices located in 65 ports, airports and borders where wild flora and fauna imports and exports permits are verified, as well as the sanitary conditions of wood and fishery products and sub-products, and also verifying all tips of Management units of wildlife. (UMAS)

**Laws**

In Mexico we have different laws that protects, conserves and establish the methods for the sustainable use of wild and captive flora and fauna.

**Ley General de Vida Silvestre**

The most important law in Mexico related with the wildlife, it’s conservation, protection and sustainable use is the “General Law for wildlife” = “Ley general de Vida Silvestre”, published on July 3, 2000 by the president Dr. Ernesto Zedillo Ponce de Leon. It’s related to the conservation and sustainable use of wildlife and their habitat in the Mexican territory and the zones where the nation has jurisdiction. With the exception of the sustainable use on timber forest and fishery, who have their own law.

**Ley General del Equilibrio Ecológico y la Protección al Ambiente. (LGEEPA) (1996)**

This is the General Law for the Ecological Equilibrium and Protection of the Environment. Includes all laws related with the environment, our natural resources and its protection. Since December 1996, the article 87 of this law (LGEEPA) permits the use of wild flora and fauna species, when privates grants a controlled reproduction and growth in captivity or semi-captivity, including a management plan to conserve and protect their populations.

**NOM-059-ECOL-2001**

Norma Oficial Mexicana, NOM-059-ECOL-2001, Protección ambiental – especies de flora y fauna silvestres de México. Published in March 2002, this norm has for object to identify the species and subspecies of wild flora and fauna in the Mexican Republic that are in risked or endangered to disappear. Through the integration of a list, which categories, classifies, and determines the risk and threats of the wildlife.

**Categories of risk:**

1. **Probablemente extinta en el medio Silvestre = Probably extinct in the wild**

   Those species natives of Mexico whose individual had disappear from the wild in the Mexican territory, from which, we have the knowledge that specimens live in captivity or outside the country.

2. **En peligro de extincion = In danger of extinction**

   Those species which distribution areas and population in the national territory had been diminish dramatically. (This category coincided partially with the categories of critically endanger and in danger of extinction on the IUCN classification).

3. **Amenazada = Threatened**

   Those species or their populations, that could get in danger of extinction or disappear in a short or middle period of time if the threats on the species continue. (This category coincided partially with the categories of low risk on the IUCN classification).

4. **Protección especial = Special protection**

   Those species and their population that could get threaten by negative factors, and has determined the
need to recover, conserve or both the habitat and populations associated with the species and species.
(This category could included the low risk IUCN classifications).

Other laws

Apart from the above laws, the hunting law, the Fishing Law, the Forest Laws and other are the fundamentals for
the conservation, protection and sustainable use of wildlife.

Inspection and Supervision

PROFEPAS (Procuraduría Federal para la Protección Ambiental) is the authority in charge to see that the laws
are carried out.

CITES, Authorised Farms for exportation of Hides

CITES has authorised 3 farms to commercialise Morelet’s crocodile hides, products and subproducts.

Cocodrilos Mexicanos s.a. de c.v., Cocomex - Mex
Number: A-MX-501 or Mx / 12.2002 / 1-1
With an estimated production of 12,000 eggs per year, it’s commercialising at present between 6500 and 4800
hides per year. Principal markets Mexico, Japan and Spain.

Industrias Moreletti sa de cv
Number: A-MX-502 or Mx / 12.2002 / 1-2
With an estimated production of 3000 to 4000 eggs per year, it’s commercialising at present around 1500 hides
a year. Principal markets Mexico, Spain and Italy.

Cocodrilos de Chiapas s.a. de c.v.
Number: A-MX-503 or Mx / 12.2002 / 1-3
Not working at present and no data obtained.

Caímanes y Cocodrilos de Chiapas
Does not need a CITES permit to export. With an estimated production of 1000 eggs per year, it’s commercialising
Caiman crocodilus.

No other farms had applied for registration, though there are a few other farms that in a few years will apply.

Activities and Work done in each Region of the Mexican Republic

To simplify the work, the Mexican Republic has been divided in four regions. Each region has different climate and
vegetation even though sharing some characteristic in the habitat. List of principal investigation projects and farms
in each region are (in Spanish):

1. North Pacific Coast, including Sinaloa, Nayarit, Jalisco, Colima and Michoacán States

   The north Pacific coast characterized by a long dry season and low jungle (Caducifolian forest) with a thin line
   of mangrove cost and short rivers. Only Crocodylus acutus occurs.

   • Abreu, Alberto et al. Evaluación genética del hato reproductor en Cocodrilos mexicanos y establecimiento de
     un programa de selección genética.

   • León, Francisco et al. Chirrihueto Lagoon, Culiacán City, Sinaloa State.

   • Huerta, Sara et al. Dinámica Poblacional del “Caimán” (Crocodylus acutus Cuvier 1807, Crocodylidae), en
     Jalisco, México.

   • Huerta, Sara et al. Interacción Hombre-Cocodrilo en la Costa de Jalisco, México.
• Ponce, Paulino et al. Relación de factores físicos del hábitat con eventos reproductivos del “Caimán” Crocodylus acutus Cuvier, 1807.

• Ponce, Paulino et al. Distribución y situación actual de las poblaciones del “caimán” Crocodylus acutus en Jalisco

• Curul, Fabio et al. Ecología y Conservación del Cocodrilo de Río (Crocodylus acutus) en Bahía de Banderas, Jalisco-Nayarit, México

• Valtierra, Marciano. Ecología y Conservación del cocodrilo americano (Crocodylus acutus) en la Reserva de la Biosfera Chamela-Cuixmala, Jalisco, México.

• Navarro, Carlos. Determinación del estatus poblacional de Crocodylus acutus en el extremo norte de Sinaloa y sur de Sonora, México.

• Cocodrilos Mexicanos, Culiacán City, Sinaloa State. Is the biggest farm in Mexico with more than 25,000 crocodiles. Reproducing and commercializing, Crocodylus moreletii.

• Reptilario Cipactli, in Puerto Vallarta city, Jalisco State. Houses around 20 crocodiles at the Puerto Vallarta University, it’s for exhibition, investigation, conservation and reproduction of Crocodylus acutus.

• Cocodrilos del Pacífico, Lagunas de Monte Negro, at Coquimatlán, Colima State. Houses more than 250 Crocodylus acutus. It’s for investigation, reproduction and sustainable use.

2. South Pacific Coast, including Guerrero, Oaxaca and Chiapas States

Caimanes y Cocodrilos de Chiapas, CAICROCHIS, in Tapachula City, Chiapas State. Breed Caiman crocodilus, Crocodylus acutus and Crocodylus moreletii. Housing over 1000 crocodilians. It has also South American species and African tortoise.

• Sigler, Luis et al. Cañón del Sumidero Project, Chiapas State, Zoomat.

• López, María de la Paz et al. Crecimiento y Desarrollo poblacional del Caimán (Caiman crocodilus) en Estado de Chiapas México.

• García, Jesús. Diseño de una estrategia de manejo del cocodrilo de río (Crocodylus acutus) en el estero La Ventanilla, Oaxaca.


• López, Andrés et al. Estado Actual de la Población y dieta alimenticia del Caimán Caiman crocodilus chiapensis en la zona de Laguna de Chantuto, Reserva la Biosfera La Encrucijada, Costa de Chiapas, México.

• Gordillo, Omar et al. Recuperación del Crocodylus acutus en la Reserva de la Biosfera La Encrucijada, Chiapas.

• Martínez, Ivonne et al. SSS Guardianes de la Selva, Pico de Oro Chiapas.

3. Gulf of Mexico, Tamaulipas, San Luis Potosí, Veracruz and Tabasco States

• Domínguez, Jerónimo et al. Contribución al conocimiento de la distribución del cocodrilo de pantano (Crocodylus moreletii) en el estado de San Luis Potosí.

• Domínguez, Jerónimo et al. Determinación de la densidad poblacional del cocodrilo de río (Crocodylus acutus) en los cuerpos de agua de Ixtapa - Zihuatanejo. Guerrero.

• Domínguez, Jerónimo et al. Desarrollo productivo y operacional en la UMA de cocodrilos paraíso Husteco Tanchachin, en el municipio de Auismón, San Luis Potosí.
• Domínguez, Jerónimo et al. Estrategias para el desarrollo productivo de cocodrilo de pantano en la Ciénega de cabezas, municipio de Tamasopo, San Luis Potosí.

• Domínguez, Jerónimo et al. Exploración para la identificación y localización de poblaciones cocodrilanas en los estados de Querétaro e Hidalgo como nuevos sitios con presencia de los Crocodylia en México.

• Domínguez, Jerónimo et al. Análisis genético de fragmentos polimoríficos de las especies de cocodrilianos mexicanos, (Crocodylus acutus, Crocodylus moreletii y Caiman crocodilus fuscus).

Industrias Moreletti, at Villahermosa City, Tabasco State. Is the second biggest farm in Mexico, with more than 5000 crocodiles, reproducing and commercializing Crocodylus moreletii.

Reptilario Cipactli, in Puerto Vallarta city, Jalisco State. Houses around 20 crocodiles at the Puerto Vallarta University, it’s for exhibition, investigation, conservation and reproduction of Crocodylus acutus.

4. Yucatan Peninsula, including Campeche, Yucatan and Quintana Roo States

• Carballar, Javier et al. Estudio, Manejo y Conservación de las poblaciones de cocodrilos en el Sistema Lagunar Nichupte, Cancún, Quintana Roo, México.

• Carballar, Javier et al. Monitoreo de cocodrilos de la reserva de la biosfera banco chinchorro.

a Romero, Miriam et al. Proyecto cocodrilo CETMAR Campeche importancia, justificación, avances y metas.

• Gómez, Yadira. “Hábitos alimentarios de Crocodylus moreletii y Crocodylus acutus en la zona norte de la Reserva de la Biosfera Sian Ka’an”

Cocodrilos Maya, in Ciudad del Carmen, Campeche State. Houses around 250 crocodiles, it’s for investigation, reproduction and commerce of Crocodylus moreletii.

Croccoun, in Cancún City, Quintana Roo State. Houses around 100 crocodiles, it’s for exhibition, investigation, conservation and reproduction of Crocodylus acutus and Crocodylus moreletii.

CET-MAR University, in Campeche City, Campeche State. Houses around 250 crocodiles at the CET-MAR University, it’s for exhibition, investigation, conservation and reproduction of Crocodylus moreletii.

Commerce, Importations, Exportations and Domestic Market

The sustainable use of wildlife, has establish the way to conserve and protect the environment and the wild population in the world.

But Mexico has become more an importer than a producer, in crocodilian terms. We’re producing around 8000 to 10,000 legal skins per year between all 12 commercial farms including the Caiman species and Crocodylus moreletii; this compared with the 250,000 hides imported every year is a big difference, because none of these imports provide incentives for the protection and conservation of the three species of crocodilians that live in our country.

These hides are transformed and 60 to 75% of the finished products are re-exported, mostly to the United States, with smaller quantities to Spain, Italy, Japan and southeast Asia (León, pers. comm., DGVS 2002).

Most imported hides come from Venezuela and Colombia, some other come from the United States, Argentina and Brazil in South America, Zimbabwe in Africa and Australia (Table 1, Fig. 1).

Principal tannery cities in Mexico are Leon in Guanajuato State, Juarez City and Chihuahua City in Chihuahua State, Guzman City in Sonora, Guadalajara City in Jalisco State, Tapachula City in Chiapas State and in Mexico City.

Most of the goods are cowboy boots, belts, bags, wallets, and smaller products.
Table 1. Imports of crocodilian hides into Mexico, 1993-2001.

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>A. mississippiensis</td>
<td>526</td>
<td>1377</td>
<td>758</td>
<td>795</td>
<td>7615</td>
<td>14,683</td>
<td>16,830</td>
<td>10,056</td>
<td>4385</td>
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<tr>
<td>C. c. crocodilus</td>
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<td></td>
<td></td>
<td></td>
<td>143</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>153</td>
</tr>
<tr>
<td>C. c. chiapensis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13,972</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13,972</td>
</tr>
<tr>
<td>C. c. fuscus</td>
<td>181</td>
<td>899</td>
<td>5650</td>
<td>43,334</td>
<td>24,550</td>
<td>74,374</td>
<td>146,165</td>
<td>260,018</td>
<td>243,334</td>
<td>798,505</td>
</tr>
<tr>
<td>C. yacare</td>
<td>210</td>
<td>9396</td>
<td>15,450</td>
<td>23,713</td>
<td>3999</td>
<td>600</td>
<td>1500</td>
<td>5444</td>
<td>60,312</td>
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</tr>
<tr>
<td>C. johnstoni</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>40</td>
<td></td>
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<td>42</td>
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<tr>
<td>C. niloticus</td>
<td></td>
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<td></td>
<td>8190</td>
<td>204</td>
<td>4550</td>
<td>19,536</td>
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<td>6102</td>
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<td>C. moreletti</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td>70</td>
<td>50</td>
<td></td>
<td>155</td>
</tr>
<tr>
<td>C. novaeguineae</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>165</td>
<td></td>
<td></td>
<td>166</td>
</tr>
<tr>
<td>C. porosus</td>
<td>100</td>
<td>152</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>272</td>
</tr>
<tr>
<td>Totals</td>
<td>708</td>
<td>2586</td>
<td>15,958</td>
<td>81,751</td>
<td>56,157</td>
<td>97,819</td>
<td>183,346</td>
<td>281,472</td>
<td>259,285</td>
<td>979,082</td>
</tr>
</tbody>
</table>

Figure 1. Imports of hides into Mexico, by genus, 1993-2001.
Some “Gavials” are *Tomistoma schlegelii*

Franklin D. Ross and Norna R. Ross

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Abstract

While examining older anatomical literature about the morphology of the trachea in crocodilians, we discovered an error in an original text, which caused a considerable amount of confusion. When reexamining the data about the tracheal rings and the rings of the exposed bronchi, and the total number of cartilage rings in the windpipes system, we conclude that the data supports contradictory systematic arrangements.

Introduction

When the anatomist Heinrich Rathke (1866) used the word "Gavialen" in the context that the number of tracheal cartilage rings in the gavials is smaller than the number in the genus *Crocodylus*, it contradicted the corresponding data in his accompanying table. What Rathke meant to say is that *Gavialis schlegelii*, now called *Tomistoma schlegelii*, has fewer tracheal rings than any species within the genus *Crocodylus* or the species *Gavialis gangeticus*. The reason for Rathke's unfortunate wording is not known. However, because Rathke’s (1866) dissections of a taxonomically diverse series of the modern Crocodylia were so completely and well reported and illustrated, his works have become an often cited source.

When Professor C.K. Hoffmann at Leiden University wrote the reptiles section in H.G. Bronn's prestigious "Klassen und Ordnungen des Thier-Reichs" book series, he relied heavily on Rathke for details and conclusions about many anatomical subjects, including the cartilage rings in the extra-pulmonary windpipes-system commonly known as the trachea and the two exposed bronchial tubes. Hoffmann's (1890: 1034) assertion that the number of tracheal rings "bei den Gavialen am kleinsten, bei den Crocdilen (ie bei der Gattung *Crocodilus*) am grossten" is remarkably similar to Rathke's (1866: 150) statement that "bei den Gavialen am kleinssten, hingegen bei den Thieren der Gattung *Crocodilus* am grossten" in that both phrases assert that the "Gavialen" (plural of gavial) have fewer cartilage rings in their tracheas, while normal crocodiles such as *Crocodylus* have the most.

In comparison with Rathke's fairly rare set of papers (1857 material listed, 1866 windpipes reported), Bronn's edited book-series containing Hoffmann's (1890) summaries of crocodilian anatomy has become widely circulated. Some authors like Reese (1915a-b) have attributed Hoffmann's (1890) German paraphrases of Rathke's original German to Rathke or to Bronn, without mentioning Hoffmann (see quotation of part of Reese's text, below); and, in this particular case, if Reese had consulted the original Rathke publication, he would have noticed the table saying that *Gavialis gangeticus* has more tracheal rings than any of the *Crocodylus* species.

Later and independently, when Steven F. Perry (1998: 36) said about "the number of cartilaginous rings in the trachea and extrapulmonary bronchi" that "the number is least in *Gavialis*, and greatest in *Crocodylus* (Hoffmann, 1890)”, Perry and his editors fell into the trap of equating "Gavialen" with *Gavialis gangeticus*, the only living *Gavialis* species today. Their compound error not only misrepresented gangeticus; but, it also misrepresented *schlegelii* because, in 1998, the genus *Gavialis* did not include *schlegelii* as a species.

Discussion

The German "Gavialen" was a compound group in 1857-1866, when Rathke (in the 1866 table especially) put *schlegelii* and *gangeticus* in the same genus; and, it is interesting to note that Reese in 1915 was also using "gavials" to include *Gavialis gangeticus* and *Tomistoma schlegelii* together, following a classification system popularized by Ditmars and based on feeding habits or "the shape of the head" as Reese (1915a: 1-3) put it. Thus it is even more difficult to understand Reese. However, Perry in 1998, is very clear wording; and, because it appeared in the "Biology of the Reptilia" series, edited by Carl Gans, it is both highly respected, and globally circulated. In its final (1998) form, the statement is totally false; because, Rathke's data in the table showed *Tomistoma* to have the least number of
trachial rings, followed then by the alligators and caymans as a group, followed in turn by the Crocodylus species; and, finally, with the most rings in the trachea is Gavialis gangeticus, as shown below in Column A, of Table 1.

Table 1. Rathke's (1866: 149-150) table, with original species names in their published order. Column A is cartilage rings in the main tracheal stem. Column B is the number of rings in the exposed left bronchus. Column C is the number in the right bronchial tube. Note that column A is the trachea ("dem Stamme") which has the "Gavialen" at the extremes of variation. Note also that columns B and C are left and right branches of the "more or less" symmetrical bronchial tubes, which are later averaged together to produce the mean bronchial numbers in Table 2, below. See other tables for translated material; and, see Table 4 especially for modern equivalents of Rathke's genera and species names.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embryo von Gavialis Schlegelii</td>
<td>51</td>
<td>36</td>
</tr>
<tr>
<td>jungen Allig. punctulatus</td>
<td>63</td>
<td>22</td>
</tr>
<tr>
<td>Embryo von Allig. Sclerops</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>jungen Allig. Sclerops</td>
<td>62</td>
<td>19</td>
</tr>
<tr>
<td>alteren Allig. Sclerops</td>
<td>66</td>
<td>18</td>
</tr>
<tr>
<td>jungen Allig. Laticius</td>
<td>66</td>
<td>12</td>
</tr>
<tr>
<td>alteren Allig. Laticius</td>
<td>60</td>
<td>16</td>
</tr>
<tr>
<td>Embryo von Allig. cynocephalus</td>
<td>65</td>
<td>25</td>
</tr>
<tr>
<td>jungen Allig. cynocephalus</td>
<td>74</td>
<td>25</td>
</tr>
<tr>
<td>alteren Allig. cynocephalus</td>
<td>74</td>
<td>19</td>
</tr>
<tr>
<td>jungen Allig. palpebrosum</td>
<td>70</td>
<td>17</td>
</tr>
<tr>
<td>etwas alteren Allig. palpebrosum</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>jungen Croc. vulgaris</td>
<td>85</td>
<td>35</td>
</tr>
<tr>
<td>alteren Croc. vulgaris</td>
<td>84</td>
<td>32</td>
</tr>
<tr>
<td>nicht reifen Embryo von Croc. acutus</td>
<td>87</td>
<td>19</td>
</tr>
<tr>
<td>eben so alten Embryo von Croc. acutus</td>
<td>89</td>
<td>24</td>
</tr>
<tr>
<td>reifen Embryo von Croc. acutus</td>
<td>88</td>
<td>30</td>
</tr>
<tr>
<td>jungen Croc. acutus</td>
<td>79</td>
<td>33</td>
</tr>
<tr>
<td>alteren Croc. acutus</td>
<td>88</td>
<td>32</td>
</tr>
<tr>
<td>jungen Croc. biporcutus</td>
<td>102</td>
<td>36</td>
</tr>
<tr>
<td>etwas alteren Croc. biporcutus</td>
<td>96</td>
<td>39</td>
</tr>
<tr>
<td>noch alteren Croc. biporcutus</td>
<td>104</td>
<td>40</td>
</tr>
<tr>
<td>jungen Gav. gangeticus</td>
<td>116</td>
<td>29</td>
</tr>
</tbody>
</table>

Note that the statements made by Rathke and Hoffmann and Reese are not only not true about the gavials in the broadest and simple descriptive sense (those two super-long snouted piscivores); but, their assertions are only describing the number of cartilage rings in the main and single-tube stem of the trachea, before the windpipes system (larynx, trachea, syrinx in crocs, bronchial pair, lungs) bifurcates posteriorly into the two exposed bronchi. If Rathke had summarized the left bronchus (Column B, Tables 1-2), for example, he would have said that the alligators have the fewest (12-25), followed by the true gavial of India (29), and that the species of Crocodylus have the most (19-40), with Tomistoma (36) in the range of Crocodylus; and, in essence, the same is true of the right bronchus, as shown in Column C, in Tables 1-2. A similarly different result is also obtained by averaging the left and right bronchi into a single "bronchial" mathematical mean, as shown in Column D, in Table 2 (where B + C, divided by 2 = D).

In Figures 2-4, the specimens identified as "Meckel" and "Cuvier" are second-hand data which Rathke obtained from the literature. The uncommon synonym (Alligator punctulatus) of the common cayman used by Rathke (1857, 1866) is distinguished from Rathke's Alligator sclerops by following Hoogmoed and Gruber (1983: 378-9) in the opinion that Jacaretingapunctulatus Spix = Caiman c. crocodilus (L.). The current names and classification of all of the specimens reported in Rathke (1866: 149-150) are made clear in Table 4, including Column F.

In Column D, in Table 2, the simple picture is that some Alligatoridae have the fewest cartilage rings in their bronchi, followed by chaos. In a theoretical sense, the number of rings in the trachea is no more important than the number of rings in the bronchi; or, even combining the two data sets for the number of rings in the whole windpipes system, as shown in Column E of Table 3 (where A plus C = E).
Table 2. Bronchial data from Rathke (1866: 149-150) including some second-hand data, with the names of all species updated; and, rearranged in order of column D. Column B is just the left bronchus (as in Table 1, but arranged here by bronchial mathematical means from column D). Column C is just the right bronchus, arranged by bronchial average (from column D). Column D is the average or mean value of the two bronchial tubes together as one number.

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>young Alligator mississippiensis</td>
<td>12</td>
<td>14</td>
<td>13.0</td>
</tr>
<tr>
<td>older Alligator mississippiensis</td>
<td>16</td>
<td>16</td>
<td>16.0</td>
</tr>
<tr>
<td>older Paleosuchus palpebrosus</td>
<td>16</td>
<td>18</td>
<td>17.0</td>
</tr>
<tr>
<td>young Paleosuchus palpebrosus</td>
<td>17</td>
<td>18</td>
<td>17.5</td>
</tr>
<tr>
<td>Meckel's Alligator mississippiensis</td>
<td>no data</td>
<td>no data</td>
<td>18.0</td>
</tr>
<tr>
<td>older Caiman latirostris</td>
<td>19</td>
<td>18</td>
<td>18.5</td>
</tr>
<tr>
<td>ripe embryo Crocodylus acutus</td>
<td>19</td>
<td>18</td>
<td>18.5</td>
</tr>
<tr>
<td>older Caiman crocodilus ssp.</td>
<td>18</td>
<td>19</td>
<td>18.5</td>
</tr>
<tr>
<td>young Caiman crocodilus ssp.</td>
<td>19</td>
<td>20</td>
<td>19.5</td>
</tr>
<tr>
<td>embryo Caiman crocodilus ssp.</td>
<td>20</td>
<td>19</td>
<td>19.5</td>
</tr>
<tr>
<td>Meckel's Caiman crocodilus ssp.</td>
<td>no data</td>
<td>no data</td>
<td>20.0</td>
</tr>
<tr>
<td>young Caiman crocodilus crocodilus</td>
<td>22</td>
<td>24</td>
<td>23.0</td>
</tr>
<tr>
<td>embryo same age Crocodylus acutus</td>
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<td>24</td>
<td>24.0</td>
</tr>
<tr>
<td>embryo Caiman latirostris</td>
<td>25</td>
<td>25</td>
<td>25.0</td>
</tr>
<tr>
<td>young Caiman latirostris</td>
<td>25</td>
<td>26</td>
<td>25.5</td>
</tr>
<tr>
<td>young Gavialis gangeticus</td>
<td>25</td>
<td>26</td>
<td>27.0</td>
</tr>
<tr>
<td>Meckel's Crocodylus acutus</td>
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<td>no data</td>
<td>30.0</td>
</tr>
<tr>
<td>Cuvier's Crocodylus niloticus</td>
<td>32</td>
<td>32</td>
<td>32.0</td>
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<tr>
<td>young Crocodylus acutus</td>
<td>33</td>
<td>32</td>
<td>32.5</td>
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<tr>
<td>older Crocodylus acutus</td>
<td>32</td>
<td>33</td>
<td>32.5</td>
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<tr>
<td>older Crocodylus niloticus</td>
<td>32</td>
<td>34</td>
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</tr>
<tr>
<td>young Crocodylus niloticus</td>
<td>35</td>
<td>35</td>
<td>35.0</td>
</tr>
<tr>
<td>young Crocodylus porosus</td>
<td>36</td>
<td>36</td>
<td>36.0</td>
</tr>
<tr>
<td>embryo Tomistoma schlegelii</td>
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<td>37</td>
<td>36.5</td>
</tr>
<tr>
<td>somewhat older Crocodylus porosus</td>
<td>39</td>
<td>40</td>
<td>39.5</td>
</tr>
<tr>
<td>even older Crocodylus porosus</td>
<td>40</td>
<td>40</td>
<td>40.0</td>
</tr>
</tbody>
</table>

In Column E, it is significant that Tomistoma does not have the fewest. We think that Rathke's arrangement of the species by tracheal rings (see Column A in Table 1) was following the science of his time by considering anterior (closer to the head) most important; and, also thinking larger (and single in this case) is better than smaller. He was likely not intending to make a taxonomic statement; but, was happy to be able to construct a short summary sentence because he had his "Gavialen" at both ends of the tracheal variation data. All that is clear is that Rathke's act of overlooking Gavialis gangeticus in his text statement was significant; and, that Hoffmann (1890) failed to catch Rathke's (1866) error. Part of Hoffmann's problem in summarizing Rathke's conclusions is the number of synonyms involved; for example, Gavialis gangeticus was called "Gav. gangeticus" and "Gav. tenuirostris" and "Gav. tenuirostris (gangeticus)" and also "Rhamphostoma tenuirostre (Gavialis)" in the first half of Rathke's (1866: 143-164) "Respiration organs" chapter.

Finally, Reese (1915a: 198-199) added some numbers to the tracheal-rings question (and put our famous "Gavialen" phrase into context), saying "The number of tracheal rings varies not only in different species but also in different individuals of the same species. There are between fifty and sixty in A. mississippiensis. According to Rathke the number of rings in the individual animal most certainly does not increase with age. The number of rings is smallest in the gavials and greatest in the crocodiles (genus Crocodylus). The number of rings in two divisions of the trachea does not increase with age except, perhaps, C. acutus and biporcarus. ... According to Rathke and others most of the tracheal rings are closed, but a varying, though at most small, number are open on the dorsal side. These openings become wider as the larynx is approached. The transverse muscle fibers which are found in the most anterior and largest of these breaks in the tracheal rings were found, says Rathke, in embryos after the middle period of incubation."
Table 3. Total windpipes-system data from Rathke (1866 incl. lit. cites) arranged in strict numerical order of column E. Column A and Column C are the same data as in Tables 1-2, though slightly expanded, and rearranged in order of column E. Column E is the total of the whole windpipes-system (trachea and bronchial-average combined).

<table>
<thead>
<tr>
<th>A</th>
<th>C</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>alteren Alligator mississippiensis</td>
<td>60</td>
<td>16.0</td>
</tr>
<tr>
<td>jungen Alligator mississippiensis</td>
<td>66</td>
<td>13.0</td>
</tr>
<tr>
<td>Embryo von Caiman crocodilus ssp.</td>
<td>60</td>
<td>19.5</td>
</tr>
<tr>
<td>jungen Caiman crocodilus ssp.</td>
<td>62</td>
<td>19.5</td>
</tr>
<tr>
<td>older Caiman crocodilus ssp.</td>
<td>66</td>
<td>18.5</td>
</tr>
<tr>
<td>jungen Caiman crocodilus crocodilus</td>
<td>63</td>
<td>23.0</td>
</tr>
<tr>
<td>Embryo von Tomistoma schlegelii</td>
<td>51</td>
<td>36.5</td>
</tr>
<tr>
<td>jungen Paleosuchus palpebrosus</td>
<td>70</td>
<td>17.5</td>
</tr>
<tr>
<td>etwas alteren Paleo. palpebrosus</td>
<td>72</td>
<td>17.0</td>
</tr>
<tr>
<td>Embryo von Caiman latirostris</td>
<td>65</td>
<td>25.0</td>
</tr>
<tr>
<td>alteren Caiman latirostris</td>
<td>74</td>
<td>18.5</td>
</tr>
<tr>
<td>Meckel's (70-80) Alligator mississippiensis</td>
<td>75</td>
<td>18.0</td>
</tr>
<tr>
<td>Meckel's (70-80) Caiman crocodilus ssp.</td>
<td>75</td>
<td>20.0</td>
</tr>
<tr>
<td>jungen Caiman latirostris</td>
<td>74</td>
<td>25.5</td>
</tr>
<tr>
<td>nicht reifen Embryo Croc. acutus</td>
<td>87</td>
<td>18.5</td>
</tr>
<tr>
<td>jungen Crocodylus acutus</td>
<td>79</td>
<td>32.5</td>
</tr>
<tr>
<td>eben so alten Embryo von Croc. acutus</td>
<td>89</td>
<td>24.0</td>
</tr>
<tr>
<td>Cuvier's (82) Crocodylus niloticus</td>
<td>82</td>
<td>32.0</td>
</tr>
<tr>
<td>alteren Crocodylus niloticus</td>
<td>84</td>
<td>33.0</td>
</tr>
<tr>
<td>reifen Embryo von Crocodylus acutus</td>
<td>88</td>
<td>30.0</td>
</tr>
<tr>
<td>jungen Crocodylus niloticus</td>
<td>85</td>
<td>35.0</td>
</tr>
<tr>
<td>Meckel's (90) Crocodylus acutus</td>
<td>90</td>
<td>30.0</td>
</tr>
<tr>
<td>alteren Crocodylus acutus</td>
<td>88</td>
<td>32.5</td>
</tr>
<tr>
<td>etwas alteren Crocodylus porosus</td>
<td>96</td>
<td>39.5</td>
</tr>
<tr>
<td>jungen Crocodylus porosus</td>
<td>102</td>
<td>36.0</td>
</tr>
<tr>
<td>jungen Gavialis gangeticus</td>
<td>116</td>
<td>27.0</td>
</tr>
<tr>
<td>noch alteren Crocodylus porosus</td>
<td>104</td>
<td>40.0</td>
</tr>
</tbody>
</table>

For Reese's "between fifty and sixty" cartilage rings in the trachea data, we take the middle number of 55 tracheal rings, partly because it leaves the FALSE and TRUE "Gavialen" at the extremes of variation, as shown in Column A, in Table 4. This arrangement is so visually attractive that even we are willing to play with the numbers to keep gators (50 is less than 51) from having the fewest cartilage rings in their tracheas, though they apparently do.

Conclusion

The data in Rathke (1866) and in Reese (1915a) about cartilage rings in the trachea is probably meaningless in a taxonomic sense; because, arranging the species and genera by bronchial counts gives different results, as does arranging the data by the numerical variation in the total exposed windpipes system (tracheal and bronchus numbers combined). All assertions that the gharials or gavials or Gavialis have the fewest tracheal rings are most likely in error; because, Tomistoma schlegelii has very few, and is at the lower extreme of alligators; while, Gavialis gangeticus has the most, and is beyond the extreme of proper crocodiles.

Literature

Table 4. Just the main-stem tracheal rings: Rathke 1866, and Reese 1915, combined and arranged in numerical order. Column F is subfamily (Tomistominae) or family (gators, crocs, gharial) classification. Column A is here expanded to include Reese’s, Meckel’s and Cuvier’s data; and, here arranged in actual numerical order.

<table>
<thead>
<tr>
<th>F</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gavialis Schlegelii = Tomistoma schlegelii</td>
<td>Tomistominae</td>
</tr>
<tr>
<td>Reese (50-60) Alligator mississippiensis</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator Sclerops = Caiman crocodilus ssp.</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator Lucius = Alligator mississippiensis</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator Sclerops = Caiman crocodilus ssp.</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator punctulatus = Caiman c. crocodilus</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator cinocephalus = Caiman latirostris</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator Sclerops = Caiman crocodilus ssp.</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator Lucius = Alligator mississippiensis</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator palpebrosus = Paleosuchus palpebrosus</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator palpebrosus = Paleosuchus palpebrosus</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator cinocephalus = Caiman latirostris</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Alligator cinocephalus = Caiman latirostris</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>M’s Allig. Sclerops = Caiman crocodilus ssp.</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>M’s Alligator Lucius = Alligator mississippiensis</td>
<td>Alligatoridae</td>
</tr>
<tr>
<td>Crocodilus acutus = Crocodylus acutus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>C’ Crocodilus vulgaris = Crocodylus niloticus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>Crocodilus vulgaris = Crocodylus niloticus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>Crocodilus acutus = Crocodylus niloticus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>Crocodilus acutus = Crocodylus acutus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>Crocodilus acutus = Crocodylus acutus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>Crocodilus acutus = Crocodylus acutus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>M’s Crocodilus acutus = Crocodylus acutus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>Crocodilus biporcatus = Croc. porosus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>Crocodilus biporcatus = Crocodylus porosus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>Crocodilus biporcatus = Crocodylus porosus</td>
<td>Crocodylidae</td>
</tr>
<tr>
<td>Gavialis gangeticus = Gavialis gangeticus</td>
<td>Gavialidae</td>
</tr>
</tbody>
</table>

Hoogmoed, M.S. and Ulrich Gruber (1983). Spix and Wagler type specimens of reptiles and amphibians in the natural history musea in Munich (Germany) and Leiden (The Netherlands). Spixiana (supplement 9) 319-415. Munich, Germany.


Rathke (1866). Untersuchungen über die Entwicklung und den Körperbau der Krokodile (= Investigations into the development and structure of the body of crocodiles). Friedrich Vieweg und Sohn: Braunschweig, Germany, i-ix, & i-275 pp.; and, plates 1-11.


Workshop Reports

Workshop 1: Skin Quality Workshop (Fritz Huchzeremeyer)

A list of skin defects was established and discussed. It was agreed that the current secrecy surrounding this issue is entirely counterproductive and it was then decided to produce a document with a description and illustration of all known defects, with their causes if known, to be presented at the next CSG meeting in 2006. The participants promised to contribute knowledge and photographic material to this end.

Workshop 2: Human-Crocodile Conflict Workshop (Rich Fergusson)

There are now over 50 CSG members who have expressed interest in this group’s activities at either the 16th or 17th Working Meetings. It was agreed that the group needed to keep in close contact to ensure activity between CSG meetings. To facilitate this a number of regional co-ordinators offered to keep contact with interested people in their areas and to compile information and updates on HCC. The regional co-ordinators are:

USA Allan Woodward (allan.woodward@fwc.state.fl.us)
Meso America Miriyam Venegas (venegasm@naos.si.edu)
Australasia Mark Read (mark.read@epa.qld.gov.au)
Africa Rich Fergusson (zeahtco@zol.co.zw)
SE Asia Nikhil Whitaker (kachugazi@hotmail.com) and S.M.A. Rashid (rashid@reptilesfarm.com)

The workshop agreed there was urgent need to deliver a number of products. It was agreed that these would be:

- Consolidated guidelines on the prevention and management of HCC that are approved by CSG that may be provided to government wildlife authorities that have the problem but no solution.

- A database of all attacks by crocodiles on humans and livestock. It was recognised that this maybe difficult to achieve in a globally compatible format but that within regions this should be achievable. There are two aims to this product - to formalise the capture and reporting of information on HCC incidents and to use this compilation to indicate how countermeasures may be applied.

- A “fact sheet” that combines information from the above two products. It is intended that this is provided to print and broadcast media pre-emptively and when HCC incidents occur, with the aim of minimising the hype that frequently appears, at least in the more developed countries.

It was further agreed that the group needed to improve the impact and reach of educational material and efforts. In this regard members of the group will react whenever possible to advise on the realities of HCC and its prevention, that “crocodile tourism” would be encouraged provided that this carries a strong message on responsible actions and that the African Educational Film Foundation would be approached to assist.

Finally it was agreed that more information and research was needed on crocodile populations, the incidence of HCC, factors increasing the risk of HCC, and countermeasures that can be employed, including harvesting to reduce crocodile populations. It was noted that harvesting alone was unlikely to provide a solution to HCC.

Workshop 3: Major Issues Affecting Sustainability of Crocodilian Trade (Don Ashley)

The results of this workshop are presented within the paper entitled “Major issues affecting crocodilian sustainable trade”, pages 341-343 in this volume.
Workshop 4: CSG Core Business (Perran Ross)

CSG is at pivotal point in its development with substantial structural and financial strength, a strong record of achievement and success and good global credibility. Impending leadership change and new and previously unforeseen issues make consideration of Core issues and guidance for the immediate time frame of 2004- to the next Working Meeting, strategically important. The 17th Working Meeting provided a unique opportunity for broad member input to this process.

After discussion at Steering Committee and with core CSG leaders, a draft ‘statement of core business’ was proposed and a process to examine the views and opinions of meeting participants on this important issues was developed.

‘The core business of the CSG is crocodilian conservation’

However, the exact direction, details and structure to achieve this general goal requires elaboration. To accomplish this, a simple questionnaire was developed and distributed to all participants on the first day of the meeting with the request that people would respond within 24 hours. Responses were collected, collated and a small team attempted a general analysis of the responses received. The questionnaire is attached as Appendix 1.

The questionnaire attempted to identify respondents according to their membership in CSG and knowledge about the relationship of CSG and its parent IUCN-SSC and then explored preferences of respondents regarding general themes and specific actions that CSG should be concerned with in the intermediate time frame of 1-3 years.

The results and analysis are severely limited by some inherent biases and constraints that must be considered before accepting the results as ‘truth’. However, we believe that this exercise did allow a free and open discussion and contributions by the respondents and should be carefully considered as a general guide to future CSG strategy development. Biases and limitations of the process include the following:

- The questionnaire was ad-hoc and not scientifically designed and therefore represents the biases of its drafters.
- The respondents are neither a random sample of CSG members nor were they a fully representative sample. Respondents were a group of CSG members and non members, present at the meeting and choosing to provide responses. The result should be interpreted with these evident biases in mind.
- A specific and obvious bias was that a large proportion of meeting participants, and therefore of respondents, was Australian and reflects their national preoccupations and concerns. This bias is clearly evident in some of the results.
- The analysis we conducted was informal and hasty, not statistically robust.

For all these reasons the results should be taken as a general indication of opinions from a specific subgroup of CSG interests and should not be generalized. Rather they should serve as a foundation for further inquiry.

We distributed questionnaires to 230 meeting participants and received 81 responses, a creditable 35% response rate. We divided the responses according to whether the respondents were CSG members or not and whether they indicated their interaction with CSG was positive and useful (Question 2) or otherwise. Five responding CSG members suggested their interaction with CSG was negative. The reasons for this discontent needs to be identified and rectified.

<table>
<thead>
<tr>
<th></th>
<th>CSG members</th>
<th>Non-Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSG +ve</td>
<td>27</td>
<td>14</td>
</tr>
<tr>
<td>CSG neutral or -ve</td>
<td>18 (5 -ve)</td>
<td>17</td>
</tr>
</tbody>
</table>

The first question we analyzed was respondents understanding of SSC-IUCN. There was a clear difference in response between members and non- members. Most CSG members claimed to understand IUCN while many non-members did not.

The estimation of the value of the association with IUCN also segregated strongly by CSG membership and less so by positive feelings about CSG. As the Chairman of SSC was present in the audience, we are gratified that overall - most members appear to value the association with SSC.
<table>
<thead>
<tr>
<th></th>
<th>CSG members</th>
<th></th>
<th>Non-Members</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CSG +ve</td>
<td>CSG -ve</td>
<td>Non-Member +ve</td>
<td>Non-Member -ve</td>
</tr>
<tr>
<td>Question 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding of IUCN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YES</td>
<td>24</td>
<td>15</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>NO</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Questions 6 &amp; 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of IUCN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ve</td>
<td>24</td>
<td>15-17</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Neutral</td>
<td>2</td>
<td>1</td>
<td>0-2</td>
<td>2</td>
</tr>
<tr>
<td>-ve</td>
<td>0</td>
<td>0</td>
<td>0-2</td>
<td>0</td>
</tr>
</tbody>
</table>

Question 12 asked respondents to choose from a list of possible ‘Core business’ topics. Some very clear positive and negative responses emerged. Percent of positive (supporting) responses are shown in the following table.

Core Business IS:
- Develop conservation policy (92%)
- Prevent extinction (83%)
- Advising national agencies (77%)
- Advising IUCN (65%)

Core Business is NOT:
- Local activism (16%)
- Political advocacy (35%)

Question 13 inquired about the most important structural elements that CSG needed to address. Again there were clear majority indications of both preferences and dislikes. The percentage of positive (supportive) responses is indicated against the sub-question of question 13 (see Appendix).

Strong support
- Fundraising for Core activity (71%)
- Broader integration of topics (66%)

Weak support
- Changing size (15%)
- Narrow commercial focus (30%)
- Increasing paid staff (38%)

Interestingly, on the question of number of members, many respondents checked both ‘do not increase’ and ‘do not decrease’ indicating they think the size of the group is about right.

Question 14 asked respondents to indicate preferences from a list of issues deemed to be important for CSG. Of interest is the poor support for some emerging and newly identified threats to crocodilians. However, traditional CSG interests remain strongly supported.

Most Important
- Sustainable management (88%)
- Habitat loss (80%)
- Critically endangered species (79%)

Least Important
- Wildlife disease (36%)
- Increased use (38%)
- Pollution (41%)

A sub-question of question 14 gave respondents an opportunity to express a preference for a species they considered of high priority. The results suggest that a few species have their dedicated proponents, but most respondents have
no species priority.

- No species preference (48)
- Tomistoma (5)
- C. porosus (5)
- Gharial (4)
- C. siamensis (3)
- A. sinensis, C. mindorensis, (2)
- Osteolaemus, Caiman yacare (1)

The final question gave respondents the opportunity to write in their own expressions of priority issues. This section is important because it is not constrained by the structure or content of the questionnaire and might more accurately reflect respondent interests. Analysis of this question was difficult, but we grouped the 118 responses into broad categories defined by consensus of the analysis team and indicate the number of similar statements for each group.

- Critically Endangered species (26 responses)
  Asia, new approaches, active programs, interaction with government

- National Conservation and Management (26 responses)
  Habitat loss, monitoring, capacity building, CITES compliance. Australian safari hunting, reintroduction programs

- Research (18 responses)
  Biology, human-croc conflict, skin quality

- Trade and Use (17 responses)
  Linking use and conservation, monitoring trade, sustainability, farming guidelines, promoting use, Occupational Health and Safety regulations in Australia.

- Information Issues (17 responses)
  Public awareness, encourage young people, exchange with diverse groups

It is unclear why a significant number of respondents suggested that increased public awareness of crocodilian issues was needed but this item received very low support in question 12.

Finally, question 9 addressed a number of possible structural rearrangements for CSG. A short and useful list emerged of issues that respondents felt CSG should address.

- Reorganize regionally (questionnaire support 46%)
- Improve contact to IUCN
- Avoid internal politics
- Diversify fundraising
- Improve networking
- Empower members

In conclusion, we feel that this exercise has provided rough but useful indicators of the sentiments of this important gathering of CSG members and supporters. It has given a large number of people the opportunity to express their views. The results, while rough, are intriguing and indicators for additional inquiry. Overall, the results suggest a rather conservative perspective by these respondents. They do not support or propose any drastic departures from current structure or activity. However, there are a number of issues, identified in the tables above that are suggested for further examination and action.

Thanks for assistance in data collection, compilation and analysis to Akira Matsuda, Sally Isberg, Col Stephenson, Amanda Rice, Laurel Converse, Vicki Simlesa and Nancy Fitzsimmons. Significant assistance with concept, the questionnaire and the development of the core business statement was provided by Harry Messel, Grahame Webb, Charlie Manolis and members of the CSG Steering Committee.
## APPENDIX

### Core Business Workshop Questionnaire

1. Are you a CSG member?  
   Yes.....  
   No.....

2. Does CSG assist your work/business?  
   Yes.....  
   Neutral.....  
   No.....

3. I contact CSG (please be honest)  
   Often.....  
   Sometimes.....  
   Rarely.....

4. I learn of CSG activity from: (check as many as you like)  
   a. CSG Newsletter  
   b. Other members  
   c. CSG Website  
   d. Direct correspondence  
   e. Working Meetings  
   f. Other.........................  
   
   Yes.....  

5. I understand CSG’s relationship to IUCN and SSC and can answer questions 6-11 below (if No, Please go to question 12)  
   Yes.....  
   No.....

6. CSG’s inclusion in IUCN is  
   Valuable.....  
   Neutral.....  
   Useless.....

7. CSG’s inclusion in SSC is  
   Valuable.....  
   Neutral.....  
   Useless.....

8. IUCN policy defines my CSG activity?  
   Yes.....  
   No.....

9. IUCN Croc Red Listing helps my work  
   Yes.....  
   Neutral.....  
   No.....

10. I am a member of other SSC groups  
    Yes.....  
    No.....

11. IUCN/SSC assists my work  
    Yes.....  
    Neutral  
    No.....

12. CSG’s “CORE” business is: (check as many as you like)  
   a. Preventing crocodilian extinction?  
   b. Developing conservation policy  
   c. Advising national agencies  
   d. Advising international treaties  
   e. Biological Research  
   f. Initiating conservation programs  
   g. Local activism  
   h. Advising IUCN and its members?  
   i. Public education  
   j. Political and advocacy  
   k. Disseminating information  
   l. Fundraising for croc conservation  
   
   Yes.....  
   No.....

   Other (please indicate)

   Yes.....  
   No.....

   Yes.....  
   No.....

   Yes.....  
   No.....
13. CSG can accomplish its Core business most effectively by the following actions, strategies and structure:
   a. More active advocacy  Yes.....  No.....
   b. More Fundraising
      i. For core CSG activity  Yes.....  No.....
      ii. To fund member activity  Yes.....  No.....
      iii. Support member fundraising  Yes.....  No.....
   c. Funding member projects  Yes.....  No.....
   d. Maintaining current structure  Yes.....  No.....
   e. Reorganising current regions  Yes.....  No.....
   f. Independent organizational status  Yes.....  No.....
   g. Becoming smaller (fewer members)  Yes.....  No.....
   h. Becoming larger (more members)  Yes.....  No.....
   i. Increase paid staff  Yes.....  No.....
   j. Narrower focus
      i. On endangered species  Yes.....  No.....
      ii. On commercial species  Yes.....  No.....
      iii. On economic/social factors  Yes.....  No.....
      iv. On habitat/landscape issues  Yes.....  No.....
   k. Broader focus integrating i.-iv.above  Yes.....  No.....
   l. Support independent member action  Yes.....  No.....

14. The most important issues facing CSG in the immediate future are:
   a. Trade regulation  Yes.....  No.....
   b. This species (please indicate)
      ........................................  Yes.....
   c. Human-croc conflicts  Yes.....  No.....
   d. Increased commercial use  Yes.....  No.....
   e. Sustainable management  Yes.....  No.....
   f. Habitat loss  Yes.....  No.....
   g. Critically endangered species  Yes.....  No.....
   h. Pollution effects  Yes.....  No.....
   i. Public perception of crocs  Yes.....  No.....
   j. Wildlife disease  Yes.....  No.....
   k. Inadequate biological knowledge  Yes.....  No.....
   l. Inadequate national programs  Yes.....  No.....
   m. Other (please indicate)
      ........................................  Yes.....

CSG’s three main priorities for the next 2-3 years must be:

#1..............................................................

#2 ..............................................................

#3 ..............................................................