Crocodile Specialist Group, Species Survival Commission

CROCODILES

World Crocodile Conference

Proceedings of the 22nd Working Meeting of the Crocodile Specialist Group

Negombo, Sri Lanka, 21-23 May 2013

(Unreviewed)

2013

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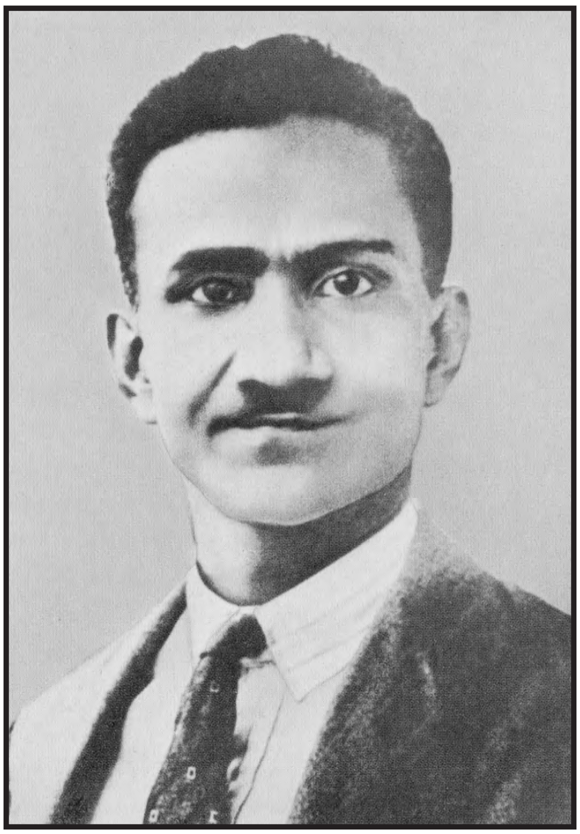

Dedicated to Dr. Paulus Edward Pieris Deraniyagala
(8th of May 1900 - 1st December 1973)

(Unreviewed)

International Union for Conservation of Nature (IUCN)
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Front cover: Saltwater Crocodile, *Crocodylus porosus.* © Ruchira Somaweera
Mugger Crocodile, *Crocodylus palustris.* © Ruchira Somaweera
Gharial, *Gavialis gangeticus.* © Ruchira Somaweera

Title Page : P.E.P. Deraniyagala. © Siran Deraniyagala

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Compilers note

Under each subject the papers are listed alphabetically according to the principal author. The papers are not reviewed. However, to maintain consistency in the publication, the compiler took the liberty only to change the format. In instances where the full papers were not received by the compiler, the abstracts sent for the ***Book of Abstracts*** were included to make the publication a complete one.

Additionally, we have also included a biographical sketch of Dr. P.E.P. Deraniyagala remembering his contribution towards crocodilians of South Asia and 3 invited papers.

Anslem de Silva
Compiler
September, 2013

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Forward

At the 21st Working Meeting of the CSG in the Philippines (Manilla 21-25 May 2012), Anslem de Silva proposed that that the next CSG Working Meeting be in Sri Lanka. He came well prepared with various pledges of assistance from Government and the private sector. The proposal was warmly accepted, not simply because of Anslem's enthusiasm (and determination), but because Sri Lanka, is a special place with regard to crocodilians. It has two species, the mugger and saltwater crocodile, and the recent status of both was poorly known despite a national passion in Sri Lanka for wildlife conservation in general. So we did eventually all assemble in Negombo, for the 22nd Working Meeting of the IUCN-SSC Crocodile Specialist Group. Some 164 people attending from 27countries.A truly international and open forum in which to discuss crocodilian conservation and management on a global scale. The CSG itself is of course extremely grateful to Anslem, to the Government of Sri Lanka, to the various private sector donors, and to each attendee, some of whom have travelled across the world at their own expense, to contribute to the meeting.

One of the world's pioneering crocodile biologists, Dr Paulus Edward Pieris Deraniyagala (1900 to1973), as Director of the National Museum of Ceylon from 1939 to 1963. A skilled scientist with diverse interests, Dr. Deraniyagala's early publications on crocodilian biology, ecology, taxonomy and embryology were pioneering and pivotal studies in the 1960's and 1970's, when global interest in crocodilian biology and conservation began to escalate. In the 1970's, Rom Whitaker travelled to Sri Lanka and undertook a series of surveys, providing the newly formed CSG of the day with a clear picture of the general status of Sri Lankan crocodiles. Muggers appeared to be widely distributed, especially among the historical water tank systems throughout the dry zone of the country, whereas saltwater crocodiles were not faring as well in the coastal rivers, creeks and associated wetlands and swamps.

Through the 1980's and 1990's crocodiles were protected under national legislation in Sri Lanka, but had few people to champion their cause. This has changed enormously over the last few years. A true highlight of the meeting agenda was the number of Sri Lankan scientists now actively working on crocodiles and both presenting and discussing their results. In revising the IUCN Red List assessment for muggers, under the direction of Dr. Perran Ross, it was very clear that Sri Lanka now has a significant national quantum with crocodiles, which in this case enthusiastically combined their first-hand knowledge of distribution and abundance to make an accurate evaluation very expediently.

Human-crocodile conflict in Sri Lanka and elsewhere was once again a significant theme in the CSG Working Group agenda. It stands as an anachronism that if conservation efforts are successful with most large crocodilian species, and their numbers increase, so to do attacks on local people and livestock. The attacks create incentives for local communities to oppose ongoing conservation efforts, and often to destroy crocodiles, in the interests of public safety, regardless of national laws. Reducing the probability of attacks at the village level by the use of Crocodile Exclusion Enclosures is a practical and cost-effective way of reducing the probability of attack, and examples are now included on the CSG website. Ontop of this, creating positive values for crocodilian conservation through publiceducation and through innovative ways of gaining sustainable but tangibleeconomic benefits from expanding crocodile populations, is being practicedaround the world. It needs to be considered in all countries where communitysupport for ongoing crocodile conservation starts to wane due to attacks.

As the contents of this proceedings demonstrate, there was once again a great diversity of research results presented at the CSG Working Meeting something for everyone. From the functioning of cells and the immune system, to the functioning of wild populations. From the secret lives of crocodilian parasites to the complexity of pen design, and the ways that may be available for assessing the links between pen design and health. Within and outside the formal sessions the level of information exchange and professional camaraderie was truly heartening. New relationships were forged and new partnerships and projects generated. The 22nd Working Meeting of the IUCN Crocodile Specialist Group in Sri Lanka was a very successful meeting and its proceedings once again provide a wealth of information on crocodilian conservation, management, sustainable use and general biology.

Dr Grahame Webb
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Plate 1. World Crocodile Conference
(22^{nd} CSG Working Meeting)

1. Makara logo of the WCC and CSG Sri Lanka (Traditional oil lamp designed and constructed by the Dept. of National Zoological Gardens, Sri Lanka and Young Zoologists' Association)

2. The WCC main Hall back drop.

3. Participants at the Hands-on-training program on crocodilians, Dehiwala Zoological Gardens

4. The Sri Lanka delegation at WCC

5. WCC delegates

Plate 2. Hands-on-training at the National Zoological Gardens

1. Director and the Deputy Director, Dept. of National Zoological Gardens welcoming the delegates

2. VIPs at the high table, opening comments by Anslem

3. Paolo Martelli's talk on restraining and examining crocodilians

4. Paolo and C. Stevenson demonstrating techniques to obtain blood

5. About to dissect a saltwater crocodile

6. Cathy Shilton's demonstration on dissecting a crocodile

7. Cathy's demonstration

8. The stomach contents

Plate 3. Steering Committee Meeting and Opening of the 22nd CSG-Working Meeting

1. Alejandro Larrierra opening Steering Committee session

2. The Steering Committee session

3. Charlie Manolis addressing the committee

4. S.M.A. Rashid presenting the country report for Bangladesh

5. Registration Desk

6. The VIP's about to be escorted to the conference hall by traditional dancers

7. Opening comments by Ruchira Somaweera

8. Chief Guest H. D. Ratnayake (Director General, Dept of Wildlife Conservation, Sri Lanka) lighting the traditional oil lamp.

Plate 4. Opening of the 22nd CSG- Working Meeting

1. Grahame Webb lighting the traditional oil lamp

2. Tom Dacey lighting the traditional oil lamp

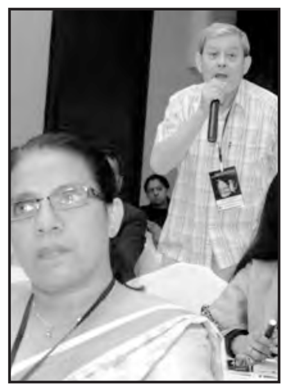
3. Hearty laugh by Hon. Tikiri Kobbekaduwa
(Governor of Central Province)

4. WCC delegates in the main conference hall

5. WCC delegate in action

6. WCC delegate in action

7. WCC delegate in action



8. WCC delegate in action

9. WCC delegate in action

10. WCC delegate in action

11. WCC delegate in action

12. WCC delegate in action

Plate 5. 22nd CSG - Working Meeting sessions

1. Veterinary Working Group round table discussion

2. A wide spread of Sri Lankan spicy food

3. The WCC financiers Imran, Aasim and Mariesz

4. Ashley Pearcy, Brandon Sideleau, Adam Britton and Rom Whitaker

5. Poster sessions

6. The two darlings of the WCC with Anlem de Silva

7. Raffle draw by Giovanna Webb

8. Charlie presenting the price to Chaminda Jayasekara,
the lucky winner of the Raffle draw

Plate 6. The Gala dinner of the WCC

1. Anslem proposing the toast

2. The 'Ice crocodile' and food frenzy

3. All sorts of grills

4. Delegates enjoying

5. Part of Philippine delegation

6. Cathy toasting

7. Delegates enjoying the auction

8. Lushes Sri Lankan traditional dancers

Proceedings: **World Crocodile Conference**
22nd Working Meeting of the IUCN SSC Crocodile Specialist Group
pp 23 - 25

P. E. P. Deraniyagala: the pioneer crocodilian researcher of South Asia

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Paulus Edward Pieris Deraniyagala was born in Colombo on 8th May 1900, the eldest son of Sir Paul E. Pieris Deraniyagala Samarasinghe Siriwardhana and Hilda Obeyesekere. Sir Paul was an eminent Sri Lankan historian, a renowned lawyer and, in 1917, the first Asian to be awarded a D. Litt. from the University of Cambridge. Hilda Obeyesekere was a prominent philanthropist.

Paulus' interest in natural history started at the age of eight, when the family lived in the coastal town of Kalutara. Here he saw his first live sea turtles and crocodiles, animals that later became his chief herpetological interests (Adler, 1989). As a boy Deraniyagala kept a menagerie of assorted invertebrates in his bedroom (Pethiyagoda, 2007). Deraniyagala had his early education at St. Thomas' College, Colombo. After his primary and secondary schooling in Sri Lanka, in 1919 he proceeded to Cambridge University to study zoology, graduating with a BA in 1922 and MA in 1923. He spent one year in Harvard College, USA and got his A.M. in 1924 (Adler, 1989). Up to this time he was known as Paul Edward Pieris, the Portuguese Christian names given at baptism but on his return to the island he resumed his ancient family name Deraniyagala. On 28th June, 1934, P. E. P. Deraniyagala married Prini Eknaligoda Molamure, a great niece of the Maduwanwela Disawa (one of the famous chieftains of the country during late 1800), a union which produced four sons: Arjun, Ranil, Siran and Isanth (Manamendra-Arachchi, 2012).

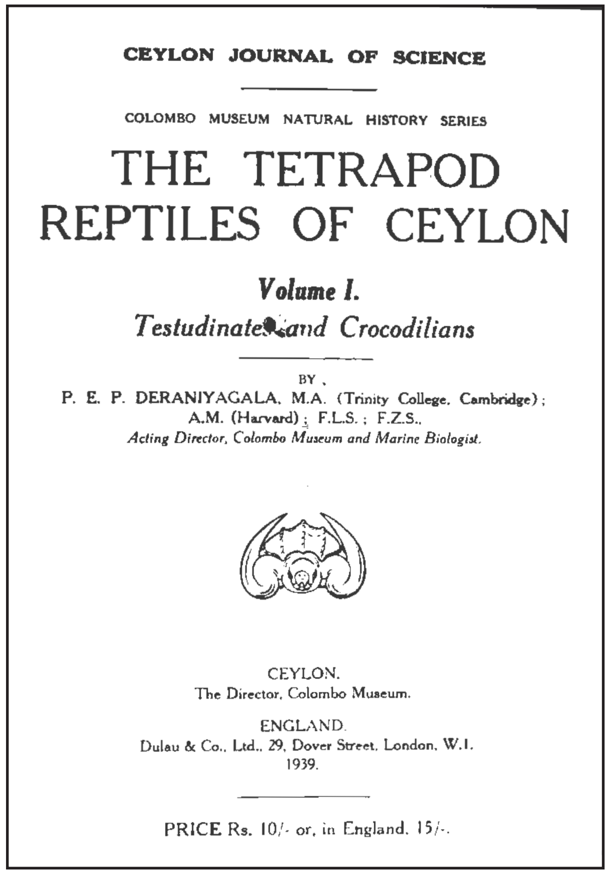
P. E. P. Deraniyagala was a prolific writer on diverse subjects and during the period 1929-63 a vast number of books and research papers were published: 54 on ichthyology and fisheries, 79 on herpetology, 15 on ornithology, 60 on mammalogy, 74 on palaeontology and geography and 32 on prehistory. The number of his research papers exceeded 300 and appeared in the National Museums Research Bulletin, *Spolia Zeylanica*, the *Journal of the Royal Asiatic Society* (Ceylon Branch) and many foreign journals. The list below represents only his publications on crocodiles. His first book, published in 1939, was the *Tetrapod Reptiles of Ceylon Vol. 1. Testudinates and Crocodilians* (Figure 2) is considered his most important work scientifically (Adler, 1989) is undoubtedly the pioneering research work done in the country. Here, Deraniyagala provide details of the external morphology, reproductive cycle, food habits and distribution of both species of the country from pages 308 to 391. In 1953 Deraniyagala published his '*A Coloured Atlas of some Vertebrates from Ceylon',* volume 2 which included accounts of the two crocodile species and in 1958 Deraniyagala published a book on Pleistocene life in Sri Lanka titled '*The Pleistocene of Ceylon'* which is still considered the definitive study of the subject.

Deraniyagala was undoubtedly one of the most outstanding Sri Lankan herpetologists to date. He was also an artist and most of his papers were illustrated with his own paintings and sketches. During his career, Deraniyagala described 22 species and subspecies of reptiles including *Melanochelys trijuga parkeri*, 1939; *Bungarus ceylonicus karavala*, 1955; *Calliophis melanurus sinhaleyus*, 1951; *Chrysopelea ornata sinhaleya*, 1945; *Eryx conica brevis*, 1951; *Lycodon striatus sinhaleyus*, 1955; *Macropisthodon plumbicolor palabariya*, 1955; *Platyplectrurus madurensis ruhunae*, 1954; *Ptyas mucosus maximus*, 1955; *Rhinophis dorsimaculatus*, 1941; *Rhinophis tricolorata*, 1975; *Uropletis ruhunae*, 1954; *Calodactylodes illingworthi* 1953; *Cnemaspis podihuna* 1944; *Geckoella yakhuna* 1945; *Hemidactylus maculatus hunae* 1937; *Hemidactylus triedrus lankae* 1953; *Hemidactylus brookii parvimaculatus* 1953. *Ophisops leschenaultii lankae* 1953; *Ophisops minor minor* 1971; *Mabuya carinata lankae* 1953; *Nessia didactylus* 1934; *Nessia hickanala* 1940 and *Sphenomorphus dorsicatenatus* 1953.

Deraniyagala discovered many invertebrate and vertebrate fossils from the Miocene deposits and plant and fish fossils from the Jurassic deposits of Sri Lanka. His discoveries from alluvial deposits of the Pleistocene period contain many fossils of mammals and reptiles such as lion, hippopotamus, gaur, two species of rhinoceros, elephant etc. He is best remembered by the Sri Lankan general public for his naming of the Mesolithic man in Sri Lanka as “Balangoda Man”. Deraniyagala stressed the importance of this prehistoric human and his geometric microliths in the stone age of Sri Lanka.

Deraniyagala occupies a unique place in the annals of Sri Lankan scholarship. In addition to being the foremost Sri Lankan prehistorian of his time (in fact, it is doubtful whether any Sri Lankan prehistorian has surpassed him since), he also excelled as a marine-biologist, zoologist, palaeontologist, archaeologist, historian, anthropologist and was a painter of international repute (Manamendra-Arachchi, 2012). At Cambridge University during early 1920's he was a champion boxer and is said to have been the first national boxer that Sri Lanka has produced. As a pupil of Seizo Usui, a member of the imperial bodyguard of the Emperor of Japan, Deraniyagala inaugurated the Amateur Judo Association of Sri Lanka of which he was the President for several decades.

Figure 1
P. E. P. Deraniyagala in the field



CEYLON JOURNAL OF SCIENCE

COLOMBO MUSEUM NATURAL HISTORY SERIES

THE TETRAPOD
REPTILES OF CEYLON

Volume I.
Testudinates and Crocodilians

BY

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ENGLAND.
Dulau & Co., Ltd., 29, Dover Street, London, W.1.
1939.

PRICE Rs. 10/- or, in England, 15/-.

Figure 2
Facsimile of the title page (original edition)

He received his first appointment in Sri Lanka on 26 June 1925 as the Second Assistant Marine Biologist, Dept of Fisheries, Colombo. Deraniyagala was appointed the Director of the Colombo Museum on 14 March, 1939, the first native Sri Lankan to hold that office. In addition to his own duties at the Museum he also acted as the Director of Fisheries, Ceylon until 17 January 1941 in an early demonstration of his versatility and capacity. With the re-organization of the museums under the Department of National Museums, Dr. Deraniyagala became its first Director, a post which he held until his retirement in 1963.

Deraniyagala was also a Visiting Professor of Anthropology at the Vidyodaya (now Sri Jayawardenapura) University from 1959 and also served as the Dean of the Faculty. He was elected as the Vice-President of the Indian Museums Association in 1944 and also served on the Editorial Advisory Board of the Journal *Museum* published by UNESCO, Paris. Deraniyagala was the elected President of the Ceylon Association for the Advancement of Science (now SLAAS) for the year 1950 and President of the Royal Asiatic Society, Ceylon Branch in 1952. It is a testimony to the esteem he was held in by the authorities that Deraniyagala was asked to act several times for the Archaeological Commissioner in addition to his own duties. He also functioned as the President of the Sri Lanka National Committee of the International Council of Museums. Deraniyagala was a member of the University of California Scientific Expedition to Africa in 1947, where he described extinct hippopotamus, tortoise and human species from the vicinity of Lake Victoria.

Although Deraniyagala was among the foremost Asian scholars in several related fields, his chief contribution to scientific knowledge has been his studies and publications on the living and extinct fauna and prehistory of Sri Lanka. His researches were extensive and have contributed immensely to the furtherance of the knowledge of fauna, not only of Sri Lanka, but also of the Indian region. A work continued with distinction by his son Siran whose *magnum opus*, "Prehistory of Sri Lanka", is recognized as the "mother book" for South Asian prehistory.

In recognition of his achievements, Deraniyagala was elected a Fellow of the American Society of Vertebrate Palaeontologists, a member of the Indian Association of Systematic Zoology, Honorary Herpetologist to the Indian Pacific Fisheries Council, Honorary Fellow of the Indian Academy of Zoologists, Honorary Advisor to the American Foundation for the Study of Man and Honorary Advisor to the Food and Agriculture Organization on the reptiles of the Indian Ocean. The International Prehistoric Congress elected Deraniyagala to the Permanent Council of the International Union of Prehistoric and Protohistoric Sciences. He served as a member of the UNESCO Committee to Study the Key Zoological Collections of South and Southeast Asia. In 1960 he was awarded an Honorary Doctorate of Science by the Vidyodaya University, Sri Lanka for outstanding research in various fields.

In addition to his outstanding academic achievements, he was also a painter of repute. Like his brother Justin who was one of Sri Lanka's best-known artists, Deraniyagala received his early instructions in drawing under 'doyen of painters in Ceylon' Gate-Mudaliyar A. C. G. S. Amarasekera. His paintings were exhibited at the International Exhibition of Paintings staged in honour of the visit of the Duke and Duchess of Edinburgh. He was associated with the Ceylon Society of Arts for a considerable period and also served as the Honorary Secretary of the National Committee of Plastic Arts of Sri Lanka.

Contributions on crocodiles by P. E. P. Deraniyagala

It is of interest to note that Heinz Wermuth of Berlin Museum and P. E. P. Deraniyagala, when he was Director National Museums, Sri Lanka issued an appeal on the urgency of the protection of crocodiles worldwide. Their appeal was first submitted to the International Union for Protection of Nature in Brussels and then circulated to 160 herpetologist's across the globe (Alice, 1956). Sri Lanka and Germany had together taken an early leading role in promoting the conservation of crocodilians of the world.
Dr. Deraniyagala passed away on the 1st of December 1973.

Acknowledgements

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22nd Working Meeting of the IUCN-SSC Crocodile Specialist Group
pp 26 - 28

A preliminary investigation into nesting and nest predation of the critically endangered, gharial (*Gavialis gangeticus*) at Boksar in Corbett Tiger Reserve, Uttarakhand, India

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Abstract

The gharial, *Gavialis gangeticus*, is an endemic crocodilian of the north Indian subcontinent and is also found in the Corbett Tiger Reserve. Surveys in Corbett National Park in 1974 recorded only five gharial whereas current estimates are 42 adults inclusive of 10 adult males and 59 individuals of smaller size classes. This study confirms that the expanded population in the Kalagarh Reservoir is breeding, although nests appear to be subject to significant predation, thought to be by *Varanus bengalenis*. Varanids are serious predators on crocodilian eggs in a number of countries. In this case, it is unclear whether such high predation levels are natural situations that apply when they live in a free-flowing river environment, or whether it is a derived state linked to the lake-type environment in which they now reside.

Key words: Gharial, *Gavialis gangeticus*, Corbett Tiger Reserve, Corbett National Park, Boksar, nest predation.
Abbreviations: Corbett Tiger Reserve (CTR), Corbett National Park (CNP)

Introduction

The gharial, *Gavialis gangeticus*, is an endemic, river dwelling crocodilian of the North Indian subcontinent, whose wild populations have been depleted throughout much of its former range (Ross and Magnusson, 1990). The western-most historic occurrence of the Gharial was the Indus River in present day Pakistan and the eastern-most (albeit from only two records in the scientific literature) was the Irrawaddy River in present day Myanmar. Today three widely separated breeding populations remain in India (Chambal River, Girwa River and the Kalagarh Reservoir/Ramganga River in Corbett Tiger Reserve) and one in Nepal (Rapti/Narayani River). The wild population was subject to an intensive conservation action program in the 1970's supported by United Nations Development Programme (UNDP)/Food and Agriculture Organization (FAO), which included 'head-starting', establishing protected areas, partial mitigation of anthropogenic pressures and physical enforcement of wildlife laws. In 1975, a breeding conservation project for gharial (and other crocodilians) was initiated with the Government of Orissa at the Nandankanan Zoological Park (Achariyo et al., 1996). The wild population recovered significantly, which was hailed a success. By the mid 2000's, the wild population was once again recognized as being in serious decline with the global adult population at no more than 200 individuals. In 2007, the International Union for Conservation of Nature (IUCN) red listing for gharials was upgraded from "Endangered" to "Critically Endangered" (IUCN, 2012).

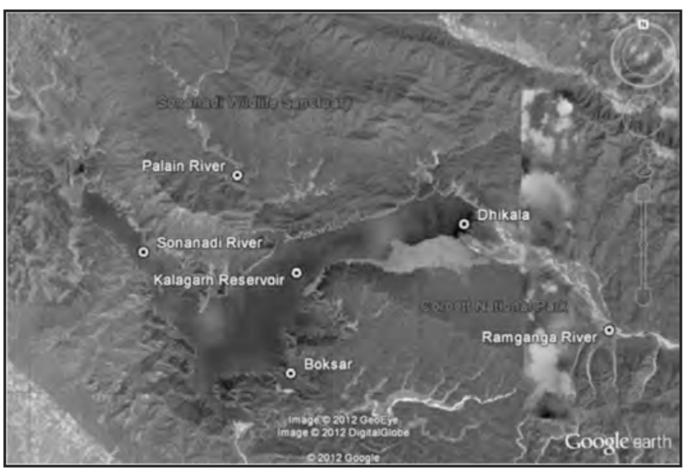

Figure 1. Point locations in CTR surveyed for Gharial.

The Corbett Tiger Reserve (Fig. 1) is one of the habitats where recruitment from released stock resulted in an increase in the adult population after the construction of the Kalagarh Dam (Basu, 1995). Surveys of the Ramganga River in Corbett National Park in 1974 recorded only five gharial and there was no evidence of any breeding, either in the form of nests or hatchlings (Whitaker, 1979). Boksar, the best known gharial habitat in the park was being inundated at the time due to the filling of the then new Kalagarh Dam (Whitaker, 1979). Gharial nesting was documented in Boksar in Corbett NP and the Palain River in the Sonanadi Wildlife Sanctuary of Corbett Tiger Reserve during extensive surveys in 2008. Nesting was during also found in 2011 preliminary nesting surveys in Boksar in Corbett National Park. The 2008 surveys were the first record of gharials breeding in the area (Chowfin 2011). Surveys of Boksar 2011 also reconfirmed gharial nesting in the area during which only Corbett National Park was surveyed. Sonanadi Wildlife Sanctuary was not surveyed as the surveys were preliminary in nature. However, predation of gharial nests in Boksar (Figure 2 and 3)was observed on both occasions with the common Monitor Lizard, *Varanus bengalensis,* being identified as the predator based on visual confirmation and spoor. The findings are of special significance as it confirms that Gharial nesting in Boksar is recent in nature.

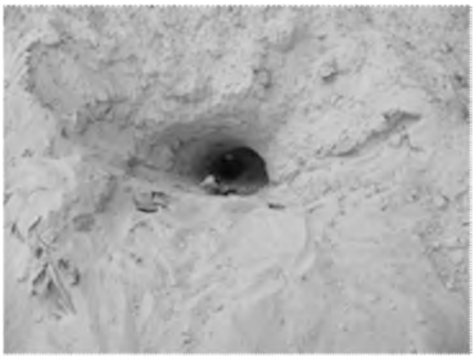

Figure 2. Gharial nest predated by *Varanus bengalensis* in Boksar in 2008

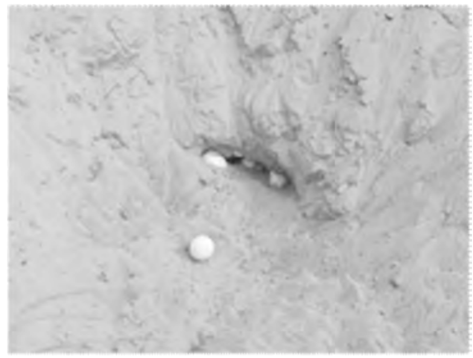

Figure3. Gharial nest predated by *Varanus bengalensis* in Boksar in 2011

Materials and Methods

Nesting surveys in CTR were conducted by six forest staff in groups of two or three in boats or on foot in 2008 (Chowfin 2010, 2011). The areas covered in the survey included the Ramganga River near Dhikala, the reservoir at Boksar, Gaujeda, the Palain and Sonanadi Rivers in 2008 and Boksar (Figure 4), Dhikala and the Ramganga River in 2011. Surveys were conducted from late March to late April which is the most frequently reported nesting period for the species in most parts of its range (Whitaker and Basu,1981). During 2008, nesting sites were identified by searching the river and reservoir banks for any signs of nesting activity and/or nests and eggshell remnants during daylight hours. Signs of nesting activity included body prints in open, sunny, sandy areas; entry and exit trails to and from the water's edge; attempted digging of egg chambers ("probe" holes) and eggshell remnants (Figure 5) towards the end of the nesting season. A global positioning system (GPS) location was recorded at all possible nesting sites during the first survey of the season. These sites were then revisited later in the nesting season to confirm actual nesting. (Chowfin, 2011)

Figure 4. Gharial nesting habitat in Boksar (CNP).

Figure 5. Egg shell remnants of one of the predated gharial nests in Boksar

Results

At Boksar (CNP) during the nesting surveys in 2008, a clutch of at least 36 eggs was found: 11 eggs were intact and banded to the distal poles, six egg shells were predated, with the tracks indicating *Varanus,* 14 eggs were intact but with broken eggshells and five additional eggs with broken eggshells were infected with a black fungus like growth. Twelve eggs were fertile. The fertile eggs, with opaque banding reaching the distal poles, were clearly in an advanced stage of development. Eggshell remnants were found at five more discrete locations in the Boksar area, indicating the presence of at least five more nests (which had been completely predated). Surveys at Boksar 2011 again confirmed the presence of gharial nesting with an intact clutch of at least 48 eggs found in the same general location as one found in 2008. In this clutch, 45 eggs were fertile and in an advanced stage of development with banding reaching the distal poles. However, many of the fertile eggs had damaged egg shells or had been predated (Figure 6 and 7). Based on observed spoor at the nest site, *Varanus bengalensis* was identified as the predator.

Fig. 6. Predated Gharial egg from a nest in Boksar in 2008.

Fig.7. Predated Gharial egg from a nest in Boksar in 2011.

Discussion

Gharials in Boksar, although originally in a free-flowing river ecosysem, seem to have successfully adapted to the lake-like environment created by the Kalagarh Dam in 1974.

Breeding is clearly occurring, although predation rates seem very high, with *V. bengalensis* the likely predator. They may be constraining the recovery of the species. These results, although preliminary, indicate that the Corbett Tiger Reserve could contain a significant breeding population of gharials, which are highly depleted throughout their range. Additionally, it is the only known population of the species to be living in a lake-like environment, as opposed to a free-flowing river system.

This suggests that nesting surveys and monitoring of nesting sites in Boksar and other areas in CTR should be undertaken more regularly, perhaps annually, and more intensely, to gain a better understanding of the productivity of the population of adult female gharials living in the area. Surveys at the time of hatching may give a better indication of the number of nests laid but not predated. The loss of eggs to predators appears to be very significant, which could be a natural occurrence (Webb et al., 1983), or a derived one linked to the lake environment.

Either way, it suggests that if the conservation goal is to increase the resident population of gharials, then a nest protection program increasing the numbers of hatchlings recruited to the wild could be warranted. Corbett Tiger Reserve may prove to be a suitable study site for examining gharial nesting in more depth, including nest site attributes and basic clutch and female characteristics.

Acknowledgements

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pp 28 - 35

An assessment of assisted recovery of *Gavialis gangeticus* in the river systems of Northeast India.

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Abstract

We present here, the result of gharial habitat suitability study in the protected riverine stretch of Northeast India between November 2010 - April 2011. We recorded suitable habitat parameters (Water depth, River bank, Midriver Island, anthropogenic disturbancs, confluence, presence of other wildlife) at either 200 m or 500 m intervals. The suitable habitats are mapped using ArcGIS software. Buffers of the each sample points were overlapped over the habitat map derived from recent satellite imagery. The study showed in terms of habitat quality, the Siang river stretch along D' Ering memorial wildlife sanctuary of Arunachal Pradesh contain the greatest proportion of suitable areas followed by the complex of Brahmaputra and Diffolu river in Kaziranga National park of Assam. Among the Other study areas, protected part of Beki River in Manas found to contain 40%, Jia Bhoreli in Nameri 29% and Brahmaputra in Orang 28% of suitable habitat for Gharial. The study identify Kaziranga- Orang complex (~140 km) and D'Ering-Dibru-Saikhowa complex (~70 km) for prioritization in future Gharial rehabilitation programme in Northeast India.
Key words: Gharial, Habitat suitability, Northeast India.

Introduction

Historical records of *Gavialis gangeticus* (Gmelin, 1789) are available from sixteen rivers of Northeast India. Four (Dibang river, Siang, Subansiri and Manas river) are the northern tributaries of Brahmaputra river. Five (Noa-Dihing, Buri- Dihing, Kopili, Kulsi, and Dhansiri rivers) are the southern tributary of Brahmaputra. Gharial occurrence records are also available from six tributaries (Makru river, Irang river, Dholeshwari river, Katakhal river and Kushiyara river) of river Barak in Southern Assam and Manipur. Eastern Assam region represent the highest number of Gharial sighting records (N~29) followed by western Assam (N~16) (Choudhury, 1992, 1998; Whitaker *et al* 1974). Barak river system contributes 8 historical records for gharials (Cooper 1951, Choudhury 1997). In last decade, authentic reports of stray sub-adult Gharials were available from Western Assam. However, our follow-up survey failed to substantiate report of “nesting populations” by Saikia et al (2011). We presume that currently no breeding population is known from river systems of Northeast India (*sensu*, Whitaker 2007).

Distribution of Gharial largely corresponds to distribution of *Nilssonia gangeticus* and *Platinista gangeticus*. Gharials Prefers deep fast flowing rivers. Adults show a preference for the comparatively velocity free State found in the deep “Kunds” or holes at river bends and confluences (Whitakar and Basu, 1983). Hussain (2009) found that 62% of gharials were seen basking on sand, 37% on rocks substrata and only 0.8% on clay. The study thus revealed that sandy part of the river banks and sand bars were the preferred basking sites for gharial. Comparatively less preference was shown for rocky banks and rocky outcrops. Clay areas are largely avoided.

Human disturbance seems to be the critical factor for basking site selection. Mid river sandy island and newly emerged mid river sand bars are often used as preferred basking sites in Girwa river of Katerniaghat wildlife sanctuary (*pers obs*.). In situations where undisturbed sandy sites are not available, gharials seem to prefer rocky outcrops as second alternative sites for basking.

Juvenile gharial <120 cm known to preferred water depths 1-3 m and avoided water depths >3.0 m. Gharial > 120-180 cm. avoided water depths 1-2 m and preferred water depths 2-3 m. They mostly used water depths >4.0 m when available. The subadult and adult gharial of size class >180 cm showed preference for water depths 4.0-5.0 m. Subadult gharials avoided water depths <2m while adults avoided depths <4m.

Lang and Whitaker (2010) reported those Gharial make seasonal movements that were shorter (4-7 km) or longer (14-16 km). Seasonal movement averaged 9.6 km. In dry season, more time is invested for basking. During high water level gharials disperse and feed. Gharial responds quickly to the riverside activity by moving away from potential threats temporarily or shift residency to other location if disturbed often.

Study area

We selected riverine stretch which comes under protected status in states of Assam and Arunachal Pradesh Beki river in Manas National Park (26°35'-26°50'N, 90°45'-91°15'E), Jia Bhoreli river in Nameri National Park (26°50'27°02'N 92°38' 93°00'E); Brahmaputra stretch in Orang National Park (92°16' -92°27' E, 26°29'-26°40' N); Brahmaputra stretch in Kaziranga National Park (26˚ 34N- 26˚ 46N 93˚ 08-93˚ 36E); Brahmaputra stretch in Dibru Saikhowa National Park (27° 30' N- 27° 45' N 95° 10' E- 95° 45' E) and D'Ering Memorial Wildlife Sanctuary (27°56'16"N, 95°26'45"E) lies sandwiched between the Siang and Sibya Rivers in East Siang District of Arunachal Pradesh.

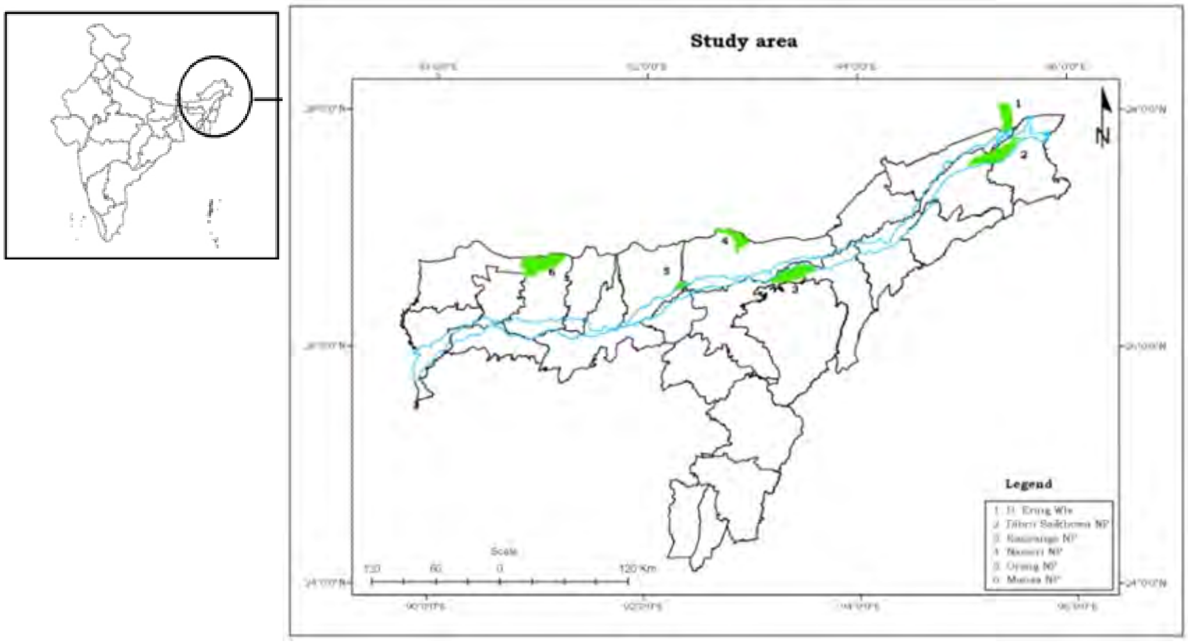


Figure1: Map of study area

Methodology

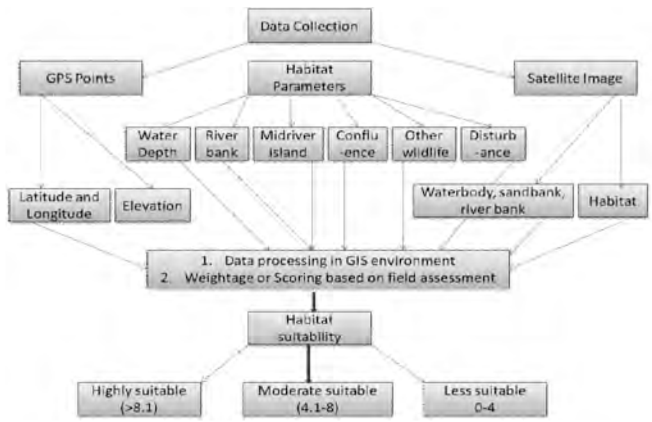
The habitat evaluation survey was conducted between November 2010 - April 2011. The survey team comprises of atleast three surveyors, GIS expert, and three Boatmen familiar with the area. In most of the cases mechanized boat was used for survey except in the case of survey in Beki River and Jia Bhoreli River where we used rubber raft of six person capacities. We followed the channel adjacent to the protected area and often getting down at the mid-river island to assess the habitat condition. Boat speed was reduced in confluences, meanderings, mid-river islands and in case of any encounter with aquatic wildlife. Two 7x 50 binoculars were used for the survey during the day.

Data collection

Habitat suitability parameters were gathered from reports of Rao and Singh (1987), Hussain (1991, 2009), Maskey et al, (1995), Whitakar and Basu (1983). In Orang and D'ering habitat parameters were recorded at 200m interval, in Manas and Nameri at 250 m interval. While in Kaziranga National Park and Dibru Saikhowa National Park data gathered at each 500 m interval. Following habitat parameters were considered for habitat suitability assessment of Gharials from present study areas- Water depth (0-2.5m, less suitable, score 1; 2.6-5 m, moderate, score 2; >5 m highly suitable, score 3) River bank (Sandy, highly suitable, score 3; Rocky, moderate, score 2; clay, less suitable score 1) Midriver Island (Present, score 1; absent, score 0), Disturbance (High disturbance, score 1; Moderate disturbance, score 2; undisturbed, score 3) confluence (Present, score 1; absent, score 0) other wildlife (Present, score 1; absent, score 0).
Midriver Island also includes the large sandbars. Extensive occurrence of sand bars and River Island is a prominent feature in the braided river channel of Brahmaputra.
Presence of other wildlife is an assessment of the tranquility of the habitat and includes presence of Water birds flocks, *Nilssonia* spp, *Pangshura* spp. and *Platinista gangeticus*.

Anthropogenic disturbance is considered as high in areas where we encountered combinations of fishing areas (gill nets, fishing camps and boat) and human settlement (cattle shed or illegal encroachments along riverbank). Moderately disturbed are the areas where we observed small scale illegal fishing practices (gill net, hook nets but no settlement along bank and no permanent fishing camp). Undisturbed areas are those devoid of any human interference except occasional forest department patrolling boat movement.

Survey track and location were recorded with a Garmin-60 GPS. Attributes (field informations) were given to each points based on field data and weightage was given according to low to high order ranges from 1 to 3 or binary data 0 and 1. Distribution mapping of sample sites was done with ARC GIS 9.3 and ERDAS 9.1 software. Finally all the weightage values were added to get the final suitability status for Gharial at each sampling points of study areas. The suitability status was divided into three classes referred to as Low, medium and high values ranging from 0 to 4, 4.1 to 8 and above 8 subsequently. Buffer analysis was used for each sample location based on the size of the river. Buffers of the each sample points were overlapped over the habitat map derived from satellite imagery.



Flow chart showing methodology

Results

In Manas National Park, the elevation varies from 97 m upstream of Beki river to 53m at downstream and average midriver water depth is 4m. Out of the 32 sampling sites 65% represent Rocky River bank and 28% sand bank. 62% of the riverine stretch is undisturbed, while 34.37% of the stretch is found to be moderately disturbed especially at lower reaches. The elevation of Jia Bhoreli river in Nameri National Park varies from 153 m at Bhalukpong point to 69 m at downstream. Average water depth is 3m. 47% of the Jia-bhoreli stretch under the Nameri Natioanl Park is having rocky bank and 41% is sandy. The rest of the river bank represent admixture of rock-sand deposition and clay deposition. 62% of the stretch is undisturbed, 24% moderately disturbed and 12% highly disturbed.

Average water depth in riverine stretch of Orang National Park is 3.12 m. Much of the river bank is sandy. 45% of the riverine stretch is undisturbed, 12% moderately disturbed and 41% highly disturbed especially at western boundary of the park due to thick human population in those areas. The elevation of the riverine stretch in Kaziranga National park varies from 54-63m. The Brahmaputra river bank is mostly sandy and the river is extensively braided in appearance. Average water depth in Brahmaputra River is 4.45m, while in Diffolu river (from confluence upto waypoint 41) average water depth is 2.3 m. 81% of the riverine stretch in Kaziranga is undisturbed, 17% moderately disturbed and only 2% highly disturbed . The elevation difference between upstream and downstream at Dibrusaikhowa varies from 92-117m. River banks are mostly sandy. Average water depth is 4.01m. 35% of the riverine area designated as undisturbed while 43% moderately disturbed and 21% highly disturbed owing to the presence of settlements along riverbank or for fishing activities. Average midriver water depth in Siang along D'ering sanctuary is >5m. 16% of the river bank of Siang River along D'ering sanctuary is rocky, 83% riverbank is sandy. 77% of the riverine stretch showed presence of midriver Islands or sandbars. 72% of the stretch is undisturbed, 16% moderately disturbed and 11% at southwestern boundary of the sanctuary is highly disturbed (owing to the presence of Ferry ghats and fishing camps).

The study showed in terms of habitat quality, the Siang river stretch along D'ering memorial wildlife sanctuary of Arunachal Pradesh contain the greatest proportion of highly suitable areas (83.33% suitable areas) followed by the complex of Brahmaputra stretch and Diffolu river in Kaziranga National park of Assam (70.8% suitability) that corresponds to suitable Gharial habitats.

Table 1: Categories of habitat suitability of the study areas as observed in the study (in percentage).

	Manas	Nameri	Orang	Kaziranga	D'ering	Dibru Saikhowa
High	40.62	29.88	28	70.8	83.33	53.94
Moderate	59.37	68.96	61.42	29.26	11.11	45.09
Low	0	1.14	10	0	5.5	2

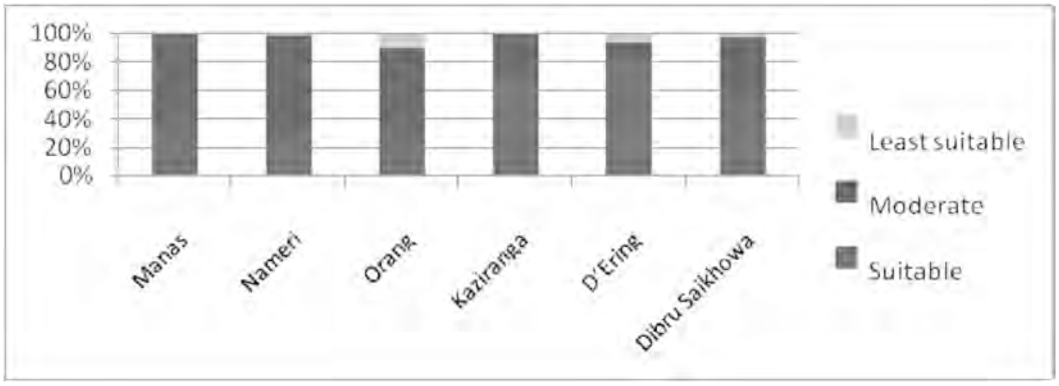


Fig. 5. Gharial habitat suitability in different study areas of Assam and Arunachal Pradesh

Discussion

The study showed in terms of habitat quality, the Siang river stretch along D' ering memorial wildlife sanctuary of Arunachal Pradesh contain the greatest proportion of suitable areas (83.33%) followed by the complex of Brahmaputra and Diffolu river in Kaziranga National park of Assam (70.8% suitability) that corresponds to suitable Gharial habitats. Among the Other study areas, protected part of Beki in Manas found to contain 40%, Jia Bhoreli in Nameri 29% and Brahmaputra in Orang 28% of suitable habitat for Gharial.

The riverine stretch of Kaziranga National park is found to be the most tranquil with 80% of undisturbed area followed by D'Ering Sanctuary of Arunachal Pradesh (72%). Brahmaputra River at Orang National Park registers highest percentange of disturbed area (41%) particularly at western boundary of the park.

The study showed that Siang river stretch along D'ering sanctuary contain the greatest proportion of suitable areas (83.33%) followed by the Brahmaputra and Diffolu river in Kaziranga National park of Assam (70.8% suitability). Thus the ~34 km long Siang river along the western boundary of the sanctuary and the Sibia river along the eastern boundary of the D' Ering might represent a future gharial conservation unit in the northeast India.

Similarly, the Brahmaputra channel along the northern boundary of Kaziranga (~56 km) is the best protected part of the river in Assam with least fishing activity. This assumption is supported by study of Wakid (2009). We recorded an average water depth in this section as ~5 m with extensive sandbank and midriver Islands. With the abudance of Fish resource and presence of undisturbed smaller tributaries (Diffolu River, ~ 38 km in length) add to the suitability of Kaziranga National Park as a possible gharial Habitat.

The locations of the Brahmaputra-tributary confluences are constantly changing due to bank erosion by the Brahmaputra. The north bank tributaries originate in the Himalayas and have high gradient and hence they carry a heavy sediment load of coarser material such as gravel and cobbles. Our survey showed that Beki River in Manas contain 65% rocky bank while 47% of the protected bank of Jia Bhoreli is rocky. Downstream sandy areas of both the rivers however falls outside the protected boundary and thus under anthropogenic pressure.

Thus we propose D'ering- Dibrusaikhowa complex (~70 km) and Kaziranga- Orang-Burachapori-Laokhowa complex (~144 km) is the largest protected stretch available among the 900 km course of Brahmaputra River in Assam and should be considered for future Gharial restocking programme in Northeast India. However, we recommend further upliftment of the protection status of D'ering sanctuary and the Orang National Park that presumbly help in future conservation effort of critically endangered crocodile.

We propose, Kaziranga- Orang-Burachapori-Laokhowa complex (~144 km) and D'ering-Dribru-Saikhowa complex (~70 km) should be prioritized for the future Gharial conservation programme in Northeast India.

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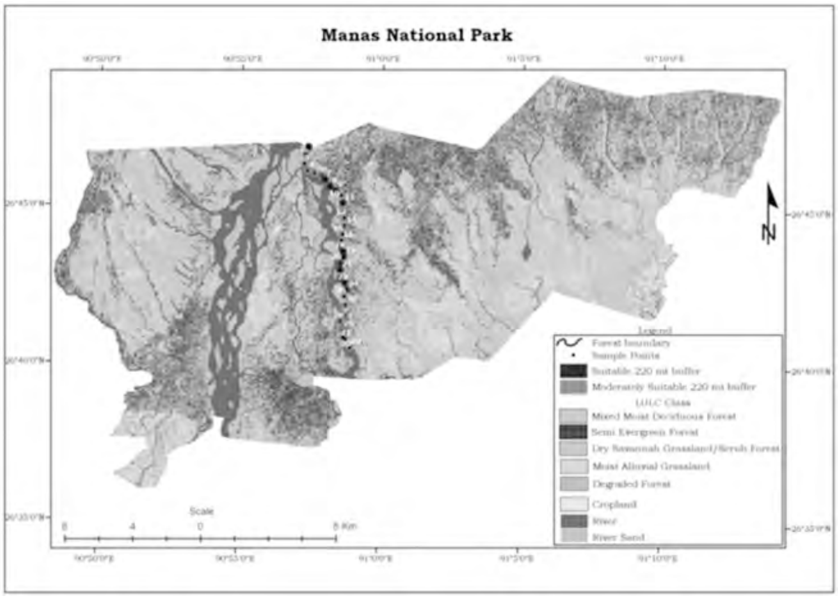
Manas National Park
Legend
Forest boundary
Sample Points
Suitable 220 mt buffer
Moderately Suitable 220 mt buffer
LULC Class
Mixed Moist Deciduous Forest
Semi Evergreen Forest
Dry Savannah Grassland/Scrub Forest
Moist Alluvial Grassland
Degraded Forest
Cropland
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River Sand
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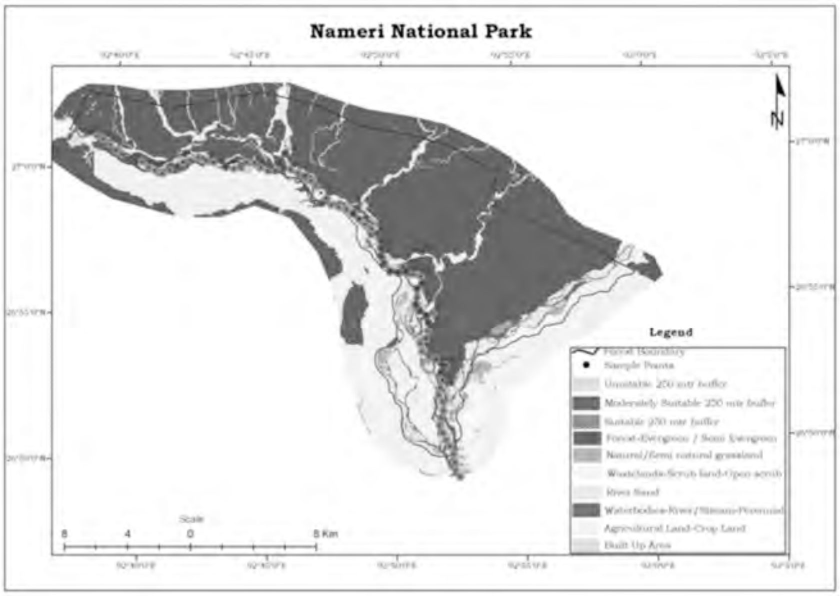
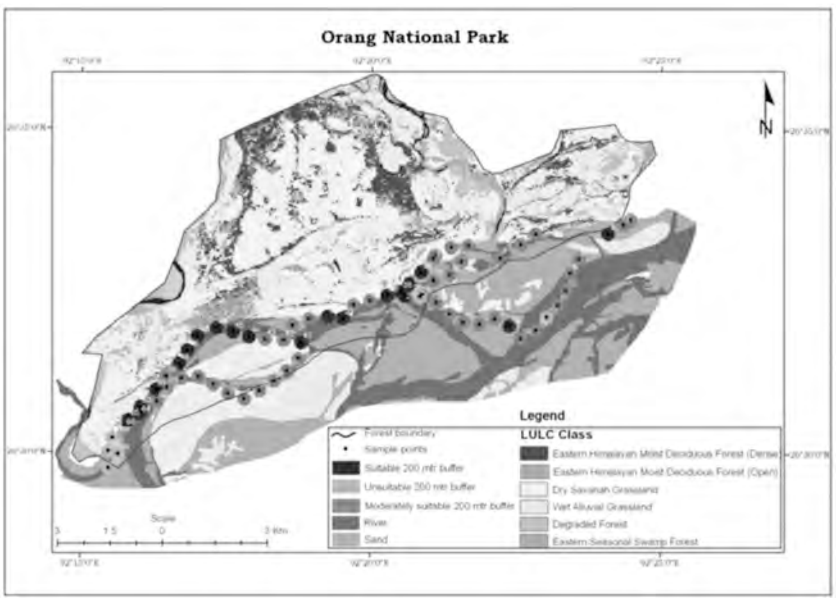
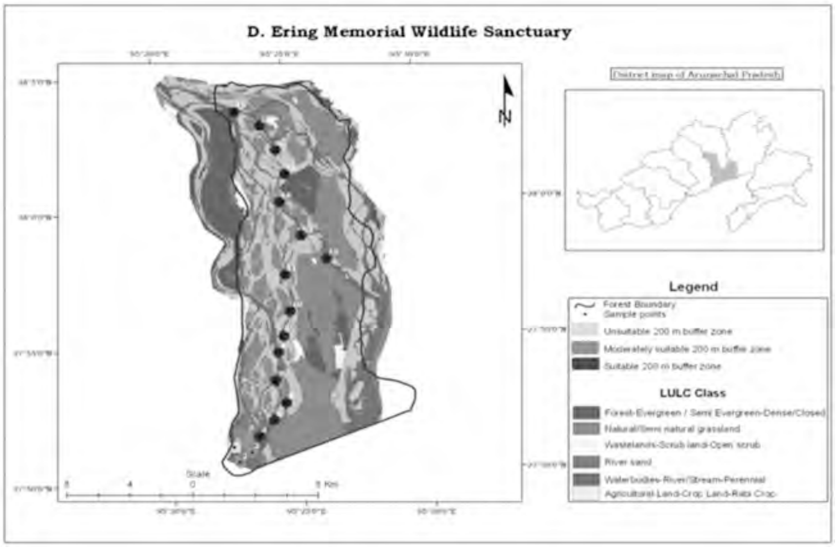
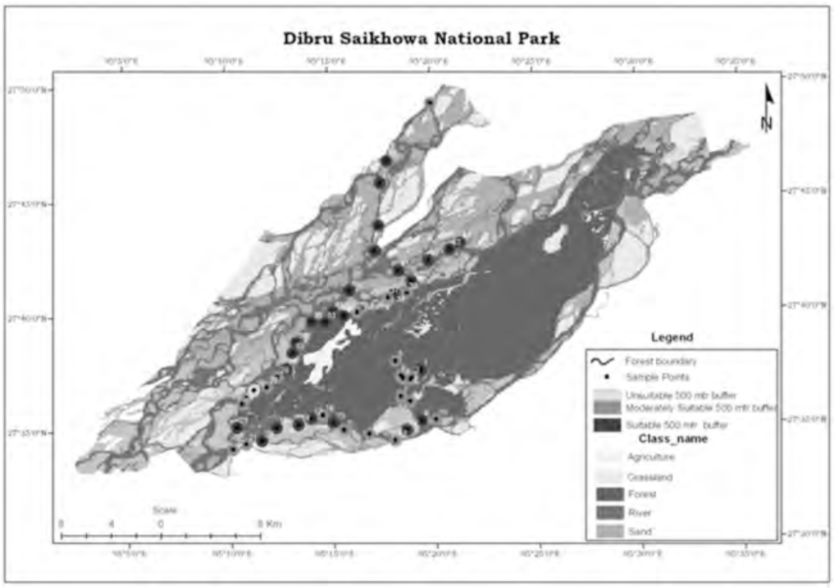
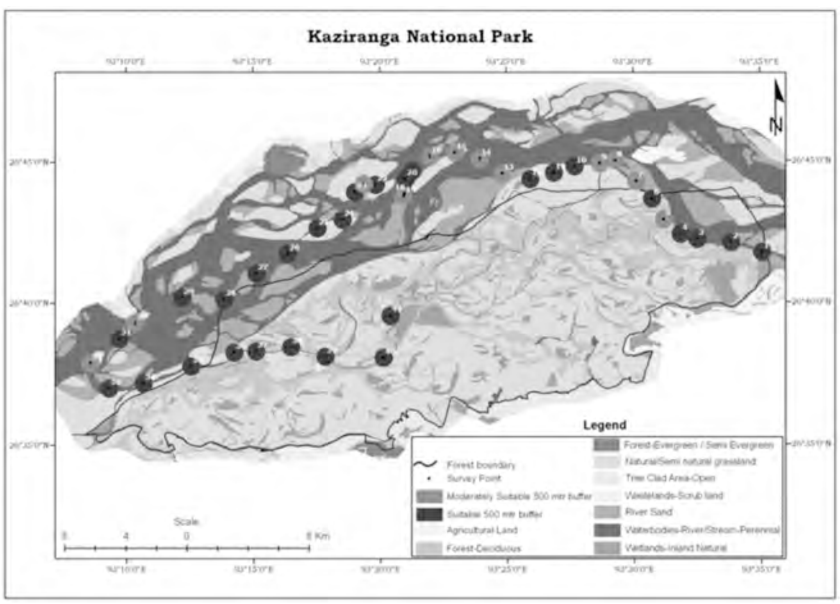

Nameri National Park
Legend
Forest Boundary
Sample Points
Unsuitable 200 mtr buffer
Moderately Suitable 200 mtr buffer
Suitable 200 mtr buffer
Forest-Evergreen / Semi Evergreen
Natural/Semi natural grassland
Wastelands-Scrub land-Open scrub
River Sand
Waterbodies-River/Stream-Perennial
Agricultural Land-Crop Land
Built Up Area
Scale
8 4 0 8 Km


Orang National Park
Legend
Forest boundary
Sample points
Suitable 200 mtr buffer
Unsuitable 200 mtr buffer
Moderately suitable 200 mtr buffer
River
Sand
LULC Class
Eastern Himalayan Moist Deciduous Forest (Dense)
Eastern Himalayan Moist Deciduous Forest (Open)
Dry Savanah Grassland
Wet Alluvial Grassland
Degraded Forest
Eastern Seasonal Swamp Forest
Scale
3 1.5 0 3 Km


D. Ering Memorial Wildlife Sanctuary
District map of Arunachal Pradesh
Legend
Forest Boundary
Sample points
Unsuitable 200 m buffer zone
Moderately suitable 200 m buffer zone
Suitable 200 m buffer zone
LULC Class
Forest-Evergreen / Semi Evergreen-Dense/Closed
Natural/Semi natural grassland
Wastelands-Scrub land-Open scrub
River sand
Waterbodies-River/Stream-Perennial
Agricultural-Land-Crop Land-Rabi Crop
Scale
8 4 0 8 Km


Dibru Saikhowa National Park
Legend
Forest boundary
Sample Points
Unsuitable 500 mtr buffer
Moderately Suitable 500 mtr buffer
Suitable 500 mtr buffer
Class_name
Agriculture
Grassland
Forest
River
Sand
Scale
8 4 0 8 Km


Kaziranga National Park
Legend
Forest boundary
Survey Point
Moderately Suitable 500 mtr buffer
Suitable 500 mtr buffer
Agricultural Land
Forest-Deciduous
Forest-Evergreen / Semi Evergreen
Natural/Semi natural grassland
Tree Clad Area-Open
Wastelands-Scrub land
River Sand
Waterbodies-River/Stream-Perennial
Wetlands-Inland Natural
Scale
8 4 0 8 Km

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Captive/ Semi-Captive Gharial management & husbandry techniques in Chitwan National Park, Nepal

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Abstract

The Gharial (*Gavialis gangeticus*) belonging to the family Gavialidae is one of the most threatened of all crocodilians. The Gharial population in Chitwan National Park (CNP) crashed down to 57 in the late 1970s. In response to this critical situation of gharial, Gharial Conservation Breeding Center (GCBC) was established in Kasara in 1978. Since, 1981 GCBC has played a crucial role in egg collection, rearing and release of gharials in major river systems of Nepal. Presently, GCBC houses 605 gharials of all age-size classes (hatchlings 244, juveniles 338, sub-adult 18 and adult 15). A total of 891 gharials have been released to supplement the wild population. Several structures are built and upgraded in GCBC for better captive management while improving the survival rates of the new born hatchlings in the breeding center.

Key words: Gharial (*Gavialis gangeticus*), Chitwan National Park, Captive Breeding, Husbandry, Nepal

Introduction

The Gharial (*Gavialis gangeticus*) belonging to the family Gavialidae is one of the most threatened of all crocodilians species (GCA, 2011). Abundant in most of the major river systems in the Indian subcontinents in the past, gharial is now believed to be extinct from Bangladesh, Bhutan, Myanmar and Pakistan. Presently, wild population is confined to a few river systems of Nepal and India (Maskey, 1989). Its distribution is limited only to 2% of their historical range with as low as 200 breeding adults remaining in the wild (Whitaker *et al.,* 1974). This represents almost 96% decline in gharial population (Whitaker et. al 1974). Realizing its critical situation, it was recently upgraded to IUCN Red list of endangered species as "critical endangered" in 2007 and is under appendix I of CITES. Gharial is a protected reptile of Nepal, under the National Parks and Wildlife Conservation Act of 1973.

The Gharial population was estimated to be around 57 during 1980 (CNP, 1998). Realizing this situation, the Gharial conservation center was established in 1978 with the aim to maintain viable wild Gharial population through re-introduction program.

Captive/Semi-captive Management Procedure

Nesting and Hatching process

Generally, Gharial lay eggs between last week of March and 1st week of April. Nests are monitored by the experienced nest watchers who keep a track of breeding females all the time. Once the nest are located, all the records and measurements(count, weight, viability) are taken, eggs are placed in plastic pot and transported via boat to Gharial Monitoring Center exactly in the same orientation as was in the nest. Eggs are re-buried in the same orientation by digging nest in natural sand bank of Narayani River at Gharial Monitoring Center and are guarded by Gharial keepers until they are hatched. Captive-laid eggs are left as such in Gharial Conservation Breeding Center (GCBC) since each of the female guard their nest and do not allow any interventions.

During 2013, we found 13 nests in the wild (Fig 1) 7 in Rapti and 6 in Narayani (Map 1). Eggs from the 4 nests from Narayani were transported to GMC, Amaltari while 2 nests were left in the wild. In Rapti river, out of 7 located nests; eggs from 3 nests were left in the wild, 2 nests were transported to GCBC and 1 nests got destroyed due to the fights between two females during nesting.

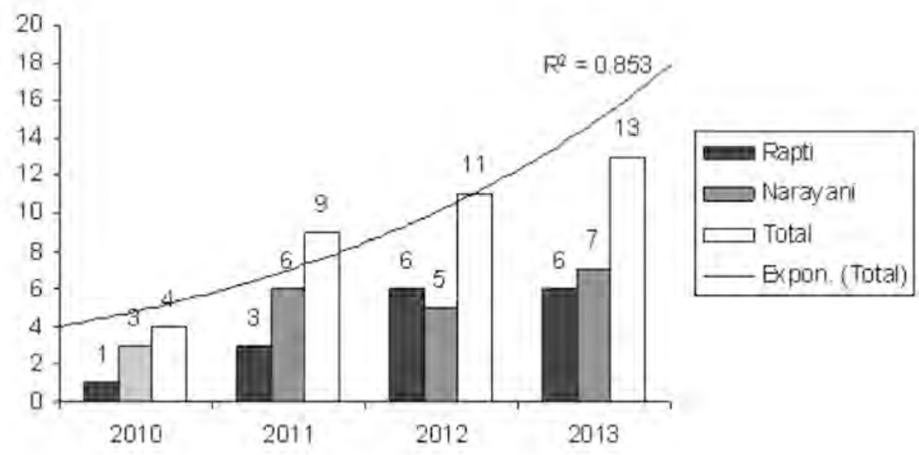

Figure 1. Trend in Gharial Nest in Chitwan National park, 2010-2013

Hatching

During hatching period as soon as hatching calls are made by hatchlings inside the nest, gharial keepers help them come out of nests. Hatching takes place during first to last week of June.

In captivity nests are mainly protected by females, although males are sometimes involved. Interestingly, males are found to take a leading role in taking care of hatchlings, producing hissing sounds when keepers or even female Gharials approach. Hatchlings also respond to the hissing vocalizations of males by going towards them rather than to females. After one week, hatchlings are relocated to separate hatchling nursery ponds (Khadka, 2010).

Captive Rearing and Management

Hatchlings begin eating small fresh fish at night after 1 week. They begin to eat during day time after one month of age. Hand feeding is done for those hatchlings that donot feed. They are fed every second day and are separated from those who feed on their own. Comparison shows that gharials that are hand fed are lesser in weight and size than those feeding on their own. At this stage, animals are graded into different pens on the basis of their size.

Photos 1,2 and 3 (Left: Hand feeding, Middle: Vitamin feeding and Right: Teeth cleaning at GCBC)

Vitamin supplement (0.2 ml or 1-2 drops per hatchling) is also provided by syringe into the mouth every second day until 6 months. During winter, the hatchling pools are covered with plastic sheets to maintain necessary heat. It helps reduce hatchling mortality during this period. Every day, the pools are cleaned up with wire brushes and all left over fish feed are removed. Similarly, for the control of bacterial growth in the water, potassium permanganate is added into the pools.

During rainy season (June-September) the hatchlings teeth is brushed up and body washed twice a month using potassium permanganate. It helps control teeth and skin fungal diseases. The Gharial grows up to or >150 cm in length after 5 years of proper rearing in captivity. This is the age at which it can survive in natural habitat.

Table 1: Gharial Survival Percentage in GCBC

Year	No. of Egg Collection	No. of Hatchlings	% of Hatchling	No. of Hatchling survival after 1 year	% of Hatchling survival after 1 year
1977	592	438	73.99	NA	NA
1978	310	162	52.26	NA	NA
1979	543	294	54.14	NA	NA
1980	264	187	70.83	NA	NA
1981	259	64	24.71	NA	NA
1982	90	38	42.22	NA	NA
1983	296	124	41.89	NA	NA
1984	40	33	82.5	NA	NA
1985	158	116	73.42	NA	NA
1989	253	144	56.92	NA	NA
1990	395	237	60	NA	NA
1991	359	281	78.27	NA	NA
1992	490	230	46.94	NA	NA
1993	428	280	65.42	11	3.93
1994	437	144	32.95	10	6.94
1995	221	97	43.89	17	17.53
1996	577	276	47.83	17	6.16
1997	311	106	34.08	20	18.87
1998	302	19	6.29	2	10.53
1999	408	101	24.75	10	9.9
2000	244	141	57.79	30	21.28
2001	291	81	27.84	27	33.33
2002	466	229	49.14	32	13.97
2003	347	169	48.7	3	1.78
2004	521	298	57.2	157	52.68
2005	510	333	65.29	80	24.02
2006	382	262	68.59	95	36.26
2007	343	117	34.11	53	45.3
2008	369	133	36.04	32	24.06
2009	101	71	70.3	41	57.75
2010	508	355	69.88	133	37.46
2011	634	256	40.38	141	55.08
2012	658	262	39.82	88	33.59
Average	366.88	184.18	50.86	49.95	25.521

Gharial Release

Gharial release is carried out almost every year in Rapti River. For this, gharials are loaded in a specially designated ventilated wooden box of size (20 x 30 x 180) cm and are transported to the soft enclosure built in an area close to GCBC with low water current. These enclosures are made up of elephant grass. Gharials remain in the soft enclosure for a week's period until they break open the enclosure and are finally released into the wild. This allows them to get adapted to the natural conditions. Till the reporting period, May, 2013 a total of 891 gharials have been released into different river systems of Nepal (Figure 2).

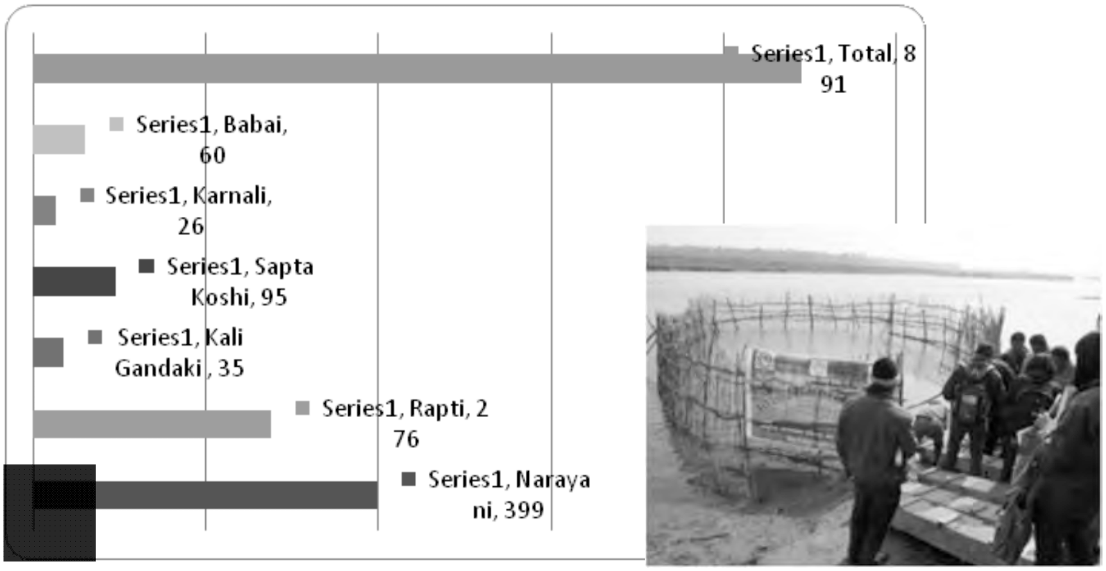

Figure 2. Gharial released in different river systems of Nepal (1981-2013)

Current Status of Gharial in GCBC, CNP

All together, GCBC has 32 smaller to large size concrete ponds/pools with sand bank available all around the pool. Water quality is maintained by replacing water every 3-4 days and cleaning the ponds. All together there are 605 small to breeding sized gharials (hatchlings 244, juveniles 328, sub-adult 18 and adult 15) at GCBC (Figure 3). Age-size classification is done on the basis of size, as hatchlings (<90 cm), juveniles (90-180 cm), sub-adults (181-300 cm) or adults (>300 cm).

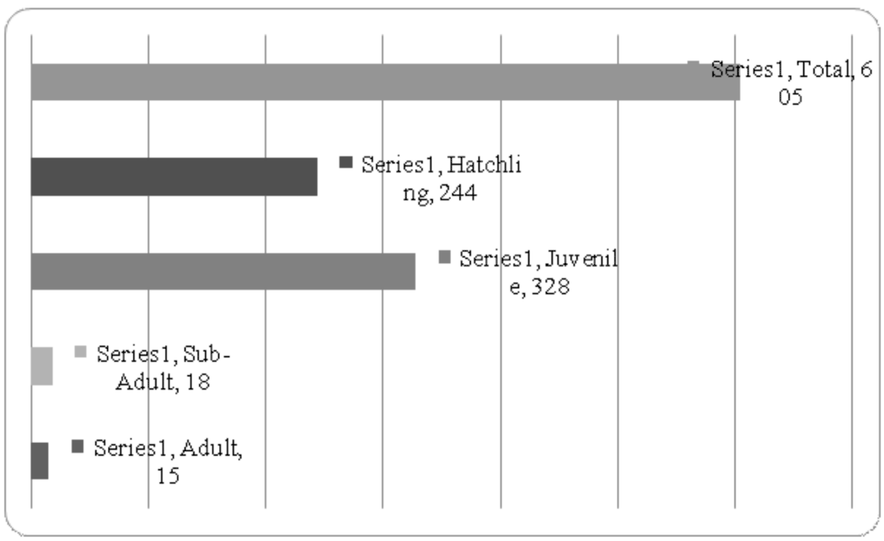

Figure 3. Current Status of Captive Gharial in GCBC, Chitwan National Park

Fish farming in GCBC

GCBC is managing live fish farming in an area of 0.15 ha nearby Gharial ponds. Water from the gharial pools are flushed into fish farm along with droppings during pool cleaning. GCBC is now practicing live fish feeding to the Gharials before releasing them into the wild. Currently, a controlled study on "Live Vs Dead Fish Feeding to gharial" is been undertaken at the center.

Revenue Collection by GCBC

GCBC initiated the collection of entry fee at the center since 2006. Entry fee of Rs 20 and Rs 100 is charged to Nepalese and International visitors respectively. This has helped in supporting the salary of 12 staff that are hired by GCBC on contractual basis.

Table 2. Revenue collection by GCBC (2006-2013)

S.N	Fiscal Year	No of Visitor Vs Revenue collected by GCBC				Total visitors	Total revenue	Remarks
		Nepalese Visitors	Revenue Collected	Foreigner	Revenue collected			
1	2006			3085	302500	3085	302500	
2	2007			6675	667500	6675	667500	
3	2008			6680	668000	6680	668000	
4	2009	908	18160	8485	848500	9393	866660	
5	2010	20124	402480	10634	1063400	30758	1465880	
6	2011	28538	570760	11947	1194700	40485	1765460	
7	2012	23395	467900	12995	1299500	36390	1767400	
8	2013	6916	138320	16550	1655000	23466	1793320	Till the end of April

Recommendations

Gharial Conservation Breeding Center was established with an aim to maintain viable population of Gharials in the wild; through head starting program. Though, this program has halted the complete extinction of the species; has not been able to meet the visionary goal. Since the year 1981, a total of 891 Gharials have been released to different river systems of Nepal but the latest study of 2013 showed 124 gharials in 4 rivers of Nepal (Rapti, Narayani, Babai and Karnali). Head starting program needs to be supported by strong governmental policies to act upon the immediate threats of sand mining, boulder mining, gill netting, excessive human pressure and pollution in gharial dwelling rivers.

In the recent years, there has been major development in GCBC such as the construction of new breeding pools, fish farm, visitor center and health laboratory through the support of WWF Nepal including LACOSTE and FDB, French NGO. For better captive management and to increase the moral of the contractual staff, they need to be hired on a permanent basis with similar benefits of governmental staff.

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Physical evaluation of Gharials

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Gharial *(Gavialis gangeticus)* is a critically endangered (IUCN, 2009) riverine species inhabiting the Gangetic and Mahanadi river systems. To save the species various programs have been launched. However, the scientific rearing and conservation still needs some improvements. During the study period at, Gharial Rearing Centre, National Chambal Sanctuary, Dewari, Morena, Madhya Pradesh juvenile and hatchling gharials were restrained manually with precautions to avoid undue stress. The different body measurements i.e. total length, head length and body weights were recorded along with sex determination. The hatchling and juvenile measurements were taken from different pools at Gharial Rearing Centre. The difference in their measurements and body condition was use to determine the health of the animals. Signs like sunken super temporal fossa, drawn in neck condition and diaphanous teeth indicate poor body condition.

Leukocyte morphology of Gharials

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The blood smears were prepared on grease free clean micro slides. Each direct smear was stained with Wright Giemsa's staining solution and leukocyte morphology was studied under oil immersion. However, it was observed that the morphology of leukocytes (heterophils, lymphocytes, eosinophils, monocytes and basophils) gharial recorded did not differ much with that of the other reptiles.

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Behavioral ecology of Gharial on the Chambal River, India

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Abstract

The Gharial Ecology Project, also known as the Gharial Telemetry Project, was initiated in June 2008 to investigate the circumstances of the 2007-08 mass die-off of gharials in the 2-4m size class, totaling 110+ individuals in the lower Chambal River. To date, 20 radio-tagged gharials have been tracked successfully throughout the annual seasonal cycle, monsoon and dry periods, for an average of 2+ years per animal, since June 2008 through May 2013. Individual gharials show different patterns of seasonal movement and residency, primarily dependent on size/age. Adult females move as far as 80-120 km each seasonal cycle to join dry season basking-breeding aggregations (>60 adults), and to locate suitable nesting areas. In contrast, sub-adult gharials exhibit restricted movements, typically 10-30 km seasonally, and occupy seasonal residencies only 5-15 km in extent. Some sedentary sub-adults showed virtually no movements, either upstream or downstream.

Gharial feed primarily during the monsoonal months of June through September, and bask daily for long periods during the winter months of November through February. Large basking aggregations form in December and January. Mixed basking groups of all age/size classes shift to primarily groups of large sub-adults and adults by mid-February when courting and mating commence. Nesting follows in late March/early April when smaller groups of reproductive females assemble near sandbanks adjacent to deep water. Yearlings (9 months old) from the previous years' hatch often remain close to the dominant male, rather than nesting females, and the male responds to nearby yearlings with specific displays. Colonial nesting sitesare located in areas of minimal disturbance, but locations shift from year to year, depending on local restructuring of the nesting sites. Females open the nests, but do not transport the young to water. Adult females and a singular dominant male remain with hatchlings for 1-2 months, attend the young, and guard them against potential predaors. Large male gharials, with well-developed and prominent gharas, remain individually associated with large groups of young (200-1000+). Large crèches remain together, and young have been observed feeding regularly on small fish.

These results are directly relevant to conservation and management. First, the long distance movements of adult reproductive females, and likely adult males responsible for breeding, indicate that an open, dynamic, free-flowing river is critical. Second, illegal fishing, sand removal, and/or riverside cultivation anywhere along the river constitutes disturbance to which wide-ranging gharials are exposed, consequently would have adverse effects on their well-being and survival. Third, the detailed behavioral observations of social and reproductive activities indicate that the gharial population inhabiting the lower Chambal is healthy and thriving, and that annual recruitment is high. Fourth, egg removal to exsitu artificial incubation facilities, and the subsequent captive rearing of young (=head starting) is not necessary for the Chambal population presently, and should be discouraged/prohibited. Fifth, any reintroduction or translocation schemes to move gharials into new habitats should take into account the proclivity for sub-adult gharials to move 10-20+ km, and for adults to move 80-100+km. Lastly, this study sheds new light on the mass die-off of 2007-08. The event was specific to gharials, rapid in its effects and restricted to 12 weeks (from early December through February), and very local in its geographic extent, extending from 12 km above the Yamuna-Chambal confluence in the lower Chambal River to 75 km upriver.

Introduction: background, rationale for project, and study objectives

The Gharial Ecology Project, also known as the Gharial Telemetry Project, was initiated in June 2008 to investigate the circumstances of the 2007-08 mass die-off of gharials in the 2-4m size class, totaling 110+ individuals in the lower Chambal River. The project was conceived and initiated by D. Basu, Rom Whitaker, and Jeff Lang to provide new ecological information about the gharial population inhabiting the National Chambal Sanctuary (NCS). In particular, the emphases were on spatial data about gharial movements, and related behavioral observations relevant to all phases of gharial life and natural history.

The general questions were: 1) how far do gharials move seasonally throughout the year, and during a lifetime?, 2) how do gharials respond to the annual monsoon, and consequent high water?, 3) how do gharials use the river habitats throughout the seasonal high water and low water periods?, 4) when and where do gharials feed?, 5) how does social behavior influence their distribution on the river?, 6) when and where do they court and mate, nest, incubate eggs, and guard hatchlings? Prior to this study, partial or incomplete information about all of the above questions was conjectured from notes recorded in captivity and/or from anecdotal observations in wild populations. Answers to these questions are necessary in order to formulate management and conservation-related strategies for the continued well-being, health, and survival of wild gharials in the Chambal which is still an open and dynamic river.

In late June 2008, with assistance from WWF-India, the Madras Crocodile Bank Trust and the Gharial Conservation Alliance received Ministry of Environment and Forests and state government permissions to capture, radio-tag, and monitor up to 30 wild gharials in the size range of 2-4m, the die-off size range, in three episodes of 10 animals/tagging operation. A rapidly advancing monsoon in June 2008 cut short the tagging effort, and only one individual was tagged, and intermittently tracked. A subsequent tagging in March 2009 resulted in 10 animals tagged, and another 10 were tagged in November 2010.

Results: New Spatial and Behavioral Findings

To date, 20 radio-tagged gharials have been tracked successfully throughout the annual seasonal cycle, monsoon and dry periods, for an average of 2+ years per animal, since June 2008 through May 2013. At present, five gharials are still being tracked into the 2013 monsoon from the 2010 group. A total of 2300+ animal-specific locations were recorded for the 2009 group, and more than 1500+ locations, 1-3 x weekly, have been logged for the 2010 group. These findings are summarized in Tables 1 and 2. Preliminary results have been published in the Wildlife Telemetry Issue of the ENVIS Bulletin, and numerous reports summarize the results to date for government departments and funding agencies (see reference list).

In brief, these ecological studies, based on detailed observations of the radio-tagged, wild gharials resident in the lower Chambal, have indicated that the population is spatially-structured. Individual gharials show different patterns of seasonal movement and residency, primarily dependent on size/age. The most remarkable finding is that adult reproductive females routinely move as far as 80-120 km each seasonal cycle to join dry season basking-breeding aggregations (>60 adults), and to locate suitable nesting areas where they nest communally and remain with eggs/young until monsoon floods arrive. Then, adults move rapidly downstream, in 30-50 km trips within days/few weeks to the lower stretches of river near the Yamuna-Chambal confluence. Then, as water levels subside, they regularly return upstream long distances to the same localities, over weeks/several months during the post-monsoon period (Figure 1)
In contrast, sub-adult gharials exhibit restricted patterns of movement, typically 10-30 km seasonally, and occupy seasonal residencies only 5-15 km in extent. Monsoon residences are located downstream, and these gharials make short upstream movements to dry season residences. Some sedentary sub-adults showed virtually no movements, either upstream or downstream. Instead, they occupied very restricted sections of river, only totaling 12-18 km in extent, regardless of season (Figure 2).

In addition to this new information on the spatial ecology of gharials living in the lower Chambal River, this study has provided, for the first time, a picture of the behavioral ecology of this population. Specifically, data have been recorded for the seasonal cycles of maintenance, social, and reproductive behaviors (Table 3). Gharial feed primarily during the monsoonal months of June through September, and bask daily for long periods during the winter months of November through February. Large basking aggregations form in December and January. Mixed basking groups of all age/size classes shift to primarily groups of large sub-adults and adults by mid-February when courting and mating commence. Nesting follows in late March/early April when smaller groups of reproductive females assemble near sandbanks adjacent to deep water. At these colonial sites, eggs incubate for 2 months, and hatch in early-mid June.

Colonial nesting sites, typically with 5-15+ nests, are located in areas of minimal disturbance, but locations shift from year to year, depending on local restructuring of the nesting sites (Figure 3). Females open the nests, but do not transport the young to water. Instead, the young move from the nest to water nearby where other hatchlings have assembled in groups. Adult females and a singular dominant male remain with hatchlings for 1-2 months, attend the young, and guard them against potential predaors. Large male gharials, with well-developed and prominent gharas, remain individually associated with large groups of young (200-1000+). Up to12 males have been observed in one season, and 16 different male-young groups are recorded over three nesting seasons, 2010 through 2012 (Table 4). Multiple females are present as well with these groups, and routinely attend/guard hatchling groups until water levels rise. Large crèches remain together, and young have been observed feeding regularly on small fish (Figure 4).

In addition, detailed behavioral observations have been made on social inteactions primarily associated with breeding. Males tolerate other males initially as large basking groups form in January and early February, but then begin to establish social hierarchies, with a dominant, large ghara male engaging in most courtship and mating at specific localities, often associated with nesting areas. In late February and early March, the dominant male patrols an area where reproductive females congregate, and courtship and mating were observed with multiple females over periods of several weeks. Then, females select nesting sites, often frequented by dominant males following breeding, but prior to nesting. At these times, yearlings (9 months old) from the previous years' hatch often remain close to the dominant male, rather than nesting females, and the male responds to nearby yearlings with specific displays.(Figure 5).

Relevance of Ecology Study Results to Management and Conservation

The results of the Gharial Ecology Project are directly relevant to the conservation and management of the gharial population inhabiting the lower Chambal River, National Chambal Sanctuary. First, the long distance movements of adult reproductive females, and likely adult males responsible for breeding, indicate that an open, dynamic, free-flowing river is critical. The lower Chambal should be maintained without obstructions and with sufficient water flow throughout the year for continued successful breeding and recruitment. Individual gharials live in 100+km of river. They inhabit downstream sections during 2-4 months of high water, and return each year to upstream segments for the remaining 8-10 months. The river is an important corridor between their widely-spaced seasonal residences, and adequate water flow connecting these areas is vital year-round, especially in the post monsoon when upstream movements take weeks to months. Likewise, any major disturbances or obstructions that would inhibit or prevent such seasonal movements would be detrimental and adversely affect the gharial population.
Second, illegal fishing, sand removal, and/or riverside cultivation anywhere along the river constitutes disturbance to which wide-ranging gharials are exposed, consequently would have adverse effects on their well-being and survival. Restriction, and eventually elimination of these activities, especially fishing and sand mining, should be viewed as necessary enhancements to riverine habitats.

Third, the detailed behavioral observations of social and reproductive activities indicate that the gharial population inhabiting the lower Chambal is healthy and thriving, and that annual recruitment is high. During the three year period from 2010 through 2012, the total nests counted were 38, 76, and 80, respectively. Hatched nests totaled 31, 48, and 69 respectively in 2010, 2011, and 2012. Using an average hatchlings per nest of 40, hatchlings during these years totaled 1240, 1920, and 2760 respectively. Furthermore, loss of eggs/hatchlings was highest among nests that were not located at colonial sites; these nests were typically lost by predation/disturbance. Usually, few if any guarding adults were present at these nests, and no guarding males were in association with these.

A possible insitu strategy would be to relocate these isolated/few nests to nearby colonial nesting areas where the probability of successful hatching would be greater, and predation loss minimized. This approach has the additional benefit of re-focusing management efforts on intact, natural nesting areas, and could be augmented with increased monitoring and protection from disturbance at these sites. This could be initiated on an experimental basis for a few years and based on the results, a decision can be taken to adopt it as the official policy.
Fourth, egg removal to exsitu artificial incubation facilities, and the subsequent captive rearing of young (=head starting) is not necessary for the Chambal population presently, and should be discouraged/prohibited. Survival of captive hatchlings has been low (mortalities over 50%) at most rearing facilities. Behavioral observations of wild hatchlings indicates that they benefit from very high pre-monsoon ambient temperatures, and begin feeding on live fish almost immediately after hatching. Adults, both attending females and guarding males, protect hatchlings from most predators until monsoon waters rise and the adults move back downstream.
Fifth, any reintroduction or translocation schemes to move gharials into new habitats should take into account the proclivity for sub-adult gharials to move 10-20+ km, and for adults to move 80-100+km. Relocations or re-introductions within restricted areas of protected riverine habitat would likely result in gharials moving into unprotected nearby sites where net fishing and/or sand mining may pose serious threats to their continued survival.

The five points enumerated above regarding the relevance of this study to management concerns are only some examples of how knowing more about gharial ecology is directly applicable to the conservation of this critically endangered species.

Undoubtedly, other management decisions/actions will be informed by accurate knowledge of gharial ecology.

Relevance of Ecology Study Results to Mass Mortality Event of 2007-08

Lastly, this study sheds new light on previous explanations/interpretations of the causes and consequences of the mass die-off of 2007-08. In fact, at present, all indications are that the event was specific to gharials, rapid in its effects and restricted to 12 weeks (from early December through February), and very local in its geographic extent, extending from 12 km above the Yamuna-Chambal confluence in the lower Chambal River to 75 km upriver (Figure 6). More than half (56/104=54%) of the deaths were located at 40-62 km upriver from the confluence, and 77% (80/104) occurred within the 29 km stretch from KheraAjab Singh (62 km upriver) to Barchouli (33 km upriver). Likewise, 77% (80/104) of deaths occurred between 8 December and 19 January, a 42 day period of unusually cold weather during the winter months.

The spatial patterns of the sub-adult gharials in this study living close to the die-off epicenter suggest that the victims of the die-off were most likely similar resident sub-adults that resided year-round in the area and did not move seasonally. Four sub-adult male gharials in the 2010 tagged group were sedentary during the 2-3 years of this study, and moved only maximum distances of 12, 17, 17, and 18 km in total extent while being monitored (Figure 2). None of these sedentary, tagged gharials were ever observed within 30 km of the confluence, and subsequent to the die-off have lived presumably unharmed in the immediate area of the maximum die-off deaths. In addition, at least one other sub-adult that was tracked in this study lived during an entire dry season in the lower reaches of the Yamuna during 2012, but subsequently has moved back into the Chambal close to where it was captured.

These observations demand a re-examination of the previous explanation for the die-off. The prevailing explanation was that gharials living in the Chambal traveled to the confluence of the Yamuna-Chambal where they fed on tainted fish from the polluted Yamuna outflow and/or moved into the lower reaches of the Yamuna where pollution is sometimes heavy and widespread. Thus, it was surmised that exposure to toxins was due to eating polluted fish sourced from the Yamuna. In light of the findings from the present study, it is more likely that there was a point source for toxins in the lower Chambal well upstream from the confluence, and presumably located in the stretch of river between the Udi and Sashon bridges. Based on the concentration of deaths in the immediate localities between KheraAjab Singh (62 km) and Chikni Tower (47 km), the epicenter of exposure was probably in this 15 km section of the river.

If so, the gharials resident in this area, particularly the sedentary sub-adult population with restricted movement patterns, were vulnerable and accounted for most of the deaths. A point source with local and rapid effects might have produced sub-lethal effects on certain sized fishes, incapacitating them so they could be easily caught by resident gharials. The gross finding of visible articular and visceral gout in the few specimens necropsied is consistent with this conjecture, but why only gharials were affected, and not muggers or other species is not known. Unusually cold weather has been implicated as an accessory condition that would have limited the capacity of affected individuals to clear the toxin fast enough to prevent lethal effects. Metabolism is well known in crocodilians to be strongly temperature dependent, and low ambient temperatures would have the effect of slowing any metabolic response to clear or otherwise neutralize an ingested toxin. The movement study results also suggest that most adult gharials would have already moved upstream prior to the period of deaths in the winter months. A re-analysis of the die-off mortality data is presently being prepared by the international team of veterinarians who produced the Final Report on Gharial Mass Mortality Event in 2007-08, with special reference to the findings of this study summarized here.

Current and Future Plans for Continuance of Ecology Study of Gharial in NCS

The current group of taggedgharial willbemonitored during the remainder of 2013 untilthe radios cease tofunction.Representative staff and advisors atMCBTwillbethe primary project staff, in addition to thetrackers, andwill visit theproject sitesperiodicallyandbe resident at Garhaita, Sashon, and Etawah,andcontinue to accessthe river habitatswithinthe NCSbyjeep, on motorbike, and on foot.

Continuance of the GharialTelemetry Project is pending,depending on availablefinancial support, operationaland logistic planning,and the necessary permissions tocontinue.A tentative schedule for 2013 is to conduct a capture-taggingof another group ofgharials to fit tracking devices for October-November when disturbance tosocial and breeding activities is low.The numberand sizes of gharialtotargetremains tobedetermined, as wellas specific locations where gharial will be tagged.

Monitoringofgharialsintheuppersegmentsofthisstretch,aswellasaselectgroupoflargeradults,includingoneormorelarge,breedingmaleswillshedadditionallightongharialecology,andprovidebaselinedataonthehealthandstatusoftheresidentgharialpopulationintheNational Chambal Sanctuary. In addition, small juveniles presumably remain in the section of river near where they hatched, and may not make appreciable seasonal movements down or up the river, much like subadults, but as yet the spatial ecology of juveniles is not known. Managementandconservationstrategies in NCS, especially those focussed on gharialsshouldbebasedongharialbiology.

There may be benefit in tagging a small number of mugger crocodiles as well. Mugger biology in the NCS is not well understood, and this species is implicated in increased conflicts with humans. Interestingly, mugger crocodiles were not affected by whatever was responsible for the gharial die-off, but the basis for this difference is not known.

Table 1:Summary of Tracking Locations for Gharial tagged with radio transmitters in NCS Abbreviations noted in legend below table.Trackablelocations aretallied for the initial groupoften(49thru75)taggedin2008---09,andforthesecondgroup(21---41)taggedinNovember 2010. During the first half of 2011, as many as 16 gharial were being tracked on a weekly/biweekly basis at Chambal locations ranging from Sashon to aboveNaangoan

ID	sex	tl(m)		2010	2010	2010	2011	2011	2011	2011				
				may- jun	july- sept	oct- dec	jan- mar	apr- jun	july- sept	oct- dec		bcl0- 2011	total locat	
49	F	2.9		KH	BD	KH	KH	KH				46	218	
51	F	2.8		DN	CH	DN	DN	DN		***		49	246	
53	F	2.3		DN	NK	DN	DN	DN		***		61	255	
55	M	2.1		CH	CH	CH	CH	CH	CH	***		97	311	
57	F	2.9		BD	BD	BD	**					38	228	
59	M	2.0		KT	CH	KT	KT	KT	CH	***		62	174	
61	F	2.9		CH	CH	CH		***		***		67	308	
63	F	3.3		?	CH	CH						33	152	
69	F	3.0		DN	CH			***		***		21	213	
75	F	2.5		DN	NK	DN	DN	***		***		35	216	
												=509	=2321	
21	F	2.9				(PN)	GH	GH	SG	GH		70		
23	F	3.6				(PN)	GH	KH*	CF	SG		64		
25	M	2.6				(PN)	GD	GD	CF	SG		17		
27	M	2.2				(PN)	PN	PN	PN	PN		59		
29	M	2.2				(PN)	PN	PN	SG	PN		64		
31	M	2.3				(KH)	KH	KH	KH	KH		63		
35	M	2.3				(KS)	GD	GD	CF	SG		56		
37	M	2.1				(KS)	KS	KS	KS	KS		53		
39	M	2.3				(PN)	KH	KH	SG	KH		34		
41	F	3.1				(BR)	GH	GH	CF	GH		68	= 495	

ID=gharialtaggedwith radio, e.g., 49 is151.49MHz, 51 is151.51MHz, etc sex: F=female, M=maletl (m)is total length in meters

Chambal location abbreviations KH=KheraAjab Singh; BD= Badpura; DN=Dinnpura; CH=Chilonga; NK=Nachnoli; KT=Koroth; PN=PituwankaNagla (Philmunnagara); BR= BarchauliGH= Gohera;SG= SashonGhat; CF=confluenceYamuna-----Chambal;GD=Godha; KS=Kasaua (PN), (KH), (KS), (BR)=capture/ release sites for gharial tagged in November 2010

***=visualobservation of tagged gharialwithradioattached, butno longer broadcasting

**=visualobservation oftaggedgharial,radiodetached

*=this female was observed to have nested at Chikni Tower, just below Khera in 2011

Table 2.Tracking Summary of ten wild Gharial with radio transmitters in National Chambal Sanctuary Movements are summarized for second group (ID21-41) tagged in late November 2010. Most were tracked weekly/biweekly; 25&37 were lost by end 2011, and 29 by early 2012. Seven were tracked for 26+months; five thru May 2013.Total animal--specificlocations in from Dec 2010 in to March 2013 = 1009 +

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Chambal River loc: GD=Godha; GH=Gohera; MG=Magheraka Pura; DN=Dinnpura; KH=Khera Ajab Singh; KS= Kasaua; CT= Chikni Tower; PN=Pituwanka Nagla (Philmunnagara); BR=Barchouli; SG=Sashon Ghat; Mahua Sunda=MS; PA=Patharra--Bihar; CF=Yamuma -Chambal confluence; YM=Yamuna; PD=Pachnada, belowY--Cconfluence. (PN),(KH),(KS), (BR)=capture/releasesites.

legends:tl--m=totallength, metres; cap=capture location; mns= months tracked; locs= location srecorded; kms= maximum movement distance, in kms; loc to CFL=locationon Chambal, relative to con fluence (CF)=0; dry= dry season location; Ukm= seasonal upstream movement, in km; wet=wet seasonlocation; Dkm= seasonal downs tream movement, in kms.

23 nested in 2011 at CT, in 2012 at DN, and 2013 at DN; 41 nested in 2012 at DN. In 2013, nesting by 41 and 21 stilluncertain.

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Lang, J.W. and Whitaker, S. (2010). Application of telemetry techniques in crocodilian research: Gharial (Gavialis gangeticus) spatial ecology in the Chambal River, India, pp.161-171,in Siva kumar, K. and Habib, B.(Eds.) Telemetry in Wildlife Science, ENVIS Bulletin. Wildlife and Protected Areas, Vol13 No. 1, Wildlife Institute of India, Dehradun 248001. INDIA

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Lang, J.W. (2013). Behavioral Ecology of Gharial on the Chambal River, India. Project Report to Ministry of Environment & Forests, Government of India, New Delhi, June 2013.

This project is a joint venture of Madras Crocodile Bank Trust (MCBT) and the Gharial Conservation Alliance (GCA), PO 4, Mahabalipuram 603104 INDIA

in collaboration with Ministry of Environments & Forests, Government of India, Uttar Pradesh and Madhya Pradesh Forest Departments, and Garhaita Village, Etawah UP.

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Table3. Summary of Gharial activities and behaviors observed on the lower Chambal River (National Chambal Sanctuary) throughout the annual cycle (shown here bimonthly). In general,gharialof all size classes are most concentrated at late winter basking sites prior to breeding, and are most dispersed at high water levels during monsoonal rains when main channel flow is swift, andresting and baskingsitesalongtheshorelinearelimited. Captureandtaggingshouldberestrictedto October--November when adults move upstream, when social interactions are minimal, and when reproductive activities do not occur.

annualc ycle		weather/season	size/age/sex distribution	spatial pattern	group size	dominant activities	riverhabitats
July-- Aug		monsoonhig h water	all sizeclasses	dispersed	1--5 5--10	feedingbaskin g	shallows, edges, side channels
Sept-- Oct		post monsoon receding water	all sizeclasses	small, mixed grps	5--10 10--20	feedingbaskin g	main channel, shallows, edges
Nov-- Dec		earlywinter cool temps	all sizeclasses	medium, mixedgrps	10--30	basking	sand bars, river bends
Jan-- Feb		latewinter cooltemps	adults– subadults multiple males >4 juveniles--s--adults	largegrps breeding marginal	30--90 5--15	basking, breeding	mid river bars, bends, rocks
Mar-- April		early summer warm temps low water	nesting females egg incubation attendent male(s)	restricted tonesting locations	10--30	trial nests, nesting, incubation	river bends, highsandbanks, w/ deep water
May--- June		pre monsoon very high temps lowest water	nesting females hatchlings guarding male=1 juveniles--s--adults	restricted tonesting locations marginal	10--30 5--15	incubation, egg hatch, creches	river bends, highsandbanks, w/ deep water

Table4: Spatial distribution of nest sites on lower Chambal River, referenced to upstream distance from Yamuna confluence (=0 km) Fourteen nest sites were used during three nesting seasons, producing 38, 76, and 80 nests respectively in 2010, 2011, and2012. The number of nests that produced hatchlings in each year are shown for each location in the bottom panel.Predated nests=( );=pd For example, the Rheasite (*RH*) had 11, 20, and 30 total nests,and 11, 19, and 28 nests hatched in 2010, 2011, and 2012, respectively. Bolded, underlinedentryindicatesthatamalewasobservedguardinghatchlingsatnestsite,andoftenresidentpost--hatching.

distance river(km)	38	46	49	54	56	74	79	85	87	93	103	107	133	161		
nesting location	**PN**	**KS**	**CT**	**KHc**	**KHf**	**CH**	**NK**	**DNu**	**DNm**	**NG**	**GH**	**GD**	**KP**	**RH**	total nests	nest sites
2010	1	(3)		4	4	3	3				3	4	(2)	11	38	10
2011	6	7	3	(7)	7	6	6			(4)	(3)	(3)	(4)	20	76	12
2012	7		(3)		20			8	12					30	80	6
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nesting location	**PG**	**KS**	**CT**	**KHc**	**KHf**	**CH**	**NK**	**DNu**	**DNm**	**NG**	**GH**	**GD**	**KP**	**RH**	nests hatched	hatch sites
2010	1	pd		**3**	**4**	**3**	2				3	4	pd	**11**	31	8
2011	**6**	**5**	**3**	pd	**3**	**6**	**6**			pd	pd	pd	pd	**19**	48	7
2012	**5**		pd		**17**			**8**	**11**					**28**	69	5

Nesting location abbreviations: PN=PituwankaNagla (Philmunnagara); KS=Kasaua; CT=Chikni Tower; KHc=KheraAjab Singh, back channel; KHf=KheraAjab Singh, main channel; CH=Chilonga; NK=Nachnoli; DNu=Dinnpura, UP side; DNm=Dinnpura, MP side; NG=Naangoan; GH=Gohera; GD=Godha; KP=Kuerapura; RH=Rhea

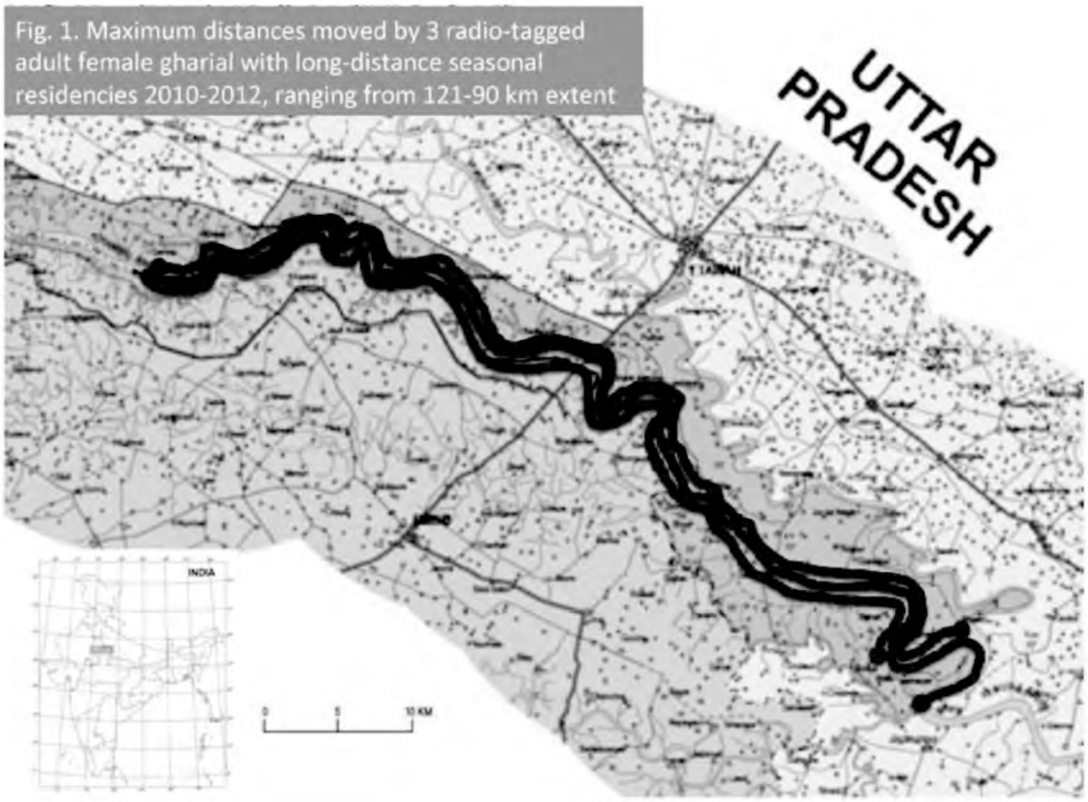


Fig. 1. Maximum distances moved by 3 radio-tagged adult female gharial with long-distance seasonal residencies 2010-2012, ranging from 121-90 km extent

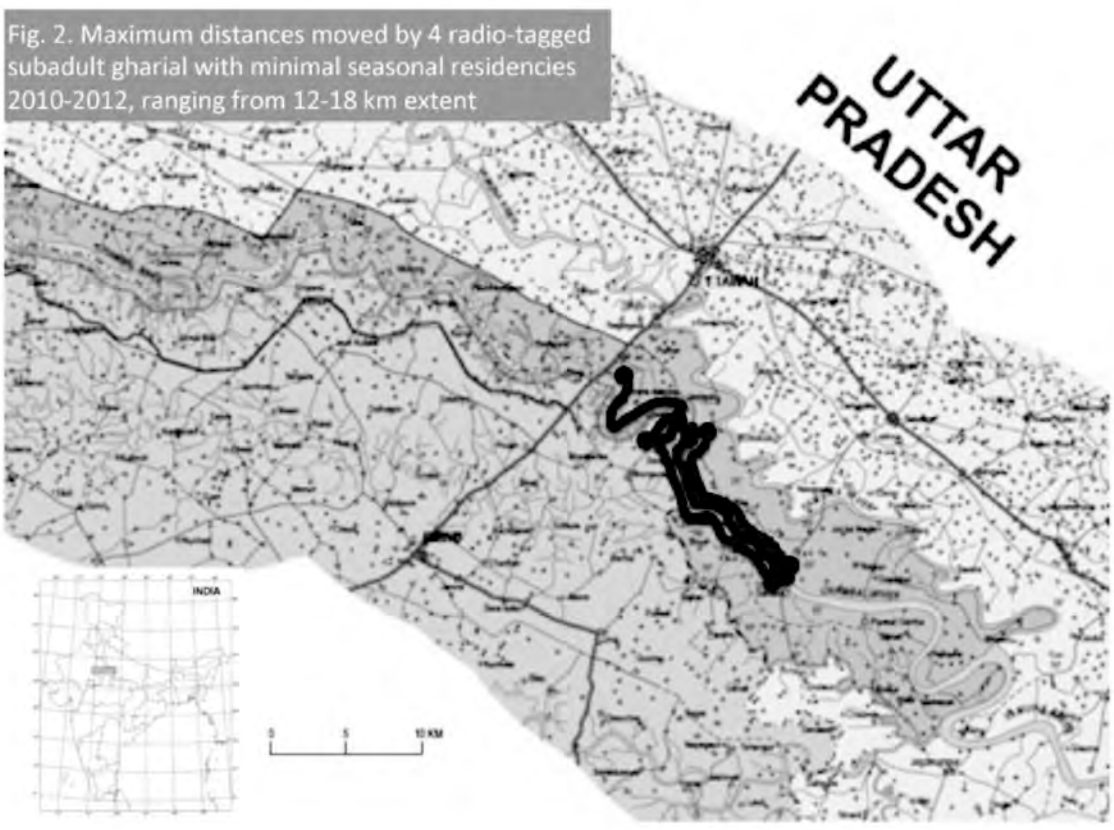
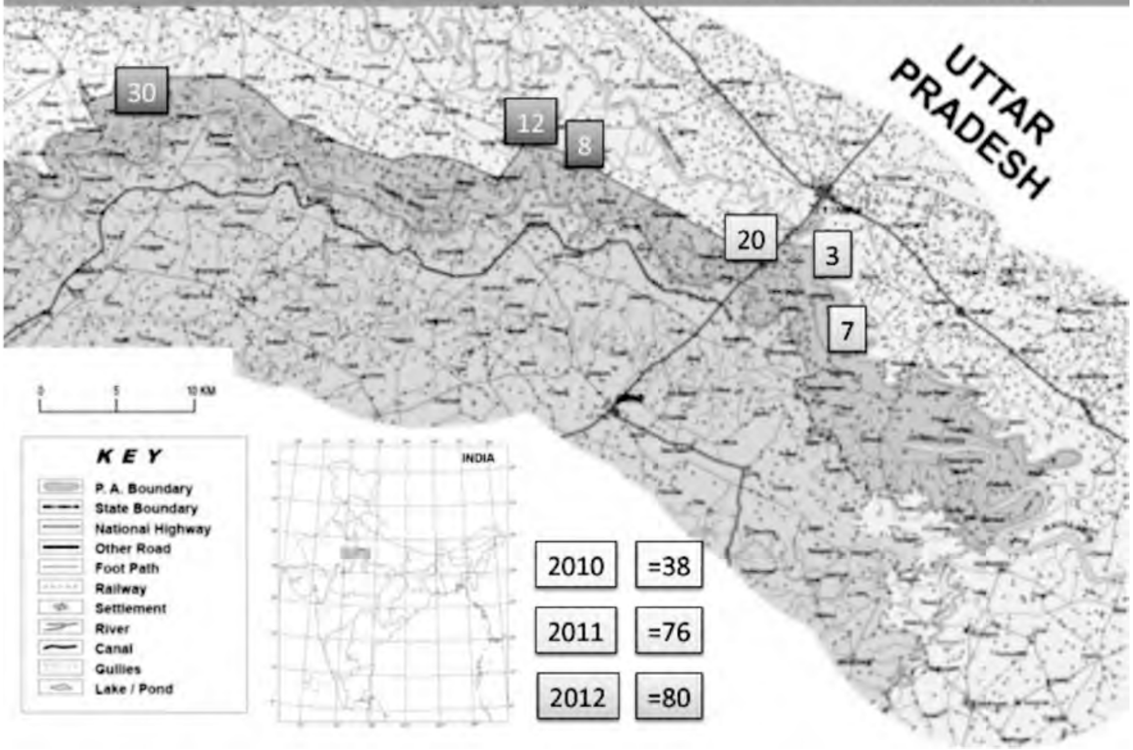
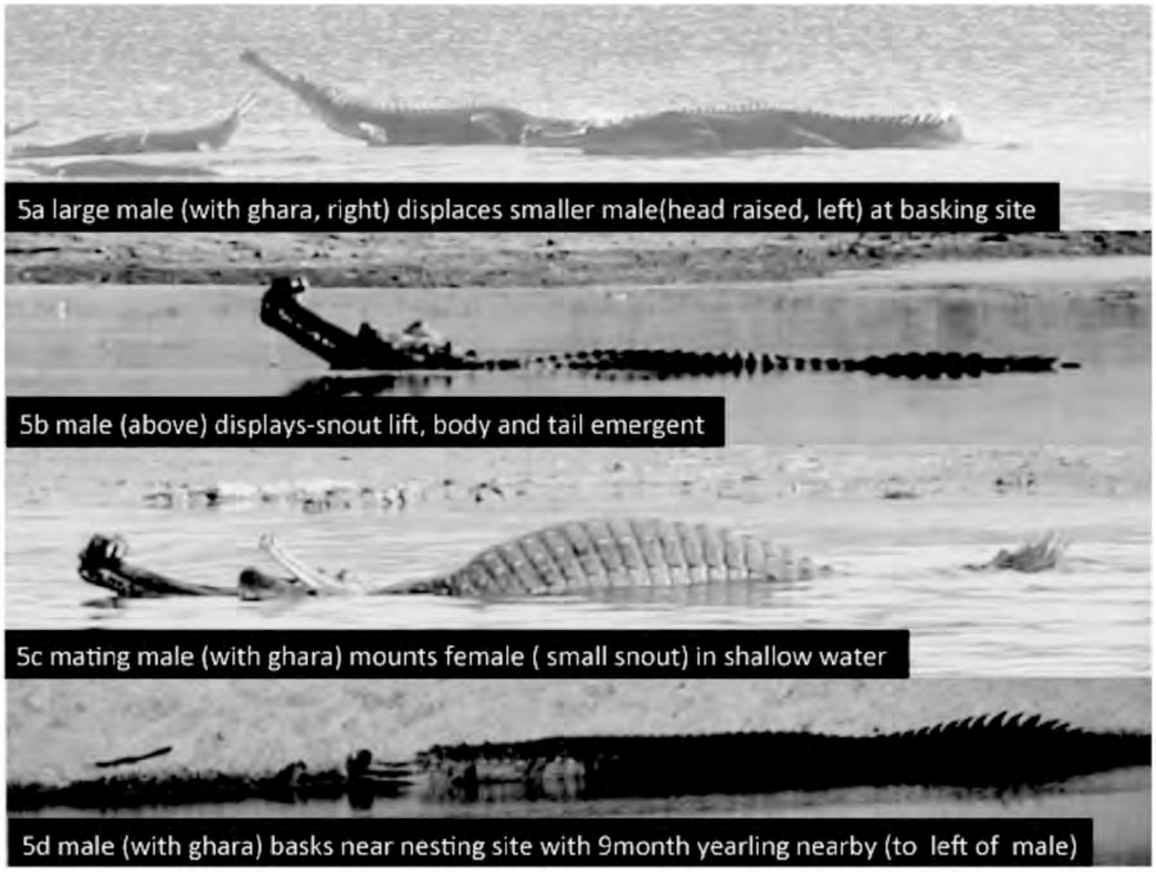


Fig. 2. Maximum distances moved by 4 radio-tagged subadult gharial with minimal seasonal residencies 2010-2012, ranging from 12-18 km extent

Fig. 3. In 2010, 2011, and 2012, nest sites, nest numbers at sites, and nest predation varied. In 2012, 6 sites had mean nest/site=13.3, range=3 to 30, & 3 new sites (dk red sq).





5a large male (with ghara, right) displaces smaller male(head raised, left) at basking site

5b male (above) displays-snout lift, body and tail emergent

5c mating male (with ghara) mounts female (small snout) in shallow water

5d male (with ghara) basks near nesting site with 9month yearling nearby (to left of male)

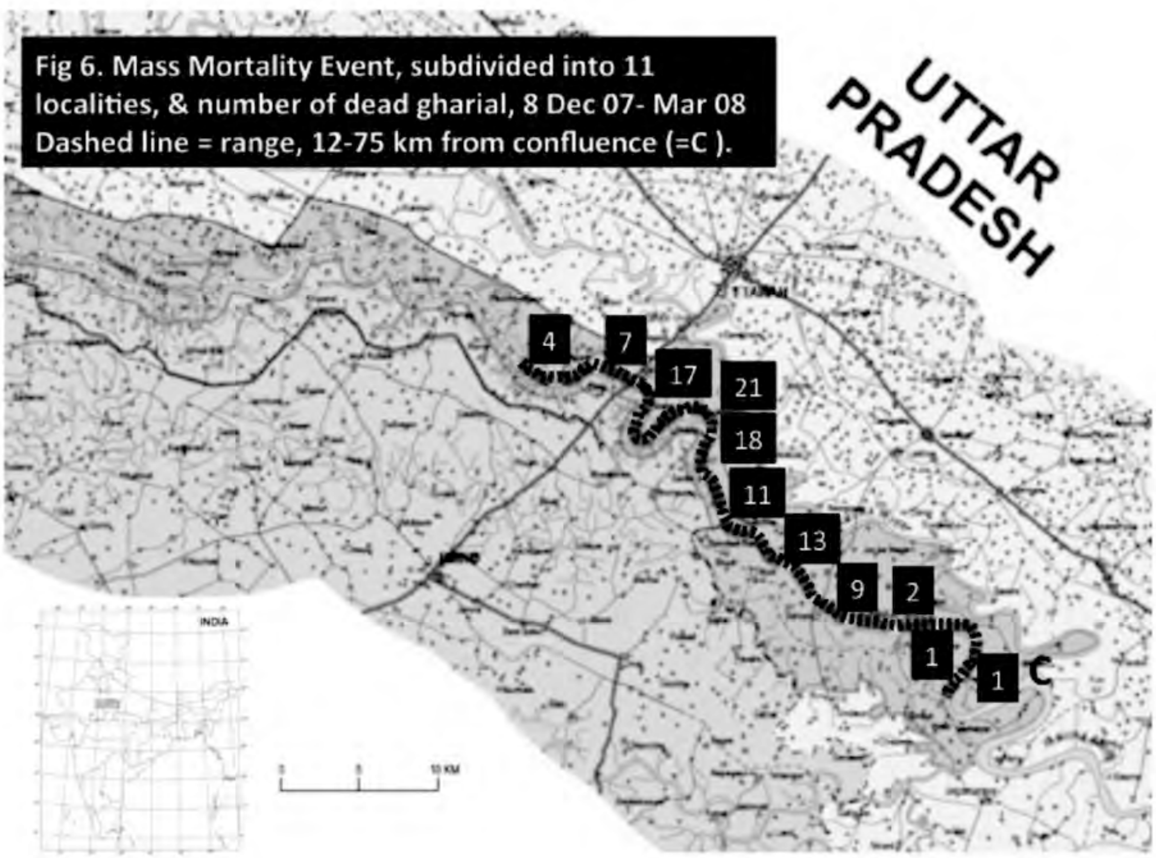


Fig 6. Mass Mortality Event, subdivided into 11 localities, & number of dead gharial, 8 Dec 07- Mar 08 Dashed line = range, 12-75 km from confluence (=C).

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22nd Working Meeting of the IUCN-SSC Crocodile Specialist Group
pp 53 - 65

Dry-season assessment of gharials (*Gavialis gangeticus*) in the Betwa, Ken and Son Rivers, India

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Introduction

While gharial (*Gavialis gangeticus*) populations are monitored in the National Chambal Sanctuary (Madhya Pradesh Forest Department annual surveys, Lang 2010, Lang & Whitaker 2010, Nair 2010, Katdare 2011, Nair et al. 2012, Lang & Kumar 2013), Katerniaghat Wildlife Sanctuary (Chaudhari 2008, Converse 2009, Choudhary 2011) and Corbett Tiger Reserve (Chowfin 2013, Chowfin & Leslie 2013), virtually nothing is known from the rest of the gharial's range in India. To address this shortcoming, the Gharial Species Recovery Plan (in prep.), and IUCN's Gharial Status Survey & Conservation Action Plan (Stevenson & Whitaker 2010) suggest an overall assessment of the status of existing gharial populations to be used as a baseline fors measuring the effectiveness of past recovery efforts. As part of this range-wide assessment of gharials in India, and following observations of gharial hatchlings in the Yamuna River, near the Ken - Yamuna confluence, (Nair 2012), we undertook surveys of 3 rivers (Rivers Betwa, Ken & Son) in the Yamuna - Ganga Drainage.

Study Area

a) Betwa River: The Betwa River originates in the Vindhyan Ranges, near Bhopal in Madhya Pradesh, and flows in a north-easterly direction for approximately 590 km to meet the Yamuna River in Uttar Pradesh near the town of Hamirpur. The project area (Figure 1, 4) includes ~100 km of the lower Betwa, between Tikri village (N 25° 53' 53.45”, E 79° 31' 24.54") and the Betwa-Yamuna confluence (N 25° 55' 2.60", E 80° 12' 48.66").

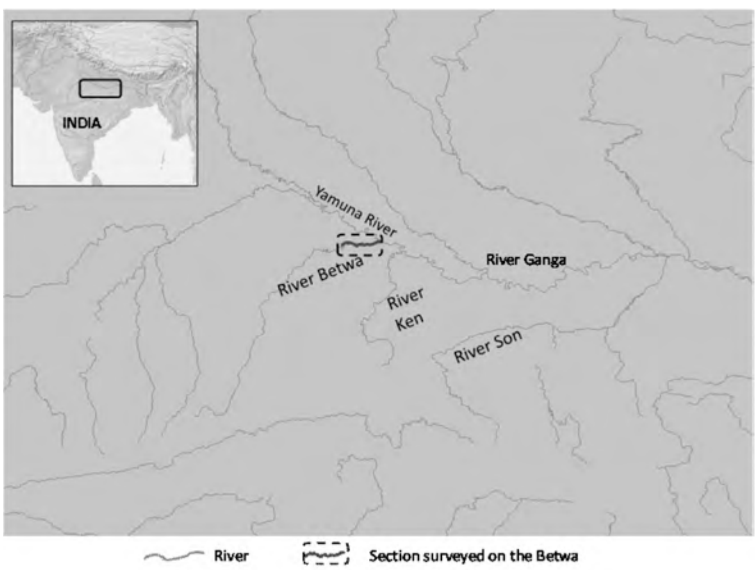

Figure 1. Map of study area (Rivers Betwa, Ken & Son) highlighting the section surveyed on the Betwa River

b) Ken River: The Ken River originates on the north-western slopes of the Kaimur hills in Jabalpur district of Madhya Pradesh (M.P.) at an elevation of about 550 m above mean sea level and joins the Yamuna River near Chilla village in Uttar Pradesh (U.P.) at an elevation of about 95 m. It forms the boundary between Panna and Chhatarpur districts in M.P., and the state boundary between Chhatarpur district (M.P.) and Banda district (U.P.). The river has a total length of 427 km, out of which 292 km lies in M.P., 84 km in U.P. and 51 km forms the common boundary. Its tributaries include Sonar, Shyamari, Kutni and Urmal Rivers among others. The Ken River basin lies between north latitudes 23°20' and 25°20' and east longitudes 78°30' and 80°32'. The total catchment area of the basin is 28,058 sq. km. (Jain et al. 2007).

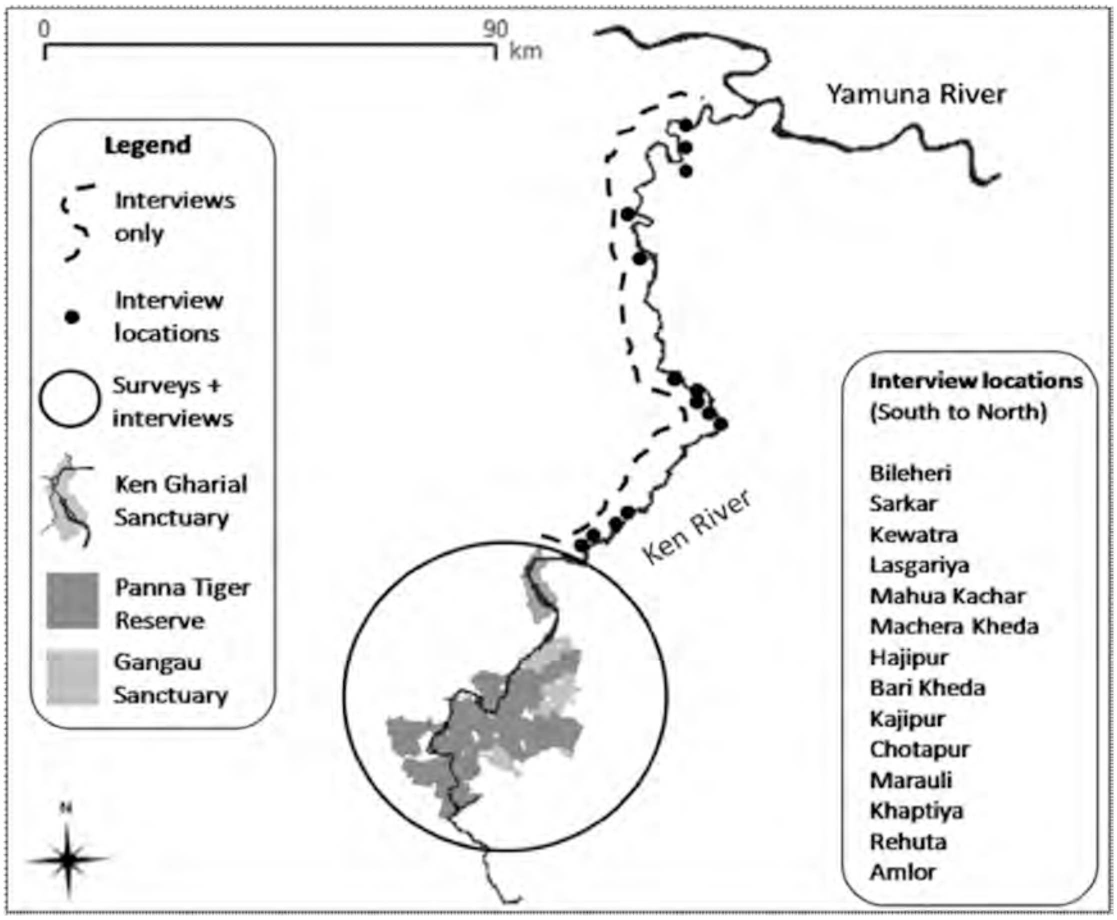

Figure 2. Map of study area, showing surveyed locations in the Ken River.

The Panna Tiger Reserve (PTR) covers 542 km^2 of the Vindhyas in north-central Madhya Pradesh. This landscape consists of two extensive, step-like plateaus separated by 3080 m high escarpments that run parallel to the Ken River (Karanth et al. 2004), and the dominant vegetation type is tropical dry-deciduous forest (Meher-Homji 1990). Approximately 55 km of the Ken River flows though / along PTR. The annual rainfall fluctuates within the range of 6001100 mm (Jayapal et al. 2007) between July and September, which is followed by the cool season between October and February. This is followed by an increasingly dry summer, when the maximum temperature may frequently exceed 45° C (Karanth et al. 2004).

Approximately 16 km, and not 45 km as reported earlier (Rao et al. 1995; Sharma et al. 1999), of the Ken River between the Barriarpur Weir (N 24°50'32.00" E 80°05'18.00") and the Ken - Urmal confluence (N 24°56'20.00" E 80°04'6.00") has been designated as the Ken Gharial Sanctuary (KGS) since 1981.

c) Son / Sone River: The Son River originates in the Maikal Range, near the town of Amarkantak (Madhya Pradesh, India), at an elevation of 600 m (Hunter 1908, Sinha & Sharma 2003). After an initial course running North-Northwest, the Son flows in an East-Northeasterly direction along the Kaimur Range. Its runs for about 784 km till its confluence with the Ganga upstream of Patna, Bihar.

The Son has a steep gradient (3555 cm per km) with quick run-off (Wikipedia 2013) and a recorded monsoonal discharge of up to 830,000 cu ft/s (Hunter 1908). However, being wide and shallow, it leaves disconnected pools of water in the remaining part of the year (Wikipedia 2013). Its tributaries include the rivers Ghaghar, Johilla, Banas, Gopad, Rihand, Kanhar and North Koel River. The total catchment area of the basin is 71,258 sq. km. (Jain et al. 2007). Water impoundments on the Son include the Bansagar Dam, Indrapuri Barrage and Dehri Anicut.

209.21 km of river length [including 160.93 km of the Son River, from the Bansagar Dam to the Singrauli (M.P.) - Sonbhadra (U.P.) border; 22.53 km of the Banas River from the Son - Banas confluence to the bridge on the Sidhi - Shahdol PWD Road; and 25.75 km of the Gopad River from the Son - Gopad confluence to the bridge on the Rewa Waidhan PWD Road] has been declared as the Son Gharial Sanctuary (SGS). It also includes 200 m on either side of the riverbank.

Figure 3: Map of study area, showing surveyed locations in the Son Gharial Sanctuary.

Field Methods, Observations and Discussion

We surveyed 3 rivers (Rivers Betwa, Ken & Son) in the Yamuna - Ganga Drainage between February and May 2013. Surveys were carried out either on foot, by row-boat or through stationary observations depending on local conditions and logistics. Two observers, equipped with binoculars, scanned the river and both banks. All observations were noted in a standardised format and their locations recorded in a Global Positioning System (GPS) unit.

a) Betwa River: Approximately 100 km of the lower Betwa, between the Betwa-Yamuna confluence (N 25° 55' 2.60", E 80° 12' 48.66") and Tikri village (N 25° 53' 53.45", E 79° 31' 24.54") was surveyed from February 02-13, 2013, moving upstream in a row-boat. Local residents were interviewed and shown photographs of gharial and mugger (*Crocodylus palustris*) to inquire the presence of both species from the Betwa River.

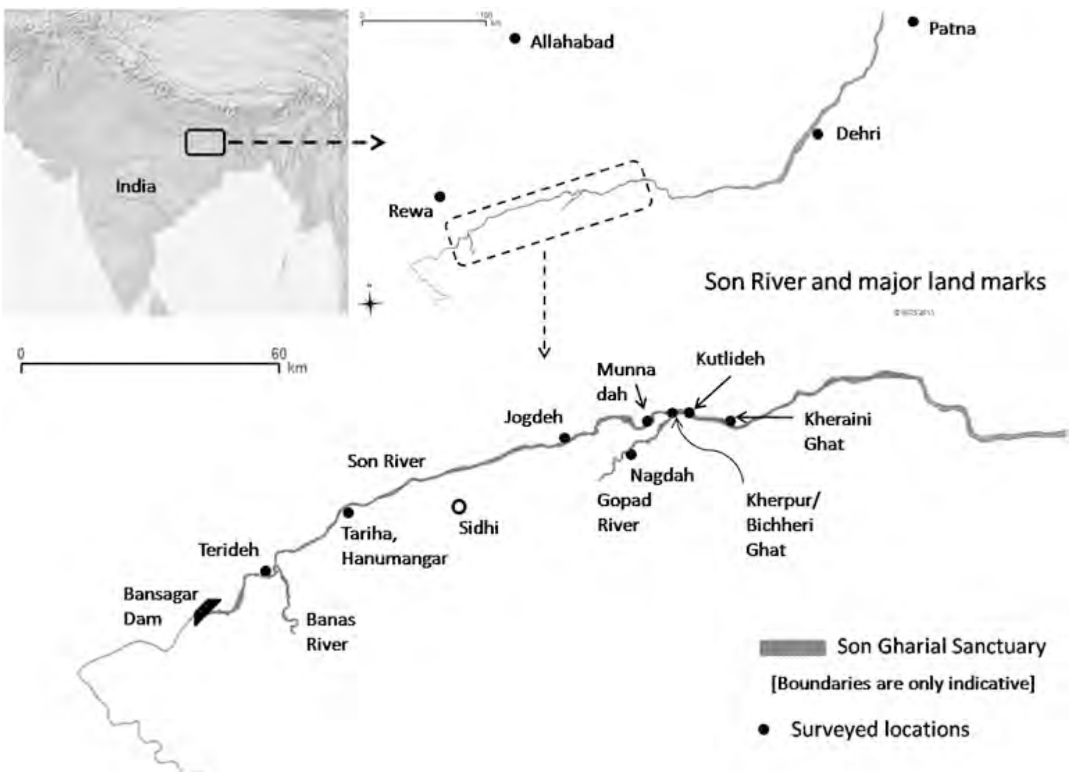

Figure 4. Satellite image of the surveyed area in the Betwa River, showing start and end locations (dark blue pins), mugger observations (light blue pins) and major sand-mining sites (shaded red).

Two muggers were detected during the survey (one each at N 25°54'49.64" E 79°36'33.56" and N 25°53'11.96" E 79°33'13.49").

The surveyed length of river was notably shallow (only observed, not quantified) and fordable at multiple locations (most boatmen simply used bamboo push-poles to navigate the river rather than row or paddle).

A range of intrusive and extractive human activities (the most common being riverside agriculture, sand-mining and fishing), and domestic activities including washing, bathing and cattle herding were observed throughout the surveyed area. Sand was being mined (in-stream and floodplain) at an industrial scale, and several makeshift bridges, to facilitate vehicular movement, had been laid out across the river near every large-scale mining site. A series of concrete pipes at the bottom of these makeshift bridges ensured the flow of water but this arrangement seemed inadequate to ensure functional connectivity for aquatic wildlife. In addition, these sites were also subject to round-the-clock activity of heavy machinery and mine workers.

While fishing was observed frequently (cast-net and gill-net), fishermen indicated poor daily catches of as little as 2-3 kg, and alleged the low-productivity to be a result of falling water levels and siltation caused by sand-mining. Local fishermen reported occasional observations and entangling of small gharial near the Betwa - Yamuna confluence during the monsoonal floods. Hunting was also reported to be widespread in the area.

Historical accounts of gharial in the Betwa are scarce. Singh (1978) notes that the gharial habitat in the Betwa has been badly disturbed and that the gharial population is either extinct or near extinction. Rao et al. (1995) reports the release of 55 gharials in the downstream section (Uttar Pradesh) of the Betwa but we could not gather any evidence to suggest their continued survival. Based on our observations in the dry, low-flow season, we believe that the lower Betwa is unsuitable for the long-term survival of gharials and that it has low conservation potential for the species.

b) Ken River: We assessed ~ 86 km of the Ken River, between where the Ken River enters Panna Tiger Reserve (N24°27'24.89" E79°51'52.16") and exits Ken Gharial Sanctuary (N24°56'18.22" E80° 04'19.33"); and conducted semi-structured, opportunistic interviews (with photographs of the gharial and mugger as visual aids) of local riverside residents to record their observations of these species in the lower ~175 km of the Ken River (Figure 5).

i) Panna Tiger Reserve(PTR): We investigated 55 km of the Ken River flowing through the Panna Tiger Reserve from 09 -17, April 2013. Observations were carried out on foot in daylight, except for a 9 km section upstream of the Gangau Dam which was covered by row-boat.

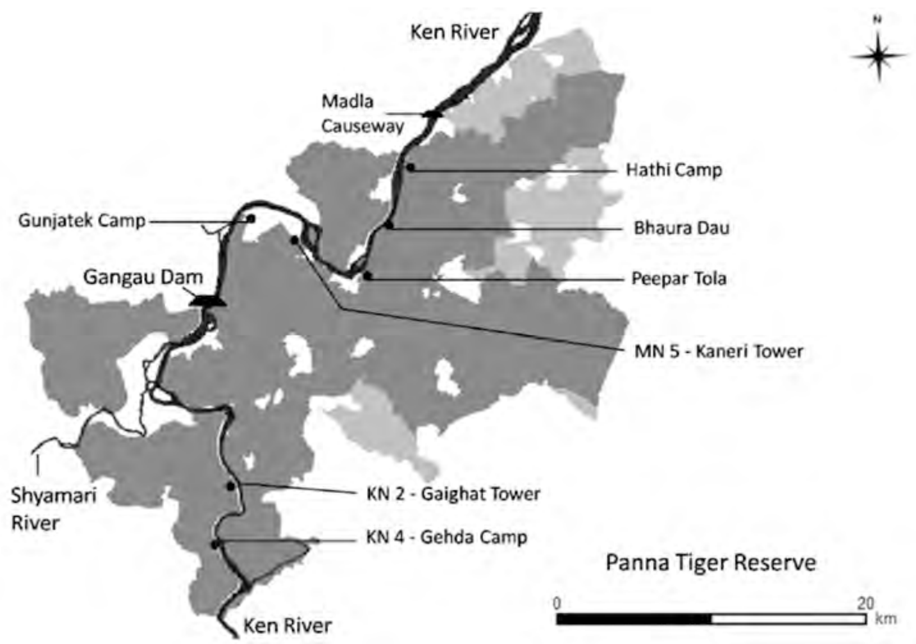

Figure 5. Map of the Ken River, flowing through Panna Tiger Reserve

We detected 56 mugger / marsh crocodiles in this 55 km section (see Table 1). We did not find any evidence (direct or indirect) of gharials in the Panna Tiger Reserve during this survey, in spite of two attempts to introduce the species here (see Table 3). Based on the number of detections (N=56) and effort, in terms of distance surveyed (55 km), we can make coarse estimates of encounter rates at 1.01 individuals / km.

Table 1. Details of mugger observations in the Ken River in Panna Tiger Reserve.

Date	No. of individuals	Location (nearest)
11.04.2013	1 juvenile	N 24°30'24.1'' E 79°51'44.9'' (Near KN 4 - Gehda Camp)
11.04.2013	2 yearlings	N 24°31'31.8'' E 79°52'43.8'' (Near KN 2 - Gaighat Tower)
11.04.2013	1 juvenile	N 24°32'43.1'' E 79°52'17.1'' (Near KN 2 - Gaighat Tower)
14.04.2013	1 juvenile	N 24°41'17.7'' E 79°53'04.4'' (Near Gunjatek Camp)
15.04.2013	1 adult 1 sub-adult	N 24°39'42.0'' E 79°56'03.1'' (Near MN 5 - Kaneri Tower)
15.04.2013	1 juvenile 1 yearling	N 24°39'07.2'' E 79°57'01.9'' (Near Peepar Tola)
16.04.2013	4 adults 5 juveniles	N 24°39'16.7'' E 79°57'11.5'' (Near Peepar Tola)
16.04.2013	1 adult	N 24°39'22.0'' E 79°57'21.0'' (Near Peepar Tola)
16.04.2013	2 juveniles	N 24°39'43.0'' E 79°57'47.5'' (Near Peepar Tola)
16.04.2013	2 adults 2 juveniles	N 24°39'50.3'' E 79°57'59.2'' (Near Peepar Tola)
16.04.2013	1 adult 1 juvenile 1 yearling	N 24°39'42.5'' E 79°58'02.6'' (Near Peepar Tola)
16.04.2013	1 juvenile / sub-adult (?) 1 yearling	N 24°39'24.8'' E 79°57'50.9'' (Near Peepar Tola)
16.04.2013	1 adult 4 juveniles	N 24°40'04.7'' E 79°58'08.6'' (Between Peepar Tola and Bhaura Dau)
16.04.2013	1 adult	N 24°40'30.2'' E 79°58'15.4'' (Near Bhaura Dau)
16.04.2013	1 adult 1 juvenile	N 24°40'45.7'' E 79°58'37.2'' (Near Bhaura Dau)
17.04.2013	3 adults 1 juvenile 1 yearling	N 24°41'12.1'' E 79°59'01.4'' (Near Bhaura Dau)
17.04.2013	3 adults	N 24°41'20.1'' E 79°59'06.2'' (Near Bhaura Dau)
17.04.2013	1 juvenile	N 24°41'28.1'' E 79°59'10.1'' (Near Bhaura Dau)
17.04.2013	1 sub-adult 1 adult	N 24°41'35.1'' E 79°59112.5'' (Near Bhaura Dau)
17.04.2013	1 adult / sub-adult (?) 3 juveniles	N 24°41'54.0'' E 79°59'17.1'' (Near Bhaura Dau)
17.04.2013	1 adult	N 24°42'06.0'' E 79°59'18.5'' (Between Bhaura Dau and Hathi Camp)
17.04.2013	1 juvenile	N 24°42'20.4'' E 79°59'21.8'' (Between Bhaura Dau and Hathi Camp)
17.04.2013	1 adult	N 24°43'35.0'' E 79°59'52.7'' (Between Hathi Camp and Madla Causeway)
TOTAL	**56**	**[21 adults; 2 sub-adults; 25 juveniles; 6 yearlings; 1 juvenile / sub-adult (?); 1 adult / sub-adult (?)]**

ii) Ken Gharial Sanctuary (KGS): We surveyed 16 km of the Ken River flowing through the KGS from 25 - 26, April 2013. Daylight observations were carried out on foot, except for a 5 km section downstream of Raneh Falls which was covered by row-boat.

Figure 6. Map of the Ken River, flowing through Ken Gharial Sanctuary.

We detected 4 mugger in this 16 km section of the Ken River (see Table 2), giving us an encounter rate of 0.25 individuals / km. However, we did not find any evidence (direct or indirect) of gharials in the KGS during this survey, in spite of several efforts to (re)introduce the species here (see Table 3).

Table 2. Details of mugger observations in the Ken River in Ken Gharial Sanctuary

Date	No. of individuals	Location (nearest)
26.04.2013	1 adult / sub-adult (?)	N 24°53'45.8'' E 80°02'36.9'' (Near Mohare ghat)
26.04.2013	2 adults	N 24°53'59.2'' E 80°02'29.2'' (Near Mohare ghat)
26.04.2013	1 adult	N 24°54'14.7'' E 80°02'06.2'' (Near Mohare ghat)
TOTAL	**04**	**[3 adults; 1 adult / sub-adult (?)]**

Previous accounts of gharials in the Ken River are ambiguous. Singh (1978) reports gharials as extinct in the Uttar Pradesh (lower) portion of the Ken River, and according to Sharma (2000) the species did not occur in the Ken Gharial Sanctuary prior to the reintroduction of captive-reared animals. However, Whitaker & Mahadev (1976) report sighting an adult gharial, and gather the presence of a few more individuals from local fisherman in the Mandla Sanctuary (we are not aware of the existence of the Mandla Sanctuary and believe this to be the Ken Gharial Sanctuary close to the town of Madla, Madhya Pradesh). Whitaker & Daniel (1978, 1980) also note the presence of a small population of gharials in the Ken River.

The Madhya Pradesh Forest Department considered KGS suitable for the management of gharials based on habitat characteristics and prey availability (Sharma et al. 1999), and as per official records maintained at KGS (Khajuraho, Madhya Pradesh), 109 gharials have been released here since its establishment in 1981 (see Table 3). In addition, 33 gharials (15 in 1996 + 18 in 1998) were released at Bhaurau Dau, PTR (N24°41'0.00" E79°58'45.00") approx. 22 km upstream of Barriarpur Weir (see Table 3).

Table 3. Official record of gharials released in the Ken River (Ken Gharial Sanctuary and Panna Tiger Reserve).

Year	Number of gharials released	Location
1982	8 (sex undetermined)	Ken Gharial Sanctuary - Mohareghat
1985	4 (2 female + 2 male)	Ken Gharial Sanctuary - Mohareghat
1987	10 (sex undetermined)	Ken Gharial Sanctuary - Mohareghat
1989	10 (sex undetermined)	Ken Gharial Sanctuary - Mohareghat
1993	15 (11 female + 4 male)	Ken Gharial Sanctuary - Mohareghat
1994	1 (sex undetermined)	Ken Gharial Sanctuary - Kat Singhar Ghat
1995	15 (all females)	Ken Gharial Sanctuary - Mohareghat
1995	1 (male)	Ken Gharial Sanctuary - Mohareghat
1996	15 (sex undetermined)	Panna Tiger Reserve - Bhaurau Dau
1998	18 (sex undetermined)	Panna Tiger Reserve - Bhaurau Dau
1998	20 (sex undetermined)	Ken Gharial Sanctuary - Mohareghat
2007	25 (20 female + 5 male)	Ken Gharial Sanctuary - Mohareghat
TOTAL	**142 (48 females + 12 males + 82 undetermined)**	

Despite the release of 142 gharials in the study area, there is no evidence to suggest that this effort has helped sustain a breeding population here. No gharials have been observed by local forest staff at Bhaurau Dau, PTR for at least three years (Shankar Verma, pers. comm.). Meanwhile, forest staff at KGS mention of the presence of only 1 female adult gharial near Mohareghat, reportedly seen 2 weeks before this survey (Lalu Kewat and Sunwa Kewat, pers. comm.). Gharial nesting and a pod of 8 hatchlings were reportedly observed in 2003, and the only known adult male has not been seen since a major flood in the Ken River in 2005 (Ibid).

The sections of the Ken River flowing through PTR and KGS are predominantly rocky, and the complementary availability of two critical components of gharial habitat - deep pools and sand deposits, are limited and widely disconnected. Individuals that move downriver in the monsoonal floods or during high water do not have the opportunity to return to the relatively protected confines of the KGS or PTR due to the several man-made barriers and disrupted flow regimes in the Ken River. Water impoundments at Gangau Dam, Ranguwan Dam, Madla Causeway and Barriarpur Weir have diminished river flow, and this is compounded in the dry, summer months. The proposed Ken - Betwa river-linking project will further aggravate the situation by the creation of the Daudhan Dam on the Ken River at a location of about 2.5 km upstream of the existing Gangau Dam and the diversion of 1020 Mm^3 of water from the Ken River (NWDA, undated).

Additionally, activities like dynamite and gill-net fishing and sand-mining on an industrial scale have rendered the non-protected sections of the Ken River too disturbed and hostile to permit gharial populations to establish themselves. Other human activities in the form of bankside agriculture, livestock herding and unrestricted human movement along the river also contribute to habitat loss and disturbances.

The Ken River supports diverse fish fauna of high conservation importance (Johnson et al. 2012, pers. obs.) and significant populations of other associated fauna like muggers and Grey-headed Fish-eagles (*Ichthyophaga ichthyaetus,* pers. obs.). However, based on the current situation and our observations of the Ken River in Panna Tiger Reserve and Ken Gharial Sanctuary in the dry, low-flow season, we are of the opinion that this is, at best, sub-optimal habitat for gharials, and not conducive to the long-term conservation requirements of the species. We suggest that future plans to reintroduce gharials in the Ken River be critically evaluated for its conservation benefits. We also suggest that the Ken Gharial Sanctuary be renamed as '*Ken River Sanctuary*' since the existing name lends a false assurance that the sanctuary provides suitable habitat and sustains a natural gharial population.

We also conducted opportunistic interviews of local riverside residents to record their observations of gharials and muggers in the lower ~175 km of the Ken River (between the downstream end of the Ken Gharial Sanctuary and the Ken-Yamuna confluence). The interviews were semi-structured, and used species' photographs as visual aids. A total of 15 group interviews were conducted across 14 villages (see Table 4). While all respondents recognised muggers from the photographs shown to them, only six recognised gharials, and of these six respondents, only one reported seeing gharials in the last 20 years. Although such interview surveys '*are likely to be subjective, biased and unreplicable*' (Magnusson 1982), our preliminary results suggest that the Ken River does not support resident gharial populations, and that the reported (Lambri Kewat, pers. comm.) and recent (Nair 2012) observations of gharials from the region may likely be monsoonal migrants or dispersing individuals from the National Chambal Sanctuary.

Table 4. Local observations of gharials and muggers in the Ken River

Location	Primary Respondent*/ Age/Gender/ Occupation	Species recognised from photographs	Local observations of gharials and muggers
Bilheri N 24°57'19.90" E 80°08'45.00"	Dhibu Kewat. 41. Male. Boatman.	Gharial: Yes Mugger: Yes	Gharials seen in the distant past. Muggers seen occasionally in monsoonal floods. No incidents of conflict reported with either species.
Sarkar N 24°58'13.90" E 80°10'06.70"	Vijay Kewat. 20. Male. Fisherman/farmer.	Gharial: No Mugger: Yes	Muggers seen occasionally in monsoonal floods. No incidents of conflict reported with muggers.
Sarkar N 24°58'13.90" E 80°10'06.70"	Avadh Bihari Shukhla. 63. Male. Retired Govt. Employee.	Gharial: Yes Mugger: Yes	Not seen either species but believes that both species may be present locally in the monsoonal floods. No incidents of conflict reported with either species.
Kewatra N 24°59'43.80" E 80°12'49.50"	Rajua Kewat. 48. Male. Fisherman.	Gharial: No Mugger: Yes	Muggers seen occasionally in monsoonal floods. No incidents of conflict reported with muggers.
Lasgariya N 25°00'00.80" E 80°13'17.50"	Group interview. All adult males. Fishermen/farmers	Gharial: No Mugger: Yes	Not seen either species. No incidents of conflict reported with either species.
Mahua Kachar N 25°10'33.08" E 80°25'25.99"	Rajua Kewat. 61. Male. Farmer.	Gharial: Yes Mugger: Yes	Reports seeing gharials almost 50 years ago and muggers prior to 2005. No incidents of conflict reported with either species.
Machera Kheda N 25°11'08.22" E 80°25'10.70"	Babu Kewat. 40. Male. Fisherman.	Gharial: Yes Mugger: Yes	Not seen either species. No incidents of conflict reported with either species.
Hajipur N 25°11'57.40" E 80°24'56.95"	Ramshankar. 32. Male. Fisherman.	Gharial: No Mugger: Yes	Muggers seen occasionally in monsoonal floods. Reports mugger killing cattle (1 calf).
Bari Kheda N 25°13'57.37" E 80°23'43.86"	Phullu Kewat. 60. Male. Farmer.	Gharial: Yes Mugger: Yes	Gharial last seen in 1992. Mugger seen about 3 years ago (~ 2010). No incidents of conflict reported with either species.
[illegible] N 25°16'31.03" E 80°21'04.49"	[illegible] 25. Male. Fisherman.	[illegible] Mugger: Yes	[illegible] No incidents of conflict reported with either species.
[illegible] N 25°30'19.94" E 80°17'33.64"	[illegible] 30. Male. Farm labour.	[illegible] Mugger: Yes	[illegible] muggers in the locality from others. No incidents of conflict reported with either species.
[illegible] N 25°34'46.88" E 80°16'36.40"	[illegible] 42. Male. Fisherman.	[illegible] Mugger: Yes	[illegible] floods. No incidents of conflict reported with either species.
[illegible] N 25°40'10.66" E 80°22'21.64"	[illegible] 38. Male. Sand mining.	[illegible] Mugger: Yes	[illegible] seen 2-3 years ago (~ 2010). No incidents of conflict reported with either species.
[illegible] N 25°42'39.26" E 80°22'42.23"	[illegible] 58. Male. Farming.	[illegible] Mugger: Yes	[illegible] monsoonal floods. No incidents of conflict reported with either species.
[illegible] N 25°44'07.84" E 80°22'49.66"	[illegible] 35. Male. Boatman.	[illegible] Mugger: Yes	[illegible] Amlor. More seen in monsoonal floods. No incidents of conflict reported with either species.

* Although the interviews were directed at the primary respondent, each interviewee unit consisted of 3-12 predominantly male respondents.

c) Son River: Based on previous reports of gharial (Sharma et al. 2011, MPFD 2013), we investigated 8 locations (see Figure 3, Table 5) in the SGS from 05 - 11, May 2013. Since daytime temperatures in summer exceed 40°C, crocodilian basking is largely restricted to the morning and evening hours. We, therefore, undertook stationary counts from suitable vantage points on the riverbank, either in the morning (0600 - 1000 hrs) or in the evening (1530 - 1830 hrs) at each of these locations to determine and record the presence, number and size-classes of gharials.

Two observers, equipped with binoculars, scanned the river and both banks. All observations were noted in a standardised format and their locations recorded in a Global Positioning System (GPS) unit. The total numbers of gharials seen during these stationary bank observations, done hourly and sorted by size-class are noted. The maximum number of gharials seen in each size class at each of these hourly counts can be used as the best estimate of the number of animals in that particular size class. Thus, summing the best estimates for each size class would provide a more accurate estimate of the total population.

Size-classes were estimated visually through a 'gestalt combination of size and shape', and categorised into 4 classes - yearlings, juveniles, sub-adults and adults. Since our observations preceded the gharial hatching season, there was no likelihood of encountering hatchlings. So, individuals <90 cm long were considered to be yearlings, those 90180 cm as juveniles, those 180300 cm as sub-adults and those >300 cm as adults. We also recorded the presence of mugger, Indian Skimmer (*Rynchops albicollis)* and freshwater turtles.

Table 5: Details of field observations in the Son Gharial Sanctuary

Date	Location	Observations
05-May-2013 & 10-May-2013	Jogdeh N 24°30'49.7'' E 82°08'33.9''	Relatively well protected (especially north bank), and a large, deep pool bounded by shallow riffles up- and down-stream. 17 gharials (By summing best estimates for each size class. Includes 2 adult males, 4 adults, 1 sub-adult / adult, 9 juveniles and 1 yearling). Known gharial nesting site. 9 muggers (By summing best estimates for each size class. Includes 4 adults, 1 sub-adult, 3 juvenile, 1 yearling). 25 - 35 Narrow-headed soft-shell turtles (*Chitra indica*). 10 - 15 Indian tent turtles (*Pangshura tentoria*); < 5 Indian soft-shell turtles (*Nilssonia gangetica*). 14 Indian skimmers The south bank at Jogdeh was frequently disturbed by livestock. We observed gill-net fishing immediately downstream of the Jogdeh pool. The lower jaw of one of the resident gharial juveniles appeared broken and may have resulted from previous entanglement in a gill-net.
07-May-2013 & 08-May-2013	Kutlideh N 24°33'26.2'' E 82°24'55.3''	Large pool bounded by shallow runs up- and down- stream. Dense aquatic vegetation indicative of eutrophication. 3 gharials (all adults). Potential gharial nesting site. 9 muggers (7 adults, 2 juveniles). 18 - 21 Indian skimmers Moderate levels of human activity observed here. River-crossing zone at the lower end of the Kutlideh pool; fishermen seen approaching the upper section of the pool with gill-nets.

08-May-2013	Kherpur / Bichheri ghat N 24°32'45.80" E 82°22'25.20"	This section was characterised by a shallow run, and did not appear to be suitable gharial habitat. High levels human activity - river-crossing, and livestock herding / wallowing.
08-May-2013	Kheraini ghat N 24°32'4.20" E 82°29'58.00"	This section was characterised by a shallow run, and did not appear to be suitable gharial habitat. We observed 2 mugger burrows nearby, beside a small, isolated pool at N 24°32'20.9" E 82°29'22.3" High levels human activity - river-crossing, and livestock herding / wallowing. 1 tractor sand-mining.
09-May-2013	**Munnadah** **N 24°32'13.9"** **E 82°19'29.6"**	**Large pool bounded by very shallow sections up- and down- stream.** **1 mugger burrow along the southern bank.** **High levels of human activity - river-crossing, firewood collection, livestock herding and miscellaneous domestic activities.**
09-May-2013	Nagdah (Gopad River) N 24°29'00.2" E 82°16'45.2"	This section was characterised by a shallow run, except for a pool at Nagdah. 1 mugger (sub-adult / adult?) Moderate - high levels of human activity - river-crossing, fishing, firewood collection and livestock herding.
11-May-2013	Terideh (near Bhaversen ghat) N 24°16'33.41" E 81°27'9.05"	Large pool (approx. 2 km long) bounded by a rapid upstream and a shallow run downstream of the bridge at Bhaversen ghat. Also site of Son - Banas confluence. Potential gharial nesting site. 4 Indian tent turtles (*Pangshura tentoria*) 2 Indian skimmers. Relatively less disturbed than other sites, but local staff report incidents of dynamite fishing in the past.
11-May-2013	Tariha, Hanumangar N 24°23'56.1" E 81°38'05.8"	This section was characterised by a shallow run, and did not appear to be suitable gharial habitat.

We observed a total of 20 gharials (17 at Jogdeh; 3 at Kutlideh) from the 8 locations we investigated (see Table 5). This included 2 adult males, 7 adults, 1 sub-adult / adult, 9 juveniles and 1 yearling. Local staff reported gharial nesting on the north bank at Jogdah (K.P. Tripathi & Anjaneya Sharma, pers. comm.), and our observations of behaviour indicative of nest attendance and nest guarding suggest the presence of as many as 4 nests (three of them on the same sand-deposit near the Jogdeh watchtower, and one approx. 300 m upstream of this sand-deposit).

Previous records of gharials in the Son River probably date back to the Babur-nama (the 16th century memoirs of Mughal Emperor Babur), which depicts a longirostrine crocodilian, most likely the gharial (Figure 7).

More recently, Whitaker & Mahadev (1976), Rao (1988) and Khan (1993, in Sharma et al. 1999) note the presence of gharials prior to the notification of the SGS in 1981. Andrews (2006) reports observing 3 trial nests and 1 nest in 2006; followed by 2 nests each in 2007 and 2008 (R.K. Sharma pers. comm., in Stevenson & Whitaker 2010). Local field staff have confirmed gharial nesting at Jogdeh every year from 2006 onwards, and 48 hatchlings were observed here in 2012, followed by 79 hatchlings in 2013 (Anjaneya Sharma, pers. comm.). The gharial nesting sites along the north bank at Jogdeh are reportedly maintained by supplementing sand from the south bank and local staff believe that this has aided successful nesting and hatching here since 2006 (ibid).

Figure 7. Babur crossing the River Son. The longirostrine crocodilian at the bottom of the illustration is likely a gharial.Illustration from the Memoirs of Mughal Emperor Babur: the Babur-nama Source: http://en.wikipedia.org/wiki/File:Babur_crossing_the_river_Son.jpg

164 gharials have been released in the SGS between 1981 and 2011 (Sharma et al. 2011) and yet, surveys in 1996, 2003 and 2010 (ibid) present a declining population trend. While we do not attempt to compare the results of our rapid assessment with previous surveys (due to differences in methodology and survey effort), we note that this assessment has detected gharials in only 2 out of 8 locations where gharials have been recorded recently (Sharma et al. 2011, MPFD 2013). While this may well be an artefact of the dry, low-flow season and/or detection biases, we speculate that fluvial action and /or disrupted flows due to the Bansagar Dam have changed the local morphology of sites like Kheraini ghat and Kherpur / Bichheri ghat which are now characterised by shallow runs (we could not locate any pools in the vicinity and adjacent sections) and thus not very optimal gharial habitats.

The Son Gharial Sanctuary represents that second longest riverine sanctuary in the country after the National Chambal Sanctuary, and based on our brief assessment, we believe that it has considerable conservation potential especially for the gharial, mugger, Indian skimmer and a range of fresh-water turtles. Earlier studies (Rao 1988, Sharma et al. 2011) have noted the suitability of the SGS for gharial, and sites like Jogdeh reaffirm that view. However, the rest of SGS does not enjoy the same level of attention and protection as Jogdeh and faces a multitude of threats and disturbances especially from fishing and sand-mining. We suggest the immediate augmentation of staff-strength and capacity to ensure effective patrolling and protection

Sand-mining in the SGS has been a long-standing problem (Vagholikar 2003) and there have been recent demands to de-notify a 31.25 km section of the Son River from the SGS for this purpose. Since sand-mining can severely jeopardise the conservation objectives of the SGS, we strongly recommend that such proposals be rejected. Sand-mining will not only compromise the integrity and lateral connectivity of this river sanctuary, but is capable of altering channel geometry, leading to channel scouring, erosion and head-cutting; undermining bridge piers and other structures; increasing sedimentation and turbidity; and significantly degrading wildlife habitat and threatening aquatic biodiversity (Meador & Layher 1998, Ashraf et al. 2011). Sand-mining also destroys critical nesting habitat for gharials, fresh-water turtles and ground-nesting birds like the Indian skimmer.

Observations of foam near Jogdeh, Munnadah and Kutlideh may be indicative of sewage and/or effluent discharge in the Son River and this needs further investigation. We suggest the establishment and maintenance of ecological-flows from the Bansagar Dam, and that changes and developments in the catchments of the Banas and Gopad rivers which flow into the SGS are monitored.

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Monitoring of Gharial (*Gavialis gangeticus)* and its habitat in the National Chambal Sanctuary, India

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Abstract

Today, commercial hunting is not the prime factor for the dwindling population of the gharial, but a variety of factors including incidental killing, destruction of habitats by agricultural practices and sand mining, egg collection etc. So, it is necessary to protect such areas where the Gharials nest regularly. From March-April there is a nesting season of the Gharial in the Chambal and it will be very easy to monitor the nesting areas and various threats to the nests of Gharials. A study has been carried out in the National Chambal Sanctuary in a 400 km stretch of the Chambal River borders Rajasthan Madhya Pradesh and Uttar Pradesh. The Chambal River was classified into five habitat types depending on the nature of the bank and the river depth during hot season. The overall topography of the Chambal River indicated that most of the south Chambal River has rocky beds compared to north Chambal River, where extensive sand banks are present. Distribution of gharial is habitat specific. The species prefer sand banks of varied nature like flat peninsulas, mid-river islands for basking and high sand banks for nesting. Information has been collected on gharial population over a period of 25 years. There is a fluctuating population size of gharial in these years. The distribution of gharials showed congregation in particular water depths during various months. During the month of November the River had a very high flow and the lateral connectivity is good. Thus gharials were widely distributed and showed affinity towards the depths of 3-7m and above 9m. Almost 40.6% and 22.2% of the gharials were found in these depth categories. Approximately 85 gharial nests were found during 2012 increasing double the number of 1998. Sighting of hatchlings after around one month of hatching is found to be very rare. When the river is under flood it was not possible to see the hatchlings, which are visible only after the flood recedes in the month of September every year. In the study stretch fishing is a major problem in addition to sand mining at some points and agriculture on the river banks. These human activities have direct and indirect impact on the gharial and its habitat. Due to sand mining activities near gharial nesting sites, the gharials have shifted their nesting activities to other areas. In the National Chambal Sanctuary more than 100 gharials have been found dead during December 2007 February 2008. These causalities occurred downstream between Barhi (Madhya Pradesh/Uttar Pradesh) and Chakranagar (Uttar Pradesh) and the length of the affected river stretch is around 35 km. Water samples from different sites were collected and analysed. It is found that the Chambal River water is pollution free in all sampling sites

Introduction

The Ganges river system in North India includes in its fauna two species of crocodiles - the Indian Gharial *Gavialis gangeticus* and the marsh crocodile *Crocodylus palustris*. The populations of gharial in India were driven to very low levels relative to their earlier abundance. The gharial has been illegally hunted throughout its range for hides, meat and medicine. In addition the loss of habitat from alteration and human settlement, and the use of nylon nets for fishing may have been significant in regulating some local populations (Sitaram and Rao 2012). By the end of 1960's the gharial population was dwindled to less than 150 animals. Information on the status and distribution of Gharial has been reported through many scientific surveys. In the Chambal River Government Organizations have actively participated to develop conservation programmes to protect Gharial from extinction. Under the *Grow and Release Programme* wild gharial eggs are being collected for artificial hatching in different rehabilitation centres. Recovery of gharial population has undoubtedly taken place since protection (Rao, 2008). The gharial rehabilitation programme has been most successful in the Chambal River where approximately 33 per cent of the animals up to age 5 were recorded to have survived within the protected National Chambal Sanctuary. The most significant reason for the higher success rate of the rehabilitation programme for the Chambal river population would; however appear to be the extensive protected river length available to the released gharials. The present study carried out in National Chambal Sanctuary is useful to understand the present status of gharial, major environmental impacts on their habitats, socioeconomic status and biological value of natural resources in the National Chambal Sanctuary.

Methodology

Study Area

The present study has been carried out in National Chambal Sanctuary, Entire area was divided into several zones and stretches for convenience of field surveys (Fig. 1). The studies were conducted while camping at the Crocodile Rearing Centre, Deori, Morena District, Madhya Pradesh and by conducting field studies in the Chambal River.

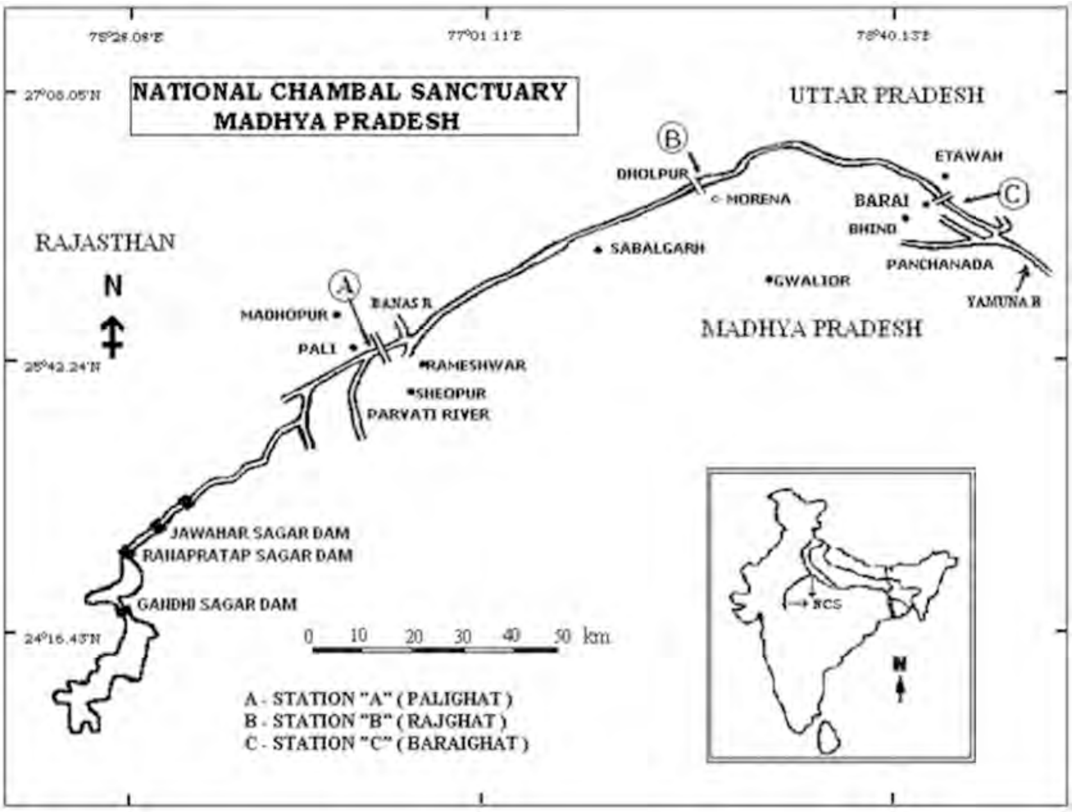

Figure 1. Map of National Chambal Sanctuary

Species location

Data was collected on the occurrence of gharial in the National Chambal Sanctuary. Different maps of the study areas environmental characteristics such as physical, social, ecological, aesthetic etc. were prepared. These maps were overlaid to produce a composite characterisation of the habitat conditions.

Gharial population monitoring

Every year the authorities of the National Chambal Sanctuary, M.P. conduct wildlife census including the gharial nest monitoring in the Sanctuary. The present study was carried along with the census operation of the field staff. Staff and volunteers are supplied with a kit bag containing binoculars, data sheets, field maps of different sections of the river, pen, pencils and writing pads. In addition instruments like thermometer to record ambient and water temperatures, GPS to record the geographical coordinates of habitat features and also to record the location of animals, cameras to take photographs of animals and human activities in the gharial habitats.

We collected information on sightings of crocodiles (both gharial and mugger), turtles (hard shell and soft shell), dolphins, otters and migratory birds with the help of binoculars. We spot gharial, muggers and turtles, mostly as they basked on land or were swimming and dolphins as they surfaced for breathing. Animals seen were recorded along with sighting time, GPS locations and nearest village name etc. on data-map sheets. Surveys were discontinued during overcast and rainy days. At few river sections, in which the survey was interrupted or rendered ineffective due to bad weather or any other reason, were resurveyed and the best count of animals recorded in these sections were used for estimating populations. The survey team also collected additional information on human activities including illegal sand mining, fishing, water extraction and agriculture. All information collected during survey has been recorded on the field map sheets. At the end of the census period reports have been collated for final analysis.

The census continued from 8 am to till 5 pm on all days in the 11 zones of the Chambal River within the National Chambal Sanctuary. During the census gharial and other animals were searched not only on the MP side of the river but also on the opposite side of the river bank on Rajasthan and UP side of the rive bank.

The river stretch, to be surveyed, was delineated on the map for each day. Modern data recorder like GPS was used in the census. The researchers in the teams were well trained on GPS recording at the training period. The longitude and latitude of gharial location, the starting and end point of the surveyed stretch were recorded on GPS. The starting point of each survey stretch was marked and coded using GPS. Subsequently the river stretch was surveyed at a low speed only observing the basking gharial. The end of each survey stretch was again marked and coded using GPS. Information like basking time, ambient and water temperature, river depth, habitat type, presence of other wildlife etc were also recorded on the census card.

Preliminary data entry was done in MS Excel by developing a format following the parameters stated above. Then, normal validation was done using print out data sheets with those of field data sheets. Raw data was downloaded from the GPS receiver to computer using Map Source Software. This raw data was not in a workable format. So the raw data was converted to a workable format like excel format. GPS was used to mark and store coordinates of the locations of gharial and other wildlife from the field.

Gharial population was also monitored every month at different areas identified as best habitats earlier. Gharials of different sizes were recorded with the help of binoculars while walking along the river and also by moving in the boats. The survey was conducted along the river bank approximately 10km distance was covered during the daily survey. The distance of 20 km was covered by vehicle or by foot according to the convenience. We observed main habitat constantly 3-4 hours .GPS location, various other activities on the gharial habitat was noted on the field data sheet. Photographs were taken by using 300 zoom lens cameras where ever possible. Data on threats to gharial and problems to its habitat in the Chambal River was collected. Data on impact of human activities on gharial in the Sanctuary was also collected.

Results and Discussion

Species diversity

The crocodile species present in the National Chambal Sanctuary are the Gharial (*Gavialis gangeticus*), and the Mugger (*Crocodylus palustris*) (Fig. 2).

Figure 2. Sympatric species of gharial and mugger basking on a rocky island

Gharial habitats

The habitat of gharial in the Chambal River is characterized by expanses of open sand which is sparsely covered with a variety of herbs, the most common in the open sand being *Tamarix* dioca (Fig. 3). The overall topography of the Chambal River indicated that most of the south Chambal River has rocky beds compared to north Chambal River, where extensive sand banks are present. Distribution of gharial is habitat specific. The species prefer sand banks of varied nature like flat peninsulas, mid-river islands for basking and high sand banks for nesting. The hydrology of Chambal River indicates that the river is a fast flowing and deep water pools at certain stretches are most suitable for gharial (Table 1). Important sand banks in the study area are mapped in the field maps.

Figure 3. Crocodile habitats in the Chambal River.

Table 1. Maximum and Minimum flows in Chambal River

S.No.	Year Maximum	Date	Level	Discharge (Cusecs)	Year Minimum	Date	Level	Discharge (Cusecs)
1.	1976	10.9.76	140.18	13670.84	1976	2.6.76	118.58	48.98
2.	1977	19.9.77	141.55	45200	1977	10.5.77	118.81	104.04
3.	1978	2.9.78	139.90	25683.53	1978	11.6.78	118.78	84.96
4.	1979	16.7.79	129.18	6160.00	1979	7.6.79	119.55	50.95
5.	1980	7.8.80	135.45	18224.29	1980	5.5.80	119.16	35.35
6.	1981	21.7.81	134.80	19707.00	1981	20.6.81	119.04	30.02
7.	1982	25.8.82	145.37	58552.96	1982	5.3.82	118.96	82.65
8.	1983	22.8.83	130.02	7247.36	1983	4.5.83	119.12	94.38
9.	1984	21.8.84	136.20	20979.00	1984	16.5.84	119.13	72.80
10.	1985	11.8.85	136.15	19950.00	1985	29.4.85	119.09	41.23
11.	1986	29.7.86	141.60	37600.00	1986	31.5.86	119.02	32.43
12.	1987	2.9.87	133.34	16085.34	1987	25.5.87	119.74	68.73
13.	1988	7.8.88	131.75	7717.94	1988	14.6.88	119.52	65.03
14.	1989	29.8.89	127.27	7882.14	1989	17.5.89	119.23	37.70
15.	1990	5.7.90	128.45	9439.82	1990	6.6.90	119.12	57.63
16.	1991	26.8.91	139.66	20079.63	1991	3.6.91	119.41	58.26
17.	1992	19.8.92	131.50	8737.84	1992	4.6.92	120.02	59.56
18.	1993	7.8.93	132.15	9056.73	1993	8.6.93	119.85	20.92
19.	1994	9.9.94	130.08	10320	1994	18.5.94	120.11	63.00
20.	1995	5.9.95	134.22	17205	1995	2.6.95	119.30	32.26
21.	1996	22.8.96	145.54	NA	1996	15.4.96	120.30	94.00
22.	1997	9.8.97	133.66	9785.99	1997	16.5.97	120.30	82.17
23.	1998	16.7.98	129.60	6817.70	1998	15.4.98	120.30	94.00
24.	1999	26.7.99	134.71	16031.04	1999	3.6.99	119.95	57.91
25.	2000	21.7.2000	132.55	12990.77	2000	19.5.2000	119.71	48.74
26.	2001	4.7.2001	135.01	15939.00	2001	16.5.2001	119.50	29.00
27.	2002	11.7.2002	131.22	19313.31	2002	12.5.2002	121.00	32.11
28.	2003	16.7.2003	130.11	17121.11	2003	17.5.2003	118.22	43.11
29.	2004	7.8.2004	132.13	12333.11	2004	13.6.2004	123.11	41.21
30.	2005	9.7.2005	130.15	13221.41	2005	3.06.2005	119.42	45.34
31.	2006	4.09.2006	132.34	14144.61	2006	4.05.2006	135.11	34.41

Source Central Water commission, Dholpur, Rajasthan

Gharial population

Gharial population was monitored during the study period from June 2007 to May 2008 (Table 2). During the 2007 and 2008 annual census of fauna, different sizes of gharial were observed by visual analysis. Sighting of gharial during monsoon season is very difficult. The field conditions are not suitable for movement on the land as well in the high flood waters. The water in Chambal is muddy and sighting of gharial is rare. Due to high floods all basking sites of gharial are submerged and there are no suitable basing sites for gharial. Gharials are sighted rarely floating in the flood water of the river. Sightings of gharial of all sizes during the flood water is not possible due to non availability of basking sites, muddy waters, inaccessibility to river due to bad field conditions and boating is not possible due to high currents.

Table 2. Population estimation of Gharial in NCS between 1978 -2008+

S. No.	Year	Gharial Population estimation (as per sightings)
1.	1978	107
2.	1979	*
3.	1980-83	*
4.	1984	451
5.	1985	605
6.	1986	628
7.	1987	-
8.	1988	820
9.	1989	-
10.	1990	982
11.	1991	-
12.	1992	-
13.	1993	898
14.	1994	1108
15.	1995	1214
16.	1996	1242
17.	1997	1289
18.	1998-2002	**
19.	2003	540
20.	2004	552
21.	2005	584
22.	2006	772
23.	2007	865
24.	2008	996

* No data available | ** No surveys | + Certain years data was obtained from Madhya Pradesh Forest Department

Monitoring of gharial population in different stretches is an indication of almost stable population after the monsoon floods in the Chambal River. The situation of gharial was normally same at these localities till next year's floods. The numbers of gharial hatchlings are significantly low in this stretch. As per the nesting data, with an average clutch size of 38 eggs for nest, it is estimated that more than 3000 gharial hatchlings were born during the hatching time ie. June (Fig. 4). However, during the monthly surveys very few hatchlings were sighted. It seems most of the hatchlings were dead during the monsoon floods.

Data on gharial population in different 5 km stretches from Pali to Rajghat during 1988 and 2013 is given in table 2-4. The data shows that the sub adult and female population was increased, but juvenile population was decreased. The young gharials were wondering type and they move downstream until they settle at a suitable place. Population trend of gharial of various sizes during 1998-2008 in the entire sanctuary is shown in table 2. The trend shows that gharial population was increased during 1994 -1997 but the population was again decreased by the year 2003. There were no population estimates during 1998 2002. It is not clear how the population was drastically decreased in the year 2003 to only 540 animals. The large number of gharial during 1995-1997 may be the addition of any released gharial in these years. Due to non availability of data on size classes of gharial in these years, the data could not be analysed systematically.

Figure 4. Gharial nesting, hatching, hatchlings and captive rearing at rehabilitation centre

Impact of Human activities

Threats to the fauna of Chambal River including Gharial recorded during the study period were fishing, cultivation, ferry services and sand mining (Fig. 5). In the study stretch fishing is a major problem in addition to sand mining at some points and agriculture on the river banks. There are more than 150 families of fishermen at Shaympur and Birpur in Sheopur District. The fishermen catch fish illegally and sell them at local as well as fish market at Sabalgadh, Morena District. Although large scale sand mining is not reported this activity of sand mining is also a major problem for habitat destruction. These human activities have direct and indirect impact on the gharial and its habitat. Due to sand mining activities near gharial nesting sites, the gharial have shifted their nesting activities to other areas. Due to this number of gharial nesting sites during 2008 were less than 2007 and new sites were not identified, inspite of vigorous searches to locate new nesting sites. Vegetable cultivation on the gharial nesting sites observed at Bagdia Sand, Baroli and Nadigaon has also shown considerable impact on the nesting of gharial during 2008.

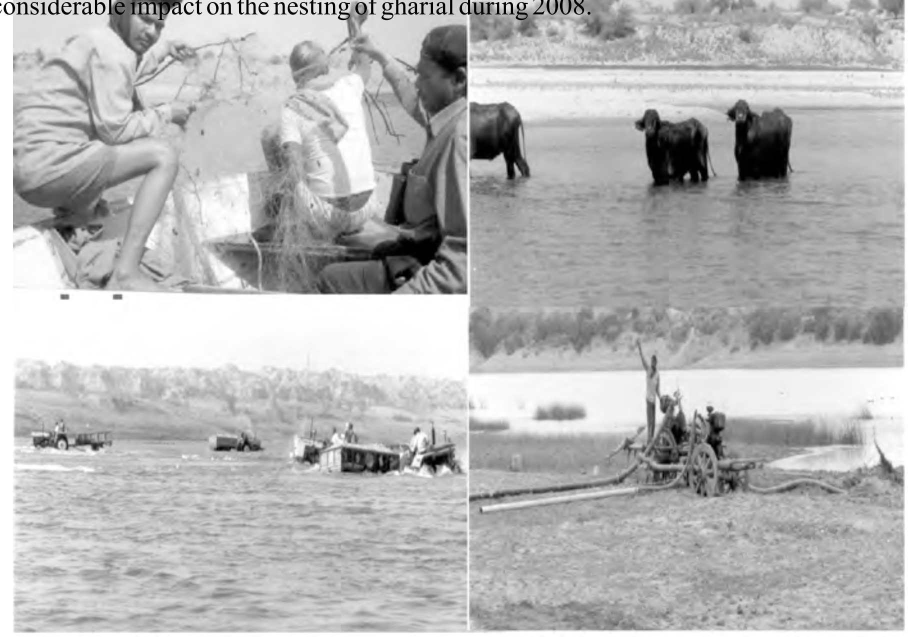

Table 3. Gharial Population from 2009-2013

Year	River stretch	Male with *Ghara*	Adults*	Sub-adults	Juvenile	Yearlings	Hatchlings	Total
2009	Pali to Pachnada	26	281	155	210	126	136	934
2010	Pali to Pachnada	30	297	130	191	113	109	870
2011	Pali to Bharreh	36	349	127	170	125	102	909
2012	Pali to Chakarnagar	32	322	147	275	79	50	905
2013	Pali to Chakarnagar	36	393	153	216	82	68	948

* Female/ Male without *ghara*

Table 4. Distribution and size class of Gharial observed during 2013

Area Covered	Approx. Dist. (kms)	Adults		Sub Adults (2-2.8m)	Juvenile (0.9-2m)	Yearlings (0.62-0.9m)	Hatchlings (0.3-0.6m)	Total of zone
		Male with ghara (>3.5m)	Male/ Female (>2.8m)					
Pali-Rameshwar	22	01	08	03	04	02	01	**19**
Rameshwar-Baroli	36	02	09	02	02	01	-	**16**
Baroli-Atar	51	03	31	10	12	04	05	**65**
Atar-Sarseni	64	04	17	05	01	-	02	**29**
Sarseni-Rajghat	30	02	14	13	10	11	12	**62**
Rajghat-Babusinghgher	36	02	26	09	16	10	05	**68**
Babusinghgher-Usedghat	40	05	58	24	20	14	08	**129**
Usedghat-Ater	40	06	102	29	31	15	11	**194**
Ater-Barhi	41	05	60	32	54	09	10	**170**
Barhi-Chakarnagar	35	06	68	26	66	16	14	**196**
TOTAL	**395**	**36**	**393**	**153**	**216**	**82**	**68**	**948**

Figure 5. Different threats to gharial like fishing, sand mining, cattle washing and water extraction in the Chambal River

Acknowledgements

We are thankful to Madhya Pradesh Forest Department for permission to conduct research activities in the National Chambal Sanctuary. We are also thankful to the Administration of Jiwaji University, Gwalior for necessary support. Different funding agencies like UGC, MOEF and GCA supported the research. We are extremely thankful to the field staff in the Sanctuary particularly Dr. R.K. Sharma and Mr. Sukhdev for local support in the field and also sharing information on gharial population.

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Status and population trends of gharial in Chambal River, National Chambal Sanctuary

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Abstract

Gharial, a critically endangered species has its last stronghold in Chambal River, National Chambal Sanctuary. The population trend of this animal has been assessed during the years 2003 to 2013. The surveys had been conducted within Pali to Pachnada. The total population has increased from 514 to 948 individuals with major increment in adult, sub-adult and juvenile populations. The density of the total population from 2003 to 2013 has increased by 84.4%. The density of adults, sub-adults and Juveniles; and yearlings and hatchlings were increased by 186.0%, 39.2% and 51.5%, respectively. Though population of gharial increased from 2003 to 2013, the populations between the years were very fluctuating and have not shown any trend. There will always be need to continuously monitor and control all the illegal activities in the Sanctuary area to safeguard this species.

Introduction

Crocodilians in present world are represented by order Crocodylia, within class Reptilia. The order includes only 23 living species. Gharial (*Gavialis gangeticus*) is the only surviving member of the family Gavialidae (Janke et al., 2005). Specialized habitat requirements and feeding habit make this animal vulnerable to any changes in the environmental conditions. Once widely distributed, gharial is now extinct in its former range of Pakistan, Bhutan, and Myanmar, and most likely in Bangladesh (Aufray, 2010). A few nests were recorded in Nepal. The largest remaining populations found in India at the four locations along the Son River, Katerniaghat, Girwa and Chambal River (Choudhury et al., 2007). The Chambal River, the last stronghold of 429 breeding adult gharials, is also under tremendous anthropogenic pressure (MPFD, 2013).

The Chambal River is one of the last surviving rivers in the greater Ganges River system that has significant conservation value in terms of biodiversity as it harbors the largest population of the Gharial (*Gavialis gangeticus*), in the world. Extensive studies have been done in the past at Chambal River for status, population trends, distribution, habitat, ecology, behavior (Sharma et. al., 2013; Hussain, 2009; Sharma 2006; Sharma and Basu, 2004; Sharma 2000; Hussain, 1999; Rao, 1999; Sharma 1999; Sharma et al., 1995; Rao and Singh, 1993; Sharma, 1993; Hussain, 1991; Rao, 1987; Rao and Sharma, 1986a, b; Rao, 1986; Sharma, 1985; Bustard, 1982; Bustard and Choudhury, 1982) and radio tracking of Gharial (Singh, 1985). As the River is being exploited for its natural resources like water, sand and fish; the gharials, by the mid-1970's was on the verge of extinction due to loss of habitat, mortality in fishing nets (Hussain, 1999; Whitaker, 1987) and poaching (Whitaker and Basu, 1983; Bustard, 1979). These anthropogenic threats have increased and continue to negotiate the survival of the species at present time.

Study Area

The National Chambal Sanctuary (N 25° 24' 33" E 76° 36' 20" to N 26° 33' 57" E 79° 00' 45") was created on the River Chambal during early 1979 primarily for the conservation management of gharial by the states of Madhya Pradesh, Uttar Pradesh and Rajasthan. The Sanctuary includes a stretch from Jawahar Sagar Dam to Kota barrage, then after a free zone of about 18 km, the Sanctuary again begins from Keshoraipatan and extends to Pachhnada where Kuwari Pahuj and Sindh rivers form a confluence with river Yamuna. The length of the Sanctuary from Keshoraipatan to Pachhnada is 572 km that includes about 15 km of Yamuna after Chambal-Yamuna confluence. The width of the river that is included inside the Sanctuary is 1000 m from either bank.

The upper Chambal basin is marked by hilly terrain belonging to the Vindhyan chain; the alluvial plains have developed into extensive ravines, which are often 10-15 km wide from either banks of the river. The area is semi-arid. The temperature in the region varies from 20°C to 48°C during winter and summer respectively. The southwest monsoon is the major source of rainfall. The mean annual rainfall over the Chambal basin was computed as 797 mm, of which about 93% falls during the four monsoon months (Hussain, 1993).

Methodology

Surveys were conducted in the stretch from Pali (25.85° N, 76. 57° E) to Pachnada (26.44° N, 79.21° E), the confluence with River Yamuna, Kunwari, Pahuj and Sindh; in the month of February during 2003 to 2013. The spatio-temporal distribution of gharials were determined by Visual Encounter Survey (VES) method (Crump and Scott, 1994) to gathered data on direct sightings of the species was used while traversing through boat in the mid-stream of the river. Survey started daily on 09:00 hrs till 17:00 hrs. The survey was conducted using motor boat and with the help of GPS device (GARMIN 12), Binoculars (12X50), Data Sheet, Field Map, Camera and Range Finder (BUSHNEL X900). The survey is generally conducted according to the weather condition prevailing at the designated time. Sunny conditions are preferred more than cloudy or foggy conditions. Thus, survey, sometimes may got postponed according to the weather condition.

The sightings of gharials were noted by two individual observers and were added to get data from either side of the river. The age and sex classes were determined according to Singh and Bustard (1982). Individuals >2.8m were considered as Adults, 2-2.8m as Sub-adults, 90cm-2m as Juveniles, 60-90 cm as Yearlings and 30-60 cm as Hatchlings. Adult males are recognized by the bulging structure (*Ghara*) above their snout.

Results & Discussions

The surveys during 2003 to 2006 were conducted within Pali to Chakarnager (26.55° N, 79.09° E). The total population during 2003 was 514 individuals with 150 adults; 265 sub-adults and Juveniles and 99 yearlings and hatchlings. During 2004 the total population increased slightly with increase in all the size classes. There were 158 adults, 276 sub-adults and Juveniles and 118 yearlings and hatchlings. During 2005 there were 169 adults, 280 sub-adults and Juveniles and 135 yearlings and hatchlings. In the year 2006 major increase in yearlings and hatchlings were observed. The total population was 772 with 178 adults, 272 sub-adults and Juveniles and 322 yearlings and hatchlings. From the year 2007 to 2010 the survey was conducted within Pali to Pachnada. During 2007, significant increase in gharial population, especially in adults, sub-adults and juveniles were observed. Total population was 865 with 208 adults, 445 sub-adults and Juveniles and 212 yearlings and hatchlings. In the year 2008, the adult population increased significantly. There were a total of 996 individuals with 326 adults, 398 sub-adults and Juveniles and 272 yearlings and hatchlings.

Population declined during 2009 with 934 animals. There were 307 adults, 365 sub-adults and Juveniles and 262 yearlings and hatchlings. During 2010, the adult population increased significantly, though total population decreased. The total population was 870 with 327 adults, 321 sub-adults and Juveniles and 222 yearlings and hatchlings. During 2011 the survey was conducted from Pali to Bhareh (26.49° N, 79.25° E). A rapid increase in the total population was observed during this period. The total population was 928 animals with 385 adults, 316 sub-adults and Juveniles and 227 yearlings and hatchlings. During the years 2012 and 2013 the survey was conducted between Pali to Chakarnagar. In the year 2012, the total population was 905 with 354 adults, 422 sub-adults and Juveniles and 129 yearlings and hatchlings. The adult population has declined though increase in the Sub-adults and juveniles provide for addition of more adults in coming years. The scenario observed during 2013 as the adult population increased to 429 animals with an increase in the total population, which was 948. There were 369 sub-adults and Juveniles and 150 yearlings and hatchlings. The population density of individual size classes and total population are presented in Table 1 and figures 1 and 2.

During 2012 and 2013, the survey was restricted to Chakarnagar as no major gharial population is observed in the stretch of Chakarnagar to Pachnada. The density of the total population from 2003 to 2013 has increased by 84.4%. The density of adults, sub-adults and Juveniles; and yearlings and hatchlings were increased by 186.0%, 39.2% and 51.5%, respectively.

Though population of gharial increased from 2003 to 2013, the populations between the years were very fluctuating and have not shown any trend. The fluctuations may be correlated with increasing anthropogenic pressure in terms of fishing, sand mining, agriculture and low water availability. There will always be need to continuously monitor and control all the illegal activities in the Sanctuary area to safeguard this species.

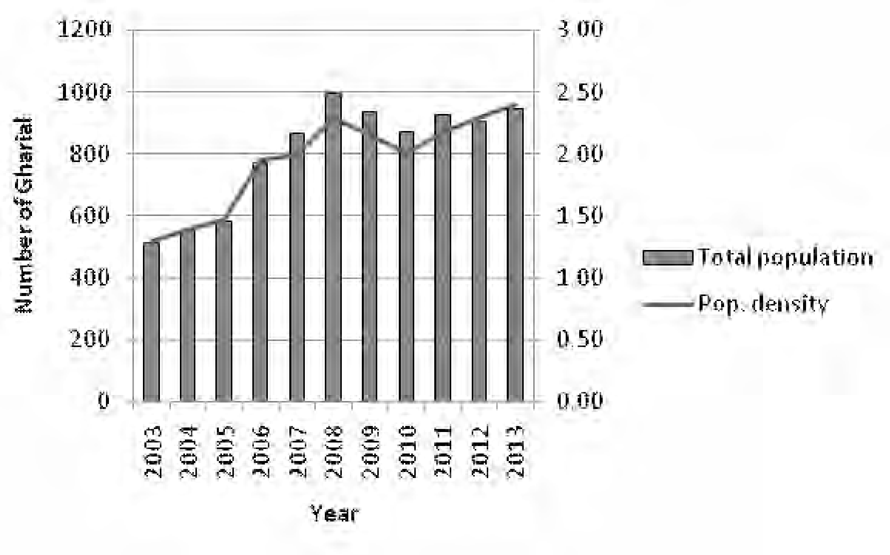

Figure 1.Total population and density of gharial during 2003 - 2013.

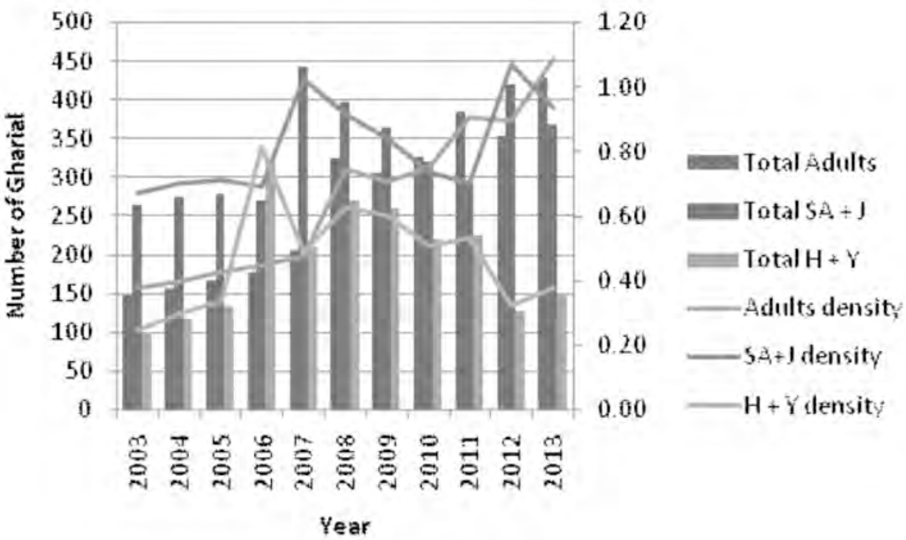

Figure 2.Population and density of individual size classes of gharial during 2003 - 2013.

Table 1. Survey years, area and density of gharial population during 2003 - 2013

Year	Section of river	Length of river	Adults density	Sub-adult+Juvenile density	Yearling+Hatchling density	Total Population density
2003	Pali- Chakarnagar	395	0.38	0.67	0.25	1.30
2004	Pali- Chakarnagar	395	0.40	0.70	0.30	1.40
2005	Pali- Chakarnagar	395	0.43	0.71	0.34	1.48
2006	Pali-Chakarnagar	395	0.45	0.69	0.82	1.95
2007	Pali-Pachnada	435	0.48	1.02	0.49	1.99
2008	Pali-Pachnada	435	0.75	0.91	0.63	2.29
2009	Pali-Pachnada	435	0.71	0.84	0.60	2.15
2010	Pali-Pachnada	435	0.75	0.74	0.51	2.00
2011	Pali-Bharreh	425	0.91	0.70	0.53	2.18
2012	Pali- Chakarnagar	395	0.90	1.07	0.33	2.29
2013	Pali- Chakarnagar	395	1.09	0.93	0.38	2.40

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Conserving the Critically Endangered Gharial *Gavialis gangeticus* in Hastinapur Wildlife Sanctuary, Uttar Pradesh: Promoting better coexistence for conservation

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Abstract

Gharial *Gavialis gangeticus* is perhaps the largest living crocodilian; is the most unique in its morphology, but sadly over the last decade has become Critically Endangered. Gharial was first recognized as an endangered species in the 1970s. Populations rebounded in the 1980s and 1990s as a result of large-scale captive rearing and head-starting programs in protected areas of India and Nepal. However, in 2008, mass death of 111 Gharial in National Chambal Sanctuary demonstrated the extreme vulnerability of the species to extinction. In order to address the conservation needs of this species, it was necessary to locate viable alternative habitats to supplement the extremely few habitats where the species currently occurs. Between 2009-2012, WWF-India in collaboration with the Uttar Pradesh Forest Department has released 494 Gharial in the River Ganga in Hastinapur Wildlife Sanctuary. Ongoing monthly surveys to document habitat use and dispersal pattern have revealed of almost 40% survival of these animals. Alongside the research, the programme integrates work with local community groups to help understand in building a striking harmonious synergy between cause of conservation and the aspiration of locals. This will help in ending unsustainable dependency on natural freshwater resources ensuring a sense of ownership and desire for stewardship towards biodiversity conservation and river health in particular.

Key words: *Gharial, re-introduction programme, River Ganga, Ecology, Conservation.*

Introduction

The Gharial is a Critically Endangered crocodilian (IUCN 2007) with fewer than 200 breeding adults estimated to survive in the wild, about half of them in one protected area: the National Chambal Sanctuary, in the states Uttar Pradesh, Rajasthan and Madhya Pradesh, India (GCA 2009). Between December 2007 and March 2008, deaths of 111 Gharial were recorded, mostly from a 40-km long segment of the river, extending from Barahi of district Bhind, Madhya Pradesh, to Udi (downstream Sahson) in district Etawah, Uttar Pradesh. Preliminary veterinary findings point out to toxicants as the cause of deaths; however, their nature, composition, source and pathway to the affected Gharial are not clear. However, these incidents demonstrated the extreme vulnerability of the species to extinction and in order to address the conservation needs of the species, it was necessary to locate viable alternative habitats to supplement the extremely few habitats where the species currently occurs. In December 2008 WWF-India in collaboration with the Uttar Pradesh Forest Department conducted exhaustive evaluation of habitat viability for the re-introduction of Gharial in the River Ganga within the Hastinapur Wildlife Sanctuary limits, following the IUCN re-introduction protocols. *Mukhdumpur village* (26°08'84.2"N Lat. and 78°04'70.0"E Long.) was found to be the most suitable site. Between February 2009 - February 2012; 419 Gharial have been released and field monitoring is continuing. Alongside the research, the study integrates work with riparian communities to help understand in building a striking harmonious synergy between cause of conservation and the aspiration of locals. This will help in ending unsustainable dependency on natural freshwater resources ensuring a sense of ownership and desire for stewardship towards species conservation and river health in particular.

Study area

Hastinapur Wildlife Sanctuary (28°46′ and 29°35′N Latitude and 77°43′ and 78°30′E Longitude) was established in 1986 in the Indo-Gangetic plains (Fig. 1). The Sanctuary encompasses an area of 2073 km^2 representing about 0.2% of the total geographical area of the Gangetic grasslands. The area of the Sanctuary mainly falls under five districts of Uttar Pradesh namely Muzzaffarnagar, Bijnor, Meerut, Ghaziabad and Jyotibafuley Nagar (Noida). Altitude of the area ranges between 130 and 150m above sea level. Three distinct seasons are recorded; winter from October to mid March, followed by summer from mid March to mid June and monsoon starts in mid June and continues till September. May and June are the hottest months when the temperature reaches about 45°C; December and January are coldest and the temperature can fall near to 0°C. The annual precipitation is about 1200mm. The vegetation of the Sanctuary can be classified into three main types - tall wet grasslands in low-lying areas that remain inundated for most parts of the year; the short wet grasslands remain dry from mid winter to the onset of the monsoon, and the dry scrub grasslands on raised grounds amidst the Ganga and on highland, also known as 'Khola' (Nawab 2000). A diverse fauna exists in the Sanctuary which makes this area a biodiversity hotspot in the Gangetic plains.

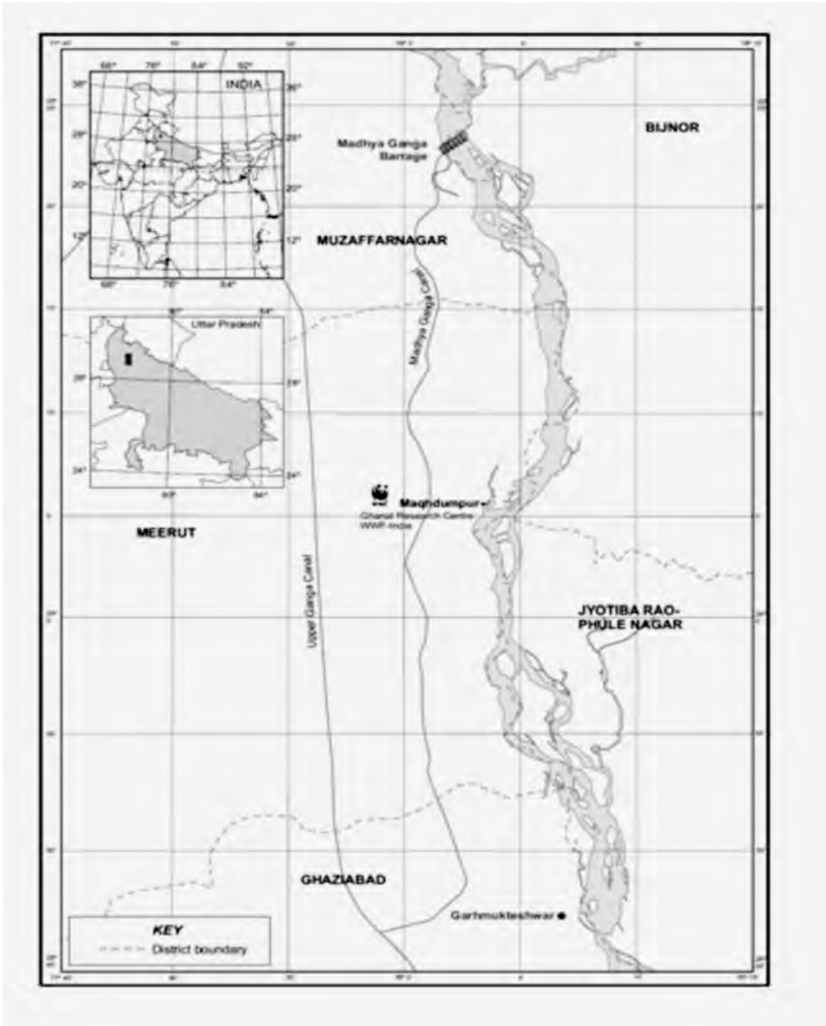

Figure 1. Map of the study area.

Methodology

Pre release survey

Protocols as outlined by Rao (1998) in the Re-introduction Specialist Group of IUCN's Species Survival Commission were followed to assess habitat viability for Gharial re-introduction in Hastinapur Wildlife Sanctuary. Intensive monitoring was conducted between 26 and 28 December 2008 along a 173 km stretch (*i.e.* from Shukhartal to Garhmukteshwar) of River Ganga within the limits of the Sanctuary. The entire stretch was surveyed by boat and distance measurements were guided by a 1:100.000 map (Topo Sheet Survey of India) and GPS. On identification of suitable habitat, data on Physical parameters, Chemical parameters and Disturbance parameters were collected.

Post release survey

Surveys were conducted from upstream to downstream covering approx. 100 km stretch (*i.e.* from Madhya Ganga Barrage to Garhmukteshwar) of River Ganga. Distance measurements were guided by a 1:100.000 map (Topo sheet survey of India) and GPS. For winter survey were conducted from 0900 to 1500 and summer survey were conducted from 0800 to 1200 and 1500 to 1730. *Ad-libitum* records were maintained during monsoon. Gharials were counted from a motor boat driven by a 25 HP Mercury engine. The motor boat moved at 710 kmh^{-1} down mid-river. Usually, two observers were stationed at the front seat of the motor boat, each searching for Gharial on either bank with 8_40mm prismatic binoculars. Ecological parameters and human activities affecting occurrence of Gharial were recorded.

Results and Discussion

Gharial release site selection

The total extent of favorable habitat recorded during the assessment of viable habitat for Gharial re-introduction was 6 km; from *Mukhdumpur village* (26°08'84.2"N and 78°04'70.0"E) till *Jalalpur Zohra village* (29°03'39.9"N and 78°04'25.4"E). A maximum of 3 sandy Islands (sand banks) free from anthropogenic pressure were recorded. Other optimum features included shallow water and deep pools, abundant prey base, moderate water current, large river width and presence of shelter in the form of shoreline vegetation. Water quality recorded was also favorable.

Gharial release, sighting frequency and relative abundance

Till February 2012, a total of 419 captive-reared Gharial have been released (Table 1). This constitutes 300 females which were 1.9 3.8 years, their total length ranged from 96 cm 167 cm and body weight ranged from 2.0 kg 12.0 kg. Males were 119 in number and were 1.9 3.8 years, their total length ranged from 120 cm 180 cm and body weight ranged from 2.0 kg 16.0 kg.

Table 1. Physical condition of captive-reared Gharial released in River Ganga at Hastinapur Wildlife Sanctuary, Uttar Pradesh.

Year	Female				Male			
	Total #	Age (Yr) (Mean±S.E)	Body Wt. (kg) (Mean±S.E)	T.B.L (cm) (Mean±S.E)	Total #	Age (Yr) (Mean±S.E)	Body Wt. (kg) (Mean±S.E)	T.B.L (cm) (Mean±S.E)
2009 N = 131	95	3.49±0.04 (2.8 – 3.8)	7.94±0.10 (6.5 – 12)	139.13±1.23 (120 – 167)	36	3.66±0.06 (2.8 – 3.8)	8.77±0.31 (6.5 – 16)	146.6±2.16 (127 – 180)
2010 N = 63	50	3.8±0.0	3.88±0.11 (2.5 – 5)	122.51±0.78 (96 – 133)	13	3.8±1.91	4.18±0.15 (3.4 – 5)	124.78±1.16 (120 – 131)
2011 N = 150	99	2.82±0.03 (1.9 – 2.9)	2.79±0.08 (2.0 – 7.5)	124.32±0.45 (120 -139)	51	2.70±0.06 (1.9 – 2.9)	2.90±0.15 (2 – 8)	124.67±0.67 (120 – 141)
2012 N = 75	56	3.51±0.06 (2.8 – 3.8)	6.28±0.13 (4.2 – 7.9)	134.55±1.07 (120 – 157)	19	3.54±0.10 (2.8 – 3.8)	6.16±0.18 (4.3 – 7.6)	133.47±1.57 (120 – 144)
419	**300**	**1.9 – 3.8**	**2.0 – 12.0**	**96 – 167**	**119**	**1.9 – 3.8**	**2.0 – 16.0**	**120 - 180**

During the course of the study overall sighting frequency of Gharial recorded was 1764 (range = 305 612). Mean sighting frequency was recorded maximum (152.5 ± 4.5) during 2012 which also relates to high encounter rate (1.5 Gharial sighted/km) (Fig. 2 & Fig. 3).

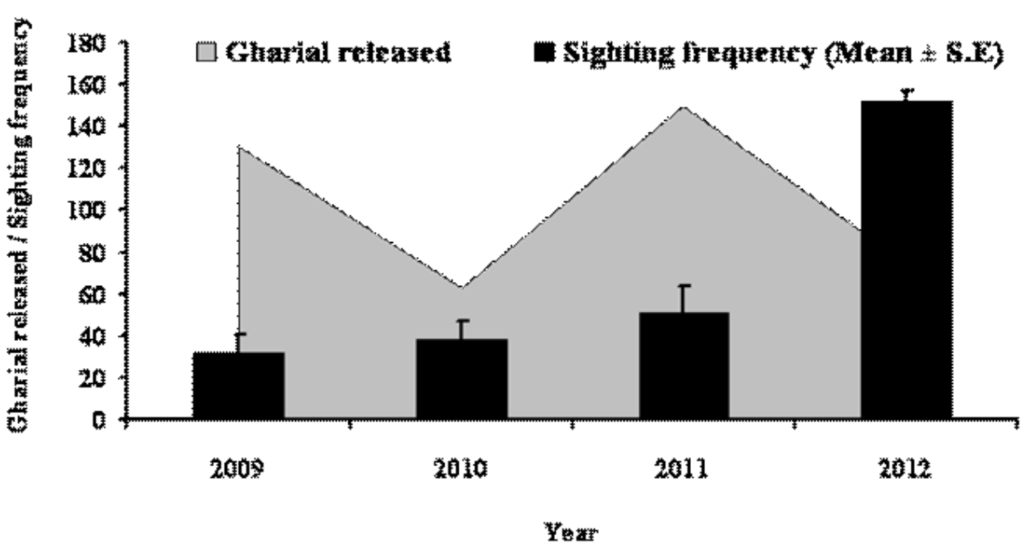

Figure 2. Sighting frequency of Gharial released in River Ganga during the course of the study.

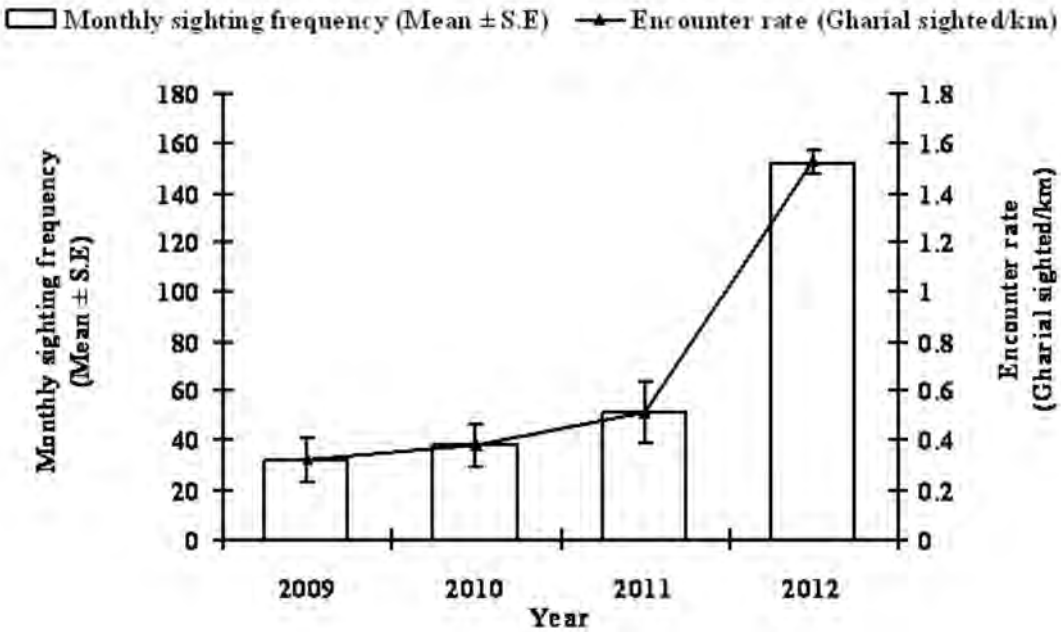

Figure 3. Encounter rate of Gharial (animal/ km) in River Ganga during the course of the study.

Biometrics of released Gharial

Between 17 December 2010 15 January 2011 biometric study was conducted. Physical (medical) examination was conducted and biometric changes of the re-captured animals were recorded. Of the 13 animals captured, 8 belonged to 2009 and 5 belonged to 2010 release respectively. The animals released in 2009 and recaptured in December 2010 showed a significant increase of 17.68kg body weight and an increase of 56cm in Total Body Length over a period of 1 year and 11 months. The animals released in January/February 2010 and recaptured in December 2010 showed increase of 10.40kg body weight and an increase of 40cm over a period of 11 months.

Threats and conservation prospects

In landscapes where natural habitats have been severely degraded through anthropogenic pressures, conservation of biodiversity is a growing issue, and the establishment of protected areas (PAs) often forms the cornerstone of conservation strategies. These PAs offer opportunities to examine the natural distribution pattern of species of conservation significance and their use of resources for planning effective restoration measures (Nawab & Hussain 2012). It is paramount to identify the nature of the threats to the species in question and is crucial in diagnosing the processes threatening the species as accurately and comprehensively as possible to ensure long term survival of the species. As detailed below, fishing, *palage* (riparian seasonal agriculture) and ferrying were recorded as major forms of disturbance to Gharial (Fig. 4) during the course of the study.

Fishing is prohibited within the Sanctuary; though it is rampant in some areas. It is more likely that Gharial can get entangled in fine mesh monofilament nets than traditional large mesh natural fiber nets. Entangled Gharial that do not drown are generally killed or have their rostrums chopped off to disentangle nets and perhaps, in retaliation for damaging nets. Gharial of all sizes are vulnerable to this threat; the impact on populations is particularly severe when mature adults are killed. Indirectly, fishing also affects Gharial by reducing fish stocks and changing prey size and species composition.

Palage or riparian seasonal agriculture

(melons, gourds, mustard and wheat) was recorded as the major form of disturbance to Gharial. This activity encroaches upon the basking and nesting sites and may also disrupt the behaviour of the animal and may even force local populations to desert the area. Disturbance and disruption of basking sites reduces habitat quality for the Gharial and may compromise their thermoregulatory behaviour, further affecting feeding, growth and reproduction. Ferrying may not directly affect the survival of the Gharial though it may indirectly contribute to the problem.

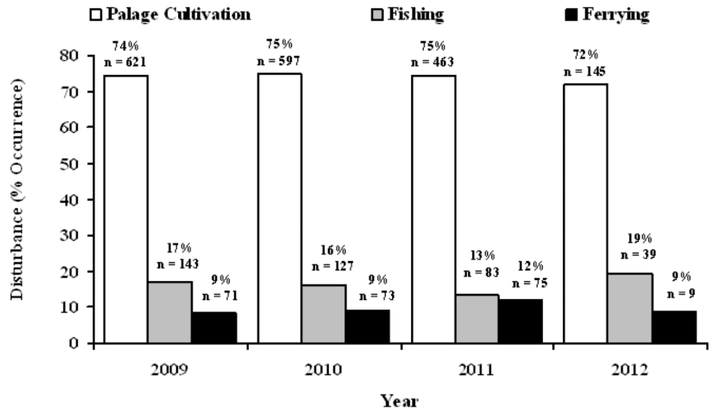

Figure 4. Disturbance activities recorded across different sampling sites in Hastinapur Wildlife Sanctuary, Uttar Pradesh.

The Uttar Pradesh Forest Department (UPFD) in 1991-92 had released a batch of 300 Gharial into River Ganga at Garhmukteshwar. However due to lack of monitoring no further records were maintained. Though the area is known to have been inhabited by wild Gharial until fairly recent times. A female Gharial (3.63 m) is known to have inhabited this area as late as 1994 (*Unpbd.*UPFD Data). Another Gharial was rescued here in 2006-2007 and later released into the Ganges at a spot further upstream. Apart from being a favorable habitat site for Gharial, the area being located in the Hastinapur Wildlife Sanctuary enjoys legal protection. Immediately below the limits of the Wildlife Sanctuary, the Ganges River and its environs downstream to the Ganga Irrigation Barrage to Narora, have been declared as a Ramsar Site with its own conservation implications. The area is currently the focus of a dolphin conservation programme of WWF-India which would concurrently benefit Gharial conservation, monitoring and protection. The findings of this *ongoing* study would help develop a Species Conservation Management Plan for Gharial in Hastinapur Wildlife Sanctuary that would inform the development of a range-wide Species Recovery Plan (SRP) for Gharial by the Ministry of Environment & Forests (MoEF), Government of India. The local communities (like fishermen and farmers) dependent on the river for their livelihoods are the important stakeholders and their participation will play a significant role in the long-term conservation of the species and their habitat. The plight of the Gharial is symbolic of the serious problems facing all river fauna in the subcontinent and unless the continuing deterioration of the region's major rivers is addressed we stand to not only lose these endangered taxa but also the use of these waters for human consumption (GCA 2009).

Acknowledgements

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Manobo-Crocodile co-existence in Agusan Marsh, Philippines: A cultural legacy of mutual benefit

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Abstract

There is mutual, yet fragile co-existence between the Manobos and the crocodiles in Agusan Marsh. Regarded as river people, the Manobo tribes of Agusan Marsh possess powers based on their cultural beliefs and values that essentially contribute in protecting their inherited lands and waterways. Their indigenous knowledge systems and practices (IKSPs) reveal that their understanding of the wetland ecosystem they belong to is holistic; that their lives' sustenance is a function of their interrelationships and interdependence with the rest of the other components in the marsh. More specifically, their IKSPs unravel their mutual co-existence with even the apex predator in the area, the crocodiles. The longevity of their co-existence that dates back since 14th century displays a relationship that is mutually beneficial to one another. It has only been in the recent years when this relationship has been threatened. Alongside the weakening protection and conservation initiatives towards the crocodiles in the marsh is the slowly eroding Agusanon Manobo culture. Reconsidering these IKSPs that are in danger of adulteration, its documentation is but imperative. Anchored to this premise, this paper presents an account of Manobo-crocodilian relations in the marsh by way of their mythical beliefs, religious rituals, cultural practices and anecdotal accounts. Focus Group Discussions and Key Informant Interviews with the chieftains of the different provinces and municipalities within and surrounding the marsh was conducted. The results from these meetings and discussions were then verified to existing literatures as well as to local historians.

Introduction

The Agusan Marsh is the home of the Agusanon Manobo that adapt to the harsh living conditions in the flood plains along Agusan Rivers that annually becomes a vast inland lake. The Agusan Marsh is an extensive flood plain of about 60 lakes and ponds that lies at the confluence of several Agusan River tributaries, a catch basin located in eastern Mindanao, Philippines (Davies 1993). This belongs to the Agusan River Basin (ARB), third largest river basin of the Philippines (river length of 350 kms. and total drainage area of 10,921 square kilometers). It was declared Protected Area by virtue of Presidential Proclamation No. 913 in 1996 under the National Integrated Protected Areas System (NIPAS) and being conferred as a RAMSAR Site in 1999 as Wetlands of International Importance.

Manobo basically means "people" or "person" a localized form of Spanish word Manuvu. The term may have originated from "Mansuba," a combination of man (people) and suba (river) meaning river people. They are among the first inhabitant of the Island of Mindanao, Philippines. According to De Jong (2010), the first Manobo settlers lived in northern Mindanao, at present Manobo tribes can be found at the hillsides and river valleys of the northeastern part of Cotabato. The Manobo appears to be a remnant of the first Austronesian invasion from Taiwan, pre-dating people like the Ifugao of Luzon while ancestors of the New Zealand Maori were a Polynesian people originating from Southeast Asia (Serrano 2008). The Agusan Manobo is one of 8 tribal groups that comprise a cluster of tribes known generally as Manobo (MCN 2012).

According to an oral tradition, the Manobos in general were lead by two brothers: Mumalu and Tabunaway, who lived by the Banobo creek, which flowed into the Mindanao River near the present site of Cotabato City. In the 14th century Sharif Kabungsuan, a muslim missionary, arrived from Johore, to convert the people of Mindanao. Tabunaway did not want to convert to Islam but told his younger brother not to reject the Muslim Faith. Tabunaway and his followers moved up the Pulangi River to the interior of Cotabato. They decided to part ways and from then on established their own tribes. These groups retained their indigenous beliefs, practices and the name of their original site, Banobo, which eventually became Manobo; the descendants of Mamalu became the Maguindanao.

Despite the fact that the various Manobo communities have been separated, there is one common thread that binds them together. The culture of each tribal group believes in one Great Spirit, usually viewed as the creator figure, or the Magbabaja. The Manobos also believe that there are many unseen spirits who can intrude in the lives of humans to accomplish their desires. These spirits are both good and evil in nature and can raise anger and pleasure. The

Manobo's reverence to these spirits dwelling in nature is the very driver of its respect towards it.

Most importantly, long before the Agusan Marsh was first recorded by Spanish Augustinian Recollects in 1622 as well as French and German anthropologists in 1880-1881 (Hontiveros 2008), the Manobo have already shared a place to live with the crocodiles. Crocodiles play an essential role in their mythic beliefs, culture and rituals. It is also a symbol of power, courage, strength and indigenous beliefs which enabled the modern day inhabitants of the marsh to live in peace and respect with the crocodiles.

Operational definition of terms

The Agusanon Manobo tribe embodies different aspects of cultural expressions such as its mythical beliefs, religious rituals, cultural practices and anecdotal accounts.

Mythical beliefs

The word myth is derived from the Greek word *muthos* which is *mythus* in modern Latin (http://oxforddictionaries.com/definition/english/myth). Myths are traditional stories, especially one concerning the early history of a people or explaining a natural or social phenomenon, and typically involving supernatural beings or events. Although generally considered as false beliefs by the greater public, the Manobos adhere to its firm hold of it being true.

Religious rituals

Ritual comes from the Latin word *ritualis* which means a religious or solemn ceremony consisting of a series of actions performed according to a prescribed order http://oxforddictionaries.com/definition/english/ritual. Rituals are oftentimes confused with ceremonies. The word "ceremony" comes from *caeremonia* which means "sacredness". Unlike ritual, ceremony includes the sacred -- it's a total experience, involving our bodies, minds, emotions, and our spirits. Intention is also very important in ceremony, just as it is in business. When intention is lostwhich can sometimes happen the ceremony can feel empty and becomes a "meaningless ritual", (Neale, 2011).

Cultural practices

Practices refer to sets of activities performed often, customarily or habitually (http://www.merriam-webster.com/dictionary/practice). These practices are most often unique to every indigenous peoples group which identifies them from the rest.

Anecdotal accounts

The word anecdote is derived from the Greek *anekdota* which means short narratives of an interesting, amusing or biographical incident http://www.merriam-webster.com/dictionary/anecdote.

Materials and methods

This study employed Focus Group Discussions and Key Informant Interviews. A semi-structured survey questionnaire was prepared. Data derived from observations, testimonies, personal accounts, were juxtaposed to that of existing written literatures and expert judgment (local historians) for the examination of information gaps. All the chieftains with jurisdiction in the marsh were the respondents.

Conceptual framework of the study

Figure 1 represents the conceptual framework of the study. It basically resembles a two-set Venn diagram; two circles overlapping each other with a well-defined area of union and intersection. The overlapping area is the area where the Manobos and the crocodiles, though as separate entities of the marshland ecosystem, share a common space of existence. This union or co-existence of two top predators is made possible by its mutually benefiting relationships. The Agusanon Manobo's mythical beliefs, religious rituals and ceremonies, cultural practices and anecdotal accounts are the tribe's expression of its mutually benefiting relationship with the crocodiles. The harmonious co-existence of both is predicted to be in peril if this space of union gets narrower and narrower; through the erosion of this indigenous culture.

Results and Discussions

Mythical Beliefs

The beliefs of the Agusanon Manobos involve the mythical world through their belief in guardian spirits that they too, worship and revere. This act of worship to the spirits puts their mythical beliefs in one of the many facets of their indigenous religion. Religious beliefs of the Agusan Manobo are related to Maguindanaon Manobo where there are many unseen spirits who interfere in the lives of humans. They believe that these spirits can intrude on human activities to accomplish their desires. The spirits are also believed to have human characteristics. They are both good and evil in nature and can be evoked to both anger and pleasure. The Manobos' beliefs and values are inherent to their strong regard for land as the source of life. They believed in the presence of spiritual unseen beings residing in their forests, rivers and animals.

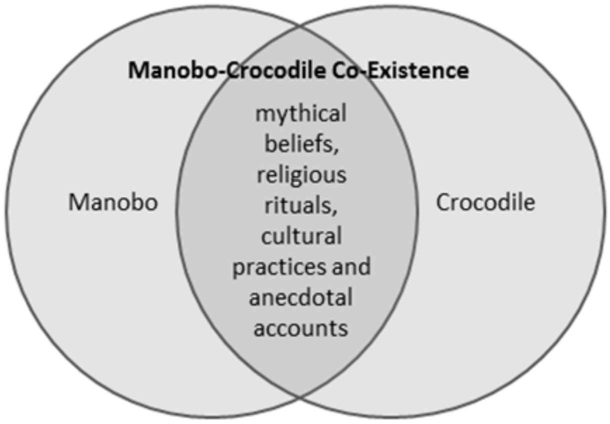

Figure 1. **Conceptual framework of the study**

The wise utilization and proper care of their resources reflects their unwavering respect to the nature's spirit, since these spirits are the guardians of these resources. An example of the exhibition of these practices is when they gather wood and their interactions with wildlife (e.g. hunting). More specifically, the Manobos do not cut hard wood, this is because they believe that the cutting of hardwood would bring about a calamity that shall devastate their homeland.

Furthermore, the Agusan Marsh Manobo, consider their people as born with a crocodile twin spirit. A person's twin spirit is literally considered a relative which also serves as a guardian to its human twin. This mythical belief is common to both the Agusanon and the Maguindanaon Manobo of the Ligawasan Marsh in Cotabato which is implicative that the Manobo Indigenous communities are intimately related to crocodiles having started a relationship with crocodiles upon birth. There have been existing literatures that narrate mythical and legendary accounts of past chieftains having connections with crocodiles upon birth:

> *"After the datu (male royal or chieftains) was born a small crocodile emerged from the mother's womb to the surprises of the couple. Believing that the creature was their son's twin, they kept it in a separate cradle besides that of the infant datu. As the datu grew so did the crocodile. The couple showered it with the same care as they did with their son. When the datu was an adolescent, the crocodile was so enormous it could no longer fit in a cage in the house. After much thought, the couple decided to free the crocodile in the river. But before that, they placed a yellow band in its neck so that they could distinguish it from other crocodiles. Many years passed. The datu now a fully-grown man developed into an incorrigible gambler. Slowly yet steadily, he squandered away his family's wealth to support his vice. His parents were worried that if he continued with his gambling activities, in time the family's wealth will be lost. While the datu was away on one of his gambling sorties, they devised a plan to save what was left of their precious gold. The next morning they ordered their servants to bring the gold to the riverbank. The couple stood at the bank and called their crocodile-child. A few minutes later, the crocodile emerged. They set all the gold onto the crocodile's back and instructed it to keep the property safe."(Mangansakan II 2008).*

Other accounts are reflected on the immoral acts and how these acts are to be dealt with by the spirits. Spirits, believed by the Manobos to be part of nature, are the ones who punish those who do immoral acts. An example of this is that a person who committed an immoral act will be punished through a lightning struck and then will be transformed into a crocodile:

> *"A male warrior named Dagye-an and his old wife Dehunajen, committed incest relationships. After committing such acts, they were struck by the anit (a supernatural lightning that was concerned with such acts) after being struck by the anit, the couple became crocodiles."*

Another version of the story above is shown below, in this story, there is a place where Dagye-an fought crocodiles after he, himself was turned into a crocodile by the strike of a lightning.

> *"There is a place called Tikgon, where actual crocodiles reside further downstream from the Sabang Kawayanan, a juncture where bamboos grow. Here Dagye-an fought a crocodile and during their fight, as the crocodile fighters splashed their tails to the river, it created the many rivers and creeks in the Middle Agusan Valley. Dagye-an was proven to be stronger than the other crocodiles who reside in Tikgon."*

Mangansakan II (2008) also cited that anthropologists Margarita Cojuangco wrote that the origin of this belief "involves two brothers and two versions". One, the datu who stole his brother's wife; the other, of the intense rivalry and drowning of a brother with his family and entourage at sea in vengeance for ill-treatment. Eventually, the adversaries all became crocodiles."

Based in the FGD conducted, the Agusanon Manobo datus expressed their belief that their forefathers and ancestors have passed on to them the belief that the crocodiles belong not to them, but to the environment. This drives them as a people respectful and considerate to the crocodiles in the wild. As recipients of the environmental services provided by the crocodiles in the wetland ecosystem, their actions toward this animal should be in harmony with its existence.

Furthermore, the Agusanon Manobos are familiar with the behavior of the crocodiles. As a community, they believe that the disturbance of the crocodiles' natural habitat through clearance of marsh vegetation, electro-fishing and any other harmful activities are detrimental to the life stages and processes of these animals. If these activities are not stopped, the co-existence of the Manobos and the crocodiles are believed to be in danger. This is because crocodiles can become aggressive when provoked, which to some extent will result to crocodiles attacking humans. There are also instances that fishing gears set-up within a known crocodile habitat is torn by crocodiles themselves.

The Agusanon Manobos further believe that the crocodiles are able to recognize a person's pure intention. When the person is identified by the crocodile to have good intentions, they voluntarily reveal themselves, allowing for them to be seen by the person, independent to either dry or rainy season. These crocodiles surface during any season depending on the intentions of those it encounters. Moreover, the Agusan Manobos articulated that once a person is granted by a crocodile to catch a sight of them, the person must only look at it, so that no harm will be done to them by the crocodile.

Some chieftains recall that in the past, ancestor fishermen tap the side of their canoes using their paddle to produce a distinct sound to convey to the crocodiles their presence and their intention to safely navigate the rivers. This activity signals the crocodiles to move away for their boats to cross safely. The respondents added that when they are aboard their canoes and they see a crocodile from a distance, they just make this sound and the crocodile sinks or leads to the opposite direction. According to them, this belief is an expression of giving respect to the crocodiles as vital members of the wetland ecosystem.

Religious rituals

Manobo religious rituals are specifically called *panawagtawag* which is a general form of ritual intended to call the spirits. This is performed by a *baylan* for a specific purpose, such as crocodile hunting, healing of the sick, and thanks giving for an abundant harvest among others. Here, the *Baylan* (the priest) calls for the *Magbabaja*, the GOD the father, creator of heaven and earth and other *Tawagon*, the spirit in-charge in a certain area. Below is the list of some identified Manobo deities. Agusanon Manobos manifest religion in their own way such as attending rituals as a form of worship to the unseen spirits that protects nature. It is believed that *Tagbanua* (spirits) are present in the area to safeguard the crocodiles. A *Baylan*(priest) offers prayer to the spirit sentinel of crocodiles, for them not to harm their community and recognized the humans. Only the *Baylan* are allowed to mention the names of unseen spirits living in the marsh. The *Tagbanua* is the general term for the overall caretaker of a certain sector or place such as:

Yumud/Lumud/Alimugkat - These are spirits taking care of those living in the water.

Sugujon - This spirit is in command order for hunting, capture and/or removal of an animal from their area.

Taegbusow - This spirit is associated with the color red (blood) and death. It usually pertains to a witch which feed on blood (human blood). According to Garvan (1931) and Montillo-Burton (1985), the Tagbusau

(Taegbusow)- are the diwata of bloodshed and revenge and, in the past, used to incite the bagani to wage war in order to appease their craving for human blood.

Inajow - The Inadyaw/Inaiyu is an example of a nonchanting celestial diwata who dwells on a lakeshore in heaven. He is the god of thunderbolt and lightning; and of wind, rain, and storm. He punishes breakers of taboos with the anit, i.e., a curse which causes physical deformities or skin diseases.

Umli - This is a collective term for beneficent deities of which little is known because they hold themselves aloof from the human race.

During rituals, there are things that must be prepared for offering. It is believed that by doing more and giving more items during the offering, more will be provided in return. Some of the items brought during offerings including the blades, weapon or swords of the male royal (Datu) or chieftains and are placed in the *Angkawan* (altar) to show respect.

Some of the items being offered and their purpose of offering during the conduct of *Panawagtawag* are presented in the table below:

Table 1. List of items used during the conduct of the *Panawagtawag*

Materials	Purpose
Live pig (40kgs. up)	Offered food for the spirits, a large animal sacrifice is offered to the spirits in exchange for big favors (e.g. hunting a crocodile).
Mallorca (wine)	The scent of a Mallorca provides a heavenly sensation for the spirits.
Biscuits	Staple partner for wine.
Apog	Staple partner for wine.
Egg	Staple partner for wine.
Candies	Sweet food offering.
Buyo/Mam-on (betel nut)	It is used for chewing during the *panawagtawag*.
Rice	Essential food offering that will be cooked afterwards.
Coins	The coins symbolize material wealth offering.
Plate	Contains the dry food offerings.
Spear (*Bangkaw*)	It is used to slaughter the offered pig.
Binuka	container of blood in which to be smelled by the Taegbusow.
Altar (Angkawan)	Serves as special and sacred platform wherein the materials and items for ritual are placed.
Mayonhow	

The first part of the ritual starts with stating the purpose and paying respect for the spirits. Here, the *Hakyad* is performed wherein live pig and other material items are offered to the unseen spirits. The liver, meat, fats and skin (formed from an image of *Binuaja* or crocodile) are grilled and served to the *Tagbanua* together with other cooked and prepared food. After which, it is considered that the unseen spirits are finished eating, offertory foods are then distributed to those who are present in the ritual. It is customary to Manobos to share to the participating visitors (dayos) these goods. It comes with a warning that the spirits will definitely know whether a person's intentions are yielding to their beliefs or not.

A ritual for thanksgiving is normally offered whenever a Manobo fisherman catches more fish in a crocodile inhabited area.

It is noted that religious rituals are performed once in a while for a specific purpose. Some are performed to call the *Tagbanua* to request permission for activities proposed to be performed in the marsh. In cases of crocodile related activities, the *yumud* or *alimugkat,* is considered as the rightful caretaker or the spirit-owner of the crocodiles. This provides a peaceful conduct of activities prior to entering the marsh.

> *"Before the capture of the largest crocodile in the marsh named lolong, a ritual was performed to call Sugujon, spirit in-charge of hunting to request the capture of an alleged nuisance crocodile in exchange to live animal offering. However, it is believed that Sugujon asks for a human life as an offer instead". Datu Cabanbanan*

This was believed to be true when a lead crocodile trapper, Mr. Ernesto *"Lolong"* Goloran Coñate, Sr, who have an Agusanon Manobo ancestry died of cardiac arrest a week before the of capture. Thus, in honor of Mr. Coñate's courage, strength and to the lives of Manobo community in the marsh, the captured crocodile was named after him. This is the etymology of the now 2012 Guinness record holder (world's largest crocodile in captivity) "*lolong*" stationed in Bunawan Nature Park, Agusan del Sur.

Cultural practices

The way of life among Agusanon Manobos is sharing the same place with the crocodiles; thus living together in one ecosystem. Low impact activity and respect to environment characterize their cultural practices as an indigenous group. Respect to life is one very clear attribute of the Agusanon Manobo cultural practices. The Spanish people that came to the Island of Mindanao have referred indigenous people of Agusan as self-righteous. They observed Agusanon natives live side by side with crocodiles and still swim in the waters inhabited by crocodiles. The response lies in the perception of the indigenous people about their knowledge on the behavior of crocodiles as well as their understanding of feeding habit and aggressiveness when aggravated. Offerings of pig during village rituals also provide food for the crocodiles and they believed that all things happened for a reason. The Manobo Tribal leader of the Lake Panlabuhan floating community revealed stories from his grandfather that in order to live and survive in their settlement, one must have an amulet (like crocodile tooth) for safety and protection.

The Manobos in the marsh are primarily fishermen. Their lives have been attached to this livelihood in a way that they have been identified with it; without fishing, there would be no Agusanon Manobos. Their fishing practices reveal that they associate the abundance of fish catch to the presence of crocodiles. According to them, crocodiles are indicators of a healthy fish population. The presence of crocodiles in the marsh means that there are still secluded and relatively undisturbed portions of the marsh where crocodiles find its refuge and establish territory. It is in these serene areas in the marsh where crocodiles breed and nurse its young. These kinds of areas are also believed by the Manobos to be breeding and spawning grounds for fishes. It has surfaced during the interviews that they perceive these areas as fish sanctuaries; an assurance of healthy fish stocks to sustain their fishing practices.

To elaborate their fishing practices further, the Manobos do fishing in a conservative and a traditional way. Largely comprised of fishermen, the floating community of Sitio Panlabuhan uses local materials and only target mature fishes. Their fish traps (bobo) are established in strategic places during the twilight of day. They then rise up early in the morning and sail on in their canoes to check these traps. The large nets are intentional for the purposes of catching only those that are mature enough for harvest. The conduct of direct fishing practices within crocodile habitats are considered as a restricted activity. Due to large area of Agusan Marsh, there are certain areas intended for crocodiles, fish nurseries, and other activities to prevent resource use conflicts. Thus, fishing areas are carefully delineated.

Furthermore, the Manobos insist that crocodile habitats are supposed to be free from disturbances. One of their main objectives is to maintain the presence of crocodiles in their natural habitat through the habitat protection. The removal of vegetation should be avoided if possible if not to be totally avoided. It is their practice to not get close to the crocodile habitat especially during the breeding month of March. It is known that crocodiles are more aggressive during this time and pose a large probability of inflicting harm to humans. Utmost care is exhibited when crossing a crocodile habitat as a sign of respect to the animal in the area. When possible, engine boats are turned off when inside a crocodile area.

In addition, the Manobos perceive that crocodiles help in maintaining the depth of river and creeks that lessens silt accumulation. This is done through the natural movements of the animal.

On the other hand, in a news article of Jeffrey Tupas (2010), he interviewed an Agusanon ethnic Manobo named Rey Calderon about their life with the crocodiles. Calderon states that "*We need to recognize them and respect their presence in the marshland. That is very important. They have to be understood and given their own space. Their territory is their territory*. *What is necessary is that we lessen our encounters with them. They are just there, living with us. They have their sanctuary and so we give them that*. He also told stories of close encounters with the crocodiles and the mysterious forces at play in the marsh.

> *"I was about 6 years old then, fishing with my father at dawn, when I first saw one. The crocodile's mouth was wide open, waiting for the prey, perhaps waiting for any of us. It was scared, but now, I realized that they were playing their role in protecting the marshjust like we do."*

A small floodplain Lake Tagsubon known as the crocodile nesting site in the vicinity of Bunawan has been declared local strict protection zone by Lake Mihaba Fisheries Association (LaMiFA), a grassroots organization, in order to limit disturbance infused by the villagers to the crocodiles.

However, an isolated case of fatal crocodile attack to a twelve-year old girl happened in 2009 at Lake Mihaba. Stories about supernatural reptiles containing spirits of tribal ancestors slightly change from reverence to fear and hysteria even though they once peacefully coexisted with the crocodiles, the top predators in the area. But according to Calderon (Tupas 2010), "*the baylanon told us that the gods were enraged over the desecration of the place. A villager somewhere far from the floating community built a house and used a galvanized iron sheet as roof. The iron sheet disturbs the water with its bizarre reflectionthat enraged the gods. The attack was a warning, a very scary warning. Some things are too difficult to explain to others but that's how things are here. Ultimately, I believe that we are being taught to show respect to people, nature and those we cannot see or explain*." The people only returned to the floating village after holding a religious ritual called *manubad-tubad* to appease the gods.

Respect for crocodiles among the Manobos also manifest in their craftsmanship and artworks. There have been known crocodile inspired designs and symbolism an Agusanon Manobo community. Some are seen inscribed in the *Kampilan* (sword) of the *Bagani* (warrior) while some are incorporated in an architectural design. Signs inscribed in these armaments are known to be symbols of courage, power and high regard for the crocodile reputation.

> *"Being an IP and an observant of the customs, traditions and practices of the Manobo tribe, the frontage design of my house is called Binuaja, a design inspired by the crocodile because long time ago, true crocodiles are considered as life of our forefathers. The existence of crocodiles are the same as the existence of our ancestors, they believe that there are no IP's if there are no crocodiles".*
> *Hawudon Mabayow-Manunuyat*

Anecdotal accounts

In the past, there are no reports of human-crocodile conflict. This may be attributed to the low human population density in the marsh, and high crocodile population. Crocodiles are likewise then observed to be scared of humans. Contrary to the present situation, humans are now the ones scared of the crocodiles. These reported human-crocodile conflicts are believed to be a result of the disturbance of known crocodile habitats. On the other hand, scarcities of fishes in the marsh may have prompted the crocodile to find more available food sources, lead to attract on livestock in the community.

> *"There were two people seen with rifle guns riding a raft made of logs, they saw a crocodile afar and wanted to shoot. However, when they are close enough to the crocodile, they got scared and made use of their rifle as a paddle to get away from the animal. This shows that that in the past there are no encounter between crocodiles and man". Datu Makahinlo Gubat*

Another story happened during one flood season in Sitio Panlabuhan, a lake floating community of the Manobo tribe. At that time, a crocodile was seen entangled in one of the fishing nets installed in Lake Bukogon.

"For five hours we thought that the crocodile was dead. I dove into the water and checked the crocodile; we were surprised to see that the crocodile is still alive. Then after about ten minutes, the animal surfaced and we saw that it was almost as big as our motorboat. We are about 30 persons then who witnessed the crocodile floating in the waters. The crocodile swam freely and did not harm us because we do not do anything to harm the animal". Hawudon Kanimbaylan

Furthermore, personal communications of Alcantara (2011) to Tribal Leader Boyet Reyes convey anecdotal evidence about the lone tourists who dropped in unannounced and unaccompanied have experienced unexplained mishaps (near drowning, injury, body pains and other misfortune). A mysterious ailment would seize an unlucky visitor, prompting him to come back and beg for healing with tribal leaders. All they wanted was respect for their forefathers and ancestral domain.

Protection Efforts

After a couple of years since an isolated crocodile fatal attack to humans, the local government of Bunawan town has organized the capture of the alleged problem crocodile in response to the growing anxiety. Since then, reports on the sighting and alleged activities as nuisance crocodiles have spread in the communities of Agusan River Basins. Other inhabitants and local authorities had gained interest to capture crocodiles to address the assumed fear of river communities. As a result, series of Protected Area Management Board (PAMB) meetings are conducted to determine specific actions and concerted efforts to address issue about crocodiles that pose threat in their respective areas. But based on the excerpts on the minutes of PAMB Executive Committee meeting on August 2011, the Agusanon Manobo agreed to take out only one crocodile from their natural habitat. In an event when mistaken individuals had been caught, no replacement will be granted from the residing Agusan Manobo.

Additionally, influx of migrants coming into the marsh, has been alarmingly observed in the recent years. These migrants come from different provinces such as Davao del Norte, Davao del Sur and as far as in the Province of Iloilo, Island of Panay. They come to the marsh in search for better living conditions as compared to the dry lands. Several others have been brought to the marsh by intermarriages with the lumads. These people come from different areas with different microcultures of their own, thereby influencing their perception and eventually their practices. This mixture of different cultures, unless resolved at first hand, poses as in imminent threat the once solid Agusanon Manobo culture. It is alarming in a sense that most of the time, only the elders in the Manobo communities in the marsh remain to be well-versed with their IKSPs. The external influences and the clashes of migrants or *dayo* as that of the lumad culture must have caused some confusions among the younger generation.

Synthesis and Conclusion

The mythical beliefs, religious rituals, cultural practices and anecdotal accounts of the Agusanon Manobos pertaining to crocodiles in Agusan Marsh altogether display their mutually benefiting co-existence. All the four components of their indigenous culture that is focused on in this study stand complementary to each other; and are reflective to crocodile protection and conservation. Their IKSPs reveal that they perceive crocodiles as co-equals. This explains their high regard to these animals. Furthermore, their IKSPs acknowledge the ferocity of crocodiles; as an animal capable of fatal attacks. This understanding, however, has not seen to create a feeling of hatred among the Manobos towards the crocodiles. Rather than taking offenses to defend themselves for possible attacks, the Manobos, fully aware of its wild tendencies and animalistic behavior, instead pay respect to these creatures. Crocodiles are therefore not considered villains in the marsh, which is contrary to popular beliefs. The continued persistence of the Manobos in the marsh will only be assured if the integrity of the wetland is maintained. It is embedded in their culture that crocodiles are indicators of a healthy wetland ecosystem. Compromising their beliefs in the importance of crocodiles in the marsh would only jeopardize their existence as a riverine community. This study furthermore sees the urgency and the need for the older Agusanon Manobo generation to impart all their IKSPs to the younger generation.

This study therefore concludes that the Agusanon Manobo culture is in one with the protection and conservation efforts currently in place. Their culture is an essential management tool to further push local and national initiatives for the said cause. Inasmuch as crocodiles are the target entities for these programs, people and communities of direct contact to these animalswhich are the Agusanon Manobos, are as equally important in designing and implementing protection and conservation approaches.

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Crocodiles in western of Sarawak, Malaysia

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Abstract

Saltwater crocodile *Crocodylus porosus* is the most common crocodile species found in Sarawak. Humans and crocodiles have been living in harmony for centuries, peacefully sharing the same landscape. However, in the past three decades, reports on human-crocodile conflicts are on the rise, bringing the assumption that the crocodile populations are bigger in size now and expanding to all rivers. This study is designed to assess the relative density of crocodile in three different rivers located in the western part of Sarawak namely Batang Samarahan, Sibu Laut River and Bako River, using the standard census survey method. For the year 2011, relative densities of crocodile were 0.53 non-hatchling/km, 1.04 non-hatchling/km, 1.8 non-hatchling/km for Batang Samarahan, Sibu Laut River and Bako River, respectively. There is no previous record on crocodile density for Batang Samarahan. For Sibu Laut River, there is a 40% decrease in density compared to year 2003 survey data. Previous survey data for Bako River are available for year 2003 and 2008. Bako River has experienced fluctuation of crocodile density, as systematic culling had been carried out as a response to fatal crocodile attack which happened in year 2006. Findings reported in this study are limited to small number of surveys conducted within the year 2011, therefore more studies should be carried out in future to get a more comprehensive picture of crocodile populations in these rivers. This paper also examined the socio-economy profile of local people living along the three rivers and reports on their perspectives towards human-crocodile conflicts.

Keywords: saltwater crocodile, density, socio-economic profile, human-crocodile conflict

Introduction

There are two species of crocodiles in Sarawak namely, *Crocodylus porosus,* the saltwater crocodile and *Tomistoma schlegelii,* the Malayan gharial. *C. porosus* is the most common crocodile which could be found in most of the major rivers and swamps in the state, whereas *T. schlegeliiis* less common, inhabiting only swampy area of Batang Lupar, Batang Sadong and freshwater wetland Loagan Bunut (Cox and Gombek, 1985). Coastal communities in Sarawak and crocodiles have been living in harmony for centuries because crocodiles play important roles in their culture. For example, folk stories associated with the legend of ferocious crocodile named “Bujang Senang” who had attacked people but could not be killed and will live forever (Ritchie and Jong, 2002). Besides that, people also believe in the aphrodisiac properties of crocodiles' reproductive organs, and the ability of the crocodile meat and other body parts to cure asthma and other sickness.

In late 80s, *C. porosus* in Sarawak was in the brink of extinction due to extensive hunting by local people. This species was hunt primarily for their skin and meat, while farm owners aim for their eggs and hatchlings to boost their farm production. *C. porosus* currently is listed under Appendix I in the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). On the other hand, it is categorized as Lower Risk / least concerned by the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threaten Species 2012. In Peninsular Malaysia*, C. porosus* is under Wildlife Conservation Act 2010 and listed as protected animals in the Sarawak Wild Life Protection Ordinance, 1998.Hence, any hunting, killing or selling of wild crocodiles in the state are prohibited. However, after a few decades protected by law, the crocodiles population in Sarawak is on the road to recovery. There are many reports regarding cases of crocodile attack on human which had concern communities living along the rivers and they assume that the population of this species is on the rise. Field survey by Sarawak Forestry Corporation (SFC) reported that there have been marked increased in the density of this species in most rivers (Tisen and Ahmad, 2010).With the recent efforts by SFC to down listing this species from CITES Appendix I to Appendix II, substantial data on crocodile's population in Sarawak is needed. Down listing *C. porosus* is important so that this resource can be utilized more openly by local communities, which can also contribute to the state economy. Moreover, lowering the number of crocodiles in the rivers may be one of the most suitable approaches to deal with human-crocodile conflicts happening along the rivers.

This paper describes findings of our survey on density of crocodiles in three different rivers in the western part of Sarawak namely Bako River, Batang Samarahan and Sibu Laut River. In addition, local communities' views related to crocodiles especially on the increasing human- crocodile conflicts in Sarawak are also highlighted in this paper.

Materials and Methods

Census survey of crocodiles had been conducted in three different rivers namely Bako River, Batang Samarahan, and Sibu Laut River in 2012 (Figure 1). Night spotting techniques following Cox and Gombek (1985), Games and Severre (1999) and Sullivan *et al.* (2010) were used during the survey where spotter (on the boat) scans shorelines or middle of the river for eyeshines using spotlight. During the survey, recordings of the location were made for all individual crocodile sighting using GlobalPositioning System (GPS). All crocodiles were categorized according to size class (hatchling, yearling, sub-adult and adult). On occasions when observers were unable to accurately estimate size class, the sighting was recorded as eyes only (EO). The commencement location andend point of a survey were also recorded using GPS as a waypoint for the calculation of linear survey distance. For density and distribution of crocodiles, data was recorded as relative density (non-hatchling/km river) as suggested by Games and Severre (1999).

Socio-economic profile and human-crocodile conflict survey had been carried out using face-to-face interview with the local people living along the rivers. Correspondents were selected randomly and subjected to standard questionnaires. The questionnaires were divided into 5 sections namely personal details, socio-economic profile, dependency on water body, crocodile awareness and human crocodile conflict. Results of the interviews were analysed in qualitative manner as well as summarizing the data in graph forms.

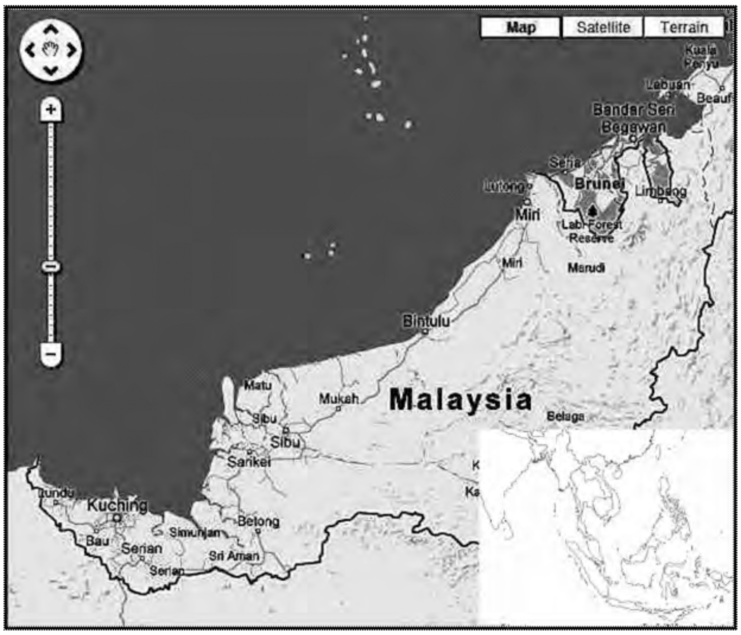

Figure 1. Locations of field samplings. 1- Batang Samarahan (N 01° 30.570', E 110° 29.364'), 2 - Bako River (N 01° 39.514', E 110° 25.946') and 3 - Sibu Laut River (N 01° 41.473', E 110° 12.299')

Results and Discussion

This section will be divided into (i) crocodile density survey and (ii) local people perspectives on crocodiles.

Crocodile Density Survey

During 2011 census survey, Bako River recorded relative density of crocodile of 1.8 non-hatchling/km, Sibu Laut River has 1.04 non-hatchling/km whereas Batang Samarahan recorded 0.53 non-hatchling/km (Table 1). For comparison, Sullivan *et al*. (2010) reported that the density of crocodiles in Queensland, Australia was 0.49 ± 0.72 (non-hatchling/km).

Table 1: **The relative density of non-hatchling *C. porosus* for surveys conducted in Batang Samarahan, Sibu Laut River and Bako River.**

River	Total number of crocodile	Distance (km) of the river surveyed	Mean relative density (non-hatchlings/km)
Batang Samarahan	112	140	0.53
Sibu Laut	15	14.4	1.04
Bako	22	12.2	1.8

Table 2. Comparison of relative density of C. porosus (non-hatchling) for Batang Samarahan, Sibu Laut River and Bako River

River	2003	2008	2011
Batang Samarahan	NA	NA	0.53
Sibu Laut	1.73*	NA	1.04
Bako	2.76*	1.03*	1.8

* Data from surveys by Sarawak Forestry Corporation (Tisen & Ahmad, 2010), NA = not available

During this survey, relative density for *C. porosus* in Sungai Sibu Laut was 1.04 non-hatchling/km (Table 1). This density was decreased almost 40 % compared to the result of survey in the year 2003 (Tisen & Ahmad, 2010) where they reported that the relative density were 1.73 non-hatchling/km (Table 2). There are several reasons that could have caused the decreasing number of crocodiles sighted in the river, such as increasing fishing activities along this river, and expanding human settlement and populations, which contribute to more rubbish and snags into the river. Furthermore, the local authority is carrying out some river bank development including building a more sophisticated jetty and other amenities near the river mouth to support ecotourism activities, for example transporting tourists to Talang-Satang National Park and Kuching Wetland National Park as well as deep sea recreational fishing. These river bank improvements may have destroyed crocodile habitats along this river due to erosion and other changes to the river ecology. There is no report on crocodile attack along Sibu Laut River in 2011, but between late 2012 and early 2013, local people complained about missing pets (cats, dogs) and live stocks, which they feared were being eaten by crocodile. As the complaints intensified, relevant state agencies and local people had joint effort to hunt the crocodile. Finally, on 28th January 2013, one male crocodile of approximately 5 meters long and 650 kg, were captured and re-located to Matang Wild Life Centre, Kuching. This centre has facilities to house many types of wild animals including crocodiles. The animal enclosures here are *ex-situ* conservation, and have been used to raise awareness among the public on issues related to wild animals.

Bako River recorded relative density of 2.76 non-hatchling/km, 1.03 non-hatchling/km, and 1.80 non-hatchling/km in the year 2003, 2008 and 2011, respectively (Table 2). Density of crocodile fluctuation in Bako River is influenced by sequence of events happening in this river, over the nine years period. Many human-crocodile conflicts were reported, one of them involved fatality in 2006, resulting chaos and high sentiments among local people. After a long commotion between local people, non-governmental agency (NGO) pro-animal rights and the state agencies, culling and relocations of crocodiles in this river had been carried out, with the aim to control the population, and the result had been reflected in the year 2008 survey as the density decreased to 1.03 non-hatchling/km. However recent survey in 2011 showed that the density of crocodile is on the rise as data recorded 1.80 non-hatchling/km, and high number of hatchlings and yearlings were recorded (Figure 2), an indication of recovery populations (Sullivan *et al*., 2010). From 2007 to 2012, there was no report on human-crocodile conflict in Bako River although crocodile attacks did happen in nearby rivers. Additionally, SFC staff had been organizing regular meetings with local community and had carried out pilot project on engaging them in ecotourism activity of firefly and crocodile watching along Bako River, with the hope that local people will benefit from the presence of crocodiles in the river rather than solely inculcate negative perception on these animals.

Based on preliminary findings during this study, no adult crocodile was spotted in Bako River and Sibu Laut River. In addition to that, no sub-adult was found in Bako River (Figure 2). Nevertheless, those rivers recorded EO, which most likely were sub-adult and adult crocodiles. Spotting of sub-adult or adults crocodiles is a challenge as they usually swims in the middle of the river and also very sensitive to disturbance (Games and Severre, 1999). The high number of hatchlings observed in the rivers during these surveys, especially towards the upstream areas suggested that successful nesting occurs in these parts of the rivers because of fewer disturbances by human. The population bias to hatchlings and yearlings is an indication of a recovering population (Sullivan *et al*., 2010).

For Batang Samarahan, high number of hatchlings (34%) and relatively high number of EO (28%) were recorded (Figure 2). EO is most likely sub-adult and adult crocodiles, inhabiting mid-river, and usually submerge when the boat tried to approach them. Almost 10 % of the total numbers of *C. porosus* observed were sub-adult while 11% were adult. Based on this preliminary finding, Batang Samarahan supports a balanced crocodile population in terms of size. The high number of hatchlings observed in this study suggests that successful nesting occurs along Batang Samarahan, the bias in the population is an indication of a recovering population (Sullivan *et al*., 2010).

High numbers of yearlings (42%) were recorded in Sibu Laut River (Figure 2). Almost 21 % of the total numbers of *C. porosus* observed in this river were hatchlings. While for survey of *C. porosus* in Sungai Bako, the highest number of cohort size recorded was yearlings (38%) where it was a relatively higher compared to hatchlings which recorded 35% from total number of crocodiles spotted. The presence of EO of 27% and 15.7 % in Bako and Sibu Laut River, respectively, indicated that the populations may also comprise adults and sub-adult crocodiles.

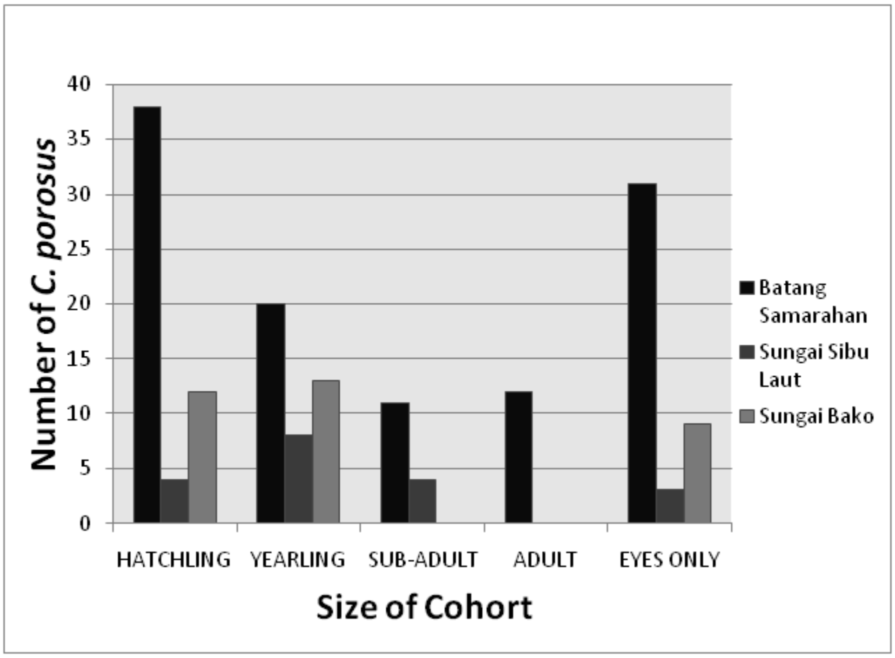

Figure 2: Number of *C. porosus* according to size of cohort recorded during the surveys in Batang Samarahan, Sungai Sibu laut and Sungai Bako.

Local People Perspectives on Crocodiles

In this study, a total of 44 people who are living in the villages along the three rivers had been interviewed, whose age range between 15 to 65 years old. Out of this pool of respondents, 43% were between 40-65 years old. For older generation (60 years old and above), most of them only received formal education up to primary school level or only educated informally on necessary life-survival skills. In contrast, 18% of the overall respondents (who are between 20 to 40 years old) were graduates from universities or colleges, reflecting the current trend of democratization of education in Malaysia, besides relatively cheap tertiary education compared to neighbouring countries

Majority of the respondents are subsistence fishermen, whereby fishing activities are carried out within the estuary river basins as well as within the coastal areas. Other respondents were civil servants, students, small-scale farmers tending small agricultural plots and self-employed entrepreneurs (Table 3).

Table 3. Summary of socio-economic profile of people interviewed during this study, whom living along Batang Samarahan, Sibu Laut River and Bako River

River	No of people interviewed	Educational Background	Occupation
Batang Samarahan	11	Tertiary level: 18% Secondary School: 55% Primary school: 9% Informal education : 18%	Fishermen: 36% Government servant: 19% Students: 9% Others: 36%
Sibu Laut River	24	Tertiary level: 5% Secondary School: 38% Primary school: 48% Informal education: 9%	Fishermen: 52% Government servant: 10% Students: 5 % Others: 33%
Bako River	9	Tertiary level: 23% Secondary School: 33% Primary school: 11% Informal education: 33%	Fishermen: 11% Government servant: 33% Students: 33 % Others: 23%

Many areas in Sarawak are experiencing rapid physical infrastructure development. For local people living near Batang Samarahan, Bako River and Sibu Laut River, tap water is now available to almost all residents, for drinking purposes and other domestic usage. Only 9% of the respondents are still depending on rain water as source of drinking water and water from rivers for other domestic use. Rivers in Sarawak have many functions including as source of water for domestic use, irrigation of agricultural plots, transportation, recreational and fishing activities (Khairudin, 2008).

Although local people do not depend on rivers as a source of water for domestic use, majority of people interviewed (61%) used rivers as a mean of transportation, to go to other villages and their agriculture plots. Therefore, the peak time people use these rivers depend on tide table, meaning that elevated rate of usage will be during the high tide in the day time. Almost 73% of the respondents do fishing, either categorized as subsistence fishing or fishing as a hobby. Among the common fishing methods mentioned by respondents are fishing rods, nets and traditional fishing traps. In general, fishing activities increased during giant prawn season in these rivers (Stuebing *et al*. 1985) and human-crocodile conflicts incidents also reported to be high during this time of the year. This could be probably due to increase in the usage of the rivers as people put more effort in their fishing activities to increase prawn catch, which will also lead to the increase of income.

As crocodiles could be easily found in almost all rivers in Sarawak (Abdullah and Hassan, 2011), 94% of the respondents claimed that they have seen crocodiles in the wild, with the range between 1 to 5 meters. They reported seeing either partially submerged crocodiles in the water column, in between the mangrove trees or those who sun-basking on the mudflat adjacent to the river mouth or on the riverbank. Almost all respondents said they will try to avoid crocodiles when using the river. However, if they encounter these animals, they will just carry on with their activities as normal, without disturbing the animals. Within river vicinity all around Sarawak, people and crocodiles had already adapted living in harmony for centuries (Ritchie and Jong, 2002), and respect for each other continues until today.

As urbanization and large scale plantation replacing the old-day serene landscape in most parts of Sarawak, increased pressure to crocodile populations is unavoidable due to destruction of habitats, decrease in food sources as well as water pollution. Coincidently, there is also an increase in human population; hence more human activities are happening along the rivers, during night, day, dusks and dawns. Increased pressure to crocodiles and humans alike, may have contributed to the increase number of reports on human-crocodile conflicts. During this study, all respondents never had any personal experience in human-crocodile conflicts; however majority of them had met or heard of people who have had the experience of being attacked by crocodiles. When respondents were asked on suggestions to handle such conflict, 49% said culling should be carried out accordingly to control the number of crocodiles in the river, 27% suggested relevant agencies should monitor crocodile behaviour and population continuously whereas 24% said aggressive ones should be transferred to crocodile sanctuaries and zoos (Figure 3).

As the leading higher learning institution in Sarawak, Universiti Malaysia Sarawak (UNIMAS) is actively involved in research related to crocodiles. Among them are: (i) assessing the genetic diversity and population structure of crocodiles using multiple molecular markers, and (ii) ecological studies on crocodiles. These scientific findings are hoped to help relevant agencies to further formulate sustainable management strategies for this valuable resource as well as help in dealing with the increasing human-crocodiles conflicts in Sarawak.

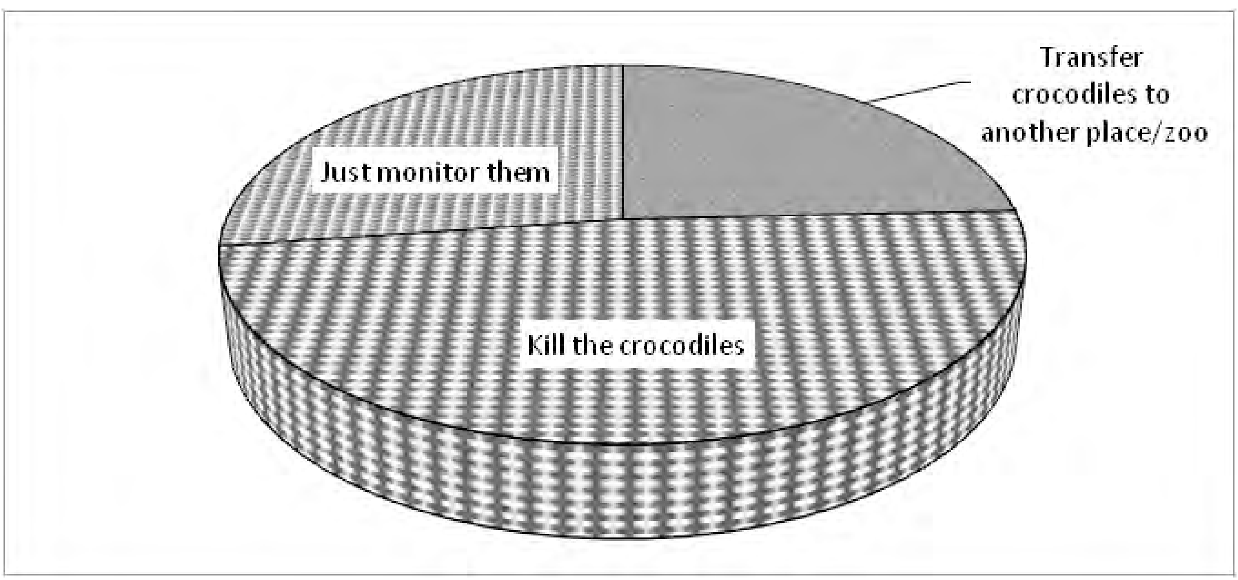

Figure 3: For human-crocodile conflicts, respondents suggested aggressive crocodiles to undergo systematic culling exercise, re-location and a more soft approach of continuous monitoring program by relevant agencies.

Conclusion

During 2011 census survey, mean relative density of 1.8, 1.04 and 0.53 non-hatchling/km were recorded for Bako River, Sibu Laut River and Batang Samarahan, respectively. Compared to previous data available, density of crocodiles in these rivers is showing decreasing trend. However, this data is considered as preliminary data, more surveys in these rivers as well as other rivers are needed to shed lights on the overall picture of density and population of crocodile in Sarawak. Pilot survey on socio-economic of local people living along the rivers revealed that (i) rivers are used heavily on daily basis, (ii) human and crocodiles continue to live in harmony, and (iii) awareness on current crocodile issues is high, but they are very concerned on the safety issues especially for their children.

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Crocodile attacks in Sarawak

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In Sarawak human and crocodiles have shared the same environment for many millenniums, and for most parts have coexisted peacefully. Relatively, few humans fell victim to the predators in the past but of lately the number of crocodile attacks have increased dramatically. Statistic has shown that a total of 118 attacks have taken place since 1941 until end of March 2013 where 64 of it were fatal while another 54 cases were reported to have caused various degrees of injuries ranging from just minor scratches to a level that have caused the victims to be bed-ridden for life. The above figure has given an average of 1.66 attacks occurring per year with a rate of 0.90 victims were killed annually by the predators. Two more attacks were just occurred in early April, 2013 where a body of one of the victims is yet to be found to this date. The increase in crocodile attacks of lately, was due to drastic increase in the population of estuarine crocodiles throughout Sarawak. Rivers that have never been inhabited by crocodiles in the past 30 years have now been infested by the man-eaters even up to its upper reaches not affected by daily tidal cycles. The enforcement of the Wild Life Protection Ordinance, 1998 is thought to be one of major factors contributing to the increase of the species. The clearings of vegetations along river banks are another factor as it promotes growth of grassy vegetations favorable for the crocodile nesting sites. Apart from various awareness programs on the species among local communities culling of dangerous individual crocodiles are part of the ongoing management program for the species in Sarawak, and some public places such as beaches have been declared as Crocodile-Free Zones.

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Assessment of saltwater crocodile (*Crocodylus porosus*) attacks in Australia (1971-2013): implications for management

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Abstract

When Saltwater Crocodiles (*Crocodylus porosus*) were protected in Australia (1969-1974) after some 25 years of unregulated hunting, the population had been reduced to less than 5% of its former abundance and comprised mainly young (small) crocodiles. In the Northern Territory (NT), which holds the majority of the Australian population of Saltwater crocodiles, the population is considered to have recovered to pristine levels of abundance, but the average size of crocodile continues to increase. The frequency of crocodile attacks (102 since 1971) is increasing over time. Here, we analyse crocodile attack data and assess future management of Saltwater crocodiles in the NT within the context of reducing human-crocodile conflict, without jeopardizing conservation goals.

Introduction

Saltwater Crocodiles (*Crocodylus porosus*) are distributed within three States/Territories in Australia: Northern Territory (NT), Western Australia (WA) and Queensland (QLD). Human-Crocodile Conflict (HCC) has no doubt been occurring since the arrival of Aboriginal people some 40,000 years ago. However, reliable and comprehensive data on attacks have only been available since the species was protected after some 25 years of unregulated hunting (WA 1969; NT 1971; QLD 1974). The last Australia-wide review of crocodile attacks assessed the available data up to 2004 (Caldicott *et al.* 2004); here we analyse data up to mid-2013, and include some additional information for the period 1855-1971.

Methods

Information on attacks by Saltwater Crocodiles was obtained from various sources, including newspaper reports, journals and other publications (general literature, books, etc.). WMI has maintained a detailed database on attacks since 1971, derived from similar sources, and including victim accounts and Government reports. Attacks on people working with crocodiles in the wild (eg researchers, crocodile farmers, crocodile hunters, wildlife rangers) were excluded from the analysis, and only attacks resulting in injury or death of the victim were considered to be "attacks".

Results

Pre-1946

Prior to 1946, Saltwater Crocodiles were mainly hunted for sport or as pests, although in the mid-1930s there was some interest in the commercial hunting for skins. The earliest report of a Saltwater Crocodile attack on a human in Australia was around 1855 (Victoria River, NT). At the time of writing, 214 *C. porosus* attacks were identified from the 1855-1945 period. This is considered an underestimate of the real number of attacks, as details are scarce, many historical attacks on indigenous people are known only from oral history, and the review of historical sources is ongoing.

A high proportion (39%) of the attacks involved indigenous people (Table 1).That most (69.2%) attacks occurred in QLD (Table 1) is considered to reflect the larger human population there relative to the sparsely populated Top End of the NT and WA at the time, although lack of reporting may also be implicated. Attacks were biased towards males (86.0% of victims; N= 207), and a most (61.7%) were fatal (Table 1).

1946-1970

Between 1946 and 1971/74, commercial unregulated hunting of Saltwater Crocodiles took place in northern Australia. The peak in hunting occurred in the first 10 years after 1945 (Webb *et al.* 1984), and a lack of Saltwater Crocodile skins in the late 1950s and early 1960s led to hunting of the less valuable Australian Freshwater Crocodile [*C. johnstoni*; protected in 1962 (WA), 1964 (NT) and 1974 (QLD)]. By the time of protection the Australian Saltwater Crocodile population had been greatly reduced. In the NT, it had been reduced to <5% of its historical abundance and <1% of its historical biomass (Fig. 1). This trend is also considered to reflect the situation in WA and QLD, except that the levels of recovery in those States is not the same as the NT, where the population is considered to have reached pre-1946 abundance, but biomass (and mean size of crocodile) continues to increase (Fukuda *et al.* 2011).

Only 18 attacks were identified in the 1946-70 period (NT 8, QLD 6, WA 4). Details for 5 attacks could not be confirmed or assigned to a year, and so could not be assigned to either the pre-1946 or 1946-71 periods. Nonetheless, the frequency of attacks during 1946-71 (0.7/y) was significantly lower than that prior to 1946 (2.4/y), which reflects the greatly reduced *C. porosus* populations (Fig. 1), increased wariness of crocodiles towards humans, and improved modes of transport and road infrastructure during the hunting period. Most attacks (72%) involved indigenous people (Table 1) and males (77.3%).

Table 1. Saltwater Crocodile attacks in northern Australia, 1855-June 2013 (information sourced mainly from newspaper reports, as well as journals and other publications). Details for 5 "attacks", including year, could not be confirmed, and they are not included here (Biddell and Stringer 1988).

State/Territory	Fatal	Non-Fatal	Total	% Fatal	Indigenous (%)
1855-1945 (90 years)	**132**	**82**	**214**	**61.7%**	**84 (39%)**
Western Australia	9	9	18	50.0%	6 (33%)
Northern Territory	39	19	58	67.2%	32 (55%)
Queensland	94	54	148	63.5%	46 (31%)
1946-1970 (25 years)	**6**	**13**	**19**	**31.6%**	**13 (74%)**
Western Australia	4	0	4	100.0%	3 (75%)
Northern Territory	2	7	9	12.5%	7 (78%)
Queensland	0	6	6	0.0%	4 (67%)
1971-June 2013 (42.5 years)	**29**	**73**	**102**	**28.4%**	**35 (34%)**
Western Australia	2	11	13	15.4%	2 (15%)
Northern Territory	18	45	63	28.6%	27 (43%)
Queensland	9	17	26	34.6%	6 (23%)

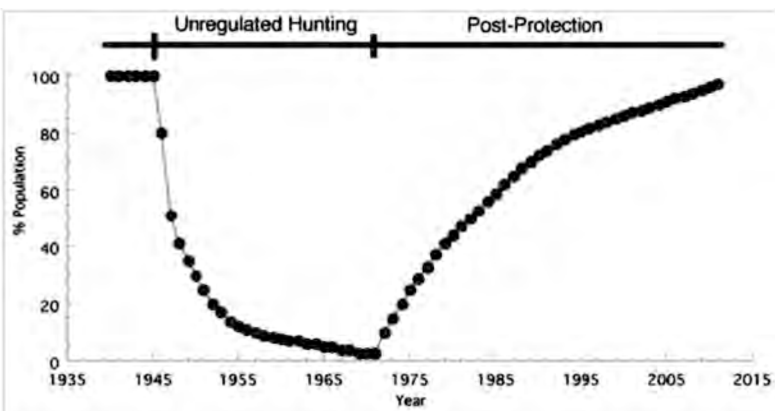

Figure 1. Estimated population trends for Saltwater Crocodiles in the NT following unregulated hunting (1946-70) and protection (1971 onwards).

1971-2013

Since protection in the NT (1971), more detailed information has been available on crocodile attacks in Australia. Since 1971 there have been 102 *C. porosus* attacks, most of which occurred in the NT (62%); QLD accounted for 25% and WA for 13%) (Table 1). Ninety-eight attacks involved one person being injured or killed, and four attacks involved two people being killed/injured - a total of 106 victims.

1. Reason for Attacks

For the 102 attacks occurring between 1971 and June 2013, the primary motivation behind the attacks by crocodiles was considered to be:

a. Nest defence: Two attacks involved adult female Saltwater Crocodiles at/near their nest site: one non-fatal attack occurred when a hunter accidently entered a nesting site, and a fatal was considered to be a case of nest defence.

b. **Mistaken Identity/Self Defence**: Eight attacks were considered to be a case of self defence or mistaken identity by relatively small crocodiles. Two of these attacks involved crocodiles (1.5-1.8 m TL) that had escaped from farms - the behaviour of these animals may have reflected time in captivity.

c. **Food/Territoriality**: Most of the remaining 92 attacks are considered to be cases of crocodiles preying on humans for food. However, territoriality cannot be ruled out as the motivation in some cases, particularly where the size of the victim was much greater than the size of the crocodile.

Notwithstanding the lack of details for many attacks prior to 1971 (Table 1), one attack was definitely a case of nest defence, but most appear to have been cases of crocodiles seeking food.

2. Fatality Rate

Around one-third (28.4%) of Saltwater Crocodile attacks in Australia since 1971 have been fatal (Table 1), and at least four the non-fatal attacks are likely to have resulted in death of the victim had it not been for the assistance of other people at the scene. Despite the relatively small number of attacks between 1946 and 1971, fatality rate (31.6%) was similar to that in post-1971 period. The assessment of pre-1946 records indicated a higher fatality rate (61.7%), which may reflect the degree of reporting of attacks that resulted in minor injuries, but it may also be indicative of the size structure of the *C. porosus* population at that time, which is considered to have been strongly biased towards large individuals.

The current (post-1970) fatality rate is similar to that reported for *C. porosus* in Sri Lanka (23.7%; De Silva 2010), but lower than that reported for Malaysian Borneo (43.7-61%; Tisen *et al.* 2011; Ambu 2011) and India (45.5%; Gopi and Pandav 2009). Similar fatality rates were recorded for *C. acutus* in Costa Rica (27.5%; Barrantes 2010) and *C. palustris* in India (22.2-42.1%; Vyas 2010; Whitaker 2008). The relatively high fatality rate (63%) for *C. niloticus* on mainland Africa (Fergusson 2004) is probably overestimated, as many non-fatal attacks in remote rural areas go unreported. This is also likely to be the case in specific countries where data are available [eg Madagascar 40.7% (Behra 1996); Zambia 67.8% (Wallace 2011)]. In comparison, only 7.6% of unprovoked American Alligator (*Alligator mississippiensis*) attacks in the USA have been fatal (Conover and Dubow 1997; A. Woodward, pers. comm.), which almost certainly reflects the smaller size and more docile nature of this crocodilian species.

3. Alcohol

Using only 75 cases where adults (>18 y; minimum age for legal alcohol consumption) were attacked since 1971, 21% of attacks are known to have involved the consumption of alcohol by the victim around the time of the attack. This rate is much higher for the 22 fatal attacks (45.5%) and lower for the 53 non-fatal attacks (11.3%). Alcohol is considered to affect the behaviour of victims, in particularly risk taking, and increases the probability of attacks.

4. Age and Sex of Victims

The majority of people attacked since 1971 were males (74.5%). Mean age of victims was 33.7 years for males (N= 69, SD= 15.01, range 5 to 75 y), 25.6 years for females (N= 23, SD= 17.09, range 5 to 60 y), and 32.0 years overall (N= 92, SD= 15.86, range 5 to 75 y).

5. Biases toward Indigenous People

A disproportionate number (34.3%; Table 1) of attacks since 1971 involved indigenous people. In the NT, at least 27 of the 63 attacks involved people of Aboriginal descent: 42.9% of all attacks; 50.0% of fatal attacks; and, 40.0% of non-fatal attacks. This bias cannot be explained by demographics alone (around 28-29% of the NT Top End population are indigenous), but it can be explained by traditional lifestyles involving hunting, fishing and gathering, and the disproportionate number of indigenous people who live in remote, traditional homelands: around 60% of Saltwater Crocodile habitat in the NT is on indigenous lands.

6. Residents versus Tourists/Visitors

Since 1971, a high proportion of Saltwater Crocodile attacks in the NT (92.1%; N= 63) and QLD (87.0%; N= 23) have involved "locals" - long-time residents aware of the risks associated with crocodiles. In contrast, in WA locals made up the minority of attacks (36.4%; N= 11). At least two of the attacks on visitors could have been avoided if normal precautions had been taken.

7. Size of Crocodiles Involved in Attacks

The smallest wild Saltwater Crocodile reportedly involved in an attack was estimated to be 0.8 m long, and the largest was 5.1 m (mean= 3.2 m, N= 87, SD= 1.03; Fig. 2). The average total length (TL) of crocodile involved in fatal attacks was 4.2 m (N= 25, SD= 0.82, range 2.1 to 5.1 m), and for non-fatal attacks it was 2.8 m (N= 62, SD= 0.83, range 0.8 to 4.5 m). There is no doubt that the majority of fatal attacks are disproportionately caused by large male crocodiles (>4 m TL) (Fig. 2), that throughout the period of assessment (1971-June 2013) have comprised an increasing proportion of the total population of crocodiles (see Fukuda *et al.* 2011).

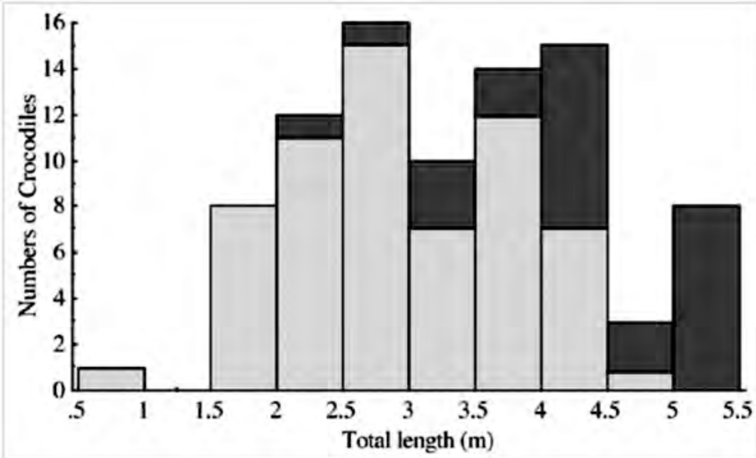

Figure 2. Size distribution of 87 Saltwater Crocodiles involved in attacks, 1971-June 2013). light = non-fatal; dark = fatal.

8. Probability of Surviving a Crocodile Attack by Different Sized Crocodiles

The bodyweight of a crocodile increases exponentially with increasing length, hence longer and heavier crocodiles are more able to attack and overpower humans than smaller ones. The probability of a crocodile attack being fatal increases markedly as size increases (Fig. 3). Indeed, all known attacks by crocodiles over 4.5 m in length across Australia have resulted in the death of the victim.

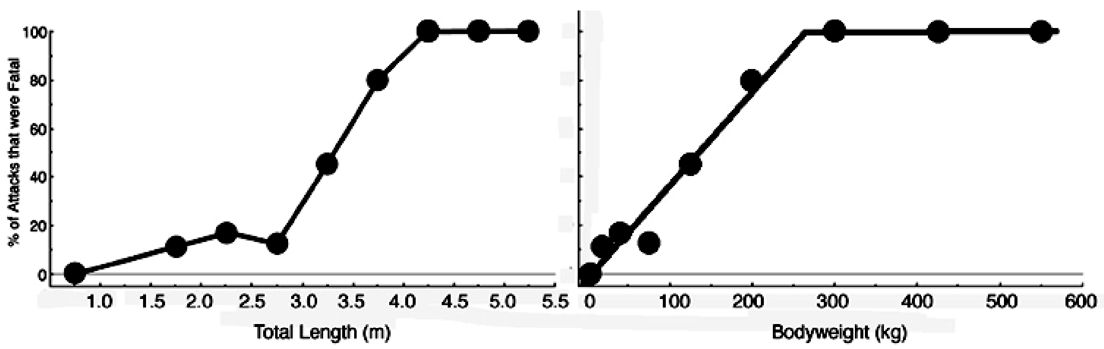

Figure 3. Proportion of Saltwater Crocodile attacks (Australia) as a function of: (left) actual/estimated total length of crocodile (in 0.5 m categories; 1.0-1.49, 1.50-1.99, etc.) and (right)estimated bodyweight of crocodile [mean derived from 0.5 m TL categories; the linear regression relationship between 0 and 300 kg was significant (r^2= 0.96, p = 0.0001)]. Seven attacks where victims received assistance were excluded.

9. Day or Night?

Most attacks by Saltwater Crocodiles have occurred during the day (all attacks 78.0%, fatal 81.4%, non-fatal 70.0%). However, this reflects the timing of activities by victims, rather than any specific preference by crocodiles. We strongly suspect that the rate of attacks would be higher during the night if the same activities were undertaken at the same frequency.

10. Effects of Season on Probability of Attack

Attacks have taken place in every month (Fig. 3), but the majority [92.4% for pre-1971 (N= 119); 85.3% for 1971-2013 (N= 102)] have occurred in the warmer months of the year (August-April), which encompasses the late dry season and wet season. Although this period is correlated with the annual courtship and breeding season (October-April), when crocodiles are thought to be more active generally, there is no real evidence that reproduction is involved. A far more plausible explanation is that the physiological maintenance costs of crocodiles increase exponentially with increasing body temperature. So when the cooler conditions of winter pass by, and water temperatures start to increase, the amount of food required to sustain a crocodile during the warmer months is much, much greater than that in the cooler months. Hence they need to consume much more food to maintain body condition when it is warmer. Recent experiments indicated that of 10 kg of food fed to captive crocodiles in warmer months, 6-7 kg were used for maintenance alone (WMI, unpublished).

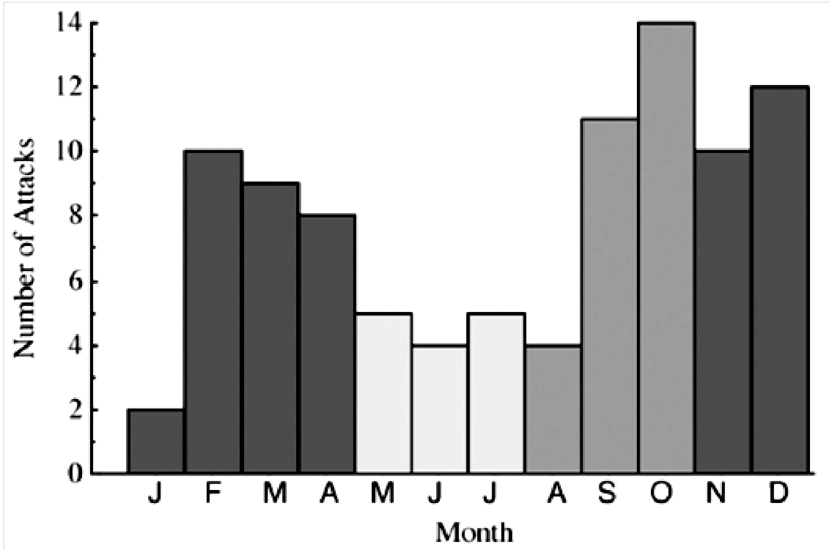

Figure 4. Saltwater Crocodile attacks in each month, 1971-June 2013. November-April= hot, wet; May-July= cool, dry; August-October= hot, dry (see Table 3).

11. Effects of Season on Frequency of Attacks

Three broad seasons can be recognised in the Top End of the NT: cool-dry (May-July); hot-dry (August-October); and, hot-wet (November-April) (Webb 1991). The frequency of attacks in Australia was highest in the hot-dry and hot-wet periods of the year (9.7/mth and 9.3/mth respectively), and lowest in the cool-dry (5.0/mth). Access to many areas is constrained during the wet season (hot-wet), when wetlands are greatly expanded. The cool-dry season encompasses the peak period of tourist visitation in northern Australia.

12. Location of Victims at Time of Attack

Not surprising, the majority (86%) of *C. porosus* attacks have occurred whilst people have been in the water (eg swimming, wading, snorkelling, scuba-diving) or on land at the water's edge (Table 2). That five attacks have occurred on land confirms that large crocodiles will leave the water in search of prey.

Table 2. Location/activity of victims during attacks in Australia (1971-June 2013).

Location (% of all attacks)	Non-Fatal	Fatal	All
Water (86.0%)			
Swimming	18	17	35
In shallow water (eg wading)	20	5	25
Shallow water (getting into boat)	2	-	2
Shallow water/water's edge	-	2	2
Snorkelling, scuba-diving	8	4	12
At water's edge (on bank)	12	-	12
Subtotals	***60***	***28***	***88***
	(82.2%)	(96.6%)	(86.3%)
Boats/Canoes (9.0%)			
In canoe	1	1	2
In boat	7	-	7
Subtotals	***8***	***1***	***9***
	(11.0%)	(3.4%)	(8.8%)
Land (5.0%)			
Asleep in tent near water	2	-	2
Asleep near water	1	-	1
Asleep on beach	1	-	1
Near crocodile nest	1	-	1
Subtotals	**5**	**-**	**5**
	(6.9%)	(0%)	(4.9%)
All	**73**	**29**	**102**

13. Activity of Victims at Time of Attack

Most (90.2%) attacks occurred while people were involved in recreational activities, including fishing and hunting. People working (non-crocodile related; eg commercial divers, researchers) at the time of the attack accounted for 7.8% of attacks, and unknown/miscellaneous attacks (eg escaping from Police) for 2.0%.

14. Canoes

Eight cases of attacks on occupants of canoes prior to 1971 were located, and all involved indigenous people. Since 1971, two attacks have involved people in canoes; a fatal attack in QLD (Normanby River, 2005) considered to have been motivated by feeding, and a non-fatal attack in the NT (East Alligator River, 1985) that may have been territorial/nest defence. These statistics do not reflect attacks that have been directed at canoes by Saltwater Crocodiles, but which have not resulted in injury to the occupants.

It is unclear why crocodiles attack canoes, but the long thin shape may appear like another crocodile, particularly from underwater, and result in behaviour associated with territoriality. Against this, people in canoes are commonly taken by Saltwater Crocodiles in Sarawak and Sabah (Malaysia), and these attacks appear to be crocodiles preying on humans for food.

15. People in Boats

Prior to 1971, 5 attacks directed at people in boats, and which led to injury/death, were identified. A further three cases did not result in injury to the boat occupants.

Since 1971, there have been 7 attacks directed at people on boats. Four of these occurred in the NT; two attacks involved relatively small crocodiles (1.8 and 2.0 m TL) and two attacks involved large (4.0 and 4.5 m TL) crocodiles, and attacks occurred during the day (N= 2) and night (N= 2). In WA, three similar attacks directed at occupants of boats involved 2.0, 2.5 and 3.0 m long crocodiles; all attacks occurred during the day.

Considering the number of boats involved in recreational activities in northern Australian rivers over the last four decades, there have been very few directed attacks on people in boats.

16. Boats

Three cases of crocodiles trying to climb into boats, attracted by dead fish (1930s) or dead crocodiles (1951) in the boats were reported. The reasons for another crocodile climbing onto a ferry (1952) were unclear.

Some cases of Saltwater Crocodiles directing attacks at boats and/or outboard motors merit particular mention:

a. "Sweetheart", a 5.1 m *C. porosus*, made numerous attacks on the propellers of outboard motors in the Finniss River in 1978-79 (Stringer and Jakku 1986). Attacks were not directed at boat occupants. The propellers may have sounded like another large crocodile, and elicited a behavioural response from "Sweetheart" (Webb and Manolis 1989).

b. In 1984 a 5.1 m long *C. porosus* attacked the outboard motor cowlings of a number of boats in the Wildman River, when the boats were tied up at the water's edge, suggesting the crocodile was "attracted" to the warmth of the motors. At night the outboard cowlings may have been mistaken for the warm head of a large mammal at the water's edge (Webb and Manolis 1989).

c. In 2012, 6 attacks on boats by *C. porosus* occurred in the South Alligator River (5) and Wildman River (1) in Kakadu National Park [Jan, Mar (2), Sep, Oct (2)], all of which occurred at night (G. Lindner, pers. comm.). Occupants were woken by crocodiles attacking the outboard motors (N= 5; 2.0, 3.5, 3.5, 4.0 and 4.0-4.5 m long crocodiles) or the boat hull (N= 1; crocodile size unknown, but large judging by puncture marks in the hull).

With respect to the attacks on boats in 2012, park staff reported a changing trend with respect to fishing activities, with more and more fishermen now fishing at night, and sleeping in their boats overnight. Although not permitted, these activities are difficult to enforce. In all 6 cases, none of the boats had peripheral lighting, which is considered to contribute to safety at night, by illuminating the boat and allowing a better view of the surrounding water (G. Lindner, pers. comm.). Interestingly, a 1934 newspaper article referred to Aboriginals maintaining fires throughout the night to "ward off crocodiles" (Thompson 1934). In areas close to Darwin (eg Adelaide, Mary), fishermen are more likely to undertake day trips, and few fishing boats tend to remain on the river at night.

There is no evidence to suggest that there is a general change in crocodile behaviour towards boats. In areas where tours involve crocodile viewing and feeding (eg Adelaide River), crocodiles respond to the large tour boats, and will generally not approach other boats closely (Lyons 1999).

17. Trends in Attacks over Time

No attacks on people were recorded in the NT in the first 8 years of protection (1971-1978), but the number of attacks has increased significantly between 1979 and 2012 (linear regression; r^2= 0.26, p= 0.002). This trend is largely due to a significant increase in the number of non-fatal attacks over time (r^2= 0.14, p= 0.027); the relationship between numbers of fatal attacks and time was not significant (r^2= 0.08, p= 0.11). Given the high variability in these trends, data within 5- and 10-year periods were lumped (eg 1971-75, 1976-80, etc.) to provide more realistic representation of trends (Fig. 5).

On this basis, the average frequency of non-fatal attacks in the NT has increased from 0.0/y in 1971-80 to 1.8/y in 2001-12, for fatal attacks it has increased from 0.2/y in 1971-80 to 0.8/y in 2001-12, and for all attacks it has increased from 0.2/y in 1971-80 to 2.6/y in 2001-12. These data are depicted on Figure 5

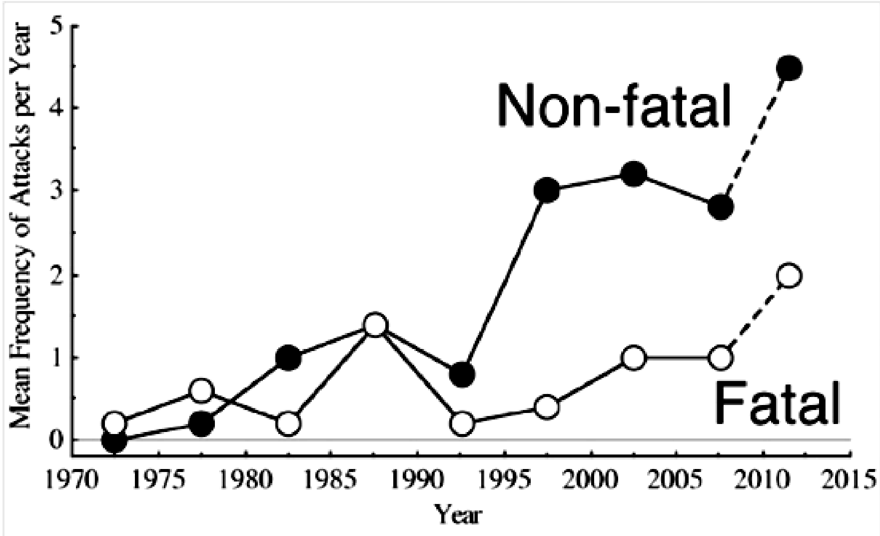

Figure 5. Frequency of Saltwater Crocodile attacks in 5-year periods (1971-2012). Data for 2011-2015 are restricted to two years (2011 and 2012; two attacks in 2013 are not included).

Discussion

The NT's ability to recover its *C. porosus* population back to the level of historical abundance is largely due to the creation of incentives to ensure that crocodiles have a positive value in the eyes of landowners and the public. Nonetheless, the increasing frequency of attacks by *C. porosus* in recent years has resulted in "calls" from the public to reduce HCC, perhaps through widespread culling.

The analysis of attacks since 1971 confirms that public education remains a critical element of management. That the majority of *C. porosus* attacks in Australia have involved locals indicates that public education programs may need to focus more on this segment of the population. That a high proportion of attacks have involved indigenous people also suggests that particular attention needs to be paid to this sector, perhaps delivered in a more culturally appropriate manner. Although traditional indigenous knowledge is important (eg where it is "safe" to swim), few indigenous people today have lived through periods of high crocodile abundance, as is the case now.

Crocodile farms in the NT rely mainly on the ranching of Saltwater Crocodile eggs, and indigenous landowners derive financial benefits through involvement in this program. In the mid-1990s, the CITES Appendix-II listing of Saltwater Crocodiles in Australia was changed from the purposes "ranching" to an "unqualified" listing. This now allowed other forms of use, such as wild harvest, to be implemented. Wild harvesting in WA was undertaken in the 1990s to provide stock for crocodile farms, and data on the impact of sub-adult/adult harvesting were generated (WMI, pers. comm.). In the NT, a trial wild harvest of adult Saltwater Crocodiles in the late 1990s was not extended into a formal program, and remains an option for future management, particularly for landowners who have limited/no nesting habitat and who are thus unable to participate in the egg ranching program. The Australian Government has previously rejected trophy hunting of Saltwater Crocodiles in the NT, although it is now considering an application from the NT which would allow a trial trophy hunting program, involving a low number of animals, to be undertaken. The proposed harvest of trophy animals is well within sustainable limits (<0.03% of the non-hatchling population), and is consistent with IUCN initiatives on trophy hunting (IUCN 2012).

Tourism is one of the main industries for northern Australia, and the ability to see crocodiles in the wild is a expectation for many visitors. Problem crocodile programs in each State/Territory deal with animals that pose a threat to humans or livestock, and some areas are maintained as crocodile-free as possible (eg Darwin Harbour), and in some cases allow for recreational purposes.

The frequency of attacks was lowest during the 1950s and 1960s, when the wild Saltwater Crocodile populations were greatly reduced due to hunting. With recovery of the populations since protection, the frequency of attacks has increased. The increasing movement of Saltwater Crocodiles into upstream freshwater areas, which are often used for recreation, is now a key management issue being addressed in the NT. The use of barriers to prevent entry of crocodiles into swimming areas, and the application of new methods to capture crocodiles being they reach such areas, are options currently under consideration. The use of Crocodile Exclusion Enclosures (CEEs) as used in Sri Lanka and India (see www.iucncsg.org/pages/ Human%252dCrocodile-Conflict.html) also merit consideration.

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Crocodile human conflict in National Chambal Sanctuary, India

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Abstract

In the National Chambal Sanctuary in India human crocodile conflict does not in itself appear to be a major problem with *Gavialis gangeticus*, but the mugger crocodile *Crocodylus palustris* is considered a threat to man because the wild populations are increasing in the Chambal River and there are cases of mugger attacking human and their livestock.. The degree to which *C. palustris* can and will attack people is largely a matter of theoretical discussion, but the recent increase in their population due to crocodile conservation and management programmes in the sanctuary, it is hard to accept that they would not pose a problem to people in the Chambal area where people were exposed to crocodiles, by using the river for washing, drinking water extraction, swimming and cattle use. Such conflicts are also highlighted by the media, it is likely that the public do fear crocodile attacks and that these fears may turn out to be serious impediments to reintroducing *G. gangeticus* into the Chambal River and other water bodies in neighbouring protected areas. Though local people receive compensation from the Government for every case of crocodile attacks they are more reluctant to agree for reintroduction of crocodiles as they feel that crocodile conservation programme is against human poverty alleviation programme. A study conducted in the Chambal River indicated that major crocodile habitats are under severe pressure due to increase in human activities, Locals use crocodile habitats for water extraction for drinking, irrigation including riverside agriculture, sand mining, and livestock grazing and washing. Due to lack of education and awareness about crocodile behavior and the basic purpose of Government run crocodile conservation programmes the locals are against the crocodile reintroduction programme. In this paper mitigation strategies to be adopted to reduce Human Crocodile Conflict are discussed.

Introduction

Conflicts between humans and animals are a serious problem in many parts of the world. The damage and destruction caused by a variety of animals to human property-and sometimes to human life-is a real and significant danger to many human communities and with the animals often killed, captured, or otherwise harmed in retaliation, these conflicts are one of the main threats to the continued survival of many species. Crocodile attacks on people are common in places where large crocodiles are native and human populations live. Only six of the 23 crocodilian species are considered dangerous to adult humans and only individuals 2 meters (6.6 ft) in length or more represent a serious danger to humans, as smaller crocodiles are considered incapable of killing a person. Frequent encounters with humans and their livestock have caused human-crocodile conflicts which result in retaliation killings (Deutsch and Coleman, 2000). Human-crocodile conflicts have been reported from different parts of the country (Whitaker, 2007, 2008), indicating possible increases in population and/or Mugger reaching larger sizes. Human-crocodile conflict studies have been carried out extensively in many parts of the world (Langley, 2005; Whitaker, 2007, 2008; Aust, 2009; Dunham *et al*, 2010; Fergusson, 2010; Udgata, 2011; Mendis, 2012, Webb, 2012; Chomba *et. al*. 2012).

Crocodiles use the riverine ecosystem for their life propagation and also use the sand bank and marshlands for basking, egg-laying and hiding place. People use the river for various purposes including fishing, sand mining, drinking water collection, washing, extraction of water for irrigation, livestock use and also use the bank for agricultural purposes. The crocodiles have to compete for water, fish stock and bank availability with humans. There is also high rate of conflict due to entanglement and death in fishing nets.

Due to Crocodile Rehabilitation programme initiated during late 1970s under Indian Crocodile Project the populations of crocodiles have been increased. The increasing mugger populations pose a potential threat to human and their livestock living in villages along the banks of Chambal River. The present study has been undertaken to assess the mugger population in the study area, causes and occurrence of conflicts, people's mentality towards the animals and to suggest measures to avoid conflicts.

An assessment of human-crocodile conflict in National Chambal Sanctuary, Madhya Pradesh was carried out from March October, 2012 at regular intervals to collect data on crocodile population in the study site, socio-economic status of the adjoining villages and human-crocodile conflict**.** Primary data were collected through field surveys and secondary data were collected from Madhya Pradesh Forest Department. This study aimed at exploring the human-crocodile conflict in terms of livestock depredation, human casualties, retaliation killing, asses the habitat sharing of crocodiles, asses the anthropogenic pressure on the river ecosystem and determine the crocodile-human conflict to suggest mitigation measures.

Methods

Study area

The Chambal River in India has the single largest contiguous population of gharial reportedly between 48% and 85% of the global population. The gharial is threatened by riverbank land-use changes, reduction in river flows, modification of river morphology, loss of nesting and basking sites, increased mortality in fishing nets and egg-collection for consumption.Few crocodiles reach maturity. Eggs drown sometimes as nests are submerged during wet season flooding and small crocodiles are eaten by jackal, mongoose, goannas, birds, fish, other crocodiles. Anthropogenic processes have physically, chemically and biologically modified India's great river ecosystems. Major part of the Chambal River has been declared as Wildlife Sanctuary during 1978 (Fig. 1). The sanctuary is protected under India's Wildlife Protection Act of (1972). Parts of the sanctuary are threatened by extensive illegal sand mining, which is endangering the fragile lotic ecosystem critical for Gharial breeding. *National Tri-State Chambal Sanctuary Management and Coordination Committee* have been formed for the management of NCS.

The present study was conducted in the National Chambal Sanctuary, Madhya Pradesh in an area of around 50 km from village Bilpur/Kuthiyana to Nayapura (Pinahatghat). Geographically, the study site lies between latitude 26°40'N - 26°51'N and longitude 78°5'E - 78°22'E (Fig. 2). There are about 15 villages along the river bank in the study area. The 15 villages selected in the present study have a population of about 6400, with overall male female ratio of 1.07. The literacy rate of the selected villages as per the census 2011 is 49.6. The average temperature of 36^0C was recorded in the study area. The minimum temperature was 15.8^0C in the month of March, however, the maximum temperature was 42.2^0c in the month of May.

The field surveys were carried out during MarchOctober 2012. For the collection of primary data regular site visits were made. The field surveys were classified into two sections, river survey and questionnaire survey for the villages.Secondary data on human-crocodile conflict was collected from records available in the Forest Department. Literature survey was also carried out by consulting different journals, newspapers, and unpublished thesis/dissertations and other study material from the libraries.

Results and Discussion

National Chambal Sanctuary is at the borders of three districts, Sheopur, Morena and Bhind in the state of Madhya Pradesh in North India. In this part of the National Chambal Sanctuary two species of crocodiles *Gavialis gangeticus* (gharial) and *Crocodylus palustris* (mugger) are present (Fig. 3). Most of the crocodiles that are present in the study area were adults and only a few among them were juvenile. 14 gharial and 19 mugger sub adults were also seen in the study area (Table 1).

Table 1. Data on occurrence of crocodiles in the study area

Category of crocodiles	No. of crocodiles			
	Gharial	%	Mugger	%
Adult	51	68.9	27	43.6
Sub Adult	14	18.9	19	30.7
Juvenile	9	12.2	16	25.7
Total	**74**	**100**	**62**	

In the 50 km River stretch, there are only 8 important basking areas of crocodiles at Kuthiyana, Babusingh ke gher, Kisrouli, Daljeet ka pura, Barsala, Sukhdhyan ka pura, Holapura and Usedghat.In the 50 km River stretch, there are 6 important nesting areas of crocodiles in the study area like Babusingh ki gher, Kisrouli, Daljeet ka pura, Barsala, Sukhdhyan ka pura and Holapura. Approximately 2 km of sand bank on small stretches are used by the Gharial for nesting.

The Gharial bask on the sand bank and mugger also use sand banks for basking, although they prefer hard soil and rocks for basking for long hours. Both crocodiles nest on sand banks at many sites. They use sand banks throughout the sanctuary wherever suitable habitats are available. Sand mining is one of the major human activities in the NCS. Sand is continually extracted in the important nesting and basking site, this is reducing the space of nesting and basking habitat and drastically changing the population trends in aquatic biodiversity.

Conservation of aquatic biodiversity in the National Chambal Sanctuary is major subject of research since 1983 (Singh, 1985; Rao, 1989; Sharma, 1991; Hussain, 2009). There are direct conflicts like injury and death of human and indirect conflicts like crocodile destroying the fishing nets, damage to fish population, predate domestic livestock. The present study is mainly focused on the crocodile-human conflict in the National Chambal Sanctuary. Large numbers of people residing in the riverside villages are directly dependent on the Chambal River. They collect sand, grow agriculture along the river banks and collect fish from the river.

Although fishing is totally banned in the Chambal River to avoid incidental mortality of aquatic animal in the gills nets, occasional illegal fishing is continuing. There are many reports of crocodile and turtles mortalities by drawing in fishing nets. Two dolphins were recorded to be killed in the fishing nets and the fishermen extracted oil from the dolphins in April 1987. Because of the fishing activities in the Chambal River the animals are facing a lot of disturbance.

People use the river for various purposes including drinking water collection, cloth washing etc (Fig. 4). People also cross the river by means of a temporary bridge, cross the river using the boats and Camelsand also the river bank is used for burial of dead bodies and extraction of water for irrigation, livestock use etc. Most of the crocodiles that are present in the study area were adults and only a few among them were juvenile. 14 gharials and 19 sub adult mugger were also seen in the study area.

Although there are reports of human crocodile conflict in the National Chambal Sanctuary, the present studies revealed that in the study area human beings are not attacked by crocodiles but livestock is attacked by the mugger crocodiles (Table 2). In several villages it is reported that 5-6 accidents have been occurred during 2011-2012. Mostly buffaloes, cows, and goats have been attacked by the mugger crocodile when they visit the river for drinking purpose.

Table 2: Percentage of injury and death to live stock by mugger crocodile

Fatalities	Cows	Goats	Buffalos	Dogs	Total
Injury	2	-	1	-	3
Death	7	15	13	2	37
Total	9	15	14	2	40

It was found that most of the people who are the residents of the sampled villages were farmers followed by fishermen and labourers. Buffalos, goats, dogs and cows are the prime victim of the crocodile in the study area. It was found that timing has a direct relationship with accidents rate in the evening hours when people are mostly indoors, however, certain accidents have occurred early in the morning. It has been calculated that 37 casualties of animals viz, cows, goats, buffalos and dogs have occurs in the area due to the conflict with crocodiles and 2 cows and 1 buffalos have become injured during the study period. 29% of the people reported that they are negatively affected by the presence of crocodile and 54% told that they do not have any affect due to presence of crocodile in the area.

Residents living close to the victim of the sampling area believed that their children fear to go to river due to the presence of crocodiles. Grazing, bathing, fishing, drinking and watering have become different for the residents in the area. The opinion of the residents regarding the discomfort of people is listed below. It was found that most of the people are aware of the crocodile behavior in these villages and 80% of the people have seen crocodile once in their life and to escape from clutches of crocodiles and 75% people think to construct alternate source for drinking water, due to the presence of crocodiles and only 9% people prefer to go for fishing.

The information revealed that most of the people who were affected by human crocodile conflict received compensation amount of Rs 5000- 10,000 as a relief from Deori Range. In the Chambal River human activities are increasing slowly. In the past the local people collected and utilized the fish for themselves, but gradually people outside the Chambal region are collecting the fish and turtles for sale in different states particularly West Bengal. Wildlife habitats were considerably altered and there are disturbances along the river by wood collectors, poachers, farmers and sand miners. Such human activities have increased instances of human-crocodile conflict. There are many reports in the sanctuary regarding killing of cattle and human by mugger crocodile in the Chambal River. It is the responsibility of the wildlife managers and researchers to take suitable measures for controlling such human-crocodile conflict in the National Chambal Sanctuary. There is a need to take education and awareness programme to the local human population, which depends totally on the river.

For over four decades the crocodile population in the Northern Territory in Australia has been increasing, crocodile attacks have been occurring, and calls for culling have been raised (Webb, 2012). It is not a simple issue to culls the problem crocodiles. A refined public education programme ensures residents and visitors are well-informed about 'crocodile safety'. Due to the negligence of people, there has been a spike in the number of crocodile attacks on humans in recent years. The growing human toll, deaths and injuries, have had a far more detrimental consequence on the crocodiles, with the villagers being provoked into poisoning, trapping and killing the crocodiles (Mendis, 2012). Local people in Mozambique are poor and regularly venture into the crocodile areas for collecting fish and are sometimes being attacked by crocodiles. Against crocodile attacks the locals opportunistically killed crocodiles and destroyed their nests because of the danger they posed and the damage they caused to fishing nets. It is suggested that good land-use planning, a long-term solution to many conflicts, is particularly relevant in Mozambique, where crocodile populations of protected areas are often in rivers that boarder these areas, and cause conflicts outside them, and where people commonly live within protected areas. Poverty may prompt fishermen to risk crocodile attack by entering rivers or lakes.

In the Chambal River indigenous crocodiles are once again abundant due to conservation and management programmes. In addition human population in different riverside villages has been increased and they and their livestock depend heavily on the river. The recovery of crocodile population and increase in human population has resulted in substantial levels of human-crocodile conflict. Conflicts between humans and wild animals are as old as the co-existence between them. They occur in all continents only varying in typology and circumstances. When human-wildlife conflicts occur, negative media reporting often exacerbates negative perceptions of the general public towards those species which cause the most conflict such as the crocodile (Chomba, *et. al.* 2012). The increased and progression loss of natural habitats and biodiversity have probably exacerbated human-wildlife conflicts and may continue in future as communities continue to ignore the need to comply with the provisions of General Management Plans in regulating human settlements. The ignorance on the general behavior of crocodiles coupled with the inability to detect crocodiles in water aggravate the conflicts. According to Chomba *et. al.* (2012) crocodiles live very close to humans without being detected. This factor together with the inability to detect crocodiles by people may be responsible for high incidences of crocodile attacks on humans and livestock. Many crocodile attacks may additionally go unnoticed and unreported, since at times, human or livestock may be stealthily taken when a person is alone or livestock is not accompanied by a person.

The findings of this study indicate that major habitats of crocodiles are under pressure due to increase in human activities. The major threat at present is habitat loss due to human encroachment, and disruption of populations through fishing and other hunting activities. In the present study it is observed that due to Crocodile-human conflict relationships between local communities and wildlife authorities is not cordial. Locals consider that crocodile programmes in the Chambal River are major obstacles for poverty alleviation as they depend primarily on the river for livelihood and Government restricts use of resources for crocodile conservation.

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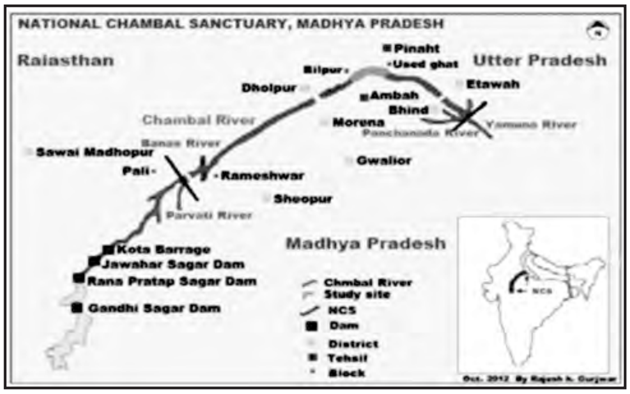

Fig.1. Map of National Chambal Sanctuary showing multipurpose dam on the upper stream, Tributaries and study sites in the present study.

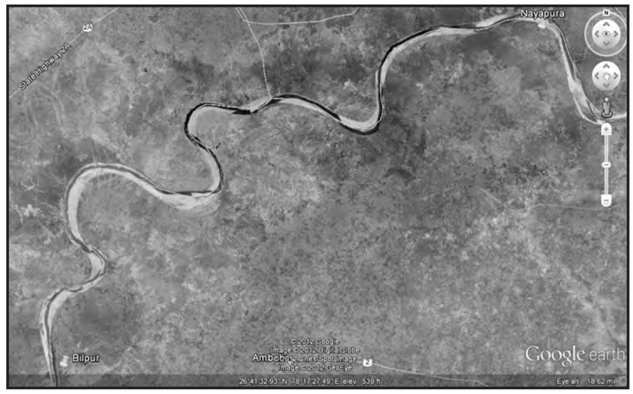

Fig. 2. Map of study area in the National Chambal Sanctuary

Fig. 3. Crocodiles (Gharial and mugger) basking in the Chambal River

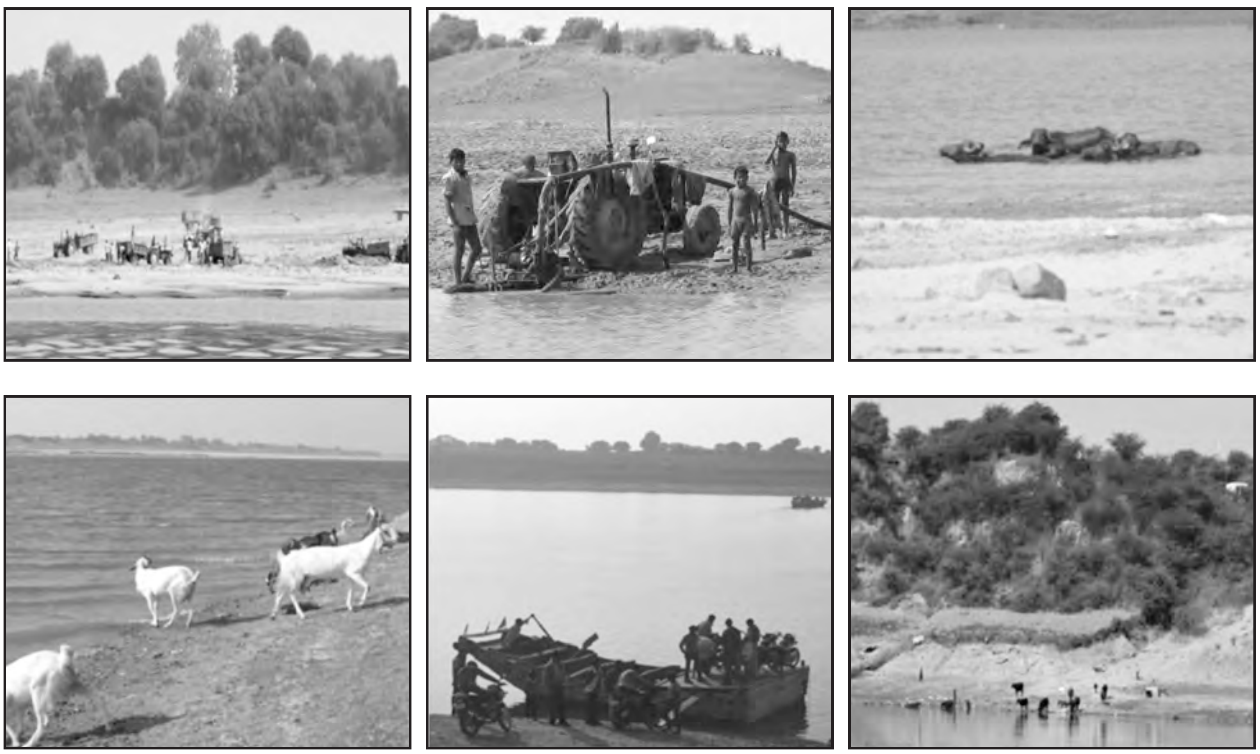

Fig. 4. Human activities (sand mining and water extraction) on the river banks

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An analysis of crocodilian attacks worldwide for the period of 2008 - July 2013

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Abstract

Attacks on humans by crocodilians have been documented reasonably well in developed countries in the last few decades. Conversely, attacks in developing countries are typically poorly documented despite those countries holding the highest frequencies of crocodilian attacks. Here we present the results of an analysis of 1237 crocodilian attacks resulting in 674 fatalities worldwide for the period of January 2008 through July 8th, 2013. Attacks were recorded from 15 crocodilian species and fatal attacks were recorded from 7 of those 15 crocodilian species. 494 attacks resulting in 285 fatalities were recorded for *Crocodylus porosus* (problem areas identified for the species include East Timor, Sumatra and East Kalimantan of Indonesia, Sarawak of Malaysia, Orissa of India, and coastal Sri Lanka), 428 attacks resulting in 309 fatalities for *C. niloticus*, 98 attacks resulting in 50 fatalities for *C. palustris* (mostly from India, particularly within Gujarat state), 69 attacks resulting in 13 fatalities for *C. acutus* (problem areas were the Pacific Coast of Mexico, Costa Rica and Panama), 36 attacks resulting in 9 fatalities for *Melanosuchus niger* (mostly from the Amazonas state of Brazil), 8 attacks resulting in 4 fatalities for *Tomistoma schlegelii*, 16 attacks resulting in 2 fatalities for *C. moreletii* (with the most severe cases coming from the Tamaulipas state of Mexico), 47 attacks resulting in no fatalities for *Alligator mississippiensis*, and 33 non-fatal attacks for 7 other species (*C. johnstoni*, *C. siamensis*, *C. mindorensis*, *C. intermedius*, *Caiman yacare*, *C. latirostris*, and *C. crocodilus*); in 8 attacks (2 of them fatal) the species responsible was undetermined (could have been either of two species present in the area). Issues encountered included a paucity of attack data being available from much the *C. niloticus* range and some of the *C. porosus* range (e.g. New Guinea, Solomon Islands), as well as information disappearing from online news archives over time resulting in a loss of records prior to when we began compiling the database. We began compiling our data in 2010, thus there is a slightly less amount of data available for 2008 and 2009 due to this loss of online reports. Attack data were compiled from a number of sources including online media reports, local wildlife officials, crocodilian experts, and relevant recent publications.

Species Reports

Crocodylus porosus

494 attacks resulting in 285 fatalities were attributed to *C. porosus* during the study period; *C. porosus* was responsible for 39.9% of all reported crocodilian attacks and 42.3% of all reported crocodilian fatalities. Indonesia was the location of the highest amount of conflict with 211 attacks resulting in 107 fatalities. Provinces with the highest numbers of attacks were East Kalimantan (35 attacks, 22 fatal), South Sumatra (22 attacks, 16 fatal), Bangka-Belitung (26 attacks, 8 fatal), East Nusa Tenggara (22 attacks, 11 fatal), and Riau (16 attacks, 8 fatal). Other countries with a high level of *C. porosus* - human conflict were East Timor (31 attacks, 26 fatal), Malaysia (57 attacks, 32 fatal), India (54 attacks, 31 fatal), Papua New Guinea (50 attacks, 40 fatal), and Sri Lanka (21 attacks, 12 fatal); it is important to note that in some areas (particularly the entire island of New Guinea) data regarding attacks is very limited and thus the number of attacks reported is likely much lower than the number that have occurred. In Papua New Guinea the vast majority of our data has been provided by Dr. Valerie Archer of Kikori District Hospital in Gulf Province; according to Dr. Archer, attacks are just as frequent in the Western province (Fly River region) and likely other areas (such as the Sepik/Ramu River regions) but that no data were available from these regions. It also appears to be highly likely the attacks within the Solomon Islands are underrepresented in our database due to a lack of reporting to the media. Australia, although home to one of the largest existing *C. porosus* populations, has a fairly low fatality rate (29 attacks, 8 fatal; 27.6%) compared to the rest of the *C. porosus* range (59.6%); the reason for this is unknown, although it may be related to better access to medical care and perhaps the smaller size of the attacking crocodiles. We also cannot discount the possibility that the media is biased towards reporting fatal attacks, and thus many non-fatal attacks may go unreported within developing regions.

Crocodylus niloticus

428 attacks resulting in 309 fatalities were attributed to *C. niloticus* during the study period; *C. niloticus* was responsible for 34.6% of all reported crocodilian attacks and 45.8% of all reported crocodilian fatalities. Collecting attack data for *C. niloticus* is problematic since most attacks occur in areas with little or no reporting occurring; in areas like Malawi attacks frequently occur along Lake Malawi and the Shire River and they are very rarely reported (Bruce Carruthers *pers. comm.*). Getting an estimate for the number of people killed by *C. niloticus* every year is very difficult; we know that at the very least dozens of people are killed in Mozambique and Uganda every year and the situation could be similar in

other areas that have little reporting (such as Somalia, Ethiopia, Burundi, etc.). The small amount of data available suggests that the species is responsible for far more attacks on humans than all other species, but little else is known.

Crocodylus palustris

98 attacks resulting in 50 fatalities were attributed to *C. palustris* during the study period; *C. palustris* was responsible for 7.9% of all reported crocodilian attacks and 7.4% of all reported crocodilian fatalities. The majority of these attacks occurred within India (83 attacks, 43 fatal) followed by Sri Lanka (11 attacks, 4 fatal) and Nepal (4 attacks, 3 fatal); no attacks were reported from Iran or Pakistan. Problem areas within India included Gujarat state (particularly around Vadodara city) (21 attacks, 14 fatal), Uttar Pradesh state (16 attacks, 4 fatal), Karnataka state (7 attacks, 5 fatal), and Madhya Pradesh state (9 attacks, 4 fatal). It is unknown if more *C. palustris* attacks occurred in Nepal but went unreported to the media.

Crocodylus acutus

69 attacks resulting in 13 fatalities were attributed to *C. acutus* during the study period; this makes *C. acutus* responsible for the highest percent of reported attacks (46.6%) and fatalities (54.2%) within Latin America, but still a fairly low fatality rate (18.8%) compared with four of the Old World species. The highest number of *C. acutus* attacks were reported from Mexico (37 attacks, 2 fatal), Costa Rica (14 attacks, 5 fatal) and Panama (8 attacks, 3 fatal). Problem locations in Mexico include Jalisco state (particularly around Puerto Vallarta) (9 attacks, 1 fatal), Quintana Roo (particularly around Nichupte Lagoon in Cancun) (7 attacks, all non-fatal), and Oaxaca (4 attacks, 1 fatal). Although the site of the most fatal attacks, the frequency of attacks within Costa Rica has dropped significantly in recent years; 71.4% of attacks and all fatalities occurred between 2008 and 2010.

Crocodylus moreletii

16 attacks resulting in 2 fatalities were attributed to *C. moreletii* during the study period. Attacks for this species were reported from Mexico (11 attacks, 2 fatal), Guatemala (3 attacks, all non-fatal) and Belize (2 attacks, both non-fatal). The majority of the Mexican attacks (8 of the attacks and both fatalities) were reported from extreme southern Tamaulipas state (Altamira, Tampico and Madero City municipalities). The first fatal attack occurred in 2008 at Contadero Lagoon in Altamira; it involved a fisherman bleeding to death after being bitten in the leg. The second fatal attack also occurred in 2008, this time at Carpintero Lagoon in Tampico city; in this incident an intoxicated man was reportedly dragged into the lake by multiple crocodiles in front of a crowd of onlookers after attempting to "pet" one of them. His body was later recovered intact without any sign of consumption by the crocodiles.

Crocodylus johnstoni

Six attacks, all of them non-fatal, were attributed to *C. johnstoni* during the study period; four of the attacks were reported from Western Australia and two of the attacks from the Northern Territory. The first WA incident occurred in 2009 when a woman was attacked while swimming within the Throssel River (Hines and Skroblin 2010) and the second WA incident also occurred in 2009, this time at Lake Argyle which is known to have one of the largest *C. johnstoni* populations in existence; this incident involved a man swimming in the lake and was apparently unprovoked (Somaweera 2011). The third WA incident occurred in 2012 at Ivanhoe Crossing on the Ord River; a teenage boy was attacked while in waist-deep water, this incident was initially logged as a *C. porosus* attack, but it has since been confirmed to have been C. *johnstoni* (Ruchira Somaweera *pers. comm.*). The fourth and final WA incident occurred in 2013 at Slatey Creek Gorge; a woman was attacked by the crocodile while swimming within a waterhole. The first NT incident occurred in 2009 in an upstream portion of the Adelaide River populated by *C. johnstoni* (rather than *C. porosus*, which is abundant along much of the Adelaide River) (Charlie Manolis *pers. comm.*); only minor injuries were inflicted on the victim. The second NT incident occurred in 2012 along the Daly River, the female victim had been hunting for turtles and may have unintentionally provoked the crocodile; she sustained severe injuries to one of her hands during the attack, nearly resulting in the loss of one of her fingers.

Crocodylus siamensis

Two non-fatal attacks were attributed to *C. siamensis* during the study period and in both cases it appears as though the attacks were defensive in nature and may have involved provocation. The first incident took place within Cat Tien National Park of Vietnam in 2008; apparently a man had been illegally fishing within the park and was attacked by a crocodile that may have been defending her hatchlings (Heng Sovanarra *pers. comm.*). The second incident took place in 2012 at Lake Mesangat in East Kalimantan of Indonesian Borneo; in this incident a fisherman may have unintentionally provoked the crocodile into attacking him while attempting to retrieve a stuck fishing line from a log. Both *T. schlegelii* and *C. siamensis* are present within the waters of Lake Mesangat, but the crocodile responsible in this case is believed to have been *C. siamensis* (Agata Staniewicz *pers. comm.*).

Crocodylus mindorensis

Two attacks, both of them non-fatal, were attributed to *C. mindorensis* during the study period; both attacks occurred within the San Mariano municipality on the island of Luzon in 2010. The first incident involved a pregnant woman bathing at Dinang Creek in barangay Cadsalan; she sustained severe leg wounds during the attack but recovered. The second incident involved a man fishing within the Catalangan River of barangay Dibuluan; it is has been suggested that he may have been "electro-fishing" and that the crocodile attacked him in response, but this has not been confirmed (van der Ploeg*et al.* 2012).

Crocodylus intermedius

Only one non-fatal attack was detailed for *C. intermedius* during the study period, although one other non-fatal attack is reported to have occurred within the same area. The report comes from the La Palmita town along the Cojedes River in 2009; the attack was quite severe, involving a fisherman losing his lower right leg to a large crocodile during the attack (Barrio-Amoros 2012).

Tomistoma schlegelii

Eight attacks resulting in four fatalities were attributed to *T. schlegelii* during the study period, all of them occurring within Indonesia; since this species is sympatric with *C. porosus* in many areas, attacks were only attributed to it when the species was specifically mentioned as the attacking crocodilian or when expert advice suggested the species was more likely to be responsible than the more dangerous *C. porosus*.

Two fatal attacks occurred within Central Kalimantan province of Indonesian Borneo, both in late 2008; in one of these incidents a large (4 meter +) *T. schlegelii* was killed and the remains of the victim were retrieved from its stomach. Two attacks, one of them fatal, occurred within the East Kalimantan province; the non-fatal incident took place in 2011 along the upper reaches of a river typically known for *C. porosus* attacks (the Sangatta River), but the victim specifically identified the attacking crocodilian as "buaya supit" (one of the local names for *T. schlegelii*, translates as "chopstick crocodile"). The fatal East Kalimantan attack occurred along the upper reaches of the Belayan River in 2010 and it has been stated that the species responsible was *T. schlegelii* (Rob Stuebing *pers. comm.*).

Within the Jambi province of Sumatra one non-fatal attack was attributed to the species in 2012; while *T. schlegelii* was not specifically mentioned in the attack article, the circumstances and location of the attack are more suggestive of that species, rather than *C. porosus*. The incident began when a man accidentally speared the crocodilian, which had been lying at the floor of a swamp, mistaking it for "labi-labi" (a soft-shelled turtle that often shares habitat with *T. schlegelii*) (Rob Stuebing *pers. comm.*). The crocodilian attacked in retaliation, seriously injuring the man. Within the Riau province of Sumatra two non-fatal attacks were reported from along the Air Hitam River of Rokan Hulu Regency in 2010 and 2013; in these cases the species was identified as *T. schlegelii* by the victims and witnesses. A single fatal attack was reported from the Rokan River near Rimba Melintang in 2010; initially we attributed this attack to *C. porosus* since both of the species inhabit this area, but following the attack a large *T. schlegelii* was killed (the reports claimed 5.5 meters in length) and "human-like" bones were recovered from its stomach.

Alligator mississippiensis

47 attacks, all of them non-fatal, were attributed to *A. mississippiensis* during the study period; all bites, even very minor and provoked incidents, are reliably recorded throughout the range of *A. mississippiensis*, so the reported number of non-fatal attacks is much higher. Many attacks by the species are provoked or defensive in nature and unprovoked attacks are fairly rare. Fatal attacks by *A. mississippiensis* are very rare, with none occurring since prior to the study period in 2007.

Melanosuchus niger

36 attacks, resulting in 9 fatalities, were attributed to *M. niger* during the study period; Brazil held the highest number of reported attacks (29) and all of the reported fatalities, but non-fatal attacks were also reported from Peru (3 attacks), Ecuador (3 attacks) and Guyana (1 attack). More attacks, including some fatalities, have also occurred within Guyana, but no details have been made available (Peter Taylor *pers. comm.*); officials within French Guiana state that no attacks by *M. niger* have occurred there (Beniot de Thoisy *pers. comm.*). Within Brazil the highest number of attack reports came from Amazonas state (24 attacks, 6 fatal), followed by Acre state (2 attacks, 1 fatal), Rondonia state (2 attacks, 1 fatal), and Amapa state (1 fatal attack). It is possible that attacks have gone unreported within remote portions of Brazil or in other parts of the range of *M. niger* (e.g. Bolivia).

Caiman crocodilus

15 attacks, all of them non-fatal, were attributed to *C. crocodilus* during the study period; attacks were reported from Brazil (8 attacks), Colombia (5 attacks), Suriname (1 attack), and Trinidad (1 attack). Four of the attacks were reported to have been provoked by the victim, although it is possible that some of the other attacks may have as well. In 2013 two attacks occurred at Campo Maior Dam of Piaui state within a 2 month period.

Caiman yacare

Five non-fatal attacks were attributed to *C. yacare* during the study period, two in Argentina and three in Brazil. The first and most severe attack occurred in 2008 at a dam in Ingeniero Juarez in the Formosa province of Argentina; in this incident a young boy lost one of his feet to the caiman. The second Argentinean incident took place along the Paraguay River in 2012; very little detail is available for this attack but it involved a fisherman being bitten. The first Brazilian incident occurred in 2011 along the Paraguay River within the Pantanal; a fisherman was attacked by a 1.5 meter caiman while cleaning fish along the edge of the river (Neto, Stolf and Haddad 2013). The second Brazilian incident took place in 2012 along a river within the Pantanal of Mato Grosso do Sul; a man was attacked by a caiman while walking along the Taquari River in the Pantanal. The third Brazilian incident occurred in 2013 along the Cuiaba River of Mato Grosso state; a man was attacked by a caiman estimated to be around 1.5 meters in length while attempting to retrieve his stuck fishing line from the river.

Caiman latirostris

Two non-fatal attacks were attributed to *C. latirostris* during the study period; both attacks occurred in Brazil and in both cases the caiman was unintentionally provoked by the victim. The first incident took place in 2009 within the Jaguaribe River of Paraiba state; a man accidentally stepped on the caiman while net-fishing. The second incident took place in 2011 within the coastal waters of Illha do Mel (Honey Island) in Parana state; a fisherman accidentally stepped onto a caiman mistaking it for a log.

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Human-Crocodile conflicts in Andaman and Nicobar Islands - a case study

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The Andaman and Nicobar Islands comprises of 572 islands, islets and rocky outcrops and is located between 06º and 14º N Latitudes and 92º and 94º E Longitudes in the Bay of Bengal. The archipelago has a total land area of 8293 km^2 and a coastline of 1962 km. The Saltwater Crocodile *Crocodylus porosus* (Schneider) is a common species throughout the Andaman and Nicobar Islands. It can be encountered in the open sea, near the shore, mangrove creeks, freshwater rivers and swamps. Human-crocodile conflicts have been reported since early 1970s in these islands. About 26 crocodile attacks including 8 casualties have been reported between 1986 till date in the Andaman and Nicobar Islands. Recently, two people were killed at the famous Radha Nagar Beach in Havelock and Bakultala in Middle Andaman. The Department of Environment and Forests captured both the problem crocodiles and released into the mini zoo at Port Blair. In such a situation, removal of the problem crocodile might provide a temporary fix, but another male will eventually dominate the creek and may again be a threat to local people and tourists. Possible reasons for crocodile attack on humans include defending individual territories, attractive food-sources such as livestock and other domestic animals and dumping of high-protein waste food materials on banks or beach areas. Proper management of the crocodile populations to reduce human crocodile conflicts include training field staff in field survey techniques and capturing crocodiles, creation of awareness among local people and tourists by providing brochures, pamphlets, posters, through newspaper write ups on crocodile biology, behavior, ecology and organizing awareness workshops. The indigenous methods developed for capturing these crocodiles are discussed in detail in this paper.

An assessment of human-crocodile conflicts in Neyyar Wildlife Sanctuary, India

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Human-crocodile conflict involving the Mugger crocodile *Crocodylus palustris* (Lesson) was studied in the Neyyar Wildlife Sanctuary, Southern India after 18 years of reintroduction. The Neyyar Dam was built in the Neyyar River in the early 1940s for the purpose of irrigation in the States of Tamil Nadu and Kerala with an extent of 8.45 km^2. The Neyyar Wildlife Sanctuary, declared in 1958, is situated in the Kerala State, southern India. The extent of the Sanctuary is 128 km^2 and lies between 8° 17' and 8° 53' North latitudes and between 76° 40' and 77° 17' East longitudes. The survey was carried out by structured questionnaire survey, interviewing the victims and also visiting the sites of attack.

Twenty-nine Mugger crocodiles were reintroduced into the reservoir in the year 1983 and crocodile attacks on livestock were reported from 1985 onwards. During the initial period of the study, 21 to 25 Mugger crocodiles were estimated but only 10 to 16 crocodiles were recorded towards the end of the study period as nine animals were removed from the reservoir to reduce the conflict. Twenty-nine crocodile attacks on humans were reported prior to the study and six occurred during the study period, including two fatalities. The attacks occurred over 26 km along the banks of the reservoir and followed previous patterns of attack behaviour. It was estimated that 2,808 houses exist in a 26 km long and 400 m wide belt on the bank of the reservoir. As local people utilise the reservoir for various purposes such as collection of drinking water, bathing, washing clothes, washing cattle, fishing and retting of coconut leaves, these communities have significant negative impacts on the crocodile population. It was suggested to monitor the crocodile population in the reservoir annually by conducting census during the months of April-May, which will assist in the proper management of crocodiles in future. Public awareness programmes may be initiated to educate the people on the precautionary measures required to live safely with crocodiles.

Human-Crocodile issues: Sarawak Report

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Sarawak, the Malaysian state of Borneo, has 22 river basins. These river systems provide local communities with mode of transportation, water and food resources as well as being bastions to huge diversity of flora and fauna including estuarine crocodiles (*Crocodylus prorosus*). For most of the time crocodiles and humans co-exist peacefully but there had been instances of serious consequences when crocodiles and humans crossed paths. Sarawak records the highest crocodile attacks in the world with an average of 10 per year. These had resulted in repeated and emotional public and political outcries for the management authority in Sarawak to take swift actions. The Sarawak State Cabinet in an effort to pacify the populace had directed the crocodile management authority to carry out state-wide culling of the crocodiles. This paper presents the human-crocodile issues and highlights efforts to formulate the Strategic Crocodiles Conservation Plan for Sarawak.

Study on *Crocodylus palustris* : co-existence of men, animal and population survey at Kheda Anand district in Gujarat, India

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Abstract

Present study is based on Population survey of *Crocodylus Palustris* and coexistence of men and animal in and around ten villages and 18 village ponds in Kheda and Anand District of Gujarat, India. Total 157 Mugger *Crocodylus palustris* were counted using day count method. The population comprised of 11 juveniles, 50 Sub Adults, 71 Adults and 25 Big size Mugger. The study was conducted during December 2011 to June 2012. Two instances of Human Crocodile conflict were recorded and people's approach towards coexistence was observed by interacting with them. The observations also include the basis of coexistence between men & animal, instances of man-animal conflicts, threats to Mugger and recommendations to reduce man animal conflict.

Introduction

The study area was 10 villages of Kheda and Anand District of Gujarat State in India and 18 village lakes were been observed for the population survey of *Crocodylus palustris.* These *Crocodylus palustris* population has been coexisting with men in these villages since times immemorial and their basis of Coexistence was the prime observation. The study also focuses awareness spread among people, Instances of man animal conflicts, suggestions to reduce man animal conflict (De silva 2011).

Conservation Status

Crocodylus palustris is also known as Mugger or Marsh Crocodile is in the Appendix I of CITES also listed a Vulnerable in IUCN Red list 2012.2.In Indian perspective *C.palustris* is protected under Schedule I in wildlife protection Act 1972.

Management Objective

Crocodylus Palustris has been always remained on the top list of attraction as along with its other peers. Mugger crocodile is principally restricted to the Indian subcontinent where it may be found in various freshwater habitat types including rivers, lakes, and marshes (Whitaker 1987, Whitaker & Whitaker 1989) So far in India a great amount of conservation work has been implemented by Government, various Zoos, and Other specialist Groups. Now Mugger population are increasing in many states of India and credit for this success lies with ex-situ conservation programme "Indian Crocodile Conservation Project (Singh 1999) and so does it flourishes in Gujarat State (Vijay Kumar 1997; Vijay Kumar et al. 1999a,b; Vyas 2008). The Management objective (Bayliss 1987) of this survey was to understand distribution of the *Crocodylus palustris* in the village lakes and the basis of Human Croc Conflict (Whitaker N 2008) as well as the approach of the people for co existence and suggestions for prevention of possible conflicts (De Silva 2008, 2010,2011).

Study Area

Study was done in two Talukas Matar & Sojitra belonging to Kheda & Anand district respectively. Where in Taluka is subdivision of a district and comprises several villages organized for revenue purposes.

Study area comprised of *Six*villages and 10 village lakes of Matar Taluka out of 10 talukas of Kheda District (http://nadiyaddp.gujarat.gov.in 2013). The district is situated between North22°.30' to 23°.18 latitude and East 72°.32 to 73°.37 longitude .The villages under study were Traj, Heranj, Nagrama, Marala, Tranja, Kathoda. Also *four* villages with 8 village lakes were studied from Sojitra Taluka one of eight Talukas of Anand District (http://ananddp.gujarat.gov.in 2013). The district is situated between 22° 6' to 22° 43' north latitude and 72° 2' to 73° 12' East longitude. Anand district is popularly known as *"Charotar".* In Gujarati, the word "Charutar" literally means a pot full of gold coins. The villages under study were Deva, Malataj, Dabhou and Maghrol of Sojitra Taluka. (Study area map Fig.1)

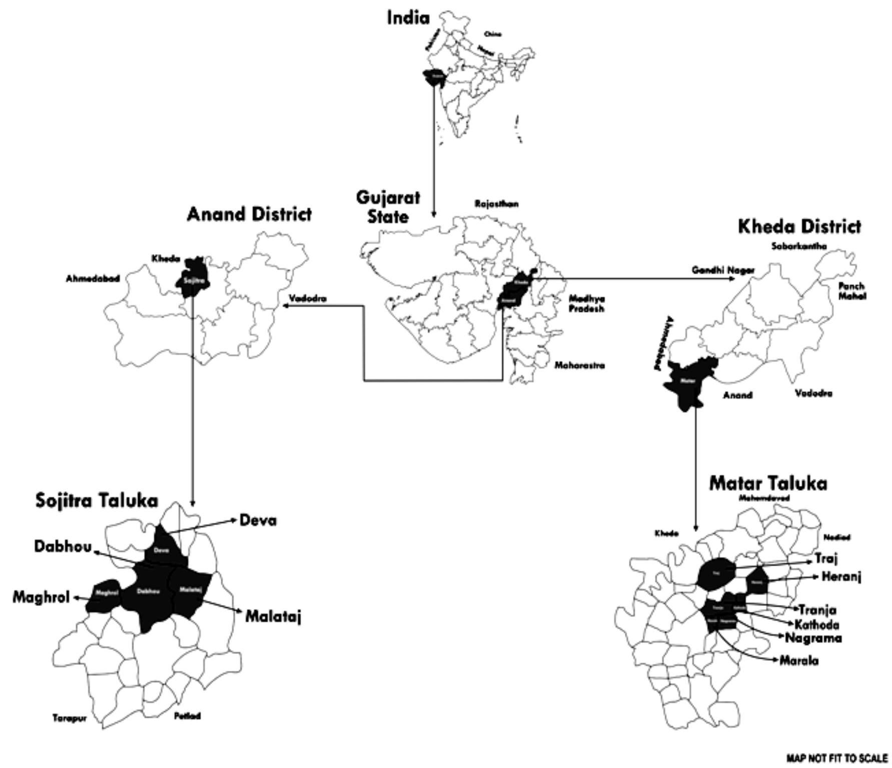

Figure 1. Study area map

Study Period

The study was conducted between December 2011 to June 2012. Each village study was divided into 10 days spread during the study period. Winter months, and pre summer seasons were selected as they are good times for counting crocodiles as in day time, they tend to bask in groups (Choudhary & Roy 1982)**(Fig.2)**

Figure 2. Group Basking Mugger Deva Village (Photo Jigar N Upadhyay)

Method

A reconnaissance of the entire area was done during the study period and Direct as well as indirect method were used for determining population of Mugger. From December 2011 till June 2012 the sites were observed by keeping a safe distance so as to avoid disturbance to the animals. A) Direct Method included day count observations done from 0600 hrs. to 1900 hrs. and basking(P. Dilip Venugopal &K. V. Devi Prasad 2007)observations were classified into Surface bask, when the crocodile observed was on the surface of the water without any movement. Prebask, when half to two-thirds of the body was still in water and, Basking, when the crocodile was completely out on land, exposing the entire body .The sizes of crocodiles were estimated visually. B) Indirect method included observations of faecal pellets, den (Fig.3) or tunnel, tracks or tails and egg shells. With the periodical interactions with local people basking sites and human animal conflicts were been identified.

Figure 3. Presence of Mugger in Den or tunnel in Heranj Village. (Photo Jigar N Upadhyay)

Results

Total 157 Mugger *Crocodylus palustris* were counted .The population comprised of 11 juveniles, 50 Sub Adults, 71 Adults and 25 Big size *Crocodylus palustris.* During the study it was observed that Population of Mugger was highest in Deva Village (58) followed by Heranj village (41).Population count is categorised as:- juvenile <1>meters, Sub Adult <1 to2> meters, Adult <2 to 3> meters, Big Size >3 meters. Also Villages Nagrama-Marala has one common lake and Tranja-Kathoda also has one common lake. The result of the population count is mentioned Taluka wise i.e. Matar Taluka Villages (Table 1) Sojitra Taluka Villages (Table 2). Population count consolidated is mentioned for both Talukas (Table 3)

Table 1. Mugger Population Count at Matar Taluka. Kheda District

Name of Village	Lake & Coordinates	Size of Lake (In Hectares) 1 hectare=2.471 Acre	Number of Animals				Total
			Juvenile <1> Mtrs	Sub Adult <1 to 2> Mtrs	Adult <2 to 3> Mtrs	Big Size 3>Mtrs	
Traj	Gaam Talav 22°40’23”N 72°38’26”E	7.8 ha	2	5	4	1	12
	Irrigation Talav 22°40'22"N 72°38'52"E	14.2 ha	0	0	0	0	0
	Salaa Talav 22°39'29"N 72°37'51"E	64.15 ha	0	0	0	0	0
Total Count Traj (a)							**12**
Heranj	Chokadiya Talav 22°40'6"N 72°41'36"E	64 ha	0	5	14	4	23
	Gaam Talav 22°40'23"N 72°38'26"E	0.90 ha	3	4	3	2	12
	Lake 2 22°39'44"N 72°41'45"E	0.28 ha	0	2	0	0	2
	Lake 3 22°39'35"N 72°41'31"E	0.30 ha	0	4	0	0	4
	Paani Talavdi 22°39'46"N 72°41'32"E	0.30 ha	0	0	0	0	0
Total Count Heranj (b)							**41**
Tranja-Kathoda	Gaam Talav 22°40'23"N 72°38'26"E	93.5 ha	0	2	4	2	8
Nagrama-Marala	Gaam Talav 22°40'23"N 72°38'26"E	114.4 ha	2	4	6	3	15
Total Count (c)							**23**
Taluka Total (a+b+c)			**7**	**26**	**31**	**12**	**76**

Table 2. Mugger Population Count at Sojitra Taluka, Anand, District

Name of Village	Lake & Coordinates	Size of Lake (In Hectares) 1 Hectare=2.471 Acre	Number of Animals				Total
			Juvenile <1> Mtrs	Sub Adult <1 to 2> Mtrs	Adult <2 to 3> Mtrs	Big Size 3>Mtrs	
Deva	Kumbharyu Talav 22°37'16"N 72°44'33"E	1.1ha	0	0	0	0	0
	Andhariyu Talav 22°37'13"N 72°44'5"E	3.5ha	2	11	9	7	29
	Malav Talav 22°37'6"N 72°43'56"E	2.5ha	0	9	10	4	23
	Kana Talav22°36'45"N 72°43'54"E	1.6ha	2	0	4	0	6
Total (a)							**58**
Malataj	Gaam Talav 22°34'52"N 72°44'58"E	1.5ha	0	4	9	2	15
Dabhou	Mandirvalu Talav 22°34'56"N 72°42'59"E	5.23ha	0	0	4	0	4
	Gaam Talav 22°35'0."N 72°43'4"E	4.27 ha	0	0	2	0	2
Maghrol	Shakti Mata Talav 22°34'32"N 72°40'56"E	3 ha	0	0	2	0	2
Total (b)							**23**
Taluka Total (a+b)			4	24	40	13	**81**

Table 3 .Human Crocodile Population Details Matar & Sojitra Taluka

[illegible] Taluka	[illegible] Lakes	[illegible] Population of villages in study	[illegible]				[illegible] Mugger Count
			[illegible] <1> Mtrs	[illegible] <1 to 2> Mtrs	[illegible] 3> Mtrs	[illegible] 3> Mtrs	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed observations

Crocodylus palustris has adapted well to reservoirs, irrigation canals and man-made ponds (De silva and Lenin 2010) .Village lakes mentioned above are used by the villages for the day today activities . These lakes are also connected with the irrigation canals which may provide passage routes to the *Crocodylus palustris* to migrate during different situations(Vyas 2008).However the presence of *C.palustris* clearly defines the strength of the ecosystem with regards to the survival and breeding in the wild. A vivid range of water birds were also sighted .During the day hours when the village lakes waters are used by village people for their daily routine the crocodiles remain on distant shores of the lakes .All these lakes are used for the purpose of washing clothes (Fig.4), bathing ,and livestock movements as well as fishing. Generally these lakes are occupied by humans between 0900 hours to 1700 hours of the day. Nesting sites were been located in around almost each lake Which was a clear indicator of their successful breeding and hatchlings were also observed. positions of these nests and their distance from the water varied from one another (Bayani et.al. 2011). However the hatchlings have multiple threats for survival since these lakes are not monitored on periodical basis. Also most of the nests were found quiet nearer to the locations with human interactions.

Human Animal Conflict

There have been few instances of crocodile's attacks on livestock and stray dogs in theses villages but most of them unrecorded. While in Village Traj. Prior to study period One incident occurred on August 2009 first week when an adult crocodile attacked a 9 year old girl named Hetal Ode who was standing on the shore of village lake along with few geese. When people shouted the crocodile that caught the girl from the waist region got frightened and started swimming back and took the girl on the small island in the lake. By that time the girl lost her life, although immediately villagers came chasing the crocodile that had left the dead body on the land and flee away. Girl was taken to hospital and declared dead.

This aroused people's anger for the first time and some 7 to 8 crocodiles were removed from the lake with the Help of NGOs and Forest department. The crocodiles were shifted to Kevadiya colony dam a protected area for crocodiles. On discussion with locals and the family of the deceased girl, I was informed that the attack was mere an instance of mistaken identity or mis-predation. (Whitaker & Whitaker 1989) where the crocodile was actually preying on the Geese.

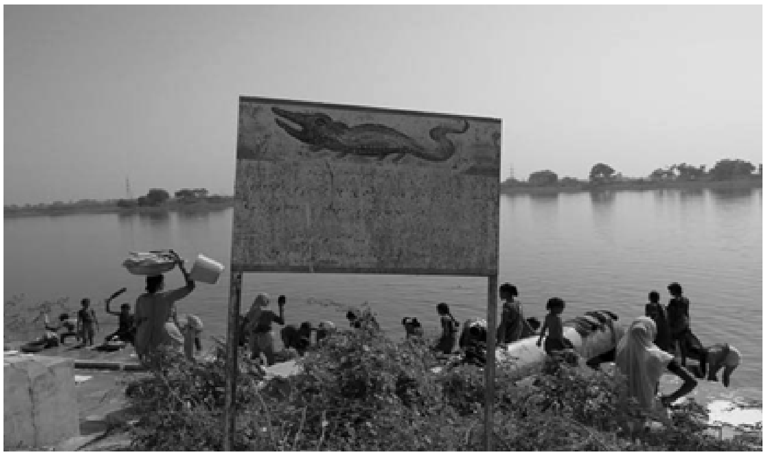

Figure 4. Use of Village Lake for daily routine activities Village Traj (Photo Jigar N Upadhyay)

Second instance took pretty three years too occur it was 3^{rd} march 2012 when a Sub adult crocodile was caught in the fishing net of fishermen .And they tied the crocodile on the lake side so as to release it after removing the fishing nets. However few kids playing nearby got little more closure to the small crocodile and in that moment the animal attacked an 11 year old boy and injured him to 25 stiches on the leg. However with timely rescue the boy was saved and shifted to hospital.

Apart of above mentioned instances of Village Traj no other incidents were recorded at any other lake. Interestingly there had been no sign boards which were found informing about crocodiles presence in the lakes except few villages .All attacks occurred whereas there were no crocodile exclusion enclosures (De Silva 2008).

Major reasons for very few man animal conflicts revealed the fact that the villagers consider Crocodiles to be associated with their religious beliefs (Vyas R[8] 2003) and also the existence is been positively accepted. Another observation was that crocodiles were not provided any kind of offerings from villagers which was purely a reason for crocodiles remaining in their territories. Lakes being large enough can sustain families of crocodiles with sufficient food. Any kind of poaching or disturbance to *C Palustris* is strictly prohibited and this act is done voluntarily by the villagers. During the research it was clearly evident that human negligence leads to crocodile attack (De silva 2010). Awareness campaigns for the importance of crocodiles in the ecosystem were been conducted in small groups during this research.

Threat: Although the existence of *C.Palustris* is accepted by the villagers and as of now there seems to be no major threat of encroachments or poaching. Major threats that were identified during this study were related to possibility of accidental attacks on humans by *C. Palustris* since there are no safety measures kept. (Fig 5)

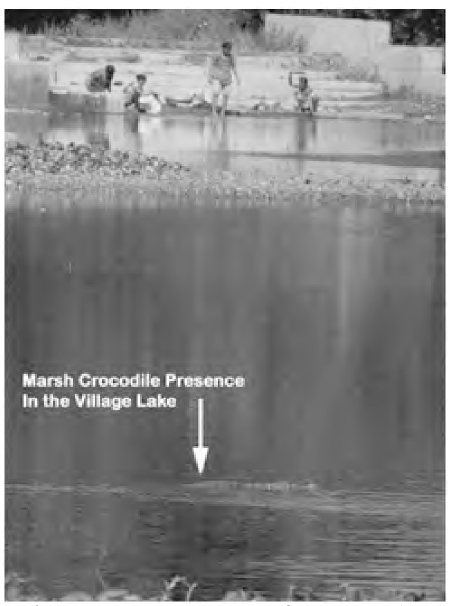

Figure 5. Women washing clothes Presence of Mugger (Photo Jigar N Upadhyay)

Apart of threats to humans, *C. palustris* in these lakes face following threats:-

a) Attacks on humans has resulted into low tolerance by people for coexistence with crocodiles.(Vyas R 2008)

b) Capturing and Reallocation of adult crocodiles to different locations. This might result into removing the breeding male or female and which can pose a threat on juveniles and hatchlings.

c) Fishing activities leading to trapping of the crocodiles i.e hatchlings, juveniles or sub adults which can also pose a threat of drowning in fishing nets (De Silva, 2008).

d) Since these lakes are connected with irrigation a major threat prevails for reduction in water levels. This leads to Crocodiles burrowing for maintaining temperature but simultaneously this can also pose a threat as chance of attacks might increase. Crocodiles might also move from these lakes and their migration might be hazardous for humans or animals.

e) Some of the lakes were observed with presence of Common Water Hyacinth (*E. crassipes*) along with other aquatic vegetation (Fig 6).

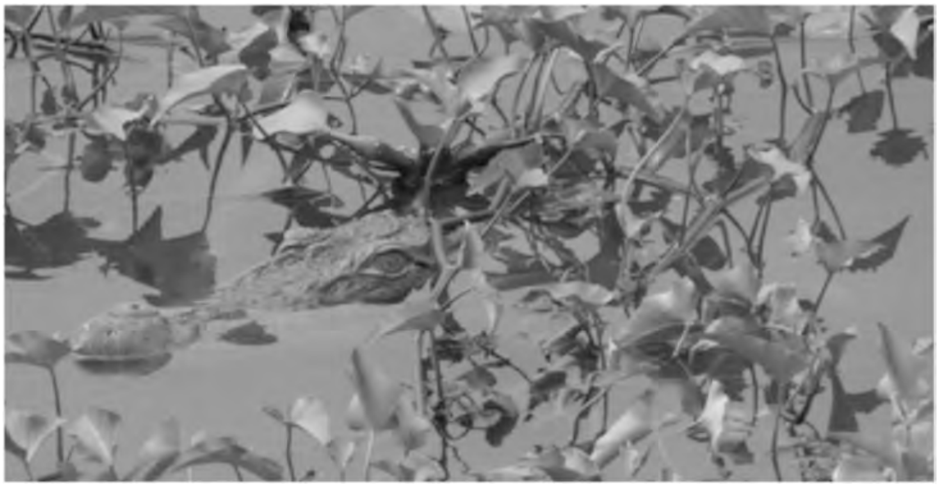

Figure 6. Aquatic Vegetation Village Malataj (Photo Jigar N Upadhyay)

Since their presence imposes a threat on many fishes also it might effect on the mobility of the *C palustris.*

Corrective measures required for eradication of above mentioned threats as this will effect a dignified presence of *C.palustris* in these lakes.

Recommendations

During the study following recommendations be proposed so as to conserve the Existence of C.palustris.

Implementation of an intense and detailed plan for the awareness of Importance of C.palustris to be conducted at villages.

1) Survey for the population Census to be conducted every year.

2) Village Lakes to be provided with properly designed Crocodile Exclusion Enclosures so as to eradicate future man animal conflicts.

3) Village lakes to be protected from encroachments.

4) Presence of Common Water Hyacinth (*E. crassipes*) and other aquatic vegetations to be controlled.

5) Fishing activities to be monitored and care should be taken to avoid entanglement of C.palustris in fishing nets by restricting areas with heavy mobility of C.palustris.

6) Ensuring proper water management in the village lakes during summer days so as to reduce migration of C.palustris in various nearby locations.

7) Strong coordinating approach to be implemented between Local wildlife enthusiasts, NGOs and Forest department.

8) Measures to ensure restriction on future possibility of poaching should be implemented.

The recommendations here are made with the due respect to the enormous efforts and understandings been displayed by the local villagers for conservation of C.palustris in their village lakes. The recommendations proposed here will create a benchmark in the field of conservation of C.palustris and will enhance the understandings of villagers in scientific manner. So as to strengthen their approach of "dignified Coexistence" with C.palustris.

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Commercial crocodile farming in Bangladesh, past, present and future possibilities

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Proposal for crocodile farm in Bangladesh came in the year 1982, by the legend Rom Whitaker. In the 7th CSG meeting 1984 a survey on crocodile farming around the world was published. All over the world crocodile farming initially began with ranching operation, which eventually converted to captive breeding. Bangladesh started crocodile farming with F2 generation in the year 2004. Starting with 75 heads Reptiles Farm Ltd. now has approximately 1500 heads of saltwater crocodile (*Crocodylus porosus*). RFL got registered with CITES in 2007 and made its first export in 2010. Through out the process RFL faced new challenges as it is first such venture in Bangladesh. The company has bright future potentials; at the same time there are plenty of challenges from the other stakeholders. This study is based on the observation made by different stakeholders in the industry and Bangladesh Forest Department. It is precisely focused on the policy issue, which needs to be addressed for the future smooth functioning of the industry.

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Microbial investigation of captive gharial hatchlings in Chitwan National Park, Nepal

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Abstract

Dead gharial hatchlings (137) aged between 6 to 42 weeks were collected from Gharial Breeding Center (GBC), autopsied and examined. Four organs (Liver, lungs, heart blood and kidney) of 102 hatchlings subjected to aerobic bacterial cultures identified Gram-positive bacteria and Gram-negative rods. Gram positive organism isolated were Staphylococcus aureus, Streptococcus spp., Actinomyces spp., Bacillus spp. and Clostridium spp. Gram negative organisms were Citrobacter freundii, Escherichia coli, Providencia rettgeri, Pseudomonas spp., Proteus vulgaris, P. mirabilis, Aeromonas spp., Klebsiella oxytoca, Morganella morganii, Salmonella spp. and Shigella spp. Fourty samples (hatchlings infected with Surahi fluke (Exotidendrium sp.) and having a distinct "Sphincter Cap") from the rectocloacal area were cultured aerobically. It resulted in the isolation of two organisms (Bacillus subtilis and Strep. viridans) of the Gram-positive group and nine organisms of the Gram-negative group. The dominant isolates were Citrobacter freundii (30%) and E. coli (20%). One hundred and forty eight culture positive samples based upon monthly mortality were analyzed and it revealed 25% infection in September, 16.89% in August, and less than 14% infection in other months. Bacterial infections in different organs detected on 148 culture positive gharial hatchlings were found to be 27.03, 42.57, 15.54 and 14.86% in liver, lungs, kidney and heart respectively. Spectrum of bacteria on 90 culture positive gharial hatchlings were only one species in 70%, two species in 21.11% and three or more bacterial species in 8.89% of the carcasses. Presence of infection in particular age group of hatchlings led to the finding that the highest percentage of infection (75%) was recorded in the 30-34 weeks old hatchlings and in an average 38.64% hatchlings had been infected by one or more bacteria.

Out of 102 hatchlings subjected to bacterial culture, 12 hatchlings (11.76%) were found negative to cultures. Culture of skin scrapings from suspected skin lesions led to the isolation of six environmental fungi without a higher prevalence of any particular species. It is concluded that higher mortality of gharial hatchlings in Chitwan was multifactorial. Bacteria, fungi, coccidia and parasites were significantly associated to these deaths, but environmental factors such as extreme temperatures and managemental deficiencies could not be ignored.

Keywords: Gharial, hatchling mortality, Citrobacter freundii, Cutaneous fungal lesions, Sphincter Cap, Gharial Breeding Centre.

Introduction and literature review

The gharial (*Gavialis gangeticus*) was literally brought back from the brink of extinction by restocking programs initiated in India (1975) and Nepal (1978). This program strategically protected gharial nest in the wild, collected eggs, raised the hatchlings in captivity and released them back into the main rivers (Cadi and Maskey, 2005). Predation by fishes, birds, jackal, civets and monitor lizards significantly reduces the survivability of the young gharial hatchlings in the wild limiting the survival rate to adulthood just to about one per cent (Dhungel, 1987); likewise, the mortality rate in captivity exceeding 30 per cent during the first year of life have been reported as a major constraint in crocodile farming (Ladds *et al*., 1995).

The mortality rate of gharial hatchlings (hatching to 1-year age) at GBC has ranged between 42.95 to 97.20%. The causes behind such high mortality include occasional predation (by mongooses), pilling up and suffocation, ant attacks, infection of skin and teeth by fungus, etc. This emphasized a need of a thorough investigation work to reveal out the major errors in management and husbandry along with the biological agents involved in the death of young hatchlings for increasing the survival rate which in turn may efficiently help in restoring and augmenting wild gharial populations.

Twenty five to 80% of the gharial hatchlings die within the first year of their life in captive breeding facilities because of skin disease, neurological disorders, retention and infection of the yolk sac and prolapse of the rectum where as the mortality rate in the second year do not exceed 10% (Maskey, 1989). Rigorous work is still important to know the involvement of pathological agents in higher percentage of hatchling mortally. The causes have not been explored well due to the difficulty in obtaining gharial specimens from the wild or because of the inaccessibility of the gharial breeding centers to the research institutions. The difficulty is further increased by the protected status of the species requiring permissions from the respective governments for activities related to scientific research and study. This has led to the poor improvements in reducing the mortalities of hatchlings particularly in the first year. Several studies related to gharial ecology, habitat and movement were carried out in the 1980's; however, studies concerning the diseases, its effect on mortality and ways to increase their viability through improved health, hygiene and veterinary interventions, were less than a handful of scientific work. Very few scientists have reported the results of investigation on gharial mortality. Clostridium spp. and *E. coli* were found responsible for hatchling deaths (Mihsra *et al*., 1993) and the need of clean water and sound management practice were emphasized to raise disease free gharial hatchlings. Pseudomonas spp. infections were found predominantly responsible for hatchling deaths (Mishra *et al*., 1996) in India. Maskey *et al*. (1998) evaluated the disastrous impact of intestinal infection in captive bred gharial hatchlings in Nepal where as Mehrotra *et al*. (2000) reported *E. coli*, *Pseudomonas aeruginosa*, Staphylococcus, Corynebacterium spp., Bacillus spp. and some fungal agents emphasizing the need of fresh running water for gharials instead of stagnant ponds. *Providencia rettgeri* (Ladds *et al*., 1996) *Morganella morganii* (Heard *et al*., 1988) *Proteus spp*. (Chakraborty *et al*. 1988), *Klebsiella oxytoca* (Flandry *et al*., 1989) *Aeromonas hydrophila* (Gorden *et al*. 1979), *Citrobacter freundii* (Novak and Seigel, 1986), *Escherichia coli* (Xuesong *et al*. 2002), *Mycoplasma* (Mohan *et al*., 1995), Chlamydia (Australia, 2006) were reported involved to cause death of other farmed species of crocodiles likewise many fungi , parasites and prorozoa were responsible to kill hatchlings crocodiles. Similarly, metabolic and nutritional diseases and death due to skeletal deformities have also been reported. Stressful phenomenon such as piling up at one corner of the enclosure or on top of each other (a normal reaction of the hatchlings to fear) may have contributed to death by suffocation or by permitting infectious agents through resulting scratches (Huchzermeyer, 2003).

This research of captive gharial hatchlings aimed at investigation of the causes of mortality of young captive gharial hatchlings to improve their viability in captivity.

Material and methods

The study was carried out at the Veterinary Teaching Hospital (VTH), Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan (August, 2006-April, 2007). Dead gharial hatchlings that hatched between June 15-28, 2006 were collected from Gharial Breeding Center. A total of 137 (six to 42 weeks old) dead hatchlings constituted the study population. These carcasses in whole were transported to IAAS Veterinary Teaching Hospital (VTH) in ice, examined immediately or wrapped individually in a plastic bag, labeled with indelible ink and stored again in the freezer (-20ºC) until necropsy. Before necropsy, each carcass was taken in a 41.50 x 30.50 x 6.50 cm plastic tray, washed thoroughly with tap water to remove all the dirt and sand particles. The hatchlings were then thoroughly washed with distilled water and soaked for five minutes in 70% dehydrated alcohol (Ethanol, B. P., Bengal Chemicals and Pharmaceuticals Ltd., Calcutta, India). The alcohol was drained thoroughly and every carcass was assigned a label written in a clean paper with dates of death, necropsy examination and its weight and length measurements recorded and photographed. External examination was followed by internal examination. Necropsy was carried out by common method and by the method described by Huchzermeyer (2003). Samples for microbiological examination were taken asceptically and inoculated immediately in nutrient, McConkey and blood agar and incubated at 37ºC for 24-48 hours and the colony characters were recorded. The colonies obtained on the agar surface were stained with Gram's stain for morphological studies and subjected to conventional biochemical tests for identification of the organisms (Barrow and Feltham, 2004). The specific single colony were also inoculated in 1 ml of nutrient broth (HiMedia Laboratories Pvt. Ltd., Mumbai, India) in a 5 ml sterilized screw capped glass vial and incubated till development of cloudiness to which was then added 1 ml of 40% glycerol (Qualigens Fine Chemicals, Glaxo Smithkline Pharmaceuticals Ltd., Mumbai, India). These were stored in a freezer and dispatched to Health Research Laboratory, Institute of Medicine, Maharajgunj, Kathmandu, in ice for further confirmatory results. Skin scrapings were treated with 10% KOH and stained with Lactophenol cotton blue (LCB) for observation of fungal elements. The samples were also inoculated in Sabouraud's dextrose agar and potato dextrose agar (HiMedia Laboratories Pvt. Ltd., Mumbai, India) and the resulting fungal growth were identified through slide culture and respective morphology of the spores and hyphae.

Results

Bacterial cultures

Internal organs (liver, lungs, kidney and heart or its blood) were subjected to bacterial cultures. Cultures revealed 19 species of bacteria-five genus of Gram positive and 10 genus of the Gram-negative rods. The Gram-positive genus were Actinomyces, Bacillus, Clostridium, Staphylococcus and Streptococcus where as the Gram-negative rods were Aeromonas, Citrobacter, Escherichia, Klebsiella, Shigella, Morganella, Proteus, Providencia, Pseudomonas and Salmonella spp. Twelve hatchlings (48 organ samples), however, did not produce any growth of organisms. The frequencies of the isolates obtained from 148 culture positive organs of 102 dead hatchlings are presented in Table 1.

Table 1. Frequency of 148 bacterial isolates obtained from four different organs of 102 dead hatchlings (August 2006-April 2007)

Bacterial isolates	Frequency of isolation	Percentage
Actinomyces spp.	04	2.70
Aeromonas spp.	02	1.35
Bacillus subtilis	02	1.35
Citrobacter freundii	48	32.43
Clostridium spp.	02	1.35
Escherichia coli	18	12.16
Klebsiella oxytoca	11	7.43
Klebsiella pneumoniae	01	0.68
Morganella morganii	06	4.05
Proteus mirabilis	07	4.73
Proteus vulgaris	14	9.46
Providencia rettgeri	04	2.70
Pseudomonas spp.	01	0.68
Salmonella spp.	05	3.38
Shigella dysenteriae	01	0.68
Staphylococcus albus	03	2.03
Staphylococcus aureus	14	9.46
Streptococcus spp.	01	0.68
Streptococcus viridans	04	2.70
Total	148	100.00

Samples from four organs (liver, lungs, kidney and heart) of each hatchling that died in different months were subjected to microbial examinations. A total of 408 organ samples of 102 hatchlings were examined and 148 organ samples (36.27%) gave positive cultures, the highest percentage of infection (25%) were found in September and lowest (3.38%) in December (Table 2).

Table 2. Percentage of infection in different months based on 148 culture positive organs of 102 hatchlings

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible].00

* Liver, lungs, kidney and heart blood samples were cultured from every hatchling

Samples that were positive for bacterial cultures were analyzed to detect the percentage of infection in the organs. It was found that the lungs tissue was infected at highest (42.57%) followed by liver and kidney; and least infection was found in the heart blood (Table 3).

Table 3. Distribution of infections in different organs based on 148 culture positive samples of 102 hatchlings

Organs	Culture positive samples	Percentage
Liver	40	27.03
Lungs	63	42.57
Kidney	23	15.54
Heart (blood)	22	14.86
Total	148	100.00

Spectrum of infections

Bacterial culture from organs resulted in the isolation of more than one bacterium from a particular hatchling. The percentage of infection by these organisms was calculated on the basis of total number of samples subjected to culture and isolates obtained. Seventy per cent of the organs harbored a single species of organism among the isolated where as about 9% revealed three or more organisms (Table 4). The details of the species of bacteria recovered are presented in Table 7.

Table 4. Percentage of bacterial isolates obtained from 90 culture positive internal organs of gharial hatchlings

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	08	[illegible]
[illegible]	[illegible]	[illegible]

Bacterial isolates and age of hatchlings

The highest percentage of infection (75%) was found in the 32-34 weeks old hatchlings followed by 18-22 (39.29%) and the least in the 22-26 weeks (20.83%) old group (Table 5). Liver, lungs, kidney and heart samples from 12 hatchlings (two of the age group six to ten weeks and 10-14 weeks, five from 34-38 weeks and one each from other groups excepting 30-34 weeks one) were found negative in bacterial cultures. Out of 12 hatchlings negative to cultures from liver, lungs, kidney and heart, four were not examined well for other problems (two in August and two in September); one each in November and December had both mature forms of Surahi fluke and a distinct "Sphincter Cap"; one hatchling each in January and April was infected by mature Surahi flukes and the later had distinct "Sphincter Cap" too. The two hatchlings that died in March had retained yolk sac and the same flukes; one had only flukes where as the other had both flukes and "Sphincter Cap".

Table 5. Percentage of infection in different age groups of hatchlings

[illegible]	[illegible] examined	[illegible]	[illegible] obtained	[illegible] infection
[illegible]10	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]-14	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]18	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]-22	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]-26	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]30	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]-34	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]38	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]-42	[illegible]	24	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	

Isolates from colon and "Sphincter Cap"

Swabs from colorectal mucosa and sphincter surface of the gharial hatchlings infected with Surahi flukes (Exotidendrium spp.) and having thickened mucosa were subjected to bacteriological culture. The results are summarized in Table 6.

Table 6. Colon and "Sphincter Cap" isolates from 40 gharial hatchlings

Organisms	No. of isolates*	Percentage
Aeromonas spp.	3	7.50
Bacillus subtilis	1	2.50
Citrobacter freundii	12	30.00
E. coli	8	20.00
Klebsiella oxytoca	2	5.00
Morganella morganii	2	5.00
Proteus mirabilis	2	5.00
Proteus vulgaris	5	12.50
Providencia rettgeri	1	2.50
Pseudomonas spp.	1	2.50
Streptococcus viridans	3	7.50
Total	40	100.00

* Only hatchlings with specific lesion were cultured

Mycological examination

Skin scrapings from six dead hatchlings were subjected to mycological studies. Cultures revealed six different species of saprophytic fungus. The result suggested that the lesions were produced by opportunistic fungal pathogens. Out of 137 hatchlings examined grossly, 26 (18.98%) hatchlings had fungal lesions on the skin (Table 8).

Table 8. Fungal isolates obtained from skin scrapings of gharial hatchlings

[illegible] (weeks)	Number	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

Table 7. Spectrum and percentage of bacterial isolates obtained from gharial hatchlings

Single species (n=63)			Two species (n=19)			Three or more species (n=8)		
Organism	**No.**	**%**	**Organism**	**No.**	**%**	**Organism**	**No.**	**%**
Actinomyces spp.	1	1.59	*E. coli* and *Salmonella* spp.	1	10.53	*Citrobacter* spp. either with *P. vulgaris* and *P. mirabilis*; or with *Klebsiella oxytoca* and *Staph. aureus*; or with Klebsiella spp. and Morganella spp.; or with *P.vulgaris* and *Staph. albus*; or with *E. coli* and *Morganella* spp.; or with *Staph. aureus* and *Actinomyces* spp.; and *Kleb. oxytoca* and *Kleb. pneumoniae* with *Staph. albus*	5	62.5
Aeromonas spp.	1	1.59	*E. coli* and *Kleb. oxytoca*	1	5.26			
Bacillus subtilis	2	3.17	*E. coli* and *P. vulgaris*	1	5.26			
Citrobacter freundii	21	33.33	*E. coli* and *Citrobcter freundii*	2	5.26			
Clostridium spp.	1	1.59	*Citrobacter* spp. and *Salmonella* spp.	2	10.53			
E. coli	8	12.70	*Citobacter* spp. and *P. vulgaris*	5	26.32			
Klebsiella oxytoca	2	3.17	*Citrobacter* spp. and *Staph. aureus*	2	10.53			
Morganella morganii	2	3.17	*Kleb. oxytoca* and *Staph. aureus*	2	10.53			
Providencia rettgeri	3	4.76	*Kleb. oxytoca* and *P. vulgaris*	1	5.26			
Proteus mirabilis	4	6.35	*Proteus mirabilis* and *P. vulgaris*	1	5.26			
Proteus vulgaris	4	6.35	*Strep. spp*. and *Actinomyce*s spp.	1	5.26	*Citrobacter* spp. with *E. coli*, *Actinomyces* spp. and *Strep. viridans*	3	37.5
Pseudomonas spp.	1	1.59						
Salmonella spp.	2	3.17						
Shigella dysynteriae	1	1.59						
Staphylococcus albus	1	1.59						
Staphylococcus aureus	6	9.52						
*Streptococcu*s spp.	1	1.59						
Streptococcus viridans	2	3.17						
	63							
Total		99.99		19	100		8	100

Discussion

This study aimed at finding the involvement of microorganisms to cause deaths in gharial hatchlings in their first year of life. Data based on four batches of hatchlings revealed 2.79-57.05% hatchling survival rate with a clear indication of high mortality and variations. Hatchling mortality rates of 97.20, 42.60, 76.90 and 61.50% in the year 2003, 2004, 2005 and 2006 respectively showed large variations. This could be due to the variations in the extent of congenital anomalies, environmental extremes precipitating a particular disease or due to the variation in the degree of care and management of hatchlings.

Many researchers are in the opinion that bacterial isolation from a crocodile should not be regarded as solely responsible for disease or death, because all the crocodile specific pathogens are opportunists, waiting for a weakened or stressed animal to produce the specific disease. Septicaemia is often produced by the fact that crocodilians are devoid of lymph nodes (Huchzermeyer, 2003). Crocodiles with septicaemic lesions due to intestinal bacteria have been reported suffering from severe stress (Huchzermeyer, 2000; Huchzermeyer and Cooper, 2000). This study also cannot exclude the probability of involvement of intestinal bacteria in causing septicemic death in gharial hatchlings due in period of stress.

Pseudomonas aeruginosa (Mishra *et al*., 1996; Mehrotra *et al*., 2000) and Clostridium spp. (Mishra *et al*., 1993) caused massive deaths of gharial hatchlings and *E. coli* (Sinha *et al*., 1988) was associated with septicemic conditions in mugger crocodiles even though such bacteria have been isolated from apparently healthy gharial hatchlings (Mishra *et al*., 1993); Gram negative rods including Salmonella spp., Proteus spp., *E. coli*, *Providencia rettgeri*, *Morganella morganii*, *Serratia marcescens* and *Aeromonas hydrophila* have been isolated from crocodilians and are implicated as responsible for diseases and death in many instances.

Citrobacter spp. has been isolated from captive Nile crocodile and from the faeces of a *Caiman crocodylus* (Roggendorf and Muller, 1976). *Citrobacter freundii* has been found associated with septicemia in American alligators (Novak and Seigel, 1986) and *C. koseri* has also caused meningitis in newborn human babies (Gross *et al*., 1973; Ross, 1979).

Aeromonas hydrophila is one of the most common bacteria associated with the aquatic environment and has caused skin lesions and septicaemia in a Nile crocodile (*C. niloticus*), yielding pure cultures from skin, internal organs and blood (Turutoglu *et al*., 2005). It was reported earlier as the sole agent but later reports showed Proteus spp., *Morganella morganii*, *Serratia marcescens* and *Klebsiella oxytoca* equally responsible for septicaemic lesions in crocodiles. It is emerging as a potential pathogen for the immune-compromised host (Chang *et al*., 1997). Various aeromonal infections, including septicaemia, have also been reported in apparently healthy individuals; the septicaemic course is often fulminant and fatal and may lack an obvious focus.

Morganella morganii is an opportunistic secondary invader originally thought responsible for summer diarrhoea in humans. Several reports implicate this organism for causing septicaemia and abscess in the brain and ovary in neonates. It had been found in a case of chorioamninonitis and meningitis in an immune-compromised patient. It has been an important cause of nosocomial infection, though it was regarded as a relatively unimportant human pathogen in the past. *Morganella morganii* has been found in cases of septic arthritis of African dwarf crocodiles (Heard *et al*., 1988) and was also isolated from juvenile *Crocodylus porosus* (Hibberd *et al*., 1996).

Providencia rettgeri infection have caused neurological disorders (swaying, swimming in circle and head tilting) and death in *Crocodylus porosus* (Ladds *et al*., 1996) and American alligator (Camus and Hawke, 2002) hatchlings in association with overcrowding or severe temperature stress respectively. The neurological disorders and death in gharial hatchlings described by Maskey (1989) seems to have caused by this species of bacteria. The frequency of infection and death of gharial hatchlings due to this organism was almost similar (2.50-2.70%) with the reports of Ladds *et al.* (1996) in *Crocodylus porosus* hatchlings. Providencia spp. has also been recovered from human urine, throat, faeces, blood and wound specimens (O'Hara *et al*., 2000). *Proteus mirabilis* and *P. vulgaris* have been isolated from captive Nile crocodile and there are reports of septicemia in crocodiles due to these organisms. *Proteus mirabilis* has also been implicated in bacteremia, meingo-encephalitis, empyema and osteomylitis particularly in very young babies (O'Hara *et al*., 2000).

Klebsiella pneumoniae and *K. oxytoca* are opportunistic pathogens found in the environment and in mammalian mucosal surfaces. They can infect neonates having impaired respiratory host defenses and produce septicaemia. *Escherichia coli* form a part of normal intestinal flora and it is the predominant bacteria responsible for urinary tract infections, neonatal meningitis, gastroenteritis and septicemia in man and animals (Chakraborty, 1995). Poor hygiene, intensive husbandry practices and younger age are common predisposing factors for *E. coli* infection in animals (Quinn *et al*., 1994). *E. coli* was found responsible for septicaemic death in gharial hatchlings (Mehrotra *et al*., 2000) and it was also recovered from severely stressed African dwarf crocodiles (Huchzermeyer and Agnagna, 1994). In this study *E. coli* comprised 12.16% among all the isolated bacteria from the internal organs of the hatchlings where as isolates from the culture of colon swabs reached 30%.

Staphylococcus is ubiquitous organism primarily found on mammalian skin and mucosal surfaces. *Staphylococcus aureus* is associated with most suppurative lesions; however, it is the common cause of bacteremia, the infection reaching the blood through lungs, gastrointestinal tract, urinary tract and skin abrasions. Mihsra *et al*. (1993) thought Clostridium spp. responsible for the death of gharial hatchlings as they isolated it from the oedematous fluid of swollen limbs but such swelling in the carcasses were not observed in this study. Actinomyces spp. isolated from gharial hatchlings at present study are probably normal flora of oropharynx or gastrointestinal tract. Several bacterial species from apparently healthy gharials (Mishra *et al*., 1993) and wild caught African dwarf crocodiles (Huchzermeyer and Agnagna, 1994) have been isolated but the opportunistic bacteria can cause serious infections in reptiles under stress condition (Ebani and Fratini, 2005). Because of this fact, bacteria isolated from the gharial hatchlings at present study may be regarded as the evidences of the mortalities. The number of skin scrapings of the fungal lesions that were cultured and identified in this study was very few but it revealed that all of them were involved only externally. Four species of fungi that were identified in this study were also reported to occur as oral flora of American alligator and intestinal flora of African dwarf crocodiles (Huchzermeyer, 2003) and two species of fungi isolated in this study are probably new records from gharial skin lesions. Extensive hatchling mortality due to fungal infections (>50%) as described by Hibberd and Harrower (1993) in *C. porosus* was not recorded in this study. Similarly, systemic involvement in other species of crocodiles as reported by others (Fromtling *et al*.,1979; Frelier *et al*., 1985; Maslen *et al*., 1988; Hibberd and Harrower, 1993; Hibberd *et al*., 1996; Thomas *et al*., 2002) were not recorded both on gross and microscopic examination of the carcasses and tissue sections. Therefore, it can be concluded that all the isolated fungi were opportunistic pathogens and invasion was secondary to stress or debilitating diseases similar to the report of Migaki *et al*. (1984).

Pseudomonas spp., *E. coli*, *Providencia rettgeri*, *Morganella morganii*, *Staphylococcus aureus,* Salmonella spp., Proteus spp., *Aeromonas* spp., Citrobacter spp. *Klebsiella spp.,* were among the isolates obtained from other species of crocodile hatchlings.

Gharial hatchlings in Chitwan were infected highly by Exotidendrium spp. and concurrent infections with Gram-negative bacteria may be responsible for high mortality. The relationship between heavy parasitism, bacterial infection and mortality may be similar to the systemic illness and death of Green sea turtles (*Chelonia mydas*) infected with higher number of spirorchid cardiovascular flukes, other internal parasites and simultaneous infections of Salmonella, *Escherichia coli* and other Gram-negative bacteria (Radial *et al*., 1998).

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Crocodile conservation breeding programme in India past and future

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Background

The first ever programme for conservation breeding of species in India initiated was of the crocodile species, whose population in the wild has been on decline. Dr. H.R.Bustard, a FAO expert on crocodiles, on the invitation by the Government of India, initiated the programme 1975 at Tikerpada in Satkoshia Gorge sanctuary (Orissa).

The Government of India with help of the UNDP set up a Central Crocodile Breeding & Management Training Institute (CCBMTI), at Hyderbad, Andhra Pradesh as part of the Project. CCBMTI offered a 9 month Diploma Course to young forest officers in all aspects of crocodile conservation including sanctuary management. The Project funded a gharial breeding complex in the Nandankanan Zoological Park in Orissa. The enclosure was designed by Dr. Bustard, which had a huge pool 9m deep (capacity 180,000 litres) with flowing and re-circulating water. The viewing point was only 9m wide on one side of the huge enclosure, the rest having a high wall to provide these shy animals with total protection. The Zoo had three adult gharials, but the male suffered repeated penile prolapse, and it was decided to obtain a large male from Frankfurt Zoo in (then) West Germany rather than capture one from the wild in India. This male reached Nandankanan and despite never having seen another gharial since a baby, mated with the Oriyan females. Thus the world's first captive-breeding of the gharial took place.

The Crocodile Conservation Project has seen the creation of first few wetland sanctuaries of the country under the provision of the Wildlife (Protection) Act, 1972. At the beginning of 1980s, the project boasted thirteen crocodile sanctuaries. Later, several other protected areas highlighted their attention to the management of crocodilians. *e.g.* Corbett National Park, Dudhwa National Park and Similipal Sanctuary and National Park, all of which are tiger reserves covered under Project Tiger.

Out of the initial list of crocodile sanctuaries, the Nagarjuna Sagar Srisailam Sanctuary (Andhra Pradesh) was later declared a tiger reserve, and the Satkoshia Gorge Sanctuary (Orissa) has been nominated for declaration as either the second tiger reserve or an elephant sanctuary. Satkoshia Gorge Sanctuary and Bhitarkanika Sanctuary have also been proposed for declaration as Biosphere Reserves.

One of the most striking features of the Crocodile Conservation Project has been the building up of a base for wildlife research in the country - beginning with the state of Orissa, and followed by Uttar Pradesh and Andhra Pradesh. The project started a trend of involving fulltime research personnel, propagating the idea that successful conservation and research must go hand in hand.

There are four species of crocodiles recorded in the zoos. The Mugger was the most common reptiles on display in the zoos. Over 2505 individuals of Mugger *Crocodylus palustris* are housed in 62 zoos in India. The endangered Long-Snouted Crocodile *Gavialis gangeticus* are housed in 40 zoos with total population of 495 individuals. The Gharials are housed in zoos of all five regions but not in Island. There are 89 nos. of Salt Water Crocodile are housed in 14 zoos of all the regions except north India. All species are listed in Schedule- I of the Wild Life (Protection) Act, 1972.

The ex situ conservation of the following crocodilian species highly recommended by the Central Zoo Authority by providing better upkeep and veterinary care for the scientific management of crocodiles species so that zoos can play significant role in conservation of crocodiles.

1. Mugger *Crocodylus palustris*
2. Gharial *Gavialis gangeticus*
3. Estuarine crocodile *Crocodylus porosus*

1. Introduction

India is one of the rich biodiversity country of the world which harbours a large number of mammals (350 species), birds (1224 species), reptiles (4808 species), amphibians (197 species), fishes (2546 species), insects (57548 species) and plants (46284 species) in a large landscape of 77.47 million hectare of forest cover. It is one of the twelve mega biodiversity country of the world and has 8% of world biodiversity.

The country faces huge challenges on account of population growth coupled with expansion of agriculture and human settlements, industrialization and resulting in environmental degradation and loss of prime/ critical habitat for a large number of species. The growing pressure on the wild population due to shrinkages of habitat and loss of critical resources for the fauna as led to dwindling of population of many species which are on the verge of extinction in various parts of the country. India has established a large protected area network comprising of 4.58% of the total geographical area and for ex-situ conservation, there are 197 recognized zoological parks housing more than 40000 wild animals in captivity across the country, which includes 2505 nos. of Muggers and 495 nos. of Gharials (as on 31.03.2013).

A study of the status of the population in captivity in zoos reveals that a large number of species are not of important conservation value. There are few species in the category, endangered and threatened which are housed in the zoos. Moreover, the species do not occur in natural social group and with unknown lineage and therefore the task of initiating a conservation breeding programme with the available population is a challenge.

Zoos in India are regulated as per the Recognition of Zoo Rules, 1992/2009 framed under the provision of the Wild Life (Protection) Act, 1972 and reflects the policy enshrined in the National Zoo Policy, 1998. The Wild Life (Protection) Act, 1972 was amended in 1992 and a Central Zoo Authority was created to oversee the functioning and management of zoo and to provide technical support to facilitate the development of zoos in the country. The main objectives of zoos as per the National Zoo Policy, 1998 is to strengthen the national efforts in conservation of rich biodiversity of the country by supporting conservation of endangered wild animals species by giving species which has no chance of surviving in the wild, a last chance to coordinated breeding programme under ex-situ conditions and raise stocks for rehabilitating them in wild as and when it is appropriate and desirable. The National Wildlife Action Plan (2002-2016) also lays emphasizes on ex-situ breeding.

Captive breeding programmes are initiated to conserve a population of endangered species which is in danger of becoming extinct but it is not known with certainty whether such efforts can really conserve genetic diversity and produce healthy offspring for re-establishing a stable self-sustaining population in the wild. Conservation biology research suggests that in breeding and loss of fitness and health of animals can occur very rapidly, with such high magnitude with the increasing number of years of an animal in captivity. Nevertheless, there are successful examples of captive bred individuals release in the wild which maintain healthy genetic diversity and continue to sustain a healthy population. There are several scientific technologies which assist in captive breeding which stored the genetic material through cryo-preservation and artificially reproduction. There are still lots of research and studies required to investigate to what extent captive breeding procedures might ultimately help in species recovery programmes and the specific genetic factor necessary to help success captive breeding programme and alternate solutions required for crocodiles. The present conservation breeding programme will also prove an important tool to collate and collect data on the following:

2. Concept and theme of conservation breeding programme for Crocodiles

Captive breeding programmes on Crocodiles was initiated in 1975 to prevent the imminent population collapse in the wild due to a large number of eliminative pressures. The ultimate aim is to conserve to genetic diversity and re-establish self sustaining population in the wild.

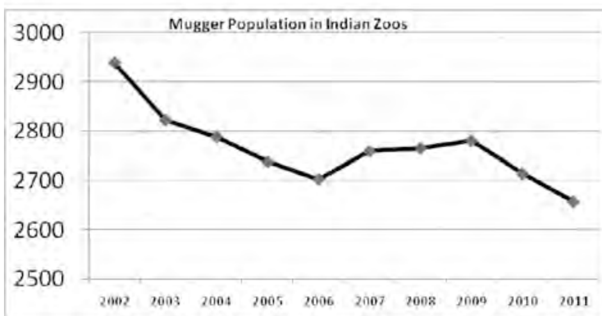
3. The need for Conservation breeding programme for Crocodiles

As we all know that Conservation breeding programme for species recovery in the wild should be initiated after careful field research to assess the status of population of a particular species in wilderness and of comprehensive assessment of the reason for decline of the species as a judgement is to be made whether the species can on its own recover in the wilderness through a species recovery strategy based on mitigation of the factors which in the first place cause the decline of the species which could be habitat degradation, change in hydrological regime of the tract, natures balance in maintaining prey-predator ration, fire and poaching. If a determination has been made that conservation alternatives are not immediately available and that captive breeding is essential for long-term survival of species. Can it be included to initiate captive breeding programme? Not as a long term conservation strategy but as a recovery technique integrated with supplementary efforts to augment and re-establish wild population. Every proposal to establish a captive population for recovery merits thorough evaluation and review. Captive breeding should not be constitute as a rehabilitation and recovery measures for species whose number has crashed in the wild below a minimum viable population. This population may still be far more viable and captive population, given the many limitations associated with captive breeding and reintroduction. Proponents of the programme justify captive breeding based on population viability enhances but regress assessment of the viability of wild in captive population is necessary. It is possible that alternative non-captive approaches may be more effective and safe than the captive approaches.
The National Zoo Policy, 1998 reiterates that if population has decline in the wild it is necessary to supplement in-situ population with the captive stock bred in ex-situ facility. This should be qualified by the fact that each species needs to be assessed whether it truly needs captive interventions. Many zoos feed that they must carry out the mandate of the policy by involving in captive breeding of Crocodiles. However, this is not the end all they may contribute by developing husbandry, reproduction, social behaviour and dietary protocols which will ultimately help raising a captive breeding stock whenever required for reintroduction.

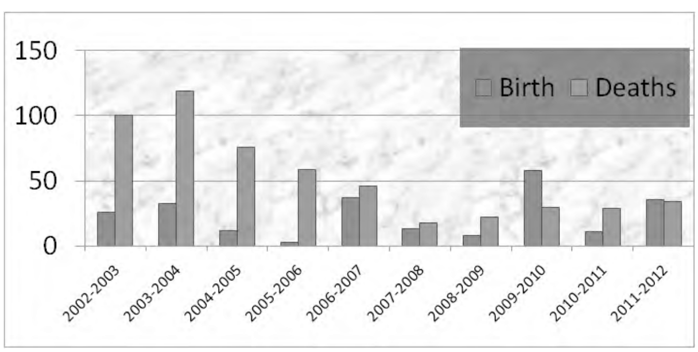
4. Breeding Programme for Muggers

Past History
The breeding programme was initiated in 1975 a Central Crocodile Breeding & Management Training Institute was established in Hyderabad, Andhra Pradesh. The first ever programme for conservation breeding of species initiated in India for the crocodile species from Nandankanan, Odisha. This Programme is considered among the successful Conservation Initiative.

At present (as on 31.or.2013) there are 2505 numbers of Muggesr are housed in 62 zoos in the country. During the last 18 years i.e. since 1995-1996, the population of Muggers have declined from 5315 numbers to 2505 number at present due to failure of breeding and high number of mortality in captivity. Inspite of Mugger bred successfully, first time in 1960 in Madras and Zoos at Ahmedabad and Jaipur. Zoos at Vadodara Zoo bred in 1964 as well as solitary record of mugger breeding than in private collection of Maharaja Gaekwad of Baroda until 1976 is exists. This success happened because of commitment shown by few organizations.



The details on the births and deaths of Muggers in Zoos during the last 10 years i.e. 2002-2012 is shown in the table given below:



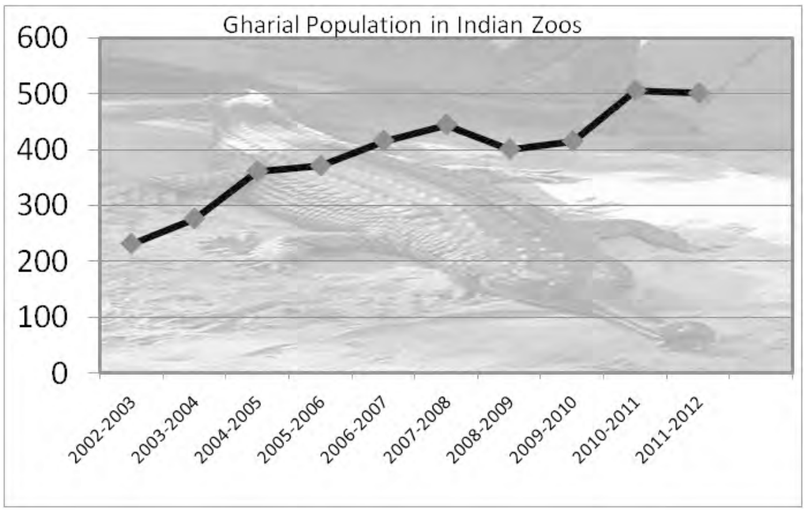
5. Breeding Programme for Gharials

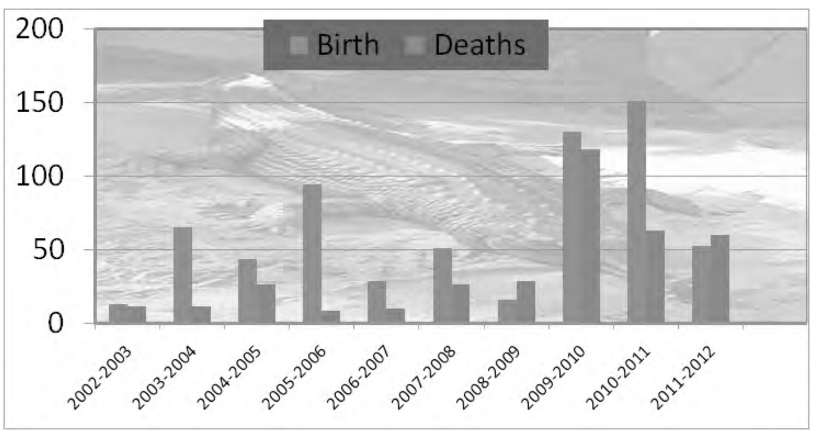
Past History

The Conservation Breeding of Gharials has the creation of first few wetland sanctuaries of the country under the provision of the Wildlife (Protection) Act, 1972.

Dr. H.R.Bustard, a FAO expert on crocodiles, on the invitation by the Government of India, initiated the programme in 1975 at Tikerpada in Satkoshia Gorge Sanctuary (Odisha). The Project funded a Gharial Breeding Enclosure in the Nandankanan Zoological Park in Orissa. The Nandankanan Zoo in Odisha, had 3 adult gharials in 1947, but the male suffered repeated penile prolapse, and it was decided to obtain a large male from Frankfurt Zoo in (then) West Germany rather than capture one from the wild in India. This male reached Nandankanan and mated and bred first time in 1980. This started similar breeding programme at at Kukrail, Uttar Pradesh under Endangered Species Project. More than 4000 reared gharial released in National Chambal Sanctuary.

There are 495 number of Gharials are housed in 40 Indian Zoos as on 31.03.2013, however the number of Gharials housed in zoos during 1995096 were 456 only, which shows significant increase in number of animals. The details on births and deaths of Gharials in Indian Zoos is given at Table…





Many zoos in India have provided naturalistic exhibits to Gharials, because of this the animals have been breeding.

6. Breeding Programme of Salt Water Crocodile

Past History

Salt water crocodile have very limited breeding records in India, however about 2000 hatchings were released in Bhitakanika and Sunderbans in 1980s. There have been instances of Salt water crocodile breeding successfully at Madras Crocodile Bank Trust, Nandankanan Zoological Park, Bhubaneshwar and Indira Gandhi Zoological Park, Vishakhapatnam. There are 89 nos. of Salt water crocodiles are housed in 14 nos. of zoos in the country.

7. Short comings/ Limitations of Captive Breeding of Crocodiles:

There is a large number of individuals who have in spite of the grand visions for captive breeding questioned a utility of the captive breeding programme provided a comprehensive summary of the limitations of captive breeding as an approach to the recovery of endangered species. These limitations are: difficulty in establishing self sustaining captive population, high cost involved in captive breeding and who were success in reintroduction which could potentially be overcome given increased resources and improved methods. Though captive breeding can form a gene pool for hundreds of species maintained in captivity for centuries and eventually as an insurance to the wild population which may rapidly dwindle in crash. Other limitations of the captive breeding programme are human habituation/ domestication and administrative continuity. The NOAH's ARC has now found acceptance as it will hold substantial gene pool which can be called as assured survival population for the safety net population. However, experts have suggested that captive breeding should not normally be recommended or initiated before careful field studies have been completed and comprehensive determination has been made that preferable conservation alternatives are not available and that captive breeding is essential for near term survival of a species. In general the species is for captive breeding and reintroduction depends on a number of factors, the most important one whether the species which are subject to threat in the native habitats due to a several eliminative/ deleterious practices and such causes are unlikely to be removed and controlled in the short-term. Conservation breeding will gain importance as the threat to biodiversity increases and it may be an important recourse for certain taxonomic groups which can be rehabilitated and species save for the extinction. Zoos are predominately contributing directly to in-situ conservation by expanding the conservation programmes beyond management of captive population by using special techniques like assisted reproduction technology which allow zoos to breed captive populations and through the long term storage of genetic material using cryopreservation.

It remains to be determined when captive breeding programme of Crocodiles are essential and warranted as ex-situ management of threatened species in zoos have to be directly linked with in-situ conservation programmes who achieve goals of conservation.

In recent years, zoos in India have generated tremendous interest in the captive breeding programmes largely due to a greater understanding at zoos are not merely to play a role for using the vast genetic resource of animal species as an exhibit for education and research but to achieve the fundamental task enshrined in the National Zoo Policy of Captive breeding of endangered species for the purpose of reintroducing dealt into wild.

Gharial exhibit at Nandankanan Zoological Park, Bhubaneshwar

8. How do we achieve success in conservation breeding?

On the experience of success stories of conservation breeding in past for the various species in India and abroad it has been recommended that to achieve success in conservation breeding for Crocodiles to follow the following line of action:-

1. Objective behind breeding Crocodilians to be defined. Not to breed Crocodiles until its objective has been defined
2. Identification of Founder Animals
3. Good off-exhibit facilities for housing

4. Standardize the husbandry practices to be followed
5. Animals nutrition, behavior, and their reproductive biology should be recorded
6. Veterinary Care of all animals should be taken on priority
7. Training for staff involved in the programme
8. Strengthening of Data, Records Keeping systems
9. Long term Management plans for breeding and post breeding of animals
10. Partners Zoos and similar organizations to be identified.

9. Future Strategies:

The Central Zoo Authority which is regulatory for all zoos in India, desired to complement and strengthen the national efforts in conservation of the Crocodiles in the country, particularly the ex-situ conservation linked with in-situ practices. It also desired that to provide better upkeep and veterinary care to the Crocodiles housed in zoos in India to ensure their conservation through best practices of management and bringing education & awareness among the people.

The following future strategies are of the Central Zoo Authority for the ex situ conservation of Crocodiles in India:

1. Continue to review the ex situ population of Crocodile and their scientific management.
2. Develop integrated long-term co-ordinated monitored programs, including crocodiles biology, behaviour and post release monitoring programme, including crocodiles biology, behaviour and post release monitoring programme with in situ managers.
3. Expand communication networks with allied professional in India and abroad.
4. Complete the marking of individuals housed in Zoos.
5. Improve the housing and enrich the enclosures to meet species requirement and husbandry protocols.
6. Look more broadly for opportunities for supplementing wild population by releasing.

10. Acknowledgements

I acknowledge my sincere thanks to Shri B. S. Bonal, Member Secretary, Central Zoo Authority (Ministry of Environment & Forests), New Delhi for his kind support and permission to attend the World Crocodile Conference held at Negombo, Sri Lanka**.**

High hatching success of saltwater crocodile (*Crocodylus porosus*) in a commercial crocodile farm of Bangladesh

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An extensive study was conducted from March 2007 to February 2012 on hatching success of saltwater crocodile (*Crocodylus porosus*) in the Reptiles Farm Ltd. (RFL) located at Hatiber village of Uthura union under Bhaluka upazila in Mymensingh. Probably, this is one of the most successful crocodile breeding programs in the world. The study was mainly based on direct field observation and some previous data collected by the farm's technicians. A special type of incubator having 98-100% moisture and 31-33^{0}c temperature was maintained to improve the hatching success. Yearly hatching success in captivity was 94.53%, 96.03%, 97.44%, 95.15% and 95.8% in 2011, 2010, 2009, 2008 and 2007 respectively. The average rate of hatching success in RFL was 95.8 ± 1.09%. In this study, 100% hatching success was found in 29 clutches out of 56 clutches. It was noted that clutch size was 19-68 eggs. Non hatching rate in the farm was 4.19% where most of the embryos had died before hatching. The average time required for incubation was 79 ± 3, 79.5 ± 4.5, 80 ± 4, 80.5 ± 4.5 and 78.5 ± 3.5 days in 2007, 2008, 2009, 2010 and 2011 respectively. This study revealed that compared to the wild habitat, captive environment in controlled conditions and predation might improve hatching rates. *Crocodylus porosus* is a critically endangered (CR) species in Bangladesh due to destruction of habitats, breeding incapability, illegal poaching, lack of awareness and other pressures. This study put emphasis on improving hatching success and creating successful crocodile farm in the world.

Food consumption and feeding habits of hatchlings and adult saltwater Crocodile (*Crocodylus Porosus*) in a crocodile farm of Bangladesh

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An extensive study was conducted on food consumption and feeding habits of hatchlings and adult (breeders) saltwater crocodile (*Crocodylus porosus*) from March 2011 to September 2012 in the Reptiles Farm Ltd (RFL) located at Hatiber village, Bhaluka, Mymensingh. The study was mainly based on direct field observation and some previous data collected by the technicians of the RFL. All crocodiles in the farm depend on provisioned food supplied by the technicians of the farm. In total 46 breeder crocodiles in 32 breeder ponds and one hatchery for hatchlings with three tubs for rearing of hatchlings up to one year were kept under observation. Average temperature of nature (^{0}C) in the farmed area was significantly correlated with average minced food consumption (g) of the hatchlings. Average food consumption was the highest in August (45.02 ±13.05 g) while temperature was the highest (30.5 ±5.5 ^{0}C). Monthly feeding quantity of hatchlings were different in 3 individual's tubs with the highest consumption in August while hatchery's temperature was 32^{0}C but air temperature of nature was the highest at 36^{0}C. Chicken, fish and beef were mainly supplied to the adults (breeders). Food was given in summer 41.4 kg/indiv and in monsoon 51.72 kg/indiv. No any provisioned food was given in winter. The highest food was given in October, probably in order to accumulation fat in their body which would provide energy in the whole winter seasons. Yearly, adult crocodiles were provisioned by 93.1 kg/individual.

Towards developing animal welfare standards for saltwater crocodiles in Northern Australia

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As crocodile farmers, we are becoming more sensitive towards the needs of our animals with the understanding that the less "stress" our management practices impose, the better our economic productivity indicators will be achieved; namely growth, survival and ultimately skin quality. However, before we can improve our management practices, we need to understand the stress dynamics imposed by our current production systems over age-cohorts and seasons. As such, a series of projects have been undertaken at two crocodile farms in the Northern Territory using plasma corticosterone as the indicator of stress. The first study showed that there was no difference between plasma corticosterone in near-harvest size communally- (n=20) or individually-housed (n=20) animals (p=0.69). However, this was conducted at one time point (July cool, dry season),butsubsequently raised further questions of seasonality and size relationships. Thus, the study was expanded to include all age categories on the farms (hatchlings, yearling, grow-outs and individual pens) with repeated measures on individuals to account for individual variation. The hatchling (n=40) and individual pen (n=100) animals were also assayed for testosterone and oestradiol levels to evaluate any interactions between these hormones. To quantify the effect of stress on innate immunosuppression, bacterial killing assays have been conducted on the hatchlings and individual pen animals using *Providencia rettgeri* (a common cause of septicaemic mortality) and *E.coli*. Additionally for the hatchlings, the effect of immune challenge with phytohem agglutinin (PHA) was assessed. The ultimate objective for the individual pen study is to understand any interaction between plasma corticosterone and blemish healing. As such, ten blemishes have been repeatedly documented for development of a blemish healing model. Both the hatchlings and individual pen animal experimental design have been structured within a genetic framework (known parentage) to quantify the underlying genetic variation in these traits.

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Computed tomography study of the cranial pneumacity of the Chinese alligator (*Alligator sinensis*)

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Abstract

Computed tomography was used to investigate and map the cranial sinuses in 2 live Chinese alligators (*A.sinensis*).

Particular attention was given to the tympanic sinus. This sinus allows communication between left and right medium ears dorsally and ventrally to the brain case which is therefore surrounded by air.

The tympanic sinus of birds evolved independently of that of the crocodilians. There is no apparent evolutionary advantage to a lighter skull in crocodilians. We review different possible functions of the various sinuses.

The skull of crocodiles is a fascinating structure that is readily recognized by scientists and laymen alike. Comparatively little attention has been given to the air spaces contained within. Nevertheless these are also very interesting and present a number of unresolved intriguing features.

Paleontologists studying archosaurian dinosaurs are fortunate in that 2 extant groups closely related to these dinosaurs persist today, aves and crocodilians. A handful of paleontologist have carried out very detailed computed tomography studies of crocodilians skulls and their sinuses in order to better understand the fossil record.

Traditional anatomy relies on very intricate written description of sophisticated tri-dimensional features interconnected and interacting with others and on two-dimensional drawings and schematics. This makes for very difficult writing, very difficult reading and very difficult understanding. With modern imaging technologies and the use of computed tomography, hard structures (including fossils) can be examined and represented visually using 3D pictures and 3D interactive video files. This makes description more accurate, uncomplicated to present and much easier to understand.

An additional considerable advantage of these virtual dissections is that scanning takes only minutes and can be carried out on live animals, or without damaging precious, sometimes unique, fossils. The images presented by the authors for the Chinese alligator and those taken from the literature for other crocodilian species speak for themselves. It is interesting to highlight the peculiar para-tympanic sinus, effectively coupling the left and right medium ears within a complex sinus encircling the braincase and communicating with the eustachian tubes.Smaller airspaces include the prefrontal sinus, quadrate and siphonealdiverticuli we will not comment on.

The functions of the para-nasal and para-tympanic sinuses are not fully elucidated but a number of hypothesis have been put forth over the centuries. These are summarized and commented upon in the two tables below. The actual mechanism by which sinuses form was most coherently and convincingly described as a "push and pull", or rather "fill and hollow", dynamic antagonism between sinusal epithelium osteoclastic hollowing of bone and bone tissue deposition.

Review of possible functions of the para-nasal and para-tympanic sinuses in crocodilians Cranial sinuses are a feature of all archosaurians and of many other groups including mammals and Man. Galen, almost 2 millennia ago, put forth the hypothesis that cranial sinuses are present for the purpose of 'equipoise', to help balance the head on the neck. While this explanation may not seem nonsensical when considering *Homo sapiens* alone and while it would be naïve to expect sinuses to have identical functions in all groups, explanations of function of a cross-taxon characteristic must be comparative and consider all taxa. Except for Man, equipoise is not relevant in other groups and therefore cannot be accepted as a possible explanation of the persistence and presence of cranial sinuses within so many groups of vertebrates.

Functions of para-nasal	Comment
Equipoise	See text above, equipoise is not relevant in other groups and therefore cannot be accepted as a possible explanation of the persistence and presence of cranial sinuses within so many groups of vertebrates.
Vocal resonators	While it is possible for sound to resonate in any cavity, animals like the giraffe that do not vocalize have well developed para-nasal sinuses
Humidification and heat exchange of inspired air	The epithelium lining sinuses is not suited for this task, unlike that of the nasal epithelium.
Increase olfactory epithelium	In species with exquisitely developed sense of smell (macrosmatic) the olfactory mucosa can invade para-nasal sinuses. Not the other way around. This arrangement is opportunistic rather than deterministic.
Shok absorption	In species where head butting is a big part of life, from woodpeckers to bovidae, the role of sinus has been shown to be minimal
Flotation device	This explanation may not be nonsensical for crocodilians but fails to satisfy a comparative evolutionary approach
Thermal insulation	Insulating the CNS is important in all animals cold or warm blooded. Behavioral evidence from finches lacking sinuses supports that these contribute to thermal insulation. Crocodilians can reach an enormous body volume and have comparatively low preferred temperatures. Insulating the CNS while gathering heat by basking would be beneficial.
Facial ontogeny, occupying space between biomechanically important pillars and optimizing facial architecture allowing maximum strength with minimum material	The idea that air spaces grow to build a frame for the final shape of the head is difficult to reconcile with known mechanisms, the 'fill and hollow' antagonism between sinus epithelium and bone tissue replaces these 3 analogous hypothesis
Weight reduction	The amount of weight shed by replacing bone with airspace is small and seems mechanically irrelevant given the powerful neck muscles. However that weight is the equivalent of a long bones from limbs and as such represent a valid metabolic economy
[illegible]-tympanic	[illegible]
[illegible]	[illegible] pressure at the tympanic membrane into displacement at the fenestra vestibuli. Para-tympanic sinus increases the total volume of the middle ear and decreases the impedance of the middle ear, especially at lower frequencies. This enhances sensitivity to lower-frequency sounds. Crocodilians have good hearing at low frequencies between 20 and 6000 Hz and hear particularly well between 150 and 3000Hz
[illegible] localize sound	[illegible]ns, like birds, lack pinnae. Coupling the eardrums allow localization of sound. Studies are needed to determine how well crocodiles can localize sound under water and whether the para-tympanic sinus plays a role in submerged directional hearing
[illegible] isolation of auditory apparatus	[illegible] inner ear from self-generated sounds is advantageous to underwater hearing and communication.

Equalization of pressure	The combined sophistication of the para-tympanic sinus and Eustachian tubes seem unnecessarily complicated to fulfill such a simple function.
Shock absorption	In species where head butting is a big part of life, from woodpeckers to bovidae, the role of sinus has been shown to be minimal
Thermal insulation	Insulating the CNS is important in all animals cold or warm blooded and evidence in birds lacking sinuses supports that sinuses contribute to thermal insulation. Crocodilians can reach an enormous body volume and have comparatively low preferred temperatures. Insulating the CNS while gathering heat by basking would be beneficial.

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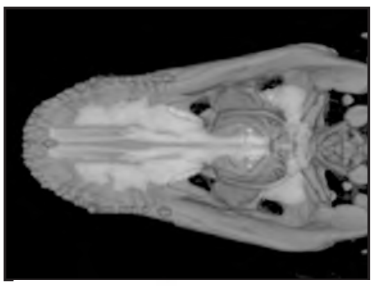
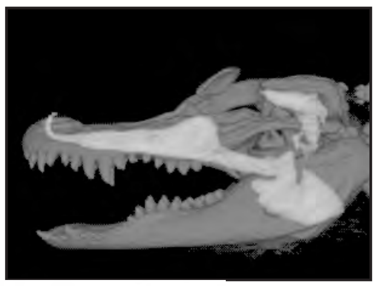
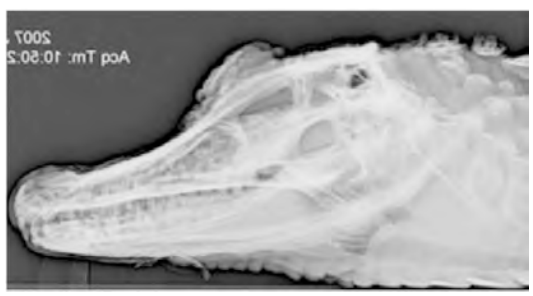
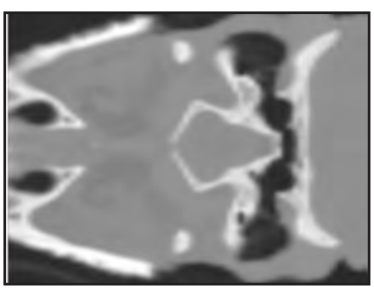
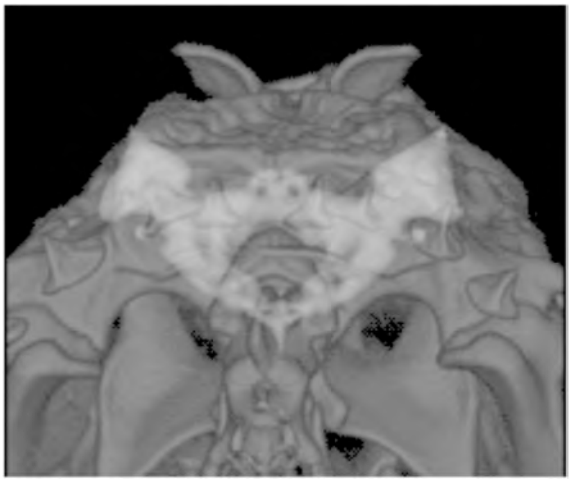
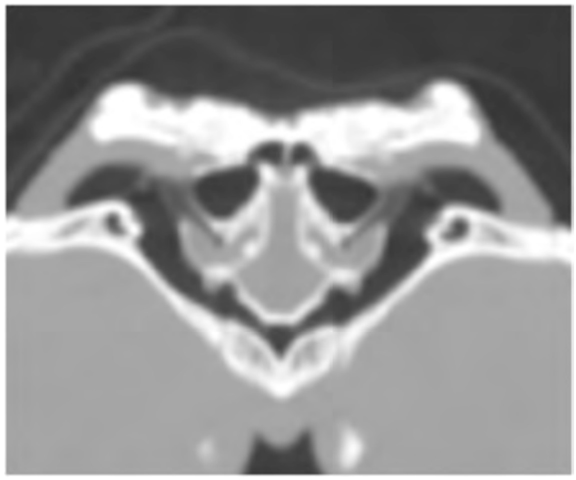
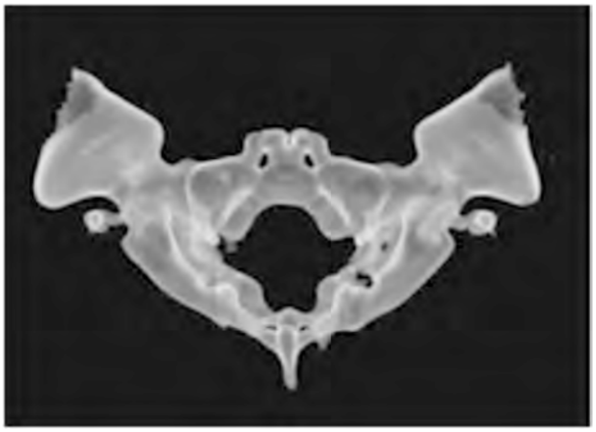



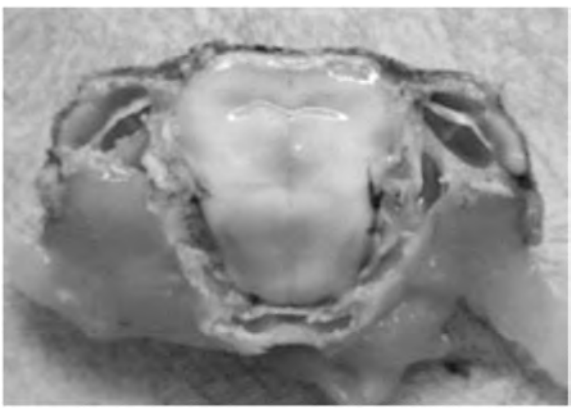
DV and lateral CT reconstruction of airsinuses and airways and DV Xrays of the skull of the Chinese alligator

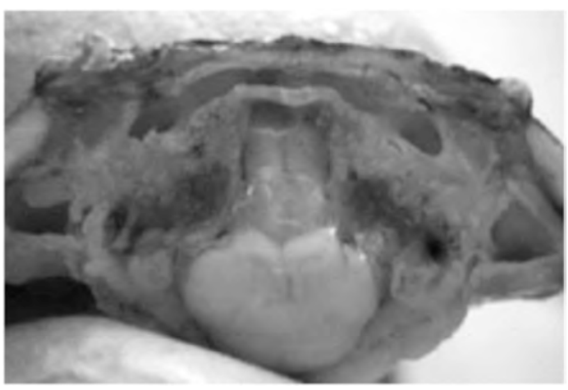






Posterior-anterior view of CT reconstruction of the para-tympanic sinus with and without bone structures and CT transverse view of the lower communication between eardrums and around the CNS





Fresh cadaver dissection of the inferior and superior inter-tympanic channels

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Managing stress in captive crocodilians

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Abstract

Captive crocodilians appear to be particularly susceptible to stress which can be defined as 'a crocodile's reaction to suboptimal conditions' or as 'a change in normal routines or environment'. This paper discusses the nature of stressors and how they compromise a crocodile's temperature dependent immune system and predispose it to infection, which may reduce productivity of juveniles and reproductive efficiency of adults in zoos, farms and large head start facilities. Good pen design is inherent to stress management and several husbandry techniques such as stocking density, group size, grading, conditioning, and the maintenance of feeding records as indicators of stress levels are discussed. A distinction is also made between the objectives of maintaining crocodiles in farms and large head start facilities and how stress management techniques may affect survival rates of released crocodiles.

Introduction

Managing stress is one of the most important issues in the management of captive crocodilians in zoos, head start facilities and farms because it is a major contributor to a lack of well-being, onset of infection and mortality. Stress may simply be defined as: -

- '*A crocodile's reaction to suboptimal conditions*' for example, overcrowding (social stress), or abnormal temperatures compromising thermoregulation (thermal stress).
- Or, '*a change in normal routines or environment*' for example, a different keeper; or a change in composition of the group causing social stress.

Stress is not an abnormal situation for livestock in the confines of captivity because animals are unable to avoid stressful situations or environments by avoidance as they may in the wild. The affect of stress varies according to severity and duration and manifests itself as poor juvenile productivity (poor growth rates and higher mortality) and lower reproduction efficiency (lower nesting frequency and fertility). Some irresponsible managers rationalise poor productivity and reproduction efficiency as acceptable because it may be similar to that of wild conspecifics but they need to realise that poor animal performance is usually a result of their own inadequacies.

In many instances, and particularly to the untrained eye, observation of captive crocodilian behaviour does not reveal levels of stress which may be confined to: -

- Individuals - for example - bullying or dominance causes social stress in subordinates.
- Groups - for example - caused by thermal stress, lack of security, or grading.
- A whole facility - for example - by overcrowding, poor diets or poor biosecurity.

Stress is frequently the underlying cause of severe outbreaks of infection because it causes the release of corticosteroids that depress the immune system which may already be compromised by a poor environment such as the effect of cold. Figure 1 shows the relationship of preferred body temperature of Australian freshwater crocodiles (*Crocodylus johnsoni*) and Saltwater crocodiles (*Crocodylus porosus*) to that of the fungal species *Fusarium.* Crocodiles are poikilothermic and as temperatures in their environment decrease their temperature dependent immune system is compromised (ie. the crocodile becomes thermally stressed) as the temperature of their environment approaches the preferred body temperature of *Fusarium* (Thomas 2004). *Fusarium* has a wide range globally and may cause substantial mortality of captive crocodiles.

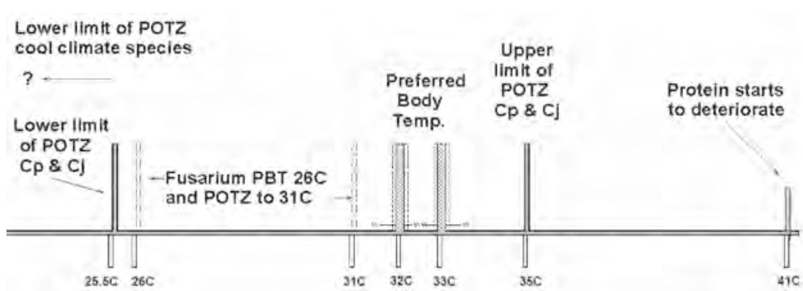

Figure 1. A temperature line showing how decreasing temperatures compromise the immune system and induce thermal stress. Temperatures in the crocodile's environment then coincide with the preferred temperature zone of the fungal species *Fusarium*: -

- PBT (Preferred Body Temperature) for crocodiles of 32 to 33C, based on incubation temperatures.
- POTZ (Preferred Optimal Temperature Zone) of 25.5 to 35C for Saltwater (*C. porosus*) and Australian freshwater crocodiles (*C. johnsoni*), established by Johnson et al. in 1976 (cited in Mayer 1995).

POTZ for *Fusarium* which prefers 26C but will survive at temperatures up to 31C (Thomas 2004).

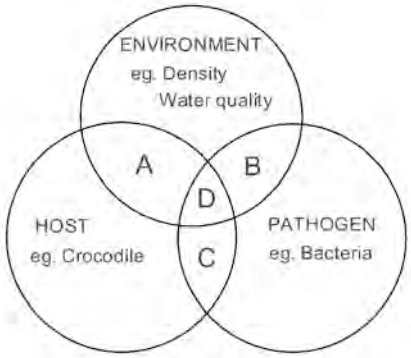

Figure 2. Sniezko's triad representing the interaction between crocodiles as a host, their environment and pathogens. These three variables constantly change and interact but when they coincide in section D crocodiles are infected. Treating the secondary infection is ineffectual because the underlying primary cause is still present.

The interaction between crocodiles as a host, their accommodation and pathogens is represented in Sniezko's triad (QDPI 2006) - note figure 2. A common scenario with hatchling crocodiles occurs when they fail to initiate feeding. Many managers resort to force feeding which is an extremely stressful experience and coincides with depletion of yolk sack anti-bodies and the onset of winter with decreasing temperatures if heating systems are inadequate. Hatchlings exposed to this type of management are frequently infected with fungus. This can be related to Sniezko's triad in which young crocodiles are subjected to stress from force feeding in a poor environment (falling temperatures) and exposed to a pathogen (fungus). These three variables coincide in section D which represents the onset of infection.

Discussion

The impact of stress varies with tolerance of conspecifics, and with age: -
Tolerance of conspecifics is a behavioural trait of particular species (note figure 3), but may vary in captivity between individual animals. For example, captive hatchling and juvenile Philippine crocodiles (*Crocodylus mindorensis*) are considered to be so aggressive by many managers of small collections that they are individually housed, and keepers in large collections of crocodilians usually know which individual adults are less tolerant (or more 'aggressive') and grant them larger safety zones during dangerous activities such as egg collection.

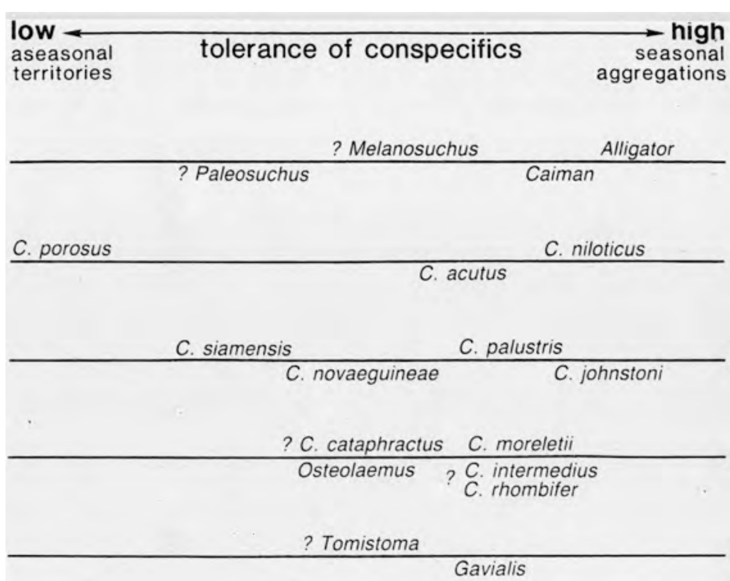

Figure 3. Tolerance of conspecifics by wild crocodilians (Lang 1987). This diagram represents the most important behavioural aspect of various crocodilian species that designers of captive crocodilian accommodation and husbandry must cater for.

1. Age. Saltwater crocodile hatchlings under 130g (approximately **one month of age**) are particularly susceptible to stress (Garnett 1983). This age usually coincides with attempts to force feed hatchlings that have not initiated feeding, which itself may be related to stress caused by several factors. Older crocodiles may habituate to some stressors such as handling, but their response may vary according to individuals or clutch (Garnett 1983) and conditioning. At Crocodile Creek Crocodile Farm (South Africa) 26 female juvenile Nile crocodiles (*Crocodylus niloticus*) of total length 1 to 1.2m died of chronic stress caused by rock blasting for a national highway one kilometre from the farm (Watson 1990).

The issues noted above relate to the impact of some stressors on different species, clutches and individuals of various ages. Managers have several means available to them to reduce this impact. They have been broadly divided into pen design and husbandry techniques: -

1. **Pen (enclosure) design**

Pen design is one of the most poorly understood and neglected aspects in the maintenance of captive crocodilians. Poor designs have a long term impact on the well being of crocodiles and productivity of farms and head start facilities, and are extremely difficult to compensate for in daily husbandry. Some relevant studies relating to the impact of social stress on reproduction include: -

- Female American alligators (*Alligator mississippiensis*) in a low stocking density averaged a nesting rate of 78.7% over three years, while those in a higher density only averaged 60.7% over three years (Joanen & McNease 1987).
- Stress may also cause infertility in females by fighting and rupturing of oviducts causing eggs to be deposited in the abdominal cavity of captive Common caiman (Palacios et al. 2004).
- According to Seebacher and Grigg (2001) the aggressive encounters of captive Saltwater crocodiles in a large lagoon and wild Australian freshwater crocodiles compromised thermoregulation of subordinate animals the same way as unfavorable environmental conditions. Dominance in Saltwater crocodiles was usually by larger animals, while female Australian freshwater crocodiles dominated smaller animals. In one animal body temperature dropped from 28ºC to 22ºC because it was unable to thermoregulate. Seebacher and Grigg suggest this dominance could have a serious affect on the physiology and general condition of subordinate animals. Certainly on one farm a colony of Australian freshwater crocodiles which annually produced 13 nests ceased production. Management attributed this to a decrease in basking sites and nest bank temperatures caused by large trees casting more shade.

In an effort to overcome these issues pen design for intolerant adult Saltwater crocodiles has evolved from natural lagoons that afford managers very little control of social stress and individual animal welfare to single or unitised pens (ie. 1:1) which provide maximum managerial benefits, but are nevertheless fraught with difficulties in establishing compatible pairs. One reason for this is probably because people are deciding which crocodiles are to cohabit.

Experienced managers are generally appreciative of the significance of stress to the well being of individual crocodiles, but nevertheless mortalities which continue to challenge our knowledge are all too frequent. Listed below are some unexplained examples of mortality in apparently healthy Saltwater crocodiles. Because there were no post-mortem examinations (except for the last example) no specific explanations as to why these animals died are included: -

- In two separate incidents large male wild caught crocodiles were released into farm breeding pens with no other occupants but in close proximity to other large established males. They could easily eyeball (direct eye contact) other crocodiles through a common fence. Both males died in a relatively short period of time with no obvious injuries, but it is possible that water quality is implicated.
- An adult captive bred female was introduced to a pen with an established male in an earth pond. She was superficially bitten when she entered the water, left the pond and 'camped' in shade under a large clump of grass. Keepers checked her frequently and she occasionally re-entered the water. In eight days she was dead. There were no obvious bite marks and the author believes that she 'died from stress', although dehydration may be implicated.
- A wild caught female crocodile was released into a small lagoon for public display in a zoo. She died several months later from septicaemia. Autopsy revealed an old wound - a mangrove root had pierced the abdominal captivity. Veterinarians concluded that stress associated with capture and release on public display with a strange male triggered septicaemia by opportunistic pathogens.

2. **Husbandry techniques for stress management**

Initially hatchlings of intolerant species are gregarious and crowd together but as they grow older some larger animals dominate and cause social stress by establishing and defending personal territories with conspecifics. If this process is left unchecked it will result in higher percentages of wasted food, decreased and erratic food consumption with a corresponding decrease in growth rates (note figure 4), a higher percentage of runts, more injuries and disease, and higher mortality rates. It should be noted that many of these variables are not specifically researched in experimental studies and so their interpretation is not always reliable.

Managers of captive crocodilians can use several techniques to overcome this process. Essentially they are stocking density, group size, grading, feeding regime and conditioning. These techniques are predominantly used in combination on commercial farms which have an objective of growing animals as fast as their genetic potential permits, but each technique should be evaluated in respect of the objectives of maintaining crocodiles in captivity ie. display, head starting or farming. For example, managers of head-starting facilities based on a farming model (ie. breeding centres) should consider the impact of conditioning for tolerance, grading and frequent human contact on survival rates of released animals.

a. Stocking density

The density of livestock in a pen influences crocodile behaviour and is best used to prevent individual crocodiles maintaining personal space. It is adjusted with growth and is part of a conditioning process used by farmers to reduce territorial disputes and achieves relative harmony within a group resulting in improved well-being and faster growth rates for grow-out stock (ie. hatchlings and juveniles). The results of some studies include: -

- Seven-month-old Philippine crocodiles (*C. mindorensis*) grew faster with lower mortality at highest stocking densities of 10 - 12 per square metre (Sumiller & Racuya 2008).
- Seven-month-old American alligators were maintained in pens with an area of 2.1m^2 for three and a half months. Growth rates increased significantly at lower density 110% increase at a density of 2.8 alligators per m^2, compared to an increased growth rate of 77% at a density of 11.1 alligators per m^2 (Elsey et al. cited in Mayer 1997).
- Saltwater crocodiles less than one month of age were accommodated in pens 1.7m^2 with 54% water at a depth of 10cm. Hatchlings at a density of 10:m^2 generally attained the best performance measured by increased total length (Webb et al. 1992).
- In a well-controlled experiment 8.5-month-old Saltwater crocodiles were graded into groups of small/medium and medium/large based on weight. Both groups recorded better growth rates at lower densities, the lowest density being 5 animals per tank of 3m x 1.3m (3.9m^2) with lower growth rates at densities of over 15 per tank. Increasing stocking density had a relatively greater impact on the small/medium animals and food conversion ratio decreased from 26 to 24% as density increased from 9 to 40 animals per tank (Mayer & Peucker 1997).

b. Group size

In a farming system hatchling Saltwater crocodiles are usually accommodated in pens at a density of approximately ten to the square metre (10:m^2) and according to Webb (1992) are best kept in groups of 40 crocodiles per pen. In figure 4 growth rates increased for hatchlings when group size in combination with stocking density decreased.

The impact of larger group sizes, while still maintaining optimal stocking densities, is poorly researched (particularly in respect of cost-benefit analysis) bu[...]re managerial problems associated with larger groups and that social st[...]

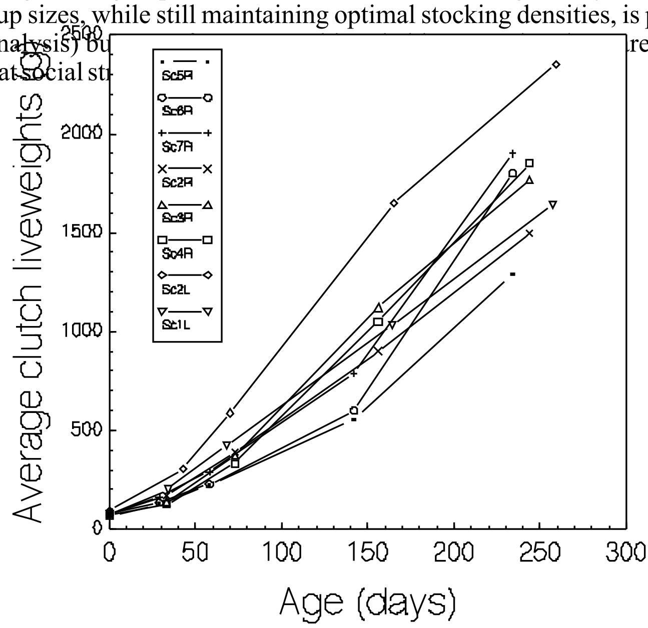

Figure 4. Graph showing results of a farm trial to assess the impact of stocking density and group size on growth rate.

Growth rate up to day 142 appears to be inhibited for clutches scute 5, 6 and 7 Right by the high stocking density of 116 animals to a pen with an area of 5m² (23:1m²) and then accelerates after 44 animals are removed, resulting in a stocking density for those remaining hatchlings (ie. clutches scute 5 and 6 Right) of 14:m², and to 8.8:m² for clutch scute 7 Right.

c. Grading

Grading is the removal of crocodiles from a particular pen with the objective of reducing dominance by size by separating small, medium and large animals into respective groups to maximise growth. Large hatchlings tend to grow well in graded or ungraded pens, but no grading results in greater size discrepancy within the group and associated stress with erratic feeding, lower growth rates of some animals, and higher percentages of runts and mortality. Some farmers grade all animals in a particular age cohort on a regular basis starting as early as six weeks of age, and managers of some head start facilities grade young animals to reduce physical injuries because they may impair the survival of individuals after release. However, one of the major causes of mortality in some released species is cannibalism, and grading to reduce the impact of dominance may impair the ability of released crocodiles to recognise larger conspecifics as a threat.

There are negative aspects to grading. It causes stress or even trauma during capture that will quite often increase susceptibility to infection or kill weaker crocodiles, particularly when associated with thermal stress in winter; and disrupts crocodiles accommodated in adjacent pens. It is possible that the whole hatchery (nursery) will go off normal feeding, and the growth of graded crocodiles will be compromised for up to three weeks while pecking orders are re-established in new accommodation. This can be interpreted as a loss of production. It should be noted that crocodiles in a hobbyist collection or research facility are often conditioned to frequent handling and are not as adversely affected by grading.

Stress associated with grading can be reduced by always leaving some water in the pond, or may consist of intermittently removing one or a few animals rather than a whole group. Removing one large dominant animal to reduce social stress is usually a temporary solution because another will soon take its place in the pecking order so consideration should be given to removing smaller animals first.

d. Feeding regime

A good feeding regime should involve a balanced diet fed out in sufficient quantities and frequency so all animals receive adequate food. In a healthy environment this will result in a continual rise in food consumption by grow-out stock. Conversely, insufficient frequency of feeding and small feed platforms will encourage more dominance and stress at feed time, and stress from overcrowding will cause erratic food consumption note figure 5. There is an obvious need for managers of head start programs to assess the relationship of captive feeding regimes to a released animal's ability to recognise and capture live prey.

e. Conditioning as part of daily activities

Conditioning is simple learning, and is integral to good husbandry. Essentially managers of captive crocodiles are conditioning their livestock to tolerate conspecifics by using a combination of the above techniques, but they also condition livestock to remain calm in the presence of keepers by working calmly and quietly. One of the wisest comments in relation to this subject comes from a sheep shearer whose daily quota may be up to 200 animals - if you want to be aggressive the sheep will retaliate, and at the end of the day the shearer (or keeper) will have suffered the most. It is generally accepted that animals intended for wild release should receive minimal human contact. One example of how this may be detr y years. After release it frequen de Ven 2012, pers. com.).

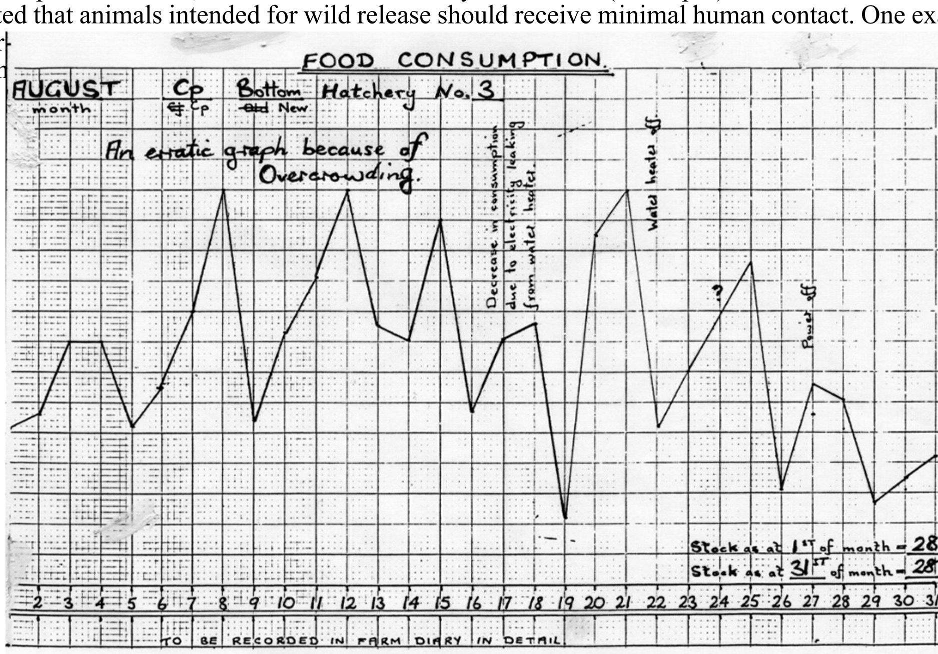

Figure 5. Food consumption graph (developed by a farm keeper for hatchery tub number 3) used to monitor stress in eight-month-old Saltwater crocodiles. Erratic consumption is caused by hatchlings that have outgrown their accommodation and need grading.

Conclusion

Susceptibility to stress in captive crocodilians can vary between species, individuals and age; and its impact is related to severity and duration. It is often poorly understood and difficult to assess visually, but management to prevent stress is nonetheless extremely important as an animal welfare issue because of its effect on the well being of individual animals and its implications in the onset of infection which may impact on the wider group. It is thus incumbent upon managers of captive animals to use tools such as feed charts and daily observation by keepers to monitor the well being of individuals and groups.

Crocodiles are maintained in captivity for various reasons for display, farming or head starting. Each of these types of captivity has a unique system which should be determined by its own objectives. For example, farmers have developed a system to manage stress with an overall commercial objective of improving productivity based on the efficient production of a blemish free skin. They incorporate certain pen designs and several techniques researched on a species-specific basis - these are stocking density, grading, group size and conditioning.

Head starting has a different objective the efficient production of animals on a species specific basis that are suitable for release and will attain a high survival rate. Most importantly managers of head starting facilities, and particularly those structured as large breeding centres, need to assess those attributes necessary for the survival of released crocodiles on a species specific basis; and then design pens and adopt stress management techniques that will enhance the survivability of these animals.

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Survey results for captive management of the Philippine Crocodile, *Crocodylus mindorensis*

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Abstract

The Philippine crocodile *(Crocodylus mindorensis)* is Critically Endangered (IUCN 2012) but captive attempts to raise young and achieve reproduction are often thwarted by their intolerance of conspecifics soon after hatching and into adulthood. Consequently many zoos and head starting facilities maintain young animals in individual pens for varying periods of time which may inhibit their ability to socialise and exacerbate their chances of achieving compatibility for reproduction in adulthood. Many adults are kept separate until a suitable time for mating.

Because of this management challenge the CSG Veterinary Group surveyed and collated information from seven zoos to assess the potential impact of enclosure design and husbandry practise on intolerance in captive hatchlings and juveniles, and incompatibility in adults. This objective could not be achieved as it was felt that not enough information could be gleaned from the survey, and the issue is confounded by variation of behavioural traits in individual crocodiles. To help explore this issue further information from Avilon Montalban Zoological Park, Palawan Wildlife Rescue and Conservation Centre (PWRCC), Silliman University and Mabuwaya Foundation head starting facility (all in the Philippines) is also included. This extra information enabled the authors to conclude that the behaviour of *C. mindorensis* may be typical of other intolerant crocodilian species to conspecifics and found some evidence to suggest it can be alleviated by alternative enclosure design, landscaping and husbandry practise such as stocking density.

Introduction

In captivity the Philippine crocodile (*Crocosylus mindorensis*) is considered to be intolerant of conspecifics it appears to be difficult to raise and breed because of territorial disputes. Consequently many zoos and head starting facilities maintain young animals in individual enclosures which may inhibit their ability to socialise and diminish their chances of achieving compatibility for reproduction in adulthood. However, at the Palawan Wildlife Rescue and Conservation Centre (PWRCC) hatchlings and juveniles are maintained in groups, and reproduction occurs in a large colony. In the absence of a stud book at the time of the 2012 CSG meeting (noting that a European Studbook has since been produced) the Veterinary Group decided to survey zoos holding *C. mindorensis* with the objective of ascertaining the success of captive reproduction in relation to enclosure design and husbandry. A questionnaire was sent to eight zoos in 2012 requesting information on: -

1. Number of mature males and females in each colony, including information on individual animals with tag numbers and origin.
2. Behaviour of animals in each colony.
3. Diet.
4. Enclosure design - by attaching photographs, sketches and/or 'floor plan' of enclosures including fence measurements, pond dimensions including depth (if an irregular shape this may be expressed as a percentage of enclosure area), enclosure furnishings, water temperatures (maximum and minimum, and whether artificially heated or not), and any other relevant information.
5. Reproductive performance for each colony.

Results

Seven zoos replied and a summary of the collated information supplied is presented in figure 2. All information is available on request.

Discussion

Survey results revealed a similarity of designs incorporating adjoining single enclosures with common mesh walls and gates imbedded in both land and water note figure 1. Outside the Philippines there has been limited reproduction of this species with the exception of Gladys Porter Zoo (USA), but this may be confounded by individual ages of animals and time to establish compatibility in new accommodation. This is likely to be the case with the European zoos surveyed, as their animals were all eight years old when the survey was undertaken and this species is considered to reach sexual maturity at 10-11 years and 15 years for females and males respectively. In 2012-13 the first breeding of a pair at Melbourne Zoo occurred at 13 and 14 years of age, female and male respectively.

Figure 1. Typical zoo exhibit for display of male and female adult *C. mindorensis* at Bergen Zoo. Note separate exhibits with intervening mesh wall to assist with achieving compatibility.

Generally exhibits were of high aesthetic standards highlighting respect for the species and complemented by interpretative and educational materials. One interesting variation in pen design is at Paignton Zoo which provides accommodation for one pair in individual enclosures with a third common 'transitional' pen available.
Both the Mabuwaya Foundation head start program (Philippines) and the Gladys Porter Zoo have hatched and raised substantial numbers of *C. mindorensis* but both institutions maintain hatchlings in individual enclosures - at Gladys Porter individual accommodation starts at approximately two months of age and continues for small juveniles (year 2). Mabuwaya transfers these animals into an open communal enclosure for socialisation and conditioning which excludes human contact except for monthly weighing. Their three stages (ie. hatchlings maintained as individuals, small juveniles in a communal enclosure mentioned above and a third wild soft release into a man-made dam) cost less than $1,000 per annum.

Avilon Montalban Zoological Park (Philippines) has also established a captive breeding program. Yuyek (2008) reports juvenile and adult mortality caused by territorial disputes with conspecifics, but notes that the introduction of Water Hyacinth (*Eichhornia azurea*) stopped fighting within groups of hatchlings and juveniles. This was thought to be successful because the floating plant acted as a visual barrier between individual crocodiles. The PWRCC has used lengths of floating timber in the past to achieve similar results. Yuyek quotes several examples of adult fighting and mortality in breeding groups. The authors note that these examples appear typical of territorial behaviour by intolerant species (Lang, 1987) but in the absence of dimensions or features of breeding pens it is difficult to make informed comment.

The PWRCC reproduce and maintain *C. mindorensis* based on a farming system. In a one year study on stocking density Sumiller and Racuya (2008) separated 91 seven month old *C. mindorensis* into two groups based on body weight. In both groups (small/medium, 400g; and medium/large, 400g) better growth occurred at a density of 5 crocodiles per square meter in tubs 0.92m x 1.36m with 50% water at a depth of 0.2m and temperature 27˚C. In the medium/large group survival was highest at high densities (10 and 8 crocodiles per square meter) and lowest at low density of 3 crocodiles per square meter. In the small/medium group highest survival rates (ie. 100%) occurred at the highest densities of 12 crocodiles per square meter, with lowest survival rates occurring at the lowest density of 5 per square meter. Mortality was mostly attributed to territorial dispute in both groups, but Sumiller and Racuya conclude that *C. mindorensis* can be maintained at densities that minimise dominance and promote growth. It is unlikely that this approach can be implemented in zoos, especially if they are located in temperate climates because of the costs of construction and provision of adequate temperatures for thermoregulation, but it does highlight density management as one means of reducing territorial disputes.

In 2008 the PWRCC stocked 159 adult *C. mindorensis*, 8590% of which were maintained as breeders (Sumiller & Cornel, 2008). The remainder were unsuitable because of physical defects or behavioural problems, which mostly consisted of aggression to conspecifics. 'Pairing time' usually resulted in 47% compatibility, and some females double clutched with an average interval of 159 days between clutches. Stocking density was approximately 10-20 square meters per crocodile and pen dividers were installed to reduce visual contact. In 2008 PWRCC had ceased breeding because of lack of space and release sites.

The first captive facility established for breeding *C. mindorensis* was at Silliman University in Dumaguete City (Philippines), in 1980. Alcala et al. (1987) recorded captive breeding from 1981 to 1984. The main enclosure for the breeding pair of *C. mindorensis* was a naturally landscaped area of 15.0 x 11.6m with a 42 square metre pool. The adult female exhibited aggression toward a conspecific female and a Saltwater crocodile (*C. porosus*) in an adjacent enclosure. Hatchlings maintained as groups tolerated each other, but fighting resulting in

mortality was recorded between juveniles. Enclosure size was increased following this, but there was no comment about individual housing. In an attempt to address some of the issues noted above, three male and four female *C. mindorensis* were accommodated in a small fenced lagoon in March 2007 at Pag Asa Farms in Mindanao. The lagoon measured approximately 28m x 39m, and was established in collaboration with Silliman University and the Protected Areas and Wildlife Bureau (PAWB-DENR). No supplementary food was offered and as of May 2012 production totalled three juveniles and 36 hatchlings (Vic Mercado 2012, pers. comm.). Limited information is available on any aggression that may have occurred within this group.

The challenges faced by managers of *C. mindorensis* in captivity should perhaps not come as a great surprise, as there is very little historical information on densities of naturally-occurring *C. mindorensis* populations. Ross (2008) was of the view that these crocodiles prefer small wetlands where they are at "relatively low densities". This does appear to be the case with most of the remaining wild populations, but it remains unclear if that is a result of external pressures (eg. habitat loss and predation) or a natural preference.

Similarly, our understanding of the internal dynamics of wild *C. mindorensis* groups and populations, whilst limited, points to intra-group aggression and territorial establishment at an early age being normal behaviours. Intra-group aggression has been observed among wild juveniles in northern Luzon Island (Philippines), as well as the establishment of individual territories by juveniles in their second year (van Weerd, 2010).

Conclusion

The survey results did not achieve the intended objective of assessing a relationship between alternative enclosure designs and husbandry on maintaining juveniles and achieving compatibility of *C. mindorensis* in zoos. It revealed similarities in housing which enabled a common method of establishing some compatibility, and similar juvenile husbandry. Conclusions from the survey are limited because: -

1. The responding zoos used similar approaches to maintaining and exhibiting their crocodiles and most had not held crocodiles for long enough to instigate changes in enclosure design that resulted in changes to compatibility with conspecifics.
2. With the exception of Gladys Porter Zoo, no zoo had bred *C. mindorensis*; although Melbourne has since done so.

This survey was the first to collate information on captive management of *C. mindorensis* in zoos outside the Philippines. As such, the results will assist all zoos maintaining the species. They will also feed into the development of a coordinated global approach to the species' husbandry, which is now timely for effective management of captive reproduction.

We would like to thank all those zoos that replied to the survey.

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Figure 2. Part 1 of collated data from questionnaire sent to eight zoos maintaining *C. mindorensis*.

ZOO	Date of Acquisit.n	M	F	Rep.n	Comments	Diet
Bergen Zoo	Both from Palawan. Male: 2004 Female: 1999	1	1	Nil	Two animals kept in separate enclosures with mesh in common walls for land and pond, problems with compatibility. Total area of 4.5m x 2.5m, water 0.5m deep at temperature of 25ºC. Land temperatures 28 – 35ºC.	Mice, rats, & freshwater fish
Cologne Zoo	From Philippines	1	1	Nil	Three part enclosure (total 62 squ.m.) separated by mesh. Two animals kept separate and introduced to third section; 2012 first mating. Water depth 1m+, temperature 28ºC.	
Danish Zoo, pair no. 1	Arrived 2006 From Krokodil Zoo	1	1	Nil	In one enclosure separated by a net. 2011 move to 'Tropical Hall' without a fence and observed dominance by size (female and later male). 16 cubic m. pond + 7 squ. m. land. Temperatures of 25 to 30ºC winter to summer. Mating observed, nesting, and eggs laid.	Rats, 4wk old chicks, freshwater fish.
Danish Zoo, pair no. 2	Arrived 2006 From Krokodil Zoo	1	1	Nil	No contact until 2011 when placed together but separated by a net, then achieved good compatibility. 12 cubic m pond + 5 squ. m. land. Mating observed, no nesting.	

Figure 2. Part 2 of collated data from questionnaire sent to eight zoos maintaining *C. mindorensis*.

ZOO	Date of Acquitisit.n	M	F	Rep.n	Comments	Diet
Gladys Porter Zoo	Both from Philippines Male: 1973 Female: arrived ? Died 2006	1		Up to 20 @ 3ft TL	Extensive off limits accommodation for adults with ability to separate animals – this was often necessary during mating. Intermittent breeding 1988 to 2004. Best reproduction on diet of fresh killed rodents. Hatchlings may be kept in a tray for one month and then a bath-tub for a month, and then have to be separated and reared singly.	Fish + min/vit. Or fresh rats
London Zoo						
Melbourne Zoo	2003, Palawan, Philippines	1	1	1st nest 1	Since 2010 – one pair about 13yrs old in adjoining accommodation with common gate, total of 12m wide x 5m front to back. Heated floor and air conditioning. Two ponds: **a.** (female) – 2m x 1.5m x 0.4m deep, **b.** (male) – 4m x 3m x 1.0m deep. Temperature of floor and pond – 24 to 30ºC winter to summer. Mating in September 2012 produced a first clutch of 4/10 fertile eggs, with one surviving hatchling.	Fish, rats, fresh meat
Paignton Zoo	On loan from Chester Zoo, Originally from Krokodil	1	1	Nil	Together since 10/9/2012. Enclosure consists of 3 adjoining enclosures/ponds heavily vegetated, plus furnishings to reduce direct eye contact. One enclosure is a 'meeting' or 'transitional' area with water lilies. Pond 2 – 7m x 5m: pond 3 – 6m x 5m. NB. Map supplied.	As above, + crayfish, & invert-ebrates.
Zurich Zoo	From Krokodil in 2007	1	1		No compatibility. At first female dominated and then male, which had been growing fast. Pen area 55 squ. m. with water volume of 12 cubic m. Land temperature 23 to 32ºC.	Chicks Fish

An introduction to reproductive study of the mugger crocodile (*Crocodylus palustris*) in Iran

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A small population of Mugger crocodiles is distributed in the southeastern part of Iran, in Sistan & Baluchestan Province, the westernmost global range of the species. The nesting season for Mugger crocodiles in Iran has been reported to be in May and consequently, the eggs hatch in July; but based on the observations made in the surveys it seems that the nesting season could be extended. From four nests found in the wild, 24, 26, 21 and 13 eggs were counted. A 2.2 m female Mugger, who had fallen into the Pishin Dam overflow pond, laid 21 eggs exposed to air on the concrete. The female crocodile was removed and relocated to a captive situation in Dargas where she laid 18 and 25 eggs in two consecutive years. The mean size for the eggs in the last three nests was calculated 75.66 mm in length, 47.72 mm in width and 91.27 g in weight. The main habitats with adult crocodiles were visited in the early hatching season to catch the hatchlings using the "spot light" method. During the studies 19 hatchlings from 7 different nests were captured from four main sites. The mean total length and weight for 19 captured hatchlings was 30.47 cm (range 29.24 to 33.90 cm) and 84.29 g (range 66.19 to 90.30 g) respectively Based on the observed and counted hatchlings in each site and comparing the clutch size, it seems that hatchlings have a high mortality rate in the early stages after hatching due to natural threats. Guarding and defense of the nests and hatchlings was evident in most studied cases. anon one occasion, a hatchling was found in a burrow, which the authors believe indicates parental care or intention of using burrows by hatchlings as a refuge in harsh situations.

Hematology and biochemistry of juvenile and yearling gharials

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Gharials (*Gavialis gangeticus)* belong to schedule I of Indian Wildlife Protection Act (1972) and are critically endangered (IUCN, 2009). But, there are critical gaps in database for normal health parameters for clinically evaluating the health status of gharial. During the study period at, Gharial Rearing Centre, National Chambal Sanctuary, Dewari, Morena, Madhya Pradesh gharials were physically restrained for detailed examination and collection of different biological samples. A concise systematic schedule was prepared for physical restraining and blood samples were collected aseptically from 8 restrained juvenile and 9 yearling gharials to analyze hemato-biochemical parameters and to establish a reference range for various parameters. The mean values of TEC (millions/µl), TLC (thousands/µl), Hb (g/dl), PCV (%), MCV(fl), MCH (pg), MCHC (g/dl), Heterophils (%), Eosinophils (%), Basophils (%), Lymphocytes (%) and Monocytes (%) for juveniles and yearlings are 0.72, 12.13, 6.65, 22.88, 319.96, 92.87, 28.77, 27.88, 5.50, 3.88, 52.63 and 11.50 and 1.18, 21.78, 7.96, 25.33, 244.00, 70.16, 31.57, 31.11, 8.44, 6.56, 43.00 and 10.67 respectively. The mean values of AST (IU/L), ALT (IU/L), ALP (IU/L), Total Protein (g/dl), Albumin (g/dl), Total Bilirubin (mg/dl), Direct Bilirubin (mg/dl), Uric acid (mg/dl), Creatinine (mg/dl), Calcium (mg/dl), Phosphorous (mg/dl), Sodium (mmol/L), Chloride (mmol/L) and Potassium (mmol/L) for juvenile and yearlings are 43.25, 74.35,43.25, 4.95, 1.93, 1.47, 0.64, 4.14, 0.55, 6.79, 2.20, 159.66, 6.67 and 104.74 and 55.73, 77.00, 64.00, 4.52, 1.91, 1.02, 0.59, 4.13, 0.53, 10.39, 3.29, 150.75, 5.77 and 101.58 respectively. Comparison of the values were made between juvenile and yearling gharials and also to the known values of crocodilians.

Host-Parasite interactions of *Osteolaemus tetraspis*, the African Dwarf Crocodile, and its gastric parasites

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Knowledge of the trophic position of *O. tetraspis* in the local foodweb network can assist in conservation management, particularly if environmental perturbations negatively affect food web connectivity. Additionally, parasites can be utilized as bioindicators to identify the strength of foodweb topology interactions, and to monitor environmental alterations. Nematode parasites were collected from *Osteolaemus tetraspis* from the Abanda cave system off the Fernan Vaz Lagoon in Gabon. A total of 95 helminths were collected from 11 infected hosts (50%) of the 22 crocodiles examined. Parasite prevalence, intensity, and abundance were analyzed to evaluate variation between size, location (inside or outside of cave), and sex of host crocodiles. No significant difference was found between the prevalence of infection inside and outside the cave system (W=280.5, P =0.3586), between sex (W=277.5, P =0.3891), or between size (W= 288.5, P=0.2703). However, sex significantly differed in mean parasite abundance (Bootstrap t-test, p=0.039), and size was significantly different in median intensity (Mood's median, p=0.01). Location and size were also shown not to affect parasite intensity (MANOVA, p=0.644). Parasitism among *O. tetraspis* was found to be homogenous and not aggregated among sub-categories of size, sex, and location (Total nematode overdispersion coefficient: 6.88619e+16). This is an interesting finding as aggregation is predicted among a population of hosts, i.e, there should be a significant difference among hosts that are infected and not infected.

Based on diet data of crocodile specimens from this study, and previous documentation of infections of *Dujardinascaris sp. infections in* other reptiles in the region, fish are hypothesized to be the intermediate hosts for this crocodilian nematode. These data provide insight of preferred prey, and the role of *O. tetraspis* in the food web.

Genetic analysis on these nematodes in correlation with genetic data of the host *O. tetraspis* will be discussed. In brief, by comparing genetic data of parasites and crocodiles (hosts), we can further clarify questions on crocodilian dispersal and population structure which can have implications for conservation. This concept can be expanded for a comparative phylogeographic study that includes specimens of *Dujardinascaris* sp. collected from every crocodilian species. An upcoming study on nematode crocodile coevolution will be discussed.

Stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) predict gastric parasite dynamics in the American Alligator (*Alligator mississippiensis*)

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In this study, we tested various hypotheses regarding patterns of gastric nematode parasitism in *Alligator mississippiensis* from estaurine and inland freshwater habitats using measurements of stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) from epidermal keratin and stomach contents. Alligators inhabit a wide geographic range in the southeastern US in which prey availability and abundance vary, influencing the hosts' parasite infracommunity. Interestingly enough, American Alligators have similar parasite infracommunities across their distribution. It is possible that the range of alligator parasite intermediate hosts is sympatric with the reptilian definite host, distinguishing the preferred prey of alligators as a result of a long co-evolutionary history between predator, prey, and parasite. Although stomach content analysis provides insight on alligator diet in the short-term, it provides only a limited account of the full spectrum of the alligator trophic interactions. Stable isotope ratios, however, provide insights into long-term trophic interactions, as turnover rates for keratinized epidermis is ~ 2 years. Additionally, parasites that are trophically transmitted provide evidence of prey consumed over an extensive period of time, providing a more accurate picture of the predator-prey dynamics.

Parasite intensity and species richness was significantly different between estuarine and inland freshwater populations (both $P<0.01$). A MANOVA performed on the combined data of $\delta^{13}C$, $\delta^{15}N$, and location significantly predicted parasite intensity ($P=0.01178$), the most significant predictors being $\delta^{15}N$ and location. Pearson correlation test showed that parasite intensity increased as $\delta^{15}N$ increased ($P=0.03933$). These data suggests variation of habitat and levels of $\delta^{15}N$ can assist in predicting alligator parasite intensity. This information can assist in identifying alligator parasite intermediate hosts.

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Necropsy report of the largest Indo-pacific Crocodile, "Lolong', in captivity at Bunawan, Agusan Del Sur, Philippines

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Abstract

"Lolong", a 6.11 meterlong Crocodylusporosus, was caught in Bunawan, Agusan del Sur, Philippines on 3 September 2011 and kept in captivity until his death on 10 February 2013. Necropsy and histopathology revealed that the cause of death was congestive heart failure complicated by late stage mycoticpneumonia and multiple organ failure. Other lesions also indicated problems in management and husbandry. Liver and kidney samples also indicated high levels of mercury at 55 and 18 ppm, respectively.

The high levels of mercury found in the liver and kidney suggested that contamination may have been present even prior to captivity. As such, Lolong's condition indicated that the Agusan Marsh is already contaminated and thus compromised as a habitat. It was strongly recommended that water quality testing be conducted throughout the marsh and steps be taken to identify the source, stop and, if possible, remove the contamination especially given its public health significance.

Introduction

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A 6.11 meterlong Indo-Pacific crocodile, christened "Lolong", was caught from Magsagansang Creek, a tributary of Agusan Marsh in Nueva Era, Bunawan, Agusan del Sur, Philippines on 3 September 2011. The animal was kept in an8 x 10 meter pen with a pond at the center about 1.5 meters deep in Bunawan. It started feeding a month after its capture and was thereafter fedabout 10 kgs of pork alternated by chicken meat every 10-20 daysusually between 7 to 11 pm. White spotsperceived as "rope pressure" marks were noted on the left front limb, tail base, and on tail end and were treated with povidone iodine (Sumiller, 2012a).Three months later, the white spots, which were eventually suspected to be fungal infection,were said to have been controlled with a combination of guava leaves extract, povidone iodine, and anti-fungal ointment (Sumiller, 2012b).

Case History

On 9 February 2013, the crocodile was observed floating in the pond, listing to its right. The on-call veterinarian visited the following day and noted a slight distension in the right chest area. He further noted that it was less active. Although it could not put weight on its legs, tail movement was observed and the animal growled when approached. Body temperature registered at 22°C. Multivitamins (20 mL) were given intramuscularly with no signs of improvement. The condition of the animal deteriorated further as the day progressed. The crocodile ceased to breathe and respond to any stimuli and was pronounced deadat 8:12 pm of 10 February 2013 (Collantes, 2013).

It should probably be noted that the animal supposedly regurgitated food a week prior to its death (Lastica and Masangkay, 2013). Apart from this matter being part of the clinical history on the histopathology report, there was no mention of the incident in any other records related to the crocodile. This was only verbally imparted by the caretaker and was never recorded in either the monitoring or clinical report prior to death.

Methods

Necropsy was conducted on 11 February 2013 from 1:50 to 7 am. Measurements were taken and the animal was examined for external lesions. Swabs were taken from the nares, ear, and cloaca for bacterial and fungal isolationand these were sent to the municipal hospital (results not received as of writing). The crocodile was then placed on its back and the skin deflected laterally to expose the ventral musculature. The ventral wall of the body was removed to expose the internal organs by cutting the soft tissues from the mandibular symphysis going lateral and caudal towards the cloaca while both clavicles were detached at the shoulder joints.

The organs were first observed in situ before the respiratory tract and heart were removed and examined separately from the rest of the internal organs. Tissue samples were collected for histopathologic and toxicologic examination. The skin and skull were then removed from the body and preserved for taxidermy at a later date. The bones were buried with muscles attached for future retrieval. Because of plans for taxidermy, the brain, brain stem,and spinal cord were not examined.

Results and Discussion

Necropsy Findings

External Examination: Old scars and ulcerations were observed on the palmar and plantar surfaces of the appendages(Figure 1). These lesions suggested constant, chronic pressure on the said surfaces. Other similar crocodilian cases in the past have proven fatal because of the ensuing systemic infection (Ross, pers. comm.)Sides of exposed teeth were apparently scraped and a 3.9 cm-long bruise on the left jaw was also observed. Clear, stringy mucus fluidconstantly dripped out of the nostrils when the animal was placed on its back. The right side of the torso appeared distended.

Figure 1. Scarring on plantar and palmar surfaceswere noted.

Respiratory Tract: The lungs were adhered to the liver, diaphragm, and pericardial ... y occluded the tracheal opening. The trachea measured over1 meter long and veere ... e looping up towards the right side then down on the same side and finally towa ... e bifurcating into the bronchi (Figure 2). Tracheal rings near the folded portions w ... n adaptation to the bends which suggests a development occurred over several years a ... s (pers. comm.), extremely long tracheas are often seen in exceptionally large cro ... e downward pull of the lungs and diaphragm when inhaling. The fold on the right t ... d folded inward. Trapped clear gas presumed to be air distended the pleural lining o ... . About 5 milliliters of yellow-brown liquid pooled at the bottom of the right side of the chest cavity. The right lung lobe exhibited a large bruised area on its dorsal aspect.These lesions alluded to a rupture in the right lung lobe. Both lung lobes were large, occupying a little over two thirds of the whole body cavity.

Petecchial and paintbrush hemorrhages were scattered throughout the length of the trachea. The white mucoidexudate extended to the bronchioles and lung tissue in increasing concentrations. Crepitation (crackling) was felt interspersed with hard masses all over the lung surface. Upon incision, the lung tissue revealedyellow, caseous nodulesscattered over dark red and almost solid (red hepatization) lung parenchyma. These nodules varied in size and solidity (Figure 3) and signified decay of dead tissues. Some nodules coalesced in several parts of the two lobes to form larger solid masses.

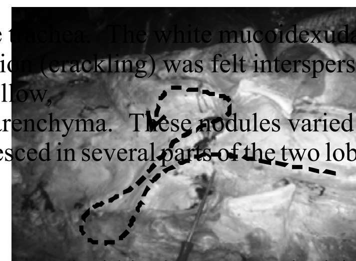

Figure 2 Broken lines show the path taken by the long trachea. Solid arrow points to distended pleural lining.

Heart: The pericardial sac was thick and almost opaque. Blood-tinged fluid was observed within the sac upon incision. White granules adhered to the sac and muscle surfaces while coronary vessels were severely injected (Figure 4). The atria appeared grayish externally. Heart muscles showed pale areas in between darker ones.About 15 mL of bloody fluid filled the right ventricle. Chicken fat clot was also present, extending to the right atrium. The right atrium was also severely enlarged (about five times the size of the left), suggestive ofvery poor circulation to the lungs over a prolonged period prior to death. The left ventricle was thick, very muscular and filled with blood. Clotted blood filled the opening to the aorta.

Figure 3. Incised surface of the lung lobe showed red hepatized parenchyma stippled with caseous nodules.

Liver: Both left and right lobes of the liver were pale. The left lobe had rounded p ... ts lateral margin. Cut surface apposed well enough suggesting that the edema, if pr ... so revealed concentric pinhead pale areas proximal to the diaphragm. All the edges o ... ut surface, again, apposed satisfactorily but showed blackish-brown parenchyma with ... re 5).

Kidneys: Both kidneys had a gelatinous consistency with loss of normal archite ... t lobulation. The left kidney was slightly larger than the right.

Fat body: Isolating the fat body proved a bit difficult due to adhesions with the mesentery. The fat body was relatively small for the size of the animal and exhibited ecchymotic hemorrhages.

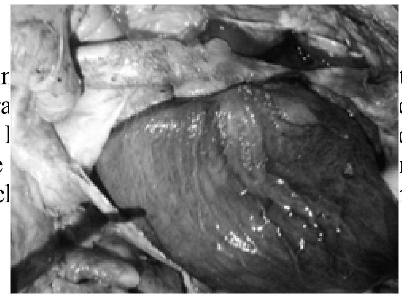

Figure 4. Thickened pericardial sac with white irregular granules adhered to the sac and muscle surfaces. Coronary vessels were distended with blood.

Digestive Tract: A significant amount of adipose tissue was noted in the abdomir to the diaphragm while blood vessels were injected all throughout the digestive tra or portion of the esophagus and at the level of the cardiac sphincter of the stomach. of the stomach were noted and it was relatively empty with only a few stones inside re noted in the small intestines. The large intestine, however, exhibited petecc ne mucosal surface at the level of the cloaca. Pale yellow granules similar to that found on the heart muscles were, likewise, found on the mucosal surface in the cloacal area.

Histopathologic Findings

Histopathologic examination was done by Lasticaand Masangkay(2013). They noted the lung parenchyma with multiple abscesses and infiltration of polymorphonuclear cells and fibrin. Edema was present in several areas while, in functional alveoli, walls were thickened. Several fungal hyphae were found, some extending into the alveoli (Figure 7).

The heart exhibited generalized edema with some lipocytes interspersed with th blood was seen in cardiac vessels consistent with the gross findings, leading th They also noted myofibrillar necrosis but this lesion was not widespread.

Figure 5.Blackish-brown parenchyma of the right liver lobe.

Extensive hepatic lipidosis was noted which resulted in loss of parenchymal architecture that, in turn, would lead to loss of function. Slight edema was noted along with numerous polymorphonuclear cells and hen parenchymal architecture as well as edema and polymorphonuclear cells. Glo also noted. Histopathology of the digestive tract was not very remarkable polymorphonuclear cell infiltration in the colon area.

Toxicologic Findings

Because of the presence of a gold mining operation near the habitat of the croc submitted for mercury testing. The liver sample registered 55 mg/kg of me There is apparently no known similar testingpreviously conducted in crocodile Thus values from other crocodilian species in other parts of the world were use

Figure 6. The stomach was empty except for a few stones and minimal brown-tinged fluid.

In Tanzania,Semanini (2010) established the median Hg levels in the Nile muscle had a median of 21 µg/kg, prompting him to note that liver samplesrec tail muscles. Similarly, the tail muscle of spectacled caimans and black caima of 291.2 µg/kg and 193.9 µg/kg, respectively. It should be noted the Ama constantly leaches into the river (Schneider et al., 2012).American alligators contaminants including Hg also used the tail muscle. This study conducted by Delany et al. (1988) recorded Hg levels ranging from 0.04 to 0.61 mg/kg and noted that mean residue for heavy metal was highest for Hg. This study prompted the authorities in Florida to ban the sale of alligator meat at the time (Axelradet al., 2011) in consideration of public health implications. A similar study on alligators in Georgia (Ruckel, 1993) also recorded low levels of Hg than “Lolong”, ranging from 0.1 to 1.4 mg/kg.

Although mercury is a naturally-occurring element in swampy areas (bioaccumulative substance that even in sublethal doses can have harmf Ruckel, 1993).Biomagnification occurs through the food chain anc susceptible to it (Delany et al., 1988). Mercury often occurs in trace le Amazon where the soil is apparently Hg-rich (Schneider et al., 2012) operationscan increase levels in the environment. Although there a environment established by various authorities, the pathogenic levels crocodiles.

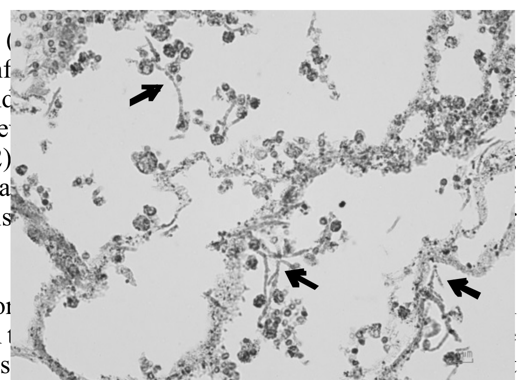

Figure 7. Fungal hyphae (arrows) were observed in the tissue sections of the the lungs.

The mercury level for “Lolong” was very much higher than those reco caimans whose environment naturally contained higher levels of Hg in remembered that tissue samples used here were from the liver while mos could not be determined if the Hg concentration in this case was enough to cause disease or even death. It was highly likely a contributor to the decline of the animal's health.

It is also highly probable that the animal was contaminated through either its food or its environment both of which originated from Agusan Marsh. This led the necropsy team to believe that Agusan Marsh may be contaminated as well. (Severalrepresentatives of various towns covering Agusan Marsh confirmed this when the necropsy results were presented to the Agusan Marsh Protected Area Management Board (PAMB). Some even stated that they have had reports declaring their waters contaminated with mercury as far back as 10 years.)

Summary and Conclusion

Based on the gross and histopathology results, the cause of death was determined to be congestive heart failure complicated by late stage mycotic pneumonia and multiple organ failure. Other lesions point to underlying management and husbandry problems that may have likely contributed to the decline in the animal's health condition. For one, the increased number of lipocytes in the heart as well as the extensive hepatic lipidosis could be a consequence of the high fat diet during captivity. That combined with inadequate pen space and depth of pond for proper movement/exercise could have contributed to the excessive deposition of fat as well the ulcerations in the appendages.

How much of the general deterioration of the health of the animal could be attributed to Hg poisoning was not determined. Given the level of Hg found in the crocodile's body, it is highly likely that the animal was already exposed to contamination even prior to his captivity. This led to the conclusion that Agusan Marsh as a crocodilian habitat is already compromised.

Recommendations

It is highly recommended that water and soil quality assays be done throughout the length of Agusan Marsh, including its tributaries and the source of the Hg contamination be identified. In addition, immediate steps need to be taken to stop further contamination and possibly reverse the condition. As a corollary to this, the communities within and surrounding the marsh need to be informed of the potential (or likely current) threat to their health and livelihood and plans for the proposed sanctuary in Agusan Marsh need to be reviewed given the possible level and extent of Hg contamination in the area.It would be a good idea to establish a set of baseline values for heavy metals especially mercury in view of the proliferation of mining operations near crocodile habitats. It might also be worthwhile to investigate the possible relationship between the age of a crocodile and the number of tracheal rings or length of the tracheaas an alternative way to determining the age of the crocodiles in the wild.

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Hematological response of siamese crocodiles (*Crocodylus siamensis*) after large volume blood collection

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Abstract

Crocodile blood used in the supplementary-fooded production has mostly received from the healthy crocodiles gone in to the slaughterhouse and died. In the present study, the crocodile blood collection process on animal life maintains of captive Siamese crocodile (*Crocodylus siamensis*) was developed from 20 crocodiles which average weight was 27 kilograms, 191 centimeters in length and 4-5 years of age. The samples were divided into 3 experimental groups and a control group according to the frequency and volume crocodile blood withdrawn as following: *Experimental group 1*: the crocodiles were withdrawn 150 ml of blood on the 1st week and the 12th week with 10 ml of blood collection every week that starting from the 2nd till the 11th week. *Experimental group 2*: withdrawn 150 ml of the crocodile blood at week- 1, - 12 and collected blood 10 ml at week- 4 - 8. *Experimental group 3*: 150 ml of the blood was collected at the 1st and the 12nd weeks. In c*ontrol group*, blood was collected every week in amount of 10 milliters for 12 weeks. The results were evaluated in crocodile blood donor behavior i.e. food feeding and social behaviors, determination of hematological values. These data revealed that although some significant difference of some hematological variables between a control group and experimental groups ($p < 0.05$) were found in some weeks, the variation occurred within reference ranges and did not represent a significant biological change. Therefore, the crocodile blood collection might be taken at least 150 ml in volume (approximately 25% of blood volume) and the duration time for each collection should not less than 12 weeks. However, the optimal blood volume has remained to be elucidated.

Introduction

Crocodile blood consumption as supplementary-fooded product is famous for Asian people especially Chinese, Hong Kong, Taiwan, and Thai because of its therapeutic properties as well as health and immunity promotion (Siruntawineti *et al.,* 2006; Chaeychomsri *et al*., 2009). The blood used in the production has mostly received from healthy crocodiles which have gone into the slaughterhouse. However, the blood received from dead crocodiles is not sufficient to keep up with production. Therefore, the crocodile blood collection process on animal life maintain of captive crocodiles has been developed. (Pitimol *et al.,* 2008) However, large volume blood collection from animals may have adverse effect on them (Voigt, 2000; Stockham and Scott, 2008; Turgeon, 2012). The symptoms depends on the blood volume lost from their body. In addition, the clinical effects of more extreme blood loss are related to the health of the blood donors, time that is adequate, nutrition in an animal's body that is essential for rebuildting its blood supply and the rate at which the blood is lost (Voigt, 2000). The purpose of this study is to determine the effects on hematological variables, after the withdrawal of 150 ml of the blood from healthy crocodiles over a period of 12 weeks. It was intended that these data will provide guidelines for crocodile blood collection, increase the crocodile blood production and promote a sustainable use.

Materials And Methods

Crocodile samples: The twenty captive Siamese crocodile (Crocodylus siamensis) used in this study were obtained from Rungtaweechai Farm, Nakhon Pathom, Thailand. They were about 27 kilograms in weight, 191 centimeters in total length, 4-5 years old and consisted of both genders. All of the samples were tagged and divided into a control group and 3 experimental groups according to frequency of hematological investigation: Experimental group-1 (E-1): investigated blood every week; Experimental group-2 (E-2): investigated blood every month and Experimental group-3 (E-3): investigated blood in the 12th weeks. Each group contained 5 crocodiles (n= 5) and was retained in single pond.
Blood collection: The crocodiles were immobilized by 220 volts of electricity and snared with catapult. Blood samples were collected from the supravertebral vein. Different equipment was used depending on the blood volume collected from crocodiles: - 1) A 21 gauge needle and 10 ml syringe were used for 10 ml of blood collection and 2) A needle and peristaltic pump were used for 150 ml of blood collection (Kasetsart University, Thailand Patent application No. 0601001179, 2006). A total volume of 150 ml of blood was collected from the 3 experimental groups in the first time and the 12th week while 10 ml of blood was collected from a control group in every week for 12 weeks. To evaluate the hematological

response of the experimental samples, 10 ml of blood was withdrawn from each sample according to the duration of planning time for hematological investigation. Two milliliters of blood was immediately placed into test tubes containing EDTA- anticoagulant, mixed well and kept at 4°C until the measurement of hematological values.

Temperature and relative humidity measurement:
The temperature and the relative humidity of captive ponds were recorded once per day because they could be influential on hematological values.

Behavior observation:
Crocodile behaviors including feeding, basking, diving as well as social behaviors were observed after blood collection. The food intakes of crocodile were determined and recorded.

Hematological measurement:
The hematological tests including total cell counts (red blood cell (RBC) -, white blood cell (WBC)-, and thrombocyte-counts), Pack cell volume or hematocrit (Hct), and hemoglobin (Hb) concentration were performed. Total cell counts were measured by using a hemocytometer. Hct was determined by using microhematocrit centrifugation. Hb concentration was measured by using Cyanmethemoglobin method. In addition, red cell indices as mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were calculated by using established formulas.

Statistical analysis:
The results were expressed as mean $\pm$ SE, analysed by using one way ANOVA, and followed by Duncan's multiple-range test. A value of $p < 0.05$ was considered statistically significant.

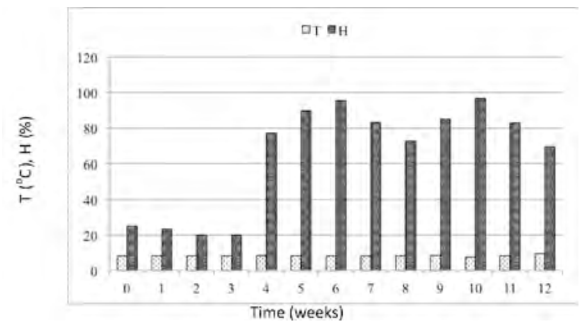


Fig 1: The effect of crocodile blood collections on RBC count, Hct and Hb of control group (Control), experimental groups (E-1, E2 and E-3) over 12 weeks after time zero. All resulted values are expressed as mean. Reference ranges (Homswat, 1996): RBC count = 0.36 2.20 x 10^6/mm^3; Hct = 15.0 29.0 %; Hb = 3.9 14.7 g/dl.
*significantly different from control group ($p < 0.05$).

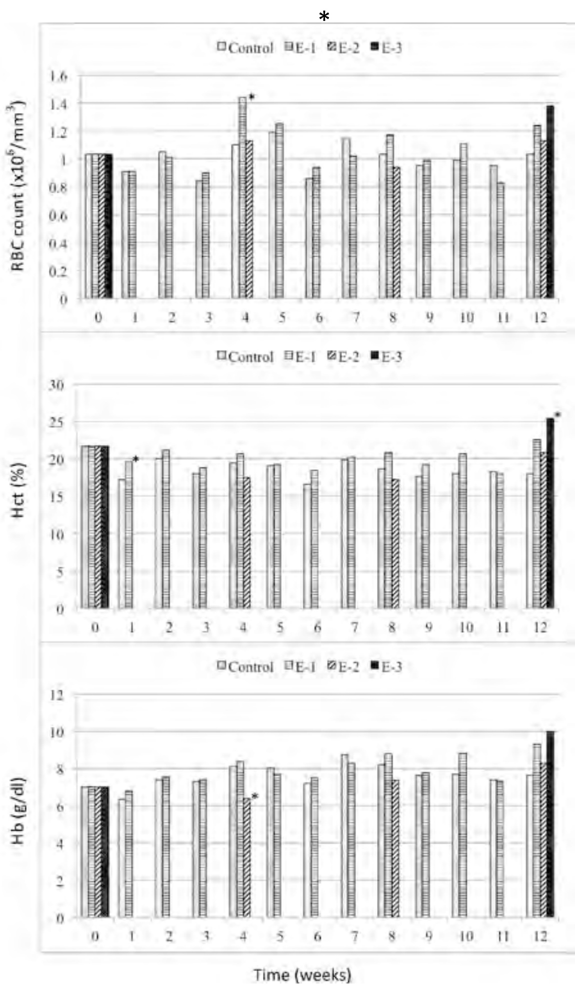


Fig 2: The effect of crocodile blood collections on MCV, MCH and MCHC of control group (Control), experimental groups (E-1, E2 and E-3) over 12 weeks after time zero. All resulted values are expressed as mean. Reference ranges (Homswat, 1996): MCV = 131.8 416.7 fl, MCH = 66.8 108.3 pg, MCHC = 26.0 50.7 g/dl
*significantly different from control group ($p < 0.05$).

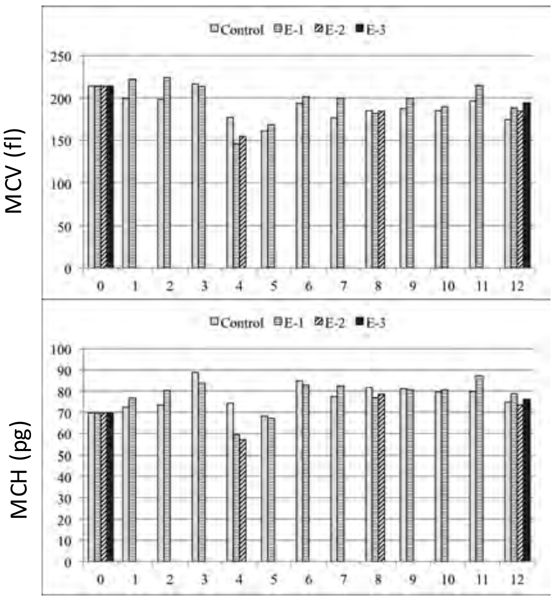
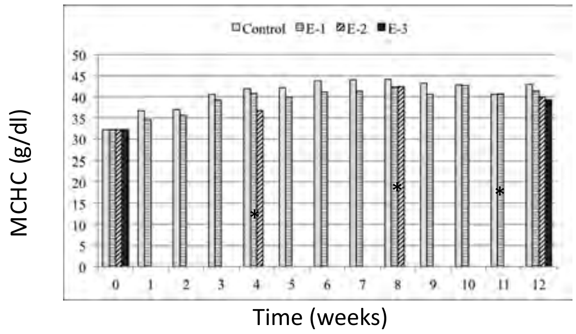


Fig 3: Temperature and relative humidity of captive ponds over 12 weeks of the experiment. All results are expressed as mean values when "T" as temperature and "H" as relative humidity.



The effects on hematological values of a control group and the 3 experimental groups over 12 weeks as a result from 150 ml of blood collection are shown in Table 1. Mostly, there were no significant differences in hematological values between a control group and experimental groups after the first time blood collection (time zero) until 12 weeks (p> 0.05). Significant differences in the value of RBC- count and Hb between the control group and the experimental groups was only found in the 4th week after the time zero while a significant difference in the Hct value was found in the 1st and 12th weeks after the time zero (p> 0.05) (Fig.1). The value of MCV and MCH had no significant difference between the control group and experimental groups over 12 weeks (p> 0.05) whereas the MCHC value had significant difference between the control group and the experimental groups in the 4th, 7th and 9th weeks after the time zero (p< 0.05) (Fig.2). In addition, there were concurrent increase in values of almost hematological variables, temperature and relative humidity in sample ponds, comparing those values with the values of previous weeks (Table 1 and Fig. 3).

Discussion

The main results of this study showed that there were no statistically significant differences (p> 0.05) in hematological values between a control group and experimental groups for 12 weeks. Although some hematilogical values had significant difference in some weeks between groups, those values remained within reference ranges at all times (Homswat, 1996). As such, although some of the statistically significant values were demonstrated, biological significance of these results probably was inconsequential.

An interesting results found in this study for the changes of RBC- count, Hb, MCV, MCH, and MCHC values is that were no significant differences between the control group and experimental group 1 in the 1st week after the first time blood collection (time zero). These data indicated that the 150 ml of crocodile blood collection (approximately 25% of blood volume) were able to replenish of erythrocytes as well as hemoglobin in erythrocyte until they became normal within only one week. This recovery time was much more rapid than other animals after the collection of a large volume of blood. For example, when approximately 8 L of blood (approximately 20% of blood volume) was withdrawn from donor horses, there were concurrent decreases in the value of Hct, Hb and RBC- count in one week after blood collection, followed by gradual recovery of these variables during the second and third weeks, almost to pre-collection values at the end of the third week (Malikides *et al.*, 2000).

Although the value of RBC- count had no significant difference between the control group and experimental group-1 in the 1st week after the time zero, the Hct value of the experimental group-1 was significantly higher than value of the control group. This result implied that there were reticulocytes mixed in the circulating blood of experimental group-1 more than in the circulating blood of the control group since reticulocytes are bigger than erythrocytes (Health and Daland, 1930; Orten, 1934; Maunder, 2011). Certainly, this data indicated that the larger volume of blood collection was withdrawn from crocodile, the longer the time was required for the replenishment of erythrocytes in the circulating blood. However, the Hct value of experimental group-1 differed from the value of the control group did not affected on the MCV value of the both groups. Moreover, the value of MCV had no significant difference between the control group and experimental group-1 in the 1st week after the time zero. This result assumed that there were just a few reticulocytes mixed in the circulating blood of experimental group-1 (Killmann, 1934; Stockham and Scott, 2008)

Besides in the 1st week after the time zero, an interesting result was also found in the 4th week after the time zero. There were concurrent increase in values of almost hematological variables, temperature and relative humidity in the sample ponds, when these values were compared with the values of previous weeks. This result suggested that crocodiles which are exothermic reptiles and unable to maintain a constant internal body temperature independently of the environment, adapted to their surroundings (Huchzermeyer, 2003). The increase of values of almost hematological variables simultaneously occurred with the sample pond's temperature increase which is consistent with Lang (1987) who reported that the growth rate of juvenile crocodiles is the fastest in maximum temperature where they are kept. The growth rate increased harmoniously with raising temperature probably suggests that the raise of temperature might be involved in the enhancement of a variety of compensatory neuroendocrine homeostatic mechanisms, facilitating rapid growth rate as well as hematopoiesis and other processes implicated with the hematology of crocodiles.

In addition, in the 4th week after the time zero, all samples in this study including the control group and experimental group-1 ate food increasingly more than previous weeks. Being held capture, disturbances and/or low temperature possibly caused the crocodiles to reduce feeding behavior in the 1st 3rd weeks after the time zero (Huchzermeyer, 2003). Therefore, the increase in feeding behavior in the 4th week after the time zero might imply that the activation of hematopoiesis and other processes involved with the hematology of crocodiles related to nutritions in an animal's body because nutrients are essential for rebuilting its blood supply (Voigt, 2000).

In the 4th week after the time zero, the value of RBC and WBC counts of the experimental group-1 were significantly higher than those values of the control group and experimental group-2 whereas the Hb value of the experimental group-2 was significantly lower than the values of the control group and experimental group-1. These implied that the crocodiles are capable of adapting very well to circumstances as a result of being the sole survivors from the ruling age of reptiles, whose ancestry dates back to the Mesozoic Era, about 265 million years ago. Moreover, the lineage of crocodilians retaining the characteristic features of the group has continued through to the present day (Alderton, 1991). Even though there were significant differences in the values of some hematological variables between sample groups in some weeks during the 5th 12th weeks after the time zero, those values remained within reference ranges (Homswat, 1996) at all times.

In conclusion, this study demonstrated that there was no adverse effects on donor crocodiles when 150 ml of blood (approximately 25% of blood volume) was withdrawn from them. Although significant differences of some hematological variables between a control group and experimental groups (p<0.05) were found in some weeks, the variations occurred within reference ranges and did not represent a significant biological change. Therefore, a crocodile could be donated their blood in volume of 150 ml every 12 weeks with no change in behavior and no adverse effect on hematological values. We suggest that the repeated 150 ml of blood collection is not detrimental to donor crocodile health and welfare. This information may provide important guidelines for regular large volume of blood collection in crocodiles. However, the optimal blood volume remains to be elucidated.

Acknowledgements

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Table 1. Results (mean ± SE) of the effect on hematological variables after withdrawing 150 ml of blood over 12 weeks

Variables	Group	Time/Values 0	1	2	3	4	5	6	7	8	9	10	11	12
	Control	1.03 + 0.04	0.91 + 0.11	1.05 + 0.13	0.84 + 0.08	1.10 + 0.06^{a}	1.19 + 0.85	0.86 + 0.08	1.15 + 0.15	1.03 + 0.08	0.95 + 0.07	0.99 + 0.09	0.95 + 0.09	1.03 + 0.07
RBC count	E-1	1.03 + 0.04	0.91 + 0.08	1.01 + 0.13	0.90 + 0.09	1.44 + 0.09^{b}	1.25 + 0.25	0.94 + 0.09	1.02 + 0.10	1.67 + 0.11	0.99 + 0.09	1.11 + 0.10	0.83 + 0.06	1.24 + 0.14
(x 10^6/mm^3)	E-2	1.03 ± 0.04	ND	ND	ND	1.13 ± 0.09^{c}	ND	ND	ND	0.94 ± 0.11	ND	ND	ND	1.13 ± 0.06
	E-3	1.03 + 0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.38 + 0.22
	Control	6.40 + 0.38	5.35 + 1.06	5.60 + 1.03	5.43 + 1.04	6.00 + 0.64^{a}	6.96 + 1.00	6.35 + 1.26	6.79 + 0.84	6.04 + 0.67	6.50 + 1.08	6.53 + 1.07	6.48 + 0.73	5.63 + 0.93
WBC count	E-1	6.40 ± 0.38	8.35 ± 0.85	7.67 ± 0.78	7.48 ± 0.63	8.33 ± 0.65^{b}	8.15 ± 1.29	6.43 ± 0.34	6.74 ± 0.83	6.18 ± 0.11	6.58 ± 0.90	5.97 ± 0.37	6.14 ± 0.62	7.85 ± 0.39
(x 10^3/mm^3)	E-2	6.40 + 0.38	ND	ND	ND	4.84 + 0.17^{c}	ND	ND	ND	5.61 + 1.38	ND	ND	ND	7.81 + 0.92
	E-3	6.40 + 0.38	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.29 + 1.15
Thrombocyte	Control	2.90 ± 0.18	2.43 ± 0.16^{a}	3.44 ± 0.31	3.33 ± 0.32	3.08 ± 0.33	4.12 ± 0.28	3.00 ± 0.46	3.20 ± 0.52	3.34 ± 0.16	3.32 ± 0.32	3.66 ± 0.20	3.61 ± 0.32	3.23 ± 0.16
count	E-1	2.90 + 0.18	3.44 + 0.37^{b}	3.68 + 0.42	3.78 + 0.33	3.97 + 0.55	4.26 + 0.76	3.56 + 0.15	3.79 + 0.16	4.42 + 0.16	3.78 + 0.63	4.68 + 0.45	3.10 + 0.04	3.85 + 0.26^{a}
(x 10^4/mm^3)	E-2	2.90 ± 0.18	ND	ND	ND	2.68 ± 0.45	ND	ND	ND	3.85 ± 0.65	ND	ND	ND	2.70 ± 0.28^{b}
	E-3	2.90 + 0.18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.01 + 0.26^{c}
	Control	7.00 + 0.33	6.33 + 0.37	7.40 + 0.49	7.30 + 0.70	8.12 + 0.45^{a}	8.01 + 0.48	7.21 + 0.72	8.71 + 0.75	8.20 + 0.65	7.61 + 0.45	7.68 + 0.51	7.38 + 0.40	7.65 + 0.44
Hb (g/dl)	E-1	7.00 + 0.33	6.78 + 0.25	7.54 + 0.26	7.40 + 0.58	8.36 + 0.36^{b}	7.69 + 0.53	7.53 + 0.37	8.29 + 0.55	8.78 + 0.37	7.78 + 0.21	8.82 + 0.60	7.34 + 0.94	9.29 + 0.50
	E-2	7.00 ± 0.33	ND	ND	ND	6.36 ± 0.66^{c}	ND	ND	ND	7.36 ± 0.84	ND	ND	ND	8.29 ± 0.54
	E-3	7.00 ± 0.33	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.98 ± 0.76
	Control	21.65 ± 0.71	17.20 ± 0.74^{a}	20.00 ± 1.38	18.00 ± 1.64	19.40 ± 1.03	19.00 ± 1.14	16.60 ± 1.78	19.80 ± 1.66	18.60 ± 1.50	17.60 ± 0.93	18.00 ± 1.45	18.20 ± 1.02	18.00 ± 1.48^{a}
Hct (%)	E-1	21.65 + 0.71	19.60 + 0.68^{b}	21.20 + 1.07	18.80 + 1.28	20.60 + 1.21	19.20 + 1.02	18.40 + 1.21	20.20 + 1.77	20.80 + 0.97	19.20 + 0.37	20.60 + 0.93	18.00 + 2.27	22.50 + 0.87
	E-2	21.65 + 0.71	ND	ND	ND	17.40 + 1.86	ND	ND	ND	17.20 + 1.59	ND	ND	ND	20.80 + 1.24^{b}
	E-3	21.65 + 0.71	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	25.40 + 1.97^{c}

Table 1 (Cont.). Results (mean ± SE) of the effect on hematological variables after withdrawing 150 ml of blood over 12 weeks

Variables	Group	Time/Values 0	1	2	3	4	5	6	7	8	9	10	11	12
MCV (fl)	Control	214.25 + 7.74	199.63 + 20.83	198.02 + 15.10	216.85 + 14.88	177.17 + 11.08	161.05 + 10.54	193.83 + 11.65	176.52 + 10.78	185.15 + 19.89	187.84 + 7.89	185.23 + 14.45	196.38 + 12.2	174.14 + 7.93
	E-1	214.25 ± 7.74	221.94 ± 19.69	224.18 ± 28.37	213.26 ± 13.97	145.80 ± 12.64	168.65 ± 20.47	201.25 ± 16.49	199.34 ± 9.02	181.59 ± 9.03	199.41 ± 17.83	189.91 ± 12.37	214.60 ± 15.5	188.57 ± 20.14
	E-2	214.25 ± 7.74	ND	ND	ND	154.51 ± 13.20	ND	ND	ND	184.65 ± 8.29	ND	ND	ND	184.61 ± 10.04
	E-3	214.25 + 7.74	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	194.18 + 16.71
MCH (pg)	Control	69.73 + 4.15	72.44 + 5.90	73.39 + 5.72	88.74 + 8.05	74.39 + 5.58	68.07 + 5.22	84.96 + 6.01	77.48 + 4.00	81.60 + 8.93	81.12 + 3.72	79.76 + 5.31	81.12 + 3.72	74.71 + 3.88
	E-1	69.73 + 4.15	76.76 + 6.87	80.40 + 11.13	83.76 + 5.73	59.44 + 5.47	67.25 + 7.77	82.85 + 7.48	82.52 + 5.07	76.90 + 4.68	80.62 + 6.80	87.13 + 6.47	81.12 + 3.72	78.89 + 12.18
	E-2	69.73 + 4.15	ND	ND	ND	57.04 + 6.16	ND	ND	ND	78.45 + 4.66	ND	ND	ND	73.35 + 3.22
	E-3	69.73 ± 4.15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	76.23 ± 6.57
MCHC (g/dl)	Control	32.19 ± 1.02	36.72 ± 1.11	37.04 ± 0.51	40.63 ± 1.43	41.94 ± 1.44	42.19 ± 0.90	43.76 ± 1.26	44.00 ± 0.50[a]	44.17 ± 1.29	43.16 ± 0.41[a]	40.58 ± 0.53	43.16 ± 0.41	42.95 ± 1.51
	E-1	32.19 + 1.02	34.58 + 0.59	35.68 + 0.87	39.32 + 1.12	40.82 + 1.57	39.97 + 1.25	41.09 + 0.84	41.31 + 0.94[b]	42.29 + 0.80	40.52 + 0.62[b]	40.72 + 2.07	43.16 + 0.41	41.34 + 2.06
	E-2	32.19 + 1.02	ND	ND	ND	36.69 + 1.34	ND	ND	ND	42.46 + 1.47	ND	ND	ND	39.90 + 1.36
	E-3	32.19 + 1.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	39.29 + 0.77

ND = Non-detected, Small letter significant difference in column ($p < 0.05$).

Habitat suitability of mugger crocodile in Sarbaz River, Iran

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Abstract

In order to study the habitat suitability and classification of Muggers in Iran, we used Habitat Evaluation Procedure (HEP) to define the best and most suitable habitats for Muggers. A habitat Suitability Index (HSI), was used to compare habitats. HSI values range between 0 (worst habitat) and 1 (best habitat).
e (HEP) to define the best and most suitable habitats for Muggers. A habitat Suitability Index (HSI), was used to compare habitats. HSI values range between 0 (worst habitat) and 1 (best habitat).
Ten natural ponds along the Sarbaz River were selected for the study. Climatic, physical and chemical characteristics of soil, water and vegetation cover, as well as some ecological characteristics, were collected during monthly surveys. Information on fauna (fishes and amphibians) and flora diversity, water depth, habitat slope and the area of ponds and number of crocodiles in habitats were also included in the study.
The significant variables were scored using Analytical Hierarchy Process (AHP) and IDRISI KLIMANJARO 8.4 software and the HSI for each habitat calculated. Cluster analysis was used to classify the habitats based on their main characteristics. Based on AHP significant parameters classified into three main categories: cover (vegetation cover, depth, slope); food (fish and amphibian species); and, chemical specification of water Like DO and Conductivity. Based on the results, the HSI for Pishin Dam pond was 1 (highest suitability), followed by other habitats with lower HSI and Kollani had the lowest HSI (0.2). In general, Muggers prefer habitats with 2-4 m water depth, mean vegetation cover of 35%, mean slope of 25-35% and high density of fish and amphibians.

HSI, material and methods

Southwestern Iran is the western most limits for the Mugger crocodile (*Crocodylus palustris*). The main habitats for crocodiles are along the main rivers, of which the Sarbaz River is the most important. Local people of the area call the crocodiles 'Gandou" and respect them, so they are not directly harmed by people. The main threats for crocodiles are natural incidents such as floods and drought (Mobaraki &abtin 2010) .No studies on habitat suitability and classification have been undertaken for Muggers in Iran. Information on habitat characteristics and requirements would provide considerable support to species management and conservation and provide the basis for responses to any deficiencies. We used Habitat Evaluation Procedure (HEP) to define and identify the best and most suitable habitats for Muggers. A Habitat Suitability Index (HSI), a nominal index representing habitat capacity for providing the needs of the species, was used to compare habitats. HSI values range between 0 (worst habitat) and 1 (best habitat).

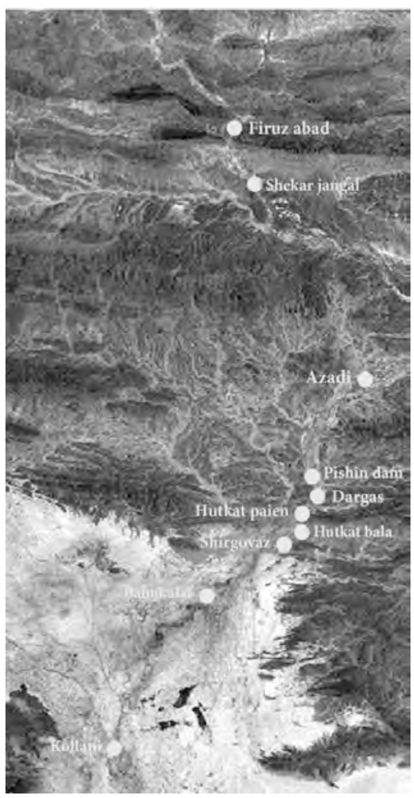

Figure 1: Selected sites/habitats along the Sarbaz River

Ten natural ponds along the Sarbaz River were selected for the study: listed from north to south - Firuz Abad, Shekar Jangal, Azadi, Pishin Dam, Dargas, Lower (Paien) Hutkat, upper (Bala) Hutkat, ShirGoovaz, Bahukalat, Kollani (near Govater Bay) (see Fig. 1) Climatic, physical and chemical characteristics of soil, water and vegetation cover, as well as some ecological characteristics, were collected during monthly surveys over the period of September 2008 to January 2010**.** Information on fauna (fishes and amphibians) and flora diversity, water depth, habitat slope and area of ponds and number of crocodiles in habitats were also included in the study.

The area of the habitat was considered as the initial criterion for selection of the habitats as study stations and comprised the highest population density, number of nests and occurrence of juvenile and adult crocodiles, based on the direct observation on crocodile occurrence in the habitats. As most sites had thick vegetation, sampling of the number and variety of species was only conducted in 10% of the areas involved. Based on number and variety of species, vegetation diversity was determined using the Ecological Methodology (software) program. Climatic variables (e.g. mean temperature, humidity, evaporation, and rainfall) were compiled from existing meteorological stations at Bahu-kalat and Sarbaz.

Monthly data were averaged for each parameter, and analyzed using SPSS (correlation between factors) .The significant variables were scored using Analytical Hierarchy Process (AHP) and IDRISI KLIMANJARO 8.4 software and the HSI for each habitat calculated. Cluster analysis was used to classify the habitats based on their main characteristics.

There were no significant differences between habitats with respect to variables such as air and soil temperature, humidity, water and soil pH, and soil structure and elements of the habitats. Moreover, correlation test did not show any significant relationship between parameters and crocodile population, with the exception of 6 variables for which significance was recorded.

Based on AHP all data, significant parameters, could be classified into one of three main categories: cover (vegetation cover, depth, slope); food (fish and amphibian species); and, chemical specification of water Like DO and Conductivity (figure 2).

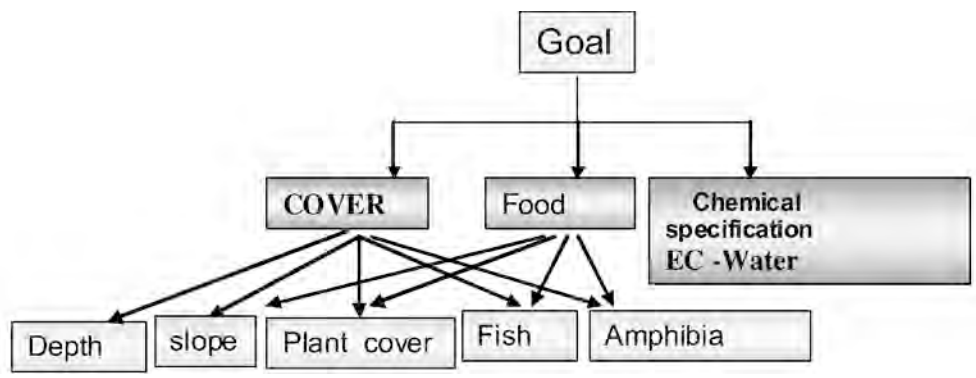

Figure 2: Analytical Hierarchy Process= AHP

Table 1: Pearson Correlation for significant parameters with respect to crocodile density

Parameter	**Pearson Correlation**	**P (2 tail)**
Water depth	0.739	0.015
Vegetation cover	0.660	0.038
Slope	0.753	0.012
Amphibians	0.864	0.001
Fish	0.674	0.032
Conductivity EC	0.650	0.042

Results

The highest mean crocodile numbers were observed in the Pishin Dam pond, 10 crocodiles, and the lowest (zero) were recorded in Kollani and Firuzabad ponds. The HSI for Pishin Dam pond was 1 (highest suitability) (Fig. 2), followed by

Shirgovaz, Dargas, Hutkat-e-bala, Hutkat-E-pain respectively (0.96, 0.84, 0.75 and 0.74). Azadi, Firuzabad and Shekar Jangal had similar HSI (0.3-0.5) and Kollani had the lowest HSI (0.2), indicating that it was the most unsuitable habitat (Fig. 3).

Dendrogram

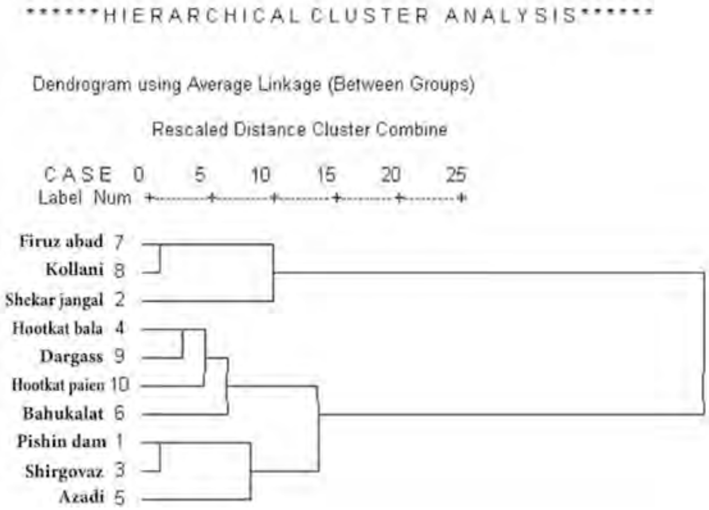

figure 3: Classification of the habitats based on the significant criteria.

Each index received a value and using the equation of ((Cb.Cnn or Cnt)1/2 the overall HSI Model prepared for the determination of the habitat suitability value for each habitat:

HSI:24.37 X1+2.9 X2+5.52 X3+4.5 X4+2.54 X5+4.9 X6

In which the X values are the significant parameters. In general, Muggers prefer habitats with 2-4 m water depth, mean vegetation cover of 35%, mean slope of 25-35% and high density of fish and amphibians (Behrouzi and etal 2010).

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Figure 4: Pishin Dam Pond as one of the most important and suitable habitat for Mugger crocodiles. Photo: Elham Abtin.

Figure 5 : Basking crocodile in Pishin Dam pond. Photo: Elham Abtin

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Molecular identification of *Crocodylus siamensis* using specific primers for reintroduction to Kangkrachan National Park in Phetchaburi, Thailand

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Abstract

Crocodylus siamensis, the Siamese crocodile, is a critically endangered species of freshwater crocodile previously distributed throughout much of Southeast Asia. Recovery plans call for reintroductions to the wild using founder individuals currently in captivity, mostly in commercial crocodile farms. On many farms *C. siamensis* has been intentionally hybridized with the estuarine crocodile, *C. porosus*, and hybrids may be difficult to distinguish morphologically. The objective of this study was to develop a new molecular identification method capable of discriminating among the crocodilian species and to apply this tool in combination with reintroduction programs. Six specific microsatellite markers from *C. siamensis* were developed and used for characterization of closely related crocodiles. A total of 120 blood samples of *C. siamensis* (based on morphological characteristics) were collected from the crocodile farms in Thailand. These samples were derived from Golden Crocodile Agriculture (Thailand) Co., Ltd., (100 samples) and Rungtaweechai Crocodile Farm (20 samples). The samples were tested using the polymerase chain reaction (PCR) compared with 4 unknown crocodile samples from Crocodile Education and Conservation Centre, United Kingdom (UK) and 4 samples of *C. porosus* saltwater crocodile as the out group. The results showed that the markers *CS*-4, *CS*-5, *CS*-20, *CS*-25, *CS*-26 and *CS*-32 could identify all species tested. Three microsatellite markers *CS*-4, *CS*-5, and *CS*-26 showed polymorphic alleles in the same species that were considered as intra-specific markers. The number of alleles per locus ranged from 1-2, and the observed heterozygosities ranged from 0.48 to 0.89. The markers *CS*-20, *CS*-25 and *CS*-32 showed monomorphic allele in *C. siamensis*. They showed only 1 allele and the observed heterozygosities ranged from 0 to 0.03. These results revealed that the samples of *C. siamensis* from Golden Crocodile Agriculture (Thailand) Co., Ltd. and those from Rungtaweechai Crocodile Farm were pure *C. siamensis* and suitable for reintroduction to Kangkrachan National Park. Another 4 unknown crocodile samples from Crocodile Education and Conservation Centre, UK were also pure *C. siamensis***.** These microsatellite markers can be used for species testing and also evaluated for assigning parentage in situations where maternity, paternity, or both. The use of these microsatellite markers has potential for application in captive breeding programs, evaluating hybridization, the effects of introductions of exotic species and to the identification of products in trade and reintroduction programs.
Keywords: Siamese crocodile, microsatellite marker, crocodile reintroduction

Introduction

In the IUCN Action Plan for crocodiles (Ross, 1998), mention is made of several species where information was needed on their genetic diversity and lineage. For example, population genetics surveys were needed for the critically endangered *Orinoco crocodile (C. intermedius),* to assess their level of genetic diversity to inform restocking and reintroduction programs. The Siamese crocodile is an endangered species that formerly inhabited wetlands and waterways of Southeast Asia. Hunting and habitat loss have reduced its population in the wild of Thailand, and most of the remaining Siamese crocodiles have been maintained and bred in captivity. Captive Breeding and reintroduction programs of pure breed Siamese crocodile back to the wild are the simplest and most efficient ways to overcome these problems. There has been an attempt to release pure bred Siamese crocodiles back into the wild to support conservation strategies, there was an increasing need to develop genetic markers in *Crocodylus* sp., particularly in *C. siamensis*. Although the microsatellite loci used had some overlap of allele sizes between species, it was possible to use assignment tests for differentiation. However, within this genus, most tests of cross-species PCR amplification indicated the presence of homologous microsatellite loci that were variable. In previous studies (Chaeychomsri *et al.*, 2008a, b) it has been shown that microsatellites from *C. siamensis* are useful marker for parentage analyses and individual identification.

Microsatellites (also called simple sequence repeats, SSRs) are a class of genetic polymorphism commonly used for mapping, linkage analysis (Dib *et al*., 1996), behavioral ecology (Schlötterer and Pemberton, 1998), population genetics (Goldstein and Schlötterer, 1999), and phylogeny reconstruction (Harr *et al*., 1998). Microsatellites are tandemly repeated sequences, where the repeating unit is 1 to 4 nucleotides long. The number of times the unit is repeated in a given microsatellite can be highly variable, a characteristic that makes them useful as genetic markers. Many reports have demonstrated several advantages of using microsatellite markers in crocodylian systematic and population genetics. Glenn *et al*. (1998) developed nuclear microsatellite markers to address questions on the genetic population structure and the mating system of American alligators (*Alligator mississippiensis*) and showed that microsatellite markers could differentiate between populations of Florida and American alligators and had a higher discriminatory power of differentiation than the allozyme isozyme markers. Davis *et al*. (2001) reported a high level of genetic variation for six populations of American alligators located throughout the southeastern United States. FitzSimmons *et al*. (2001) developed 26 new microsatellite markers from the DNA of *C. acutus*, *C. porosus* and *C. johnstoni* to compare the population genetic structure in crocodylian families and tested loci for *Crocodylus* spp., which represented the first microsatellite loci found in Crocodylus.

This paper describes the potential utilization of the microsatellites as molecular markers in *C. siamensis* and for identification of a closely related species. These markers will be a useful tool for a captive breeding program, developing conservation strategies and for understanding the genetic structure of the remnant wild populations of this species.

MATERIALS AND METHODS

Sample collection

Blood samples were taken from freshwater and saltwater crocodiles (based on morphological characteristics) by collecting from the anterior dorsal sinus and stored in the heparinized tubes as described by Chaeychomsri *et al*. (2008a, b). The samples of freshwater crocodile were derived from Golden Crocodile Agriculture (Thailand) Co., Ltd., (100 samples) and Rungtaweechai Crocodile Farm (20 samples) while the samples of saltwater crocodile were taken from Rungtaweechai Crocodile Farm (4 samples). Four unknown crocodile samples from Crocodile Education and Conservation Centre, UK were received as ethanol-preserved blood.

DNA extraction

Genomic DNA of crocodiles was isolated from red blood cells by using the QIAamp DNA Blood Mini Kit (QIAGEN) according to the manufacturer's protocol. DNA concentration and purity were assayed by spectrophotometry and agarose gel electrophoresis (Sambrook *et al.*, 1989).

Microsatellite analysis

Six microsatellite primers previously described by Chaeychomsri *et al.* (2008a) were utilized for this study with primer sequences and PCR conditions shown in Table 1. PCR amplification was carried out in 50 µl reaction mixture containing 200 ng DNA as the template. Genomic DNA 10.0 µl (20 ng/l), 10x PCR buffer (+ $MgCl_2$) 5.0 l, 2.5 mM dNTP 4.0 l, Forward primer (F) (10 pmol/l) 2.0 l, Reverse primer (R) (10 pmol/l) 2.0 l, Taq DNA polymerase (2 unit/l) 0.5 l, sterile distilled water 26.5 l were added and PCR was performed in a DNA thermal cycler (GeneAmp PCR System 9700, PE Applied Biosystems) programmed for 3 min at 94°C for initial denaturation. Following the initial denaturation the thermal cycler was programmed for 35 cycles of 1 min at 94°C for denaturation, 1 min at 60-70°C depended on each primer pairs (Table 1) for annealing and 1 min at 72°C for extension. The PCR products were analyzed by electrophoresis in a 1% agarose gel in 1x TBE buffer (Sambrook *et al.*, 1989) in parallel with 100-bp DNA ladder (Invitrogen) and bands were visualized by ethidium bromide staining. Images were analyzed using Gene Tools image analysis and quantification software version 4.01c (Syngene, UK) and sizes of microsatellite alleles were determined by comparing with 100-bp DNA ladder. Allele frequencies, number of alleles per locus, expected and observed heterozygocities (He and Ho) were calculated using GENEPOP software package (Raymond and Rousset, 2001).

Results

Six microsatellite markers were amplified by PCR to assess the level of polymorphism in *C. siamensis* (n=120), *C. porosus* (n=4) and 4 unknown crocodile samples. The PCR conditions used were optimal for amplification of microsatellite markers from *C. siamensis* and thus may not be optimal for the other species to test all taxa.

PCR products from loci *CS*-4 (Fig. 1A), *CS*-5 (Fig. 1B), *CS* 20 (Fig. 2A), *CS*-25 (Fig. 2B), *CS*-26 (Fig. 3A), and *CS*-32 (Fig. 3B) showed a clear polymorphic pattern in *C. siamensis.* The average observed heterozygosity (Table 1) was 0.23 (range 00.49) and average expected heterozygosity was 0.32 (range 00.89).

PCR products from loci *CS*-20 (Fig. 2A), *CS*-25 (Fig. 2B) and *CS*-32 (Fig. 3B) showed a clear pattern of single specific

band in *C.siamensis*. Additionally, all products scored were 249, 180 and 245 bp, respectively.
PCR products from loci *CS*-4 (Fig. 1A), *CS*-5 (Fig. 1B) and *CS-26* (Fig. 3A) showed a clear polymorphic pattern in *C. siamensis.* The average observed heterozygosity (Table 1) was 0.37 (range 0-0.49) and average expected heterozygosity was 0.41 (range 0.12-0.68).
For heterozygocity, the results showed that Ho is very low in *C. siamensis* (0-0.89) and revealed that most of *C. siamensis* were inbred in the same species, or have purebred in the farm. The PCR product size of loci *CS*-4, *CS*-5, *CS*-20, *CS*-25, *CS*-26 and *CS*-32 can identified *C. siamensis* and *C. porosus* and hybrid (Fig. 4A and B). These results showed difference in alleles size in *C. siamensis* and *C. porosus*.

Table 1 Microsatellite DNA primers from *C. siamensis*, 5'->3' PCR primer sequences, annealing temperature (Ta), size length, number of alleles, observed and expected heterozygosity (Ho and He)

Locus	Primer sequence:(5'->3')	Ta (°C)	Observed allele size (bp)	No. of allelles	*Ho*	*He*
CS-4	F: CCATGCCCTACCACACAACTG R: CAAACACAAAGGCATTCAAAGATG	65	200, 240	2	0.53	0.40
CS-5	F: TCTCTCCTTCTTTCTGCTTGTGC R: GTGCAAGGTCTGTACCTGTGTGA	65	200, 240	2	0.89	0.49
CS-20	F: CCTTCCGCCCAAAATAATTGC R: CCCTGCACTAACAAGGAGCAG	60	249	1	0	0
CS-25	F: ATCCTCAGTGTCATCTGCTCACC R: TCTTCCCTGCTCACCTTTCTTTC	65	180	1	0.02	0.01
CS-26	F: GCCATGTGTACTAACTGGGAAGTC R: GCCATTTTTAGTCAGGTTGTTGC	65	240-280	2	0.48	0.42
CS-32	F: GTACCAAGCCCCTTTAACACCTG R: GGGGAGAAGGAAACTAGGAGAGG	68	245	1	0	0.03

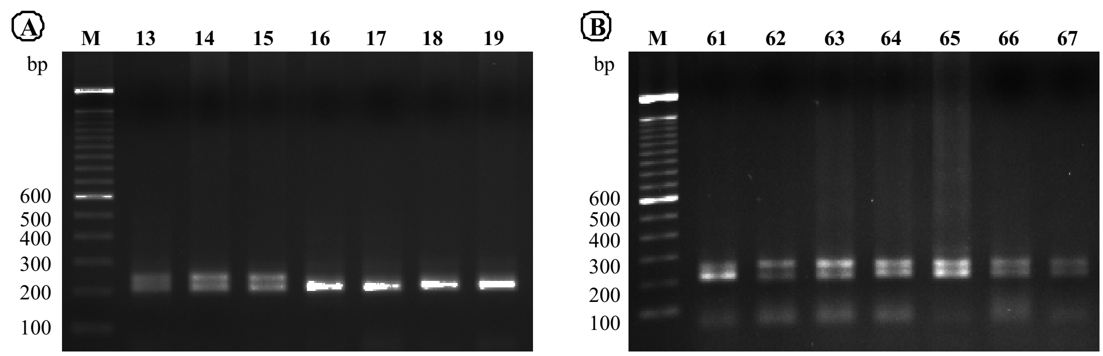

Figure 1 Agarose gel electrophoresis of PCR products generated from crocodile DNA samples using *C. siamensis* microsatellite loci. (A) locus *CS*-4 and (B) locus *CS*-5. The numbers at the top of the figure indicate samples derived from freshwater crocodile used in this study. M, 100-bp DNA ladder.

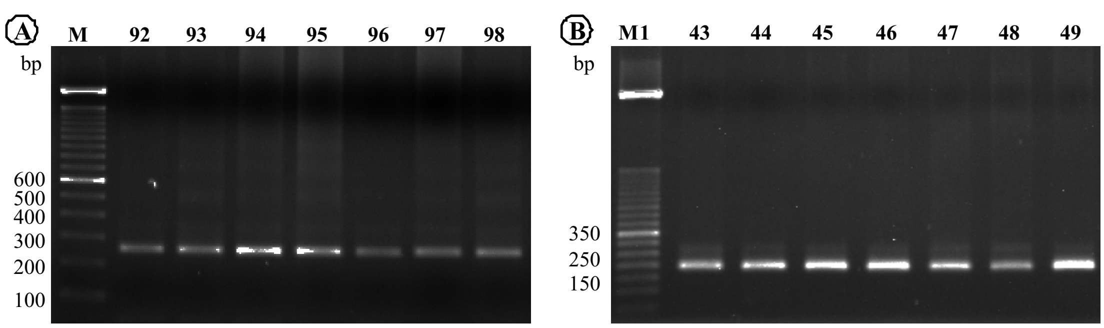

Figure 2 Agarose gel electrophoresis of PCR products generated from crocodile DNA samples using *C. siamensis* microsatellite loci. (A) locus *CS*-20 and (B) locus *CS*-25. The numbers at the top of the figure indicate samples derived from freshwater crocodile used in this study. M, 100-bp DNA ladder; M1, 50-bp DNA ladder.

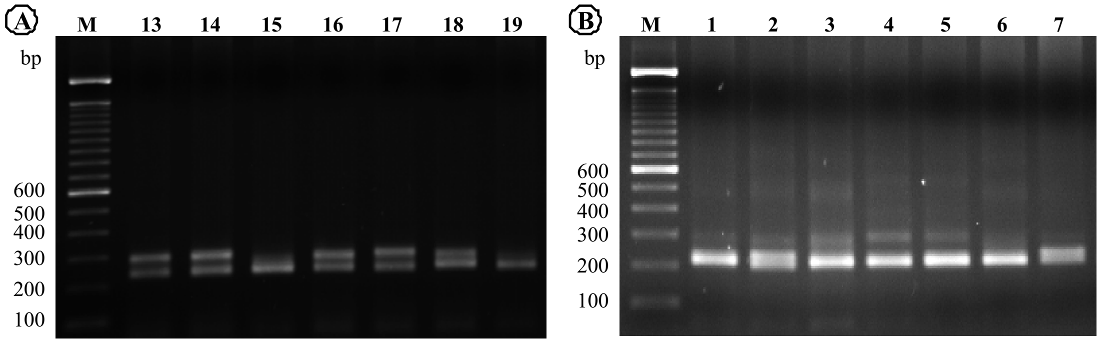

Figure 3 Agarose gel electrophoresis of PCR products generated from crocodile DNA samples using *C. siamensis* microsatellite loci. (A) locus *CS*-26 and (B) locus *CS*-32. The numbers at the top of the figure indicate samples derived from freshwater crocodile used in this study. M, 100-bp DNA ladder.

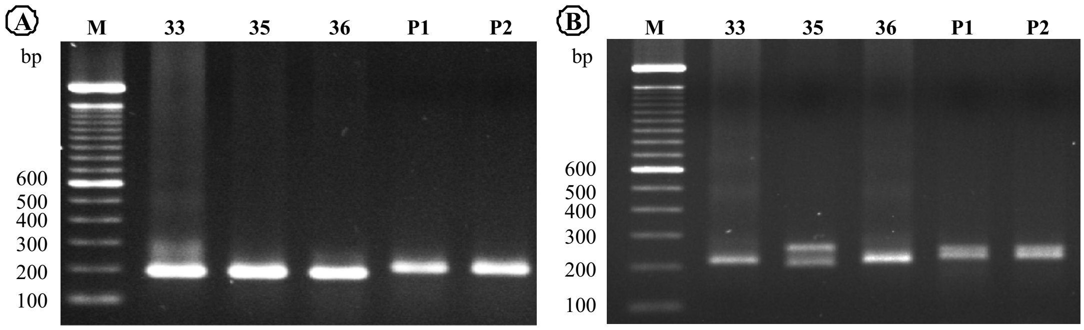

Figure 4 Agarose gel electrophoresis of PCR products generated from crocodile DNA samples using *C. siamensis* microsatellite loci. (A) locus *CS*-25 and (B) locus *CS*-32. The numbers at the top of the figure indicate samples derived from freshwater crocodile and the additional P letters refer to the samples from saltwater crocodile used in this study. M, 100-bp DNA ladder.

Table 2 Observed allele size from all loci and total number of crocodiles per locus

Locus	Allele size (bp)	Sample		
		GCA (n=100)	RCF (n=20)	CECC (n=4)
CS-4	200	95	18	4
	240	54	4	-
CS-5	200	94	18	4
	240	84	4	-
CS-20	249	100	20	4
CS-25	180	100	20	4
CS-26	240	91	16	4
	280	45	8	-
CS-32	245	100	20	4

GCA, Golden Crocodile Agriculture (Thailand) Co., Ltd.
RCF, Rungtaweechai Crocodile Farm
CECC, Crocodile Education and Conservation Centre

Discussion

Even with these results, the initial applications of these primers are promising. These data from populations of *C. siamensis* and *C. porosus* indicated that several loci would be quite useful for species identification in crocodile. In a captive population of *C. siamensis,* it appeared that there would be enough genetic variation to determine paternal exclusion in clutches. It is hoped that these primers will enable the application of genetic investigations in other studies of order Crocodylia. As in other species, these genetic markers offer the most powerful insights when they are combined with available demographic or behavioral data. In addition, using both mtDNA and microsatellite markers will be the most effective means of elucidating questions on gene flow and population history.Additionally, a combined approach using both mtDNA and microsatellite markers will be the most effective for elucidating questions of gene flow and population history. The availability of these microsatellite markers will allow comparative studies of mating systems and population structure among crocodilians.

For heterozygosity, the observed heterozygosity (*Ho*) of *CS-20, CS-25* and *CS-32* was very low in *C. siamensis* ranging from 0-0.02. This indicated that 100 samples of *C. siamensis* from Golden Crocodile Agriculture (Thailand) Co., Ltd. and 20 samples of *C. siamensis* from Rungtaweechai Crocodile Farm have been inbred in the same species, or have been purebred in the crocodile farm. Thus, selection for individuals with higher heterozygosity as is typically recommended (Moritz, 1999) is possible for the planned reintroduction into National Park. This strategy is indicated theoretically, to provide a greater range of options upon which selection can, if indeed variation at dinucleotide microsatellite loci provides a surrogate measure of variation in coding regions of the genomic DNA. Whether or not this assumption is met, selecting individuals with higher heterozygosity (if all other concerns are equal) remains a risk minimization strategy.

For the reintroduction effort, it is important to confirm that the captive population consists of mostly purebred *C. siamensis.* These results have been useful in identifying captive hybrids of the Siamese crocodile, *C. siamensis*. Of equal concern in reintroductions and augmentations is the possibility of breaking up locally adapted gene complexes through outbreeding among different source populations (Storfer, 1999). If this is true for *C. siamensis*, then it will remain an inherent problem for this and other crocodilian reintroductions, because crocodile farms typically have individuals originating from widely scattered populations. Records may not have been kept, individuals might not be marked for identification and breeders are typically put into large communal pens. One could argue that to avoid the problem of out breeding depression, only the most productive lineages should be selected for reintroduction (if indeed this information is known). However, this runs the risk of selecting individuals who are best suited to captive rather than wild situations. The extreme contrast between out breeding depression versus hybrid vigor is something that undoubtedly occur make comparisons.

Conclusion

In these studies we evaluated 6 microsatellite markers from Siamese crocodile (*C. siamensis*) and their transferability to other Crocodylus species. These microsatellite markers were evaluated in captive breeding crocodile farm for species testing. These markers composed of *CS*-4, *CS*-5, *CS*-20, *CS*-25, *CS*-26 and *CS*-32 can identify all species. Three microsatellite markers showed polymorphic alleles in the same species that were considered as intra-specific markers. These markers composed of *CS*-4, *CS*-5, and *CS*-26. *CS-20*, *CS-25* and *CS-32* showed monomorphic allele in *C. siamensis*. They showed only 1 allele and the observed heterozygosities ranged from 0 to 0.03. These microsatellite markers can be used for species testing and also evaluated for assigning parentage in situations where maternity, paternity, or both. It is recommended that more microsatellite markers should be used in these situations. Therefore, the use of these microsatellite markers will allow a fast screening, and have potential for application in captive breeding programs, evaluating hybridization, and reintroduction programs.

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Crocodile blood capsule-Kasetsart university research product, the first registered as dietary supplement in Thailand: development and trends

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Abstract

Crocodile blood capsule, a dietary supplement, is the world and Thailand's first crocodile blood product based on research studies conducted by the Crocodile Research Unit, Department of Zoology, Faculty of Science, Kasetsart University (KU). This health supplement from Siamese crocodile (*Crocodylus siamensis*) blood contained 100% natural ingredients rich in protein, which are useful iron, minerals and vitamins. With KU innovative processes in the large blood volume blood collections and freeze drying, it presented no bacteria and heavy metal contaminations. In collaboration with private sector, KU has made an effort to enhance clean and safe production processes at the acute, sub-chronic, and chronic levels, and to study the efficiency of freeze dried crocodile blood product, which has subsequently approved by the Food and Drug Administration (FDA) of Thailand, Ministry of Public Health, as a dietary supplement since the year 2008. Then, KU exclusive permitted in intellectual properties related to crocodile blood capsule production and transferred the technology to WaniThai Limited Partnership under "WaniThai" brand that has received certificate from Thai FDA as No. 10-1-04752-1-0001 and No. 10-1-04752-1-0002. Moreover, it has been widely known among the general public for support good health in many consumers who suffer with anemia, cancer, AIDS and diabetes. Moreover, the research results in rats presented the correlation with their improvement of anemic condition and reduction of blood sugar level. Since, insulin like growth factor-I (IGF-I) was found in Siamese crocodile serum and good evidence in diabetes cases, recently, the crocodile blood product has been developed for diabetes supplement designed as crocodile serum capsule. In addition, the donation of crocodile blood was studied by development of blood collection process on animal life maintains in captive Siamese crocodile for sustainable supplying. Therefore, these data demonstrate a good case in value adding of the crocodile blood and its applications.

Background and Significance

Siamese crocodiles (*Crocodylus siamensis*) are an important economic animal of Thailand. They are easy to raise and grow fast. The amount of money and time spent on raising a crocodile are small. They are classified as a protected animal in accordance with the Wildlife Amnesty Act, B.E. 2535 (1992) that can be traded under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). There are more than 25 certified crocodile farms. Currently, there are more than one million crocodiles in Thailand. Crocodile is an important medicinal animal. Asian people, especially in China, Hong Kong and Taiwan, believe that consumption of crocodile meat and blood will enhance immune response, which helps prevent allergies and asthma. Moreover, it is a kind of prehistoric animal that has survived until these days. It depends on its lung to breathe. A crocodile can stay underwater for a long time after each breath. When it is injured as a result of fighting with other crocodile or any other reasons and has a large and deep wound, it can still remain underwater while its immunity system can effectively prevent an attack of underwater bacteria and other micro-organisms. Its wound heals quickly. Crocodile's immunity system is very effective in fighting against bacterial infection. This ability to fight against infection of micro-organisms is an innate quality that can be found in many other animals, such as insects, shrimps, fish, frogs, snakes, cows, pigs, and human beings.

Crocodile blood that runs through and nourishes all parts of the body may contain important chemical compositions, both organic and inorganic, as well as various minerals serve as nutrients, immune system, and substances capable of fighting against undesired conditions. In rearing crocodiles, no medicines, vaccines or growth hormones are used. No infection of significant diseases, such as foot and mouth disease, anthrax, mad cow disease, bird flu, and parasite, is reported. Thus, this crocodile blood contains various components that are more valuable and essential than the blood of many other animals, but there are many problems that have to be solved, such as small amount of blood that can be collected, a high chance of contamination, production process that is not clean or efficient enough and improper form of product.

Therefore, many research studies in Siamese crocodile blood have been done and led to creative ideas, inventions capable of solving technical problems, original inventions that have never been produced before and can be used for industrial, agricultural and commercial purposes.

Development of Crocodile Blood Capsule as Dietary Supplement

The research team in the Crocodile Research Unit, Department of Zoology, Faculty of Science, Kasetsart University (KU) conducted a research study on efficiency of crocodile plasma in inhibiting bacterial growth and found that it was capable of inhibiting the growth of many kinds of bacteria (Chaeychomsri *et al*., 2003; Siruntawineti *et al*., 2004 (b)). The research findings are in agreement with those of the research studies conducted in United States of America and Australia (Merchant *et al*., 2003). Later, research studies were conducted to determined feasibility of producing supplement food from crocodile blood. In Thailand, crocodiles are reared in farms and feed on chicken carcass from standard plants. However, for safety and confidential consumption of crocodile blood, the crocodile research started with a study of helminthes in the blood and intestines of crocodiles from all over the country (Siruntawineti *et al*., 2004 (a); Chaeychomsri *et a*l., 2004). A total of 384 crocodiles were used as the research sample in accordance with distribution ratio of the crocodiles throughout the country. No helminthes were found in the crocodiles' blood and intestines. This shows that the blood of crocodiles from crocodile farms nationwide was free from helminthes and could be developed into a supplement food. As a result supporting in large amount of blood collection limited of bacteria contamination, apparatus for collecting a large volume of blood was invented and a patent application was filed in 2006 (Thai patent application No. 0601001179, Kasetsart University, 2006). In order to achieve a clean and high quality product free from bacterial contamination and made in a form of capsule for easy consumption, a process for freeze dried crocodile blood preparation was created (Thai Petty Patent No. 5074, Kasetsart University, 2006). After that, in collaboration with private sector, we made an effort to enhance clean and safe production process. To study the efficiency of freeze dried crocodile blood product, toxicity studies at acute, sub-chronic, and chronic levels in experiment rats were performed (Chaeychomsri *et al*., 2006; 2009). The result revealed that administration of 5000 mg/kg (body weight) per day or a dosage of 6 capsules/day for six months did not cause toxicity to the experiment rats or result in abnormalities of biochemical substances in the blood, such as blood sugar, blood urea nitrogen (BUN), creatinine, alkaline phosphatase, and alanine transaminase. Moreover, it did not cause abnormalities in tissues, kidney, liver, and intestine. Regarding a study of heavy metal contamination in crocodile blood capsules, the result shows that contamination of mercury and arsenic was not found. Contamination of bacteria capable of causing diseases in humans, such as *Escericia coli*, Salmonella, *Staphylococcus aureus*, and Clostridium, was also not found. These data support the clean and safety of the crocodile blood product (Figure 1). Since 2009, the crocodile blood product based on Kasetsart University - research studies have been approved by FDA - Thailand as a dietary supplement product**.** This is the first registered of dietary supplement originated from crocodile blood in Thailand and as the first world's record.

Kasetsart University has permitted for using intellectual properties and transferred production technology exclusively to “Wanithai Limited Partnership”, since 2008. Crocodile blood capsules under the trademark of “Wanithai” are available in the market and many consumers with anemia and diabetes have told the research team that their anemia conditions and blood sugar level are improved.

Then, our research team studied compositions of crocodile blood (Siruntawineti *et al*., 2010) and found that its main compositions included nutrients shown in Table 1. This means that crocodile has all nutrients that our body needs in a small amount per day. It also contains protein that carries many kinds of essential nutrients into and out of cells. Afterwards, there was a test to determine the effect of crocodile blood on iron deficiency anemia (IDA). The test was performed on IDA-induced rats with hemoglobin value of 5.58 gm% and normal rats with the hemoglobin value of 15.14 gm%. After feeding the IDA-induced rat freeze dried crocodile blood as supplement food for three week in an amount of 250 mg/day, their hemoglobin value was improved to 13.7% whereas the hemoglobin value of iron deficiency anemic rats was 8.8 gm% (Chaeychomsri *et al*., 2007, 2009 ; Siruntawineti *et al.*, 2008).

Moreover, the IDA rats receiving crocodile blood as supplement food has normal value of hemoglobin. This is in line with information received from anemic persons who reported that after consuming freeze dried crocodile blood, they became less fatigue and were able to work better. The research team continued to keep experiment rats that recovered from anemia and breed them naturally. It was also found that the anemic rats receiving crocodile blood as supplement food had more offspring than the control group and the group with anemia throughout the experiment did. This showed that crocodile blood was able to strengthen the body and eating crocodile blood increased a chance for these experiment rats to have more offspring and easier than the control group.

Healthy captive crocodiles

Apparatus/ Needle and method involved in crocodile blood collection
(Thai patent application No. 0601001179. and No. 0801000372.
Kasetsart University, 2006 and 2008, respectively)

Raw material of a large volume of clean crocodile blood

Pasteurization process

Creative freeze-drying/ Process for dried crocodile blood preparation and its product
(Thai petty patent No. 5074.
Kasetsart University, 2006)

"Crocodile Blood Capsule" in "WaniThai" brand
Product from research studies of Kasetsart University
Thai FDA No. 10-104752-1-0001
(Dietary supplement)
With High-quality, clean, safe, standard & easy consumption

Figure 1. Significance/ concept and protection of intellectual properties of Kasetsart University involved in crocodile blood capsule production as Thailand dietary supplement

Table 1. Nutrient Composition of Freeze Dried Crocodile Blood

Nutrition	Quantity	Unit
Proteins	83.1	%
Minerals	4145.28	
Iron (Fe)	164	mg/100g
Calcium (Ca)	90	mg/100g
Sodium (Na)	1458	mg/100g
Phosphorus (P)	574	mg/100g
Magnesium (Mg)	22.5	mg/100g
Minerals	4145.28	
Vitamin A	10.61	mg/100g
Vitamin B1	0.17	Mg/100g
Vitamin B2	0.23	Mg/100g
Vitamin B6	0.22	Mg/100g
Vitamin B12	0.20	Mg/100g

The KU-crocodile blood capsule is a product that contains good source of natural iron in the form of heme in red blood cell. In general, the people who suffer with anemia will have synthetic iron pills. Long consumption of the iron pills regarded with the enlargement of liver and spleen in anemic patients. Thus, a comparative study on consumption of iron pills (Group 1) and freeze dried crocodile blood (Group 2) as supplement food was conducted by inducing both groups to have anemia in four weeks; then giving the first group with iron pills and the second group with freeze dried crocodile blood for six months. At the end of experiment, when carcasses of the experiment rats were examined, it was found that, unlike the first group, the second group did not have enlarged livers and pancreas.

A study on recommended dosage of crocodile blood showed that a large quantity of crocodile blood did not cause toxicity to the body. Recommended dosage was 1-2 capsules per day before meal. A smaller quantity was also effective in health enhancement, but it would take a longer time. Consumption of the crocodile blood in conjunction with vitamin C will result in better improvement of blood cells. Generally, it is recommended to have crocodile blood while your stomach is empty because it will increase the body's ability to absorb essential nutrient (Chaeychomsri *et al.*, 2006).

Trends and Application of the Dietary Supplemented Crocodile Blood Products

With regard to enhancement of blood system and immunity, the research team found that with a good blood system and improvements in red blood cell, white blood cell and platelet generation, consumers were able to better fight against bacterial infection and became less exhausted because their red blood cells could efficiently carry oxygen to all parts of the body while strong white blood cells were able to effectively fight against diseases. Regarding the data collected from consumers with immune deficiency, large quantity of viruses in their blood and low CD4 white blood cell count, it was found that after consuming crocodile blood for some time, their CD4 count became higher and eventually similar to that of normal people, enabling them to live their lives like normal people. With regard to a study of amino acids in crocodile blood, it was found that there were more amino acids in crocodile blood than those in the blood of chickens, cows, and pigs (Siruntawineti *et al*., 2010). The types and quantities of such amino acids are shown in Table 2. All types of amino acids in crocodile blood were in a large amount. These amino acids are precursors for the body to enhance cells under control of our genetic system. When there are a lot of precursors available for use, cells will be effectively and correctly generated as determined by our genes.

Table 2: Types and Quantities of Amino Acids in Freeze Dried Crocodile Blood

Amino Acids	Quantities	Unit
Alanine	5442.63	Mg/100g
Arginine	4145.28	Mg/100g
Aspartic acid	7538.34	Mg/100g
Cystinne	2798.19	Mg/100g
Glutamic acid	9960.25	Mg/100g
Glycine	3164.57	Mg/100g
Histidine	5226.33	Mg/100g
Isoleucine	2054.58	Mg/100g
Leucine	7761.15	Mg/100g
Lysine	7508.79	Mg/100g
Methionine	1197.69	Mg/100g
Phenylalanine	3800.96	Mg/100g
Proline	3802.51	Mg/100g
Serine	4862.37	Mg/100g
Threonine	3255.68	Mg/100g
Tryptophan	1006.58	Mg/100g
Tyrosine	3824.22	Mg/100g
Valine	3756.28	mg/100g

According to data obtained from cancer patients undergoing chemotherapy or radiotherapy, after a period of consumption of KU-freeze dried crocodile blood, there were improvements in red blood cell, white blood cell and platelet generation to the point that the patients were allowed by physicians to continue their chemotherapy or radiotherapy. It was also found that the patients who had freeze dried crocodile blood had less side effects than those who did not have freeze dried crocodile blood. This is an important issue that the research team is determined to study in detail in order to obtain a clear answer.

Normally, the main consumer of the KU-crocodile blood capsule is anemic patient. After being informed by anemic persons about the impact of freeze dried crocodile blood and reduction in blood sugar, the research team further studied what substance helped reducing the blood sugar and found that in crocodile blood, there was a great amount of insulin like growth factor (IGF1). The level of this insulin like growth factor in freeze dried crocodile blood was not different from that in the fresh blood (Siruntawineti *et al.*, 2009). Later, a research study was conducted on experiment animals by giving diabetes-induced animals freeze dried crocodile blood. It was found that the diabetic rats' blood sugar was restored to normal level in four weeks after receiving the freeze dried crocodile blood, but they still had diabetes. This showed that freeze dried crocodile blood and plasma could help reducing the blood sugar at a level. Recently, the crocodile blood product has been developed for diabetes supplement designed as "crocodile serum capsule" (Thai patent application No. 0901001229, Kasetsart University, 2009). It is the second food supplement product that may give the advantage for diabetic patients. However, more research in clinical trial should be performed. In industrial scale, crocodile blood used in the production has mostly received from healthy crocodiles gone into the slaughterhouse. So, the blood received from dead crocodiles has not enough plenty to produce the product. Therefore, crocodile blood collection process on animal life maintain of captive crocodiles has been created. (Pitimol *et al*. 2008). The donation of crocodile blood was studied by development of blood collection process on animal life maintains in captive Siamese crocodile for sustainable supplying (Thai petty patent No. 7468, Kasetsart University, 2009). This will be a new crocodile blood product with differ in process of blood collection to maintain live crocodiles. In the past, crocodile blood was waste. For these data of KU-WaniThai crocodile blood capsule demonstrated that the crocodile blood useful and has been added value with researches and scientific creations. It is a good case in value adding of the crocodile blood and its applications to support sustainable use.

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Effects of fire Ant (*Solenopsis invitica*) predation on *Alligator mississippiensis* hatchlings

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Red fire ants are known to colonize mound nests of American alligators, and attack hatchlings at the time of hatching. These predatory attacks often results in consumption of the hatchling(s) by fire an colonies, and those that survive exhibit reduced growth rates and increased morbidity. We exposed newly hatched, wild-caught alligator hatchlings to red fire an colonies for different amounts of time. Increased exposure of alligator hatchlings to fire ants resulted in increased morbidity. In addition, longer exposure times resulted in higher plasma corticosteroid levels, and indicator of physiological stress. However, we observed a decrease in the total leukocyte counts, and a decrease in heterophil/leukocyte ratios, another indicator of stress. These data indicate that the red fire ant attacks may have an immunosuppressive effect of alligator hatchlings.

Assessment of nest attendance of the American Alligator (*Alligator mississippiensis*) using a modified motion sensitive camera trap

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Previous data from our laboratory has shown that motion-sensitive, infrared (IR)-based camera traps are not reliable for the quantitative capture of images of alligators. Therefore, we designed a camera trigger mechanism which included an electrical circuit board, coupled to a camera, which powered an IR Led light. The circuit was designed to turn the IR LED on for 2 seconds every five minutes. In the field, the IR LED was positioned such that the light was pointing directly into the IR detector of the camera. Therefore, the cameras were stimulated to take photos every five minutes, throughout the entire nesting period. The data revealed that alligators attend and maintain their nests more frequently during the first four to seven days after egg deposition, and then attendance is decreased. Nest attendance increased toward the end of the incubation period as eggs neared the hatching stage. In addition to nest visitation data, we also gained information concerning nest predation.

Salinity and alligator egg shape variation: A geometric morphometric analysis

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Past studies have dismissed the importance of egg shape in crocodilians, Squamates, and turtles and deemed eggs shape in birds and other amniotes as similar, in relation to functionality. The complexity of crocodilian eggs has been examined and both turtle and Squamate eggs have recently been regarded as physiologically more intricate than bird eggs. This study introduces a physiological approach to monitor alligator populations in freshwater and low salinity environments by quantifying egg shape in correlation with varying salinity. We introduce a fractional semi landmark shape template method to quantify egg shape within a geometric morphometric framework. This approach is beneficial because it allows for the quantification of shape for curved structures, such as eggs, which lack homologous landmarks. The results from this study suggest that alligator egg shape is correlated with varying salinity levels, such that variation in alligator egg shape at low salinities changes in gradient like fashion while salinities high enough to be deemed stressful result in reversion back to a low salinity egg shape or desiccation. This study elucidates a correlation that can be implemented in management and breeding techniques and opens the door to in depth physiological examination of the system

Progress report on crocodilian genome sequencing

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Genome and transcriptome sequences have been generated for the saltwater crocodile, *Crocodylus porosus*, the American alligator, *Alligator mississipiensis*, and the Indian gharial, *Gavialis gangeticus*. These sequences are being analysed and annotated by The Crocodylian Genomics Consortium, coordinated by Dr. David Ray of Mississippi State University. As well as automated gene identification and annotation of the sequences for alligator and crocodile, accessible via a GBROWSE viewer and freely available to all interested parties (go to http://gatorwiki.soe.ucsc.edu/doku.php?id=start for details on access), the genome sequences are available for direct interrogation via BLAST and manual analysis to authorized members of the consortium via CoGE or by using other more specialized bioinformatics tools. The genome sequences of all three species are already at a relatively advanced stage of assembly and annotation but further refinement is also underway. Large numbers of SNPs (single nucleotide polymorphisms) have been identified in both alligator and crocodile as part of the initial genome sequencing, with preliminary results suggesting lower levels of genetic variability in these crocodylians compared with other vertebrates. Currently a concerted effort of large scale SNP identification and genotyping via sequencing is being implemented in the saltwater crocodile. These genome sequences represent very valuable resources for all crocodylian researchers. Updated details and resources are available at http://crocgenomes.org

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Disturbance effects on a South African river and the impact on the Mutale River *Crocodylus niloticus* population

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Abstract

In 2000, major floods occured in several rivers within South Africa, resulting in alterations of river shape and biodiversity. The Mutale River was greatly affected by these floods and changed from a narrow, deep river often associated with a gorge and a clear riparian area, to the now flat, shallow river with a multitude of small pools. With these physical alterations in the river, the macrobiota in the river also changed. This river now hosts larger crocodiles in deeper pools, while crocodiles of varying size inhabit the runs between the pools. Currently, the Mutale River is under consideration to become a reserve for Nile crocodiles, *Crocodylus niloticus*. As of January 2013, heavy rains induced a large flood in Limpopo province, further flattening the river and delivered large amounts of sediment downstream. We found that the percent of suitable breeding habitat has doubled, the water quality has improved and the crocodile population is still present in a 15km stretch of river after the January 2013 floods. While these results indicate habitat improvement for breeding individuals, there has been a loss of habitat for larger crocodiles in the river. These results point towards the sensitivity of the Mutale River to disturbance by floods, which could lead to future degradation of *Crocodylus niloticus* habitat. This makes continued monitoring of this area necessary for a successful crocodile reserve and also highlights the sensitivity of South African rivers and vulnerability of Nile crocodiles to these disturbances.

Introduction

The availability of South Africa's freshwater resources has a poor outlook for the near future. According to the National Biodiversity Institute (2004), 84% of ecosystems associated with larger rivers are considered vulnerable (Colvin *et al.* 2011). The increase in human settlement and development around rivers, coupled with global climate change which is predicted to increase the occurrence of extreme weather events, the state of river ecosystems is increasingly vulernerable. With 82 % of rivers already threatened, 44% of which are also critically endangered, the conservation of these scarce water sources is of serious concern. South Africa is a dry region, receiving an average of only 490 mm of rainfall annually (Colvin *et al*. 2011). This aridity has direct implications for river flow and water availability, particularly for the rural communities that use rivers as primary water sources, as well as for the species that inhabit them. River conservation in South Africa is focussed on the catchment areas in the east. However, this leaves the majority of the river systems susceptible to anthropogenic influences before they reach protected areas. Monitoring of these highly valued and vulnerable systems is imperative for their conservation.

Management of crocodiles is closely linked to river conservation, as they form an important component of aquatic ecosystems (Davis and Day 1998). The only crocodile found in South Africa is the Nile crocodile, *Crocodylus niloticus*, whose range is restricted to the northern and eastern regions and shrinking further as a result of habitat destruction (Alexander and Marais 2007). Populations of *C. niloticus* are relatively high in protected areas (Fergusson 2010); however, they are still being heavily impacted by upstream activity in the unprotected areas. Crocodiles in South Africa are listed as 'vulnerable' by the IUCN. Threats to these include habitat loss, human-crocodile conflict, anthropogenic impacts from land use and active hunting for the crocodile skin trade (Ross 1998 from Botha 2005, Combrink *et al.* 2011).

Water quality is an important variable in assessing river health. Crocodiles, as apex predators, can serve as important indicators of a healthy river system (Mazzotti *et al.* 2009). Their health is closely linked to the health of food webs, diversity and productivity of other species and to freshwater flow. Crocodile population responses, including their distribution and abundance, are directly related to changes in environmental condition, thus these responses are valuable for assessment of disturbance impacts for both river and crocodile conservation.

A significant population of *C. niloticus* is found in Mutale River of the HaMakuya district, South Africa. The Mutale River is part of the Limpopo catchment, and has low levels of pollution and human-crocodile conflict despite being an important water resource for the surrounding villages (Celestino et al. 2012 cited by Correa et al. 2012). It contains all size classes of crocodiles, although mostly juveniles and mid-size individuals (Botha 2005). After extensive flooding in 2000, the Mutale River became more shallow and wide, and had significant impacts on the species composition of the

Mutale River (A. Pearcy *pers. comm*.). The recent flood in January 2013 was less intense than that of 2000, but may still have had a significant impact on the river. This potential change is of particular interest at this time as the HaMakuya section of the Mutale River is being considered for national recognition of reserve status.

In this study, we attempt to assess the vulnerability of the Mutale River to a shape-altering flood and the concurrent indirect effects on the *C. niloticus* population. Given the specific habitat requirements, we are looking to determine the effect of the January 2013 floods on the crocodile habitat of the Mutale River, as well as the sensitivity of this habitat to disturbances.The results of our survey will be useful in determining if this river continues to offer suitable habitat for crocodiles for a protected area.

Methods

Study Site

We conducted our study during the wet season, March 10^{th} to 12^{th} 2013, in the riparian zone along the Mutale River. The river is part of the Limpopo catchment in the Limpopo province, of Northeastern South Africa in a wide river valley. We traversed three survey sections of the river with one section above the gorge (starting point: S22.63764, E30.74460) and two sections below the gorge (S22.35506, E30.47463), (S22.32964, E30.47624). We collected habitat quality data over an 11.1 kilometer stretch below and upstream of the gorge (Figure 1) and multiple water quality samples from the three sections of river.

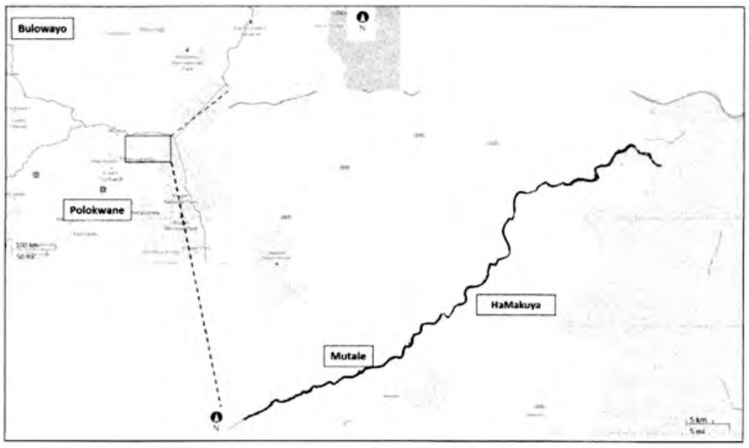

Figure 1. Map of the Mutale River. The area circled is the survey range.

Study Species

The Nile crocodile's (*Crocodylus niloticus*) distribution ranges across most of central and southern Africa (Fergusson 2010). *C. niloticus* populates lakes, rivers, freshwater swamps, and even brackish pools in tropical and sub-tropical environments. They tend to avoid fast flowing water and favor slightly murky water. During the dry season, crocodiles create nests by digging holes into sand banks. Egg incubation in the nests lasts for 75-95 days and once hatched the nest is guarded for another 6-8 weeks (Fergusson 2010).

Habitat Assessment

In order to reassess the viability of a crocodile conservation plan in our study section of the Mutale River, we conducted an investigation of the aquatic and terrestrial habitat characteristics and the current status of the Nile crocodile population in the region. We surveyed a total of 11.1 kilometers of river over a three day period from mid-morning (11am) to late afternoon (3pm). Due to the necessity of terrestrial habitat for breeding and basking, we recorded the length of all the sandbanks within a seven meter distance from the river. The seven-meters was chosen as the nests found previously within the river are in this space. In addition to measuring sandbanks, we recorded the length of rocky areas, unusable areas (including gorge or cliff walls), and other areas (included debris piles and reed beds) both in the river and on both sides of the banks. Since crocodiles prefer to live in slow moving water, we also included the flow rate of the river in our riverscaping data based on whether it consisted of rapids, runs, or pools. We used Garmin BaseCamp to measure the distances of the different habitat areas of the river (Garmin BaseCamp). This habitat assessment information was analyzed through a percent breakdown of the sandy areas, rocky areas, unusable areas, other areas, and river flow intensity type to evaluate suitable crocodile habitat along the surveyed section of the river.

To determine water quality, we took measurements of temperature, pH, velocity, turbidity, elevation, and depth every 500 meters along the river. We measured temperature with an infrared thermometer and elevation with a Garmin GPS System

(GPSmap 60CSx). Turbidity was assessed by counting the number of visible dots of different sizes on a piece of paper, out of five, that could be seen through a clear plastic bottle filled with the sample water. Velocity was measured by determining the amount of time it took for a meter long string attached to a water-soaked apple to fully extend. Using a tape measure to find depth, we measured three randomly selected points at the sample site's edge. We collected three macroinvertebrate community samples every 1000 meters within each survey section of river. For safety, these samples were collected in rapids since crocodiles tend to avoid fast flowing water. The water was disturbed within the site for five minutes and we collected debris by holding a net directly downstream of the disturbance. Six people then performed active searching on the sample for fifteen minutes. The collected taxa were identified using an invertebrate identification guide (Gerber and Gabriel 2002).

The water quality data was assessed using the South African Scoring System (SASS) Version 5 Rapid Bioassessment Method (Dickens and Graham 2010). The average score per taxon (ASPT) was calculated for the macroinvertebrates found in each site. We used ASPT instead of SASS scores as a conservative estimate of river quality and as a comparison to previously conducted studies (Dickens and Graham 2010).

Disturbance Assessment

To assess the broad scale changes and sensitivity of the Mutale River to a disturbance, we compared riverscaping data before and after the January 2013 floods. We accomplished this comparison using percentage breakdown of habitat type pre- and post- disturbance (Dzumaga 2012). We only compared above gorge data because that was the only section of the river where the pre- and post- disturbance data overlapped.

River quality pre- and post- disturbance were also compared in order to assess the sensitivity of the Mutale River to disturbance. Significant drivers of variation in river quality were identified using Principle Component Analysis (PCA). The PCA was calculated using JMP (2010) with the inputs including ASPT, pH, velocity, temperature, width, average depth, and elevation for all ten sample sites. ASPT scores were used as a comparison tool between pre- and post-disturbance river quality.

Crocodile surveys

We conducted night spotlight surveys over a three-day period. Since crocodiles are most active after sunset, we walked back along the same stretch of river surveyed during the day and located crocodiles from 2000 to 2300. We detected crocodiles based on their distinctive red eye shine reflection. Life stages were confirmed through day sightings or full body visuals. This survey, along with signs of crocodile activities we observed during our daily data collection, gave us an indication of the current demographic distribution of the Nile crocodile in this portion of the river. It also allowed us to compare crocodile population distributions over several seasons.

Results

Habitat Assessment

Along our survey section of the Mutale River, we surveyed sections covering bank both above and below the gorge and took measurements of water quality at 10 sites along this stretch. In this total length surveyed, we found a similar percent of the banks covered by sand (37%) and terrain unusable by *C. niloticus* (32%) (Figure 2). We found the majority of the river to be comprised of runs (41%) with relatively few pools (5%) (Figure 3). Water quality throughout the surveyed area was relatively high, with an average ASPT score of 8.99 for the 10 water quality sites.

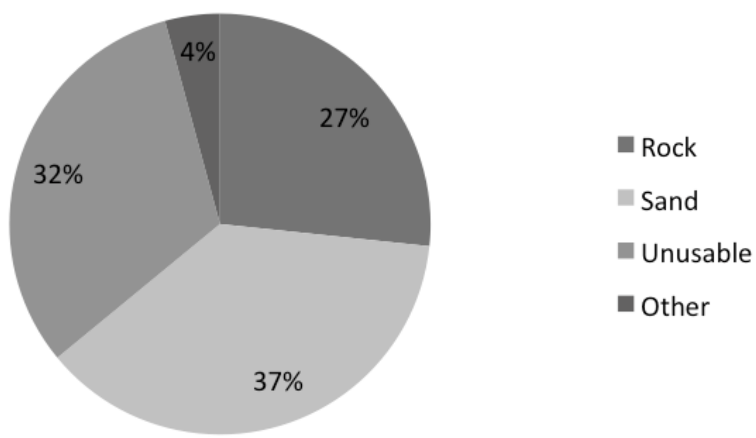

Figure 2: Percentage breakdown of terrestrial habitat along surveyed section of the Mutale River.

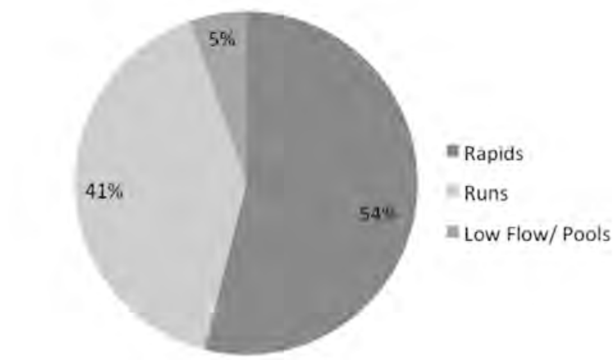

Figure 3: Percentage breakdown of water flow in surveyed section of the Mutale River.

Sensitivity of Habitat to Disturbance

To assess how the January 2013 floods have affected the composition of the banks of the Mutale River and its water quality, we compared our data to data collected in October 2012 for an overlapping stretch of river above the gorge. The amount of sand bank coverage more than doubled from pre-flood (12%) to post-flood (28%), doubling potential nesting habitat for *C. niloticus* (Figure 4a, 4b). The percentage of pools in this section of the Mutale however, decreased from before the flood (30%) to after the flood (2%).

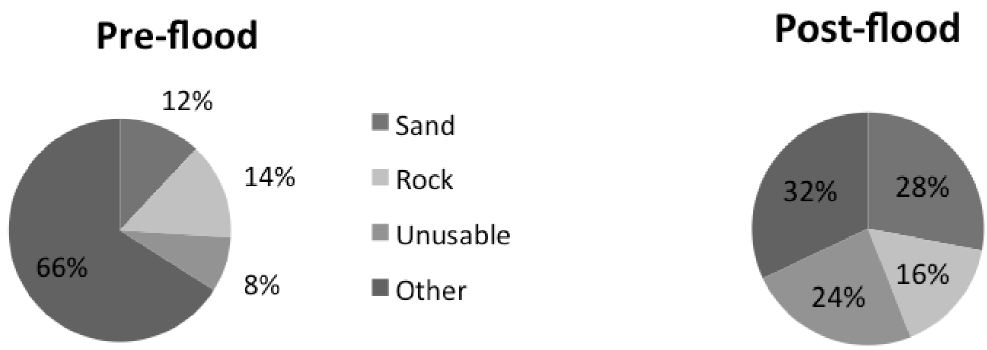

Figure 4: (a) Percentage breakdown of above gorge section of the Mutale River in October 2012. (b) Percentage breakdown of above gorge section of the Mutale River in March 2013.

We performed a Principal Component Analysis of our water quality measurements which revealed that 37.1% of the variation seen in water quality is accounted for by principal component 1 (PC1), which is driven by temperature (-0.42325), width, (0.52720), average depth (-0.41521) and elevation (0.48122). Principal component 2 (PC2) accounted for 25.5% of the variation in water quality and is driven by pH (0.60520), velocity (0.57121) and temperature (0.42631) and the principal component 3 (PC3) accounted for 15.7% of the variation and was driven by ASPT scores. These principal components can be generally described as being driven by either physical properties of the river, as is the case for PC1, or chemical properties, as is the case for PC2 and PC3. There is no clear clustering of the points and little variation among them, indicating uniform water quality throughout the river (Figure 5)

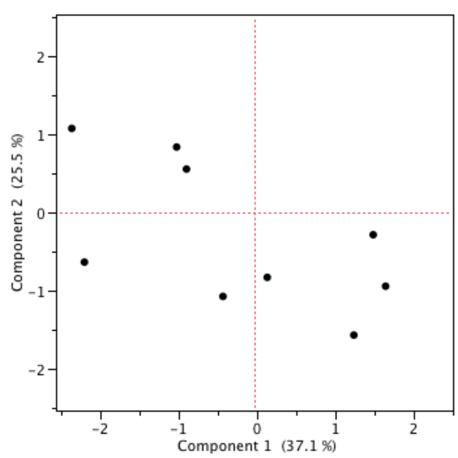

Figure 5: PCA output showing the relationship between water quality sites along the surveyed section of the Mutale River for principal component 1 and 2.

When this PCA output is compared to the output generated by data collected prior to the January 2013 floods, where 98.6% of the variation in water quality was accounted for by PC1, which was driven by depth (-0.973) and temperature (-0.225). We see that the variables most heavily weighted in accounting for water quality variation are common, but the amount of variation they account for has changed.

To assess how the floods affected water quality, we compared the ASPT scores we calculated to those calculated from the data collected before the flood. There is no overlap between the two sets of scores, with post-flood scores higher than pre-flood scores. Additionally, there is much less variation among the post flood scores than the pre-flood scores, indicating that post-flood water quality is more uniform and higher than pre-flood water quality throughout the river (Figure 6).

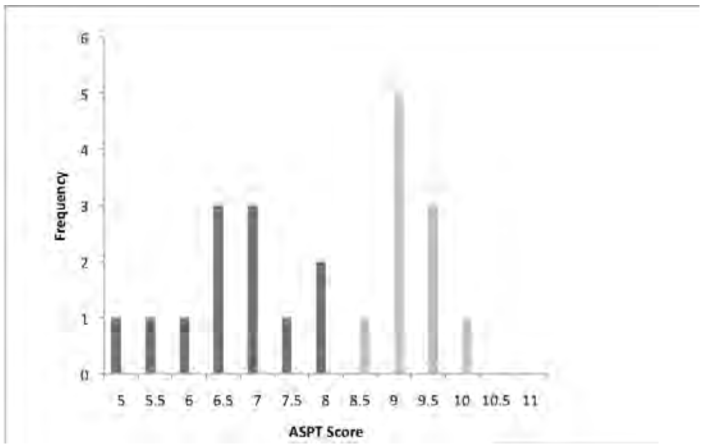

Figure 6: Frequency distribution of ASPT scores for the October 2012 survey (blue) and the March 2013 survey (red).

Crocodile population in the Mutale

We surveyed the *C. niloticus* population along our study site to assess how this population has been affected by changes in river composition. When compared to data from past studies, we found the number of individuals to have steadily increased regardless of season or flood disturbance (Figure 7). In our survey, we found the majority of (14 of 20) individuals to be sub-adults (Figure 8)

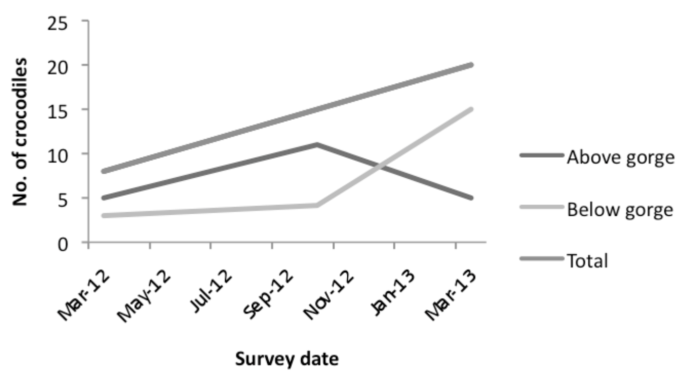

Figure 7: Change in the *C. niloticus* population size in our surveyed section of the Mutale River over time.

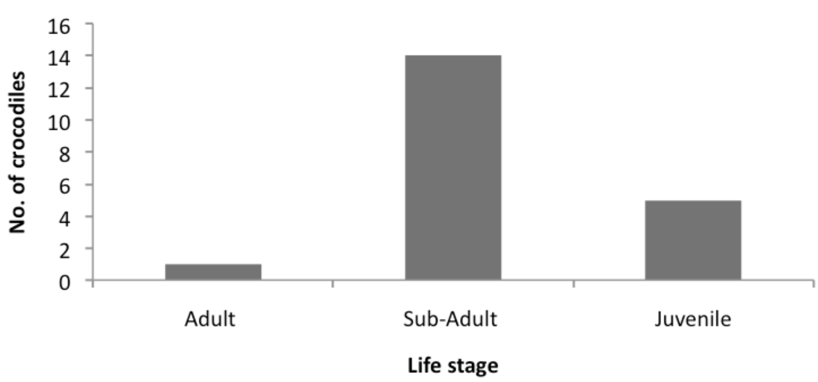

Figure 8: Age distribution of *C. niloticus* found in the March 2013 survey

Discussion

The protection of the vulnerable Nile crocodile presents an important issue for conservation in South Africa, especially since the crocodile is an apex predator and thus serves as an indicator of ecosystem health and water quality. In order to determine if the HaMakuya section of the Mutale River continues to offer suitable habitat for a protected area, we assessed the quality of crocodile habitat remaining after the January 2013 floods. We also examined the overall sensitivity of the system to such disturbances. In terms of post-disturbance habitat, the presence of a significant amount of sand banks along the crocodile buffer region of the river suggests that the terrestrial habitat remains favorable to crocodiles. Such sandbanks present optimal habitat for nesting sites (Fergusson 2010). Comparisons of our habitat assessment to the pre-flood data show that breeding habitat has actually increased post-disturbance, as a result of sediment deposition. Similarly, the 46% of the river that consists of runs or pools indicates that this section of the Mutale has remained deep enough to present suitable hunting and resting habitat for the crocodiles in the water. Furthermore, the overall quality of the water has increased post-flood. This could be because the recent flood had a cleansing effect, potentially removing pollutants and debris from the river.

However, not all the changes were as encouraging. As was the case with the major 2000 floods, this recent disturbance both widened and flattened out the river (A. Pearcy *pers. comm.*). As a result, the number of deep, slow moving pools, which represents ideal crocodile habitat within the river, decreased after the recent January floods. Furthermore, our PCA suggests that most of the variation observed along the river is attributable to properties such as width and depth; physical factors that are very sensitive to flooding effects. Since the relative importance of these physical factors in explaining variation has changed from before the floods, we can assume that these variables are sensitive to disturbance. Therefore, future floods may continue the flattening trend of the river, and potentially leave very little suitable pool habitat for the crocodiles.

The Mutale River's lack of deep pools may be attributing to the small number of adults found within our survey site. Only one fully grown adult was surveyed. The larger crocodiles may have moved downstream with the floods and have not yet returned or simply could be missing from this population. Either way, continued monitoring of the crocodile population will be necessary if the river is to serve as a protected area for this species.

Given the persistence of the crocodile population along the Mutale River after the recent floods, as well as the relatively favorable change in crocodile nesting habitat resulting from the flood, we have concluded that the HaMakuya region of this river continues to present a suitable conservation area for crocodiles. However, due to the flattening of the river as well as the sediment deposition associated with the recent flooding, the Mutale River now more closely resembles the Olifants River (A. Pearcy *pers. comm.*). Therefore, in order to avoid another crocodile die-off similar to the pansteatitis epidemic that the Olifants experienced from 2008-2009, conservation measures around the Mutale may be necessary to minimize the polluting effects of development (Ferreira and Pienaar 2001). As *C. nilotocus* numbers continue to decline in South Africa, the creation of such protected areas will be crucial in maintaining the species and offering a model for the rest of Africa in terms of balancing development with both crocodile and freshwater habitat conservation.

Acknowledgements

We would like to thank OTS students for helping with field work, the Tshulu Camp Staff, and Fhatuwani Makuya for aiding us in completing this study.

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Effects of freeze-dried crocodile serum supplementation on blood glucose level in diabetic Spraque dawley rats

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Abstract

Previous studied showed that freeze-dried crocodile blood contain 677.2 ± 3.41 ng/gm of insulin-like growth factor-I (IGF-1). IGF-1 is synthesized in the liver upon stimulation by growth hormone and involved in cell replication, proliferation, protein synthesis, carbohydrate homeostasis, and bone metabolism. Recently, crocodile blood was developed as food supplement, dried crocodile blood capsule. According to preliminary study of the diabetic patient that consumed crocodile blood capsules showed the decreasing of blood sugar. Therefore, effects of freeze-dried crocodile serum supplementation on blood glucose level in Diabetic Spraque Dawley rats were performed by using 48 Spraque Dawley Rats. The experiments were divided in to 8 groups with 6 each and feeding for 8 weeks. Control group was fed on high fat corn starch based on AIN93G diet. Fourty two Spraque Dawley rats were induced to be diabetic which blood glucose level >400 ng/dl by streptozotocin 40 ng/kg single dose. They were performed to diabetic and experimental group 1-6. Diabetic group was fed on high fat corn starch based on AIN93G diet. The experiment groups 1-3 were fed on high fat corn starch based on AIN93G + freeze dried crocodile serum 310, 465 and 620 mg/kg/day respectively. The experiment groups 4-6 were fed on high fat corn starch based on AIN93G + freeze dried crocodile blood 1000, 1500 and 2000 mg/kg/day respectively. The results revealed that blood glucose level of experiment group 1-3 that supplemented with freeze-dried crocodile serum reduced to be normal in 4 week. In addition, blood glucose level of experimental group 4-6 that supplemented with freeze-dried crocodile blood still to be diabetic after 4 week. The present data demonstrated that freeze-dried crocodile serum have effects on reduction of blood glucose level better than freeze-dried crocodile blood.

Introduction

Freeze-dried crocodile blood in capsule was newly developed as a supplemented food product in Thailand (Chaeychomsri *et al*., 2006, 2009 ; Kasetsart University, patent application 2006 ; Siruntawineti *et al*., 2006, 2008) as KU (Kasetsart University) -crocodile blood capsule. It has been widely consumed not only for its nutritious composition, but also for its claimed medicinal value. Diabetes mellitus is an endocrine disorder characterized by hyperglycemia and glycosuria due to absolute or relative lack of insulin. Its incidence is increasing with alarming mortality and morbidity. There is an increasing demand for anti-diabetic products due to the drawbacks associated with insulin and oral hypoglycemic agents. From studying of pre- and post consumptions of KU-crocodile blood capsule in 2006, it demonstrates the good efficacy in a reduction of blood glucose level and good wound healing in consumers who suffer with diabetes (diabetic pateints). It has been hypothesized that there is IGF-1, a like substance that acts as insulin hormone (Rosen, 1999) in the serum part of crocodile blood. Then, the freeze-dried crocodile serum was studied (Siruntawineti *et al*., 2009) and presents that in Siamese crocodile serum has IGF-1 (67.28 ± 4.79 ng/ml). Moreover, the level of IGF-1 in freeze-dried crocodile serum is not different from in the fresh serum. In 2009, Chaeychomsri and Siruntawineti were created process for large volume of crocodile serum production and its product (Thailand Patent application No. 0901001229, 2009). To clarify the beneficial effect of this freeze-dried crocodile serum capsule, the present study was performed to determine effects of freeze-dried crocodile serum supplementation on blood glucose level in diabetic Spraque Dawley rats.

Materials and Methods

Collection of crocodile blood: The blood in large volume was collected from Siamese crocodiles (Crocodylus siamensis) that captives at Rungtaweechai Crocodile Farm, Don Toom District, Nakhonpathum Province, Thailand according to a KU-patented method (Chaeychomsri and Siruntawineti, 2006).
Freeze-dried crocodile serum/ blood preparation: Process for freeze-dried crocodile serum production of Thai patent application No. 0901001231, Kasetsart University (Chaeychomsri and Siruntawineti, 2009) was performed as following. After special separation with aseptic technique, the mass crocodile serum was pasteurized and prepared in tray and freeze-drying using freeze dryer (Lyomaster, USA). The freeze-dried serum was powdered by graining at sterile condition and stored at $4^{\circ}C$ until use. For freeze-dried crocodile blood preparation, the whole crocodile blood that descript in previous part was done as in freeze-dried crocodile serum.
Laboratory animals: The Animal Ethics Committee of Kasetsart University, Thailand approved the use of laboratory animals in this study. Spraque Dawley male rats with weight 150-200 gm were used. Control group that the rat (n = 6)

treated high fat corn starch (HFCS) base on AIN93G diet. The other rats (n = 42) were diabetic induction by Streptozotocin 40 ng/kg, single dose intraperitonial injection. After one week, all rats were fast overnight before blood glucose determination from the tail vein of each rat using a portable glucometer with Glucose oxidase based method (Accu-chek Performa , Roche Diagnostics Ltd., Thailand). The rat was classified as diabetic rat when blood glucose was more than 400 mg/dl. After that the rats were randomly divided into 7 groups as follow:- *Diabetic rats group*: the rats received high fat corn starch (HFCS) base on AIN93G diet.; Experimental groups 1-3 or *Diabetic rats Freeze-dried serum consumption groups* that the rats consumed HFCS base on AIN93G diet with freeze-dried crocodile serum in concentrations of 310, 465 and 620 mg/kg/day, respectively ; Experimental groups 4-6 or *Diabetic rats Freeze-dried crocodile blood consumption groups* that the rats were fed HFCS base on AIN93G diet with freeze-dried crocodile blood in concentrations of 1000, 1500 and 2000 mg/kg/day, respectively. All rats were housed individually in hanging wire-mesh cages in a room with a controlled temperature of 25-29°C and a 12:12-h light-dark cycle with 30-70% relative humidity. The rats were allowed unlimited access to food and distilled water. Daily food and water intakes and body weights were recorded weekly for 12 weeks.

Experimental procedure: The rats were fed the experimental diets for 12 weeks. After 4, 8 and 12 weeks, animals were fasted for 24-hours prior to blood collection from tail vein. The blood was determined for blood glucose with a portable glucometer (Accu-chek Performa, Roche Diagnostics Ltd., Thailand). At the end of the 12th week, rats were euthanized and the body organs such as pancreas, liver, kidney, were removed, cleaned with ice phosphate buffer saline, then collected and fixed with Bouin's fixative. Tissues slides were prepared and stained with hematoxylin and eosin. The slides were examined by a pathologist. All values were compared to control group at the same time of treatment. Data are presented as means ± SEM.

Results and Discussion

During the experiments, it was observed that the food and water intakes of the *Diabetic rat groups* were less than in *control rat group*. However, in *Diabetic rats Freeze-dried serum consumption groups* showed the higher values than in *Diabetic rats group* and *Diabetic rats Freeze-dried crocodile blood consumption groups* (Figure 1). All diabetic animals presented the reduction of blood glucose level after establishment of the diabetic condition in the 4th week. Nevertheless, at the end of the experimental period rats treated with freeze-dried crocodile serum had gained weight lesser when compared to untreated and treated freeze-dried crocodile blood diabetic animals (Figure 2). Moreover, the diabetic rats fed freeze-dried crocodile blood (experimental group 4-6) demonstrated the lower of blood glucose when compared with non-treated diabetic rats. These results revealed that blood glucose level of diabetic rats that supplemented with freeze-dried crocodile serum was reduced to be normal blood glucose baseline in 4 weeks. The present data demonstrated that freeze-dried crocodile serum have effects on reduction of blood glucose level better than freeze-dried crocodile blood. In addition, diabetic rats supplemented with freeze-dried crocodile serum exhibited no alteration of kidney as in control group. Conversely, the kidney of diabetic rats demonstrated the abnormal of kidney including the wild space between Bowman's capsule and glomerular part that may due to the thickness of the Bowman's capsule basement membrane (Figure 3). In conclusion, the results in this study demonstrated that freeze-dried crocodile serum has efficiency for reduction of blood glucose level in Diabetic Spraque Dawley rats in at least 4 weeks. and may useful as food supplement in diabetic patient.

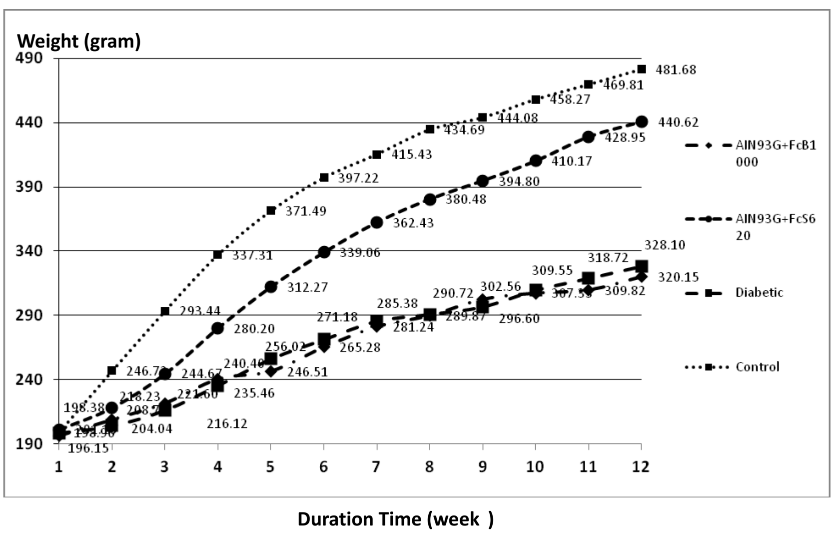


Figure 1. The body weight of experimental rats in control group, Group II (the rats treated with crocodile bile powder at 300 mg/kg body weight) and Group III (the rats consumed crocodile bile powder at the dosage of 2000 mg/kg body weight). These values were recorded weekly for 12 weeks.

Fasting Blood Glucose (mg/dl)

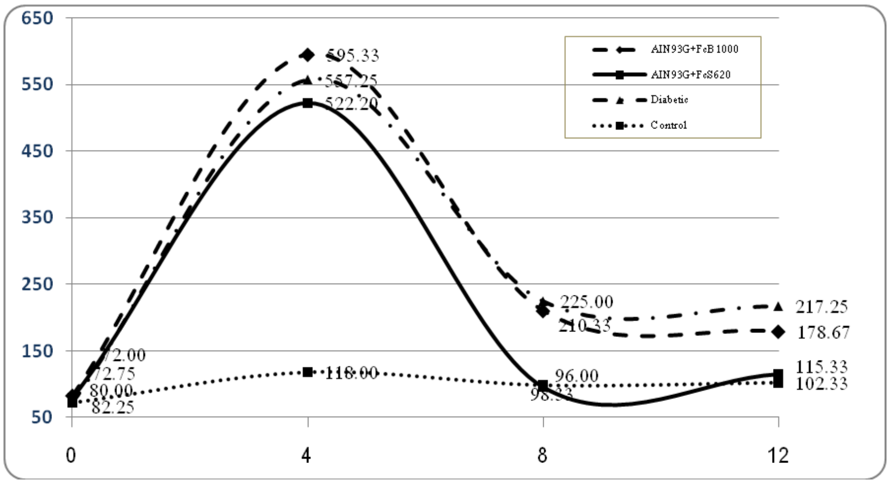
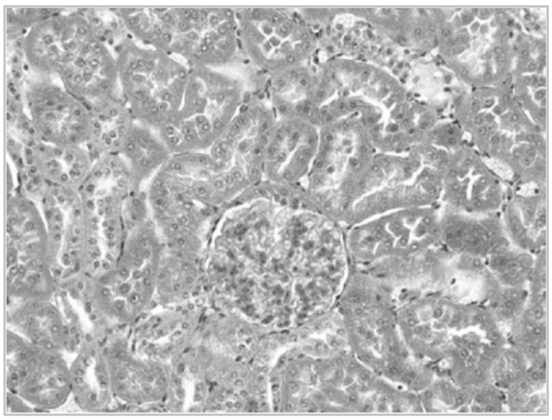
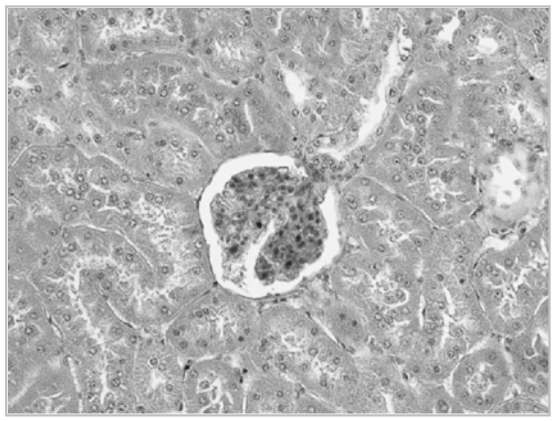


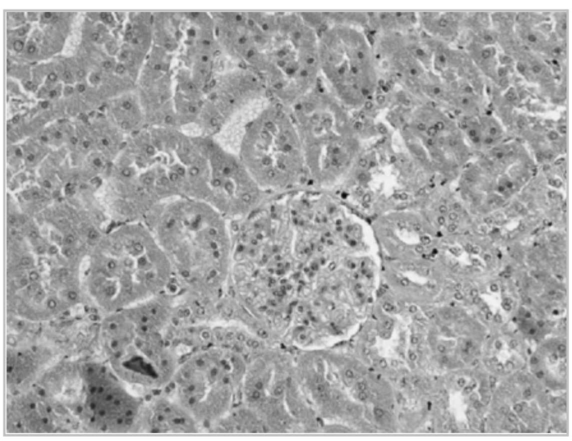
Figure 2. Blood glucose levels of control rats (Control), diabetic rats (Diabetic), diabetic rats treated rats with freeze-dried crocodile serum in concentrations of 620 mg/kg/day, (AIN93G+FcS620) and diabetic rats treated rats with freeze-dried crocodile blood in concentrations of 1000 mg/kg/day, (AIN93G+FcB1000). These values were recorded weekly for 12 weeks.



(A) Control rat



(B) Diabetic rat



(C) AIN93G+FcS620 rat

Figure 3. Histopathological examination of Sprague-Dawley rat kidneys after 12 weeks of experiments, hematoxylin and eosin staining

(A) Kidney cell of control group
(B) Abnormal sign of kidney cell from diabetic rat
(C) Kidney cell of diabetic rat supplementary fed with freeze-dried crocodile serum, 620 mg/kg/day, (AIN93G+FcS620 rat)

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Three aliens and a predator: interactions between dingoes, passion vines, cane toads and freshwater crocodiles in arid Australia

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Human induced species introductions are one of the greatest threats to global biodiversity. Introduced species can have varying impacts on the viability of crocodilian populations but very limited information is available on these complex interactions, despite them providing excellent opportunities to understand the ways in which crocodilians deal with novel challenges. We studied the interactions between three introduced species and the Australian freshwater crocodile (*Crocodylus johnstoni*) at Lake Argyle in seasonally arid north western Australia, where dingoes predate on crocodile nests, passion vines modify nesting habitats and cane toads cause mortality of crocodiles through direct poisoning. We examined how the distinctive attributes of this relatively naïve lakeside landscape have affected predator guilds and fashioned unique predator prey interactions. Dingoes (*Canis lupus dingo*: introduced to Australia 3500 4000 yrs ago) were responsible for 98% of all predator visits to crocodile nests and the predation risk lasted throughout the incubation period and at hatching. Nest vulnerability was linked to abiotic features of the nest sites rather than to features of the nests.

Many nesting sites at the lake have been invaded by passion vine (*Passiflora foetida* var. *hispida*: introduced to Australia before 1900s) over the last few years and crocodiles actively avoided beaches with this species. Dingoes fed on the fruits of this plant and potentially spread them among nesting beaches when they defecated, further accelerating the spread of this vine. Studies are underway to investigate long term impacts of this plant on the crocodile population. In early 2009, toxic cane toads (*Rhinella marina*: introduced to Australia in 1935) arrived and have been spreading ever since. We monitored crocodile densities and body sizes, the spread and movement of cane toads and the diet of crocodiles to understand the interactions between the two species. Crocodiles commonly encountered toads, but contrary to expectation, crocodile mortality was rare, and crocodile numbers did not decrease through time, nor differ between toad infested versus toad free areas of the lake. In a broader study we investigated potential reasons for spatial heterogeneity of cane toad impacts (in some other areas, crocodile numbers have been decimated by toad arrival) and the potential mechanisms through which crocodile populations can recover.

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Impact of a severe flood event on survivorship of hatchling *Crocodylus johnstoni* in northwestern Australia

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Introduction

In seasonal tropical environments, the magnitude and timing of monsoonal rainfall vary among years (Englehart and Douglas, 2001, Moron *et al*., 2003; Pittock *et al*., 2006), with strong effects both on native animals and plants (Collins *et al*., 1981; Pandey and Singh, 1992) as well as on the humans that depend upon those systems (Baddiley, 2003; Mahmudul *et al.*, 2011). Rainfall averages have increased in the many parts of the world during the latter part of the last century (Diaz *et al*., 1989; IPCC 2007; Vinnikov *et al*., 1990). Additionally, higher than average or extreme rainfall events has also increased over the last century and projected to continue increasing under a variety of emissions scenarios (CCSP 2008; Ishak *et al*., 2010). For example, from 1950 to 2005, extreme daily rainfall intensity and frequency has increased in most parts of northwestern Australia (Kingsford *et al*., 2009; Steffen *et al*., 2009; CSIRO and BOM, 2011), and in recent years several tropical areas have experienced devastating floods as a result (e.g. Bennett *et al*., 2006; Done *et al*., 2007). Inter-annual variation in monsoonal flooding is natural, but because extreme weather events are predicted to occur more frequently and strongly in a changing climate (Knutson *et al*., 2010; Salvat and Wilkinson, 2011), we need to understand the pathways by which more frequent, longer and/or extreme flooding influences the biota.

For terrestrial species, severe flooding may result in mortality by drowning of individuals (Cornelius *et al*., 2007) or their prey, as well as reduced access to prey and critical habitats (Larriera and Piña, 2000). But are aquatic species also impacted by severe flooding? Here we present the results of a study which examined the impact of a severe flood on survivorship of hatchling Australian freshwater crocodiles (*Crocodylus johnstoni*) in a large anthropogenic lake in northwestern Australia.

Methods

Field sampling.- We conducted the study at Lake Argyle (16°29´S, 128°75´E), northeastern Western Australia, in the wet-dry tropics of Australia. Lake Argyle is the largest artificial lake in Australia (>880km^2 at normal water level), constructed in 1971 under the Ord River Irrigation Scheme, and is recognized as an important wetland under the Ramsar Convention. It contains one of the largest *C. johnstoni* populations in Australia (Webb and Manolis, 2010), but saltwater crocodiles (*C. porosus*) has been only sporadically recorded in the system (Somaweera, 2011). Hatchling *C. johnstoni* in this lake largely select shoreline vegetation mats (made of distinct clusters of submerged as well as emergent and floating-leaved macrophytes including *Najas graminea, Hydrilla verticillata, Potamogeton tricarinatus, Valisneria spiralis, Myriophyllum verrucosum, Chara* sp. and *Nymphoides indica*) as their living space, a selection *driven both by higher prey availability and lower predation risk* (Somaweera *et al*., 2011a). In order to monitor the amount of preferred habitat available for hatchlings, we delineated the area covered by shoreline vegetation at 16 sites within six sections at north-western portion Lake Argyle on a 1:20 000 topographical map during daytime surveys conducted in March 2009, November 2010 and August 2011. All 16 sites were bordered by steep hills and rocky alcoves, a common shoreline feature in the northern sections of the lake.

As a part of a multi-disciplinary study, between 2008 and 2010, annual spotlight surveys for crocodiles (Messel *et al.*, 1981) were conducted in November, for 6-9 nights per month, from 1800-2300 h (15hp engine on a 3.7m boat). Hatchling *C. johnstoni* were caught and individually marked by tail-scute clipping (**Jennings *et al.*, 1991**) within the 16 sites. The following August (2009-2011) we recaptured the crocodiles and measured them for lengths and weight.

We obtained data on daily water levels of the lake from the Kununurra Water Corporation and daily rainfall data from two weather monitoring stations (Lake Argyle resort 16.11°S, 128.74°E and Kununurra Aero 15.78°S, 128.71°E: Australian Bureau of Meteorology, 2011).

Statistical analysis.- One-way ANOVAs were conducted using JMP 5.01 software (SAS Institute, Cary, NC, USA) to compare among-survey variations in vegetation cover, recapture rates and growth of hatchlings; and used linear regressions to analyze the effect of habitat loss on crocodile survival and size. Our comparisons of growth and recapture rates were based on nine-month old hatchings from 2008 (recaptured in 2009), 2009 (recaptured in 2010) and 2010 (recaptured in 2011), respectively.

Additionally, we used program MARK software (Version 6.1; Cooch and White, 2011) to estimate survival () and recapture probabilities (*p*) of *C. johnstoni* from Lake Argyle between February 2009 and August 2011 (total eight trapping occasions). We formulated a series of *a priori* candidate Cormack-Jolly-Seber models for and *p*, and implemented these in program MARK following White and Burnham (1999). Previous long-term mark-recapture studies have documented age-specific survival in *C. johnstoni* (Webb and Smith, 1984) so we included age structure in our models. Our null model was one in which survival and recapture rates were age-dependent, with three age classes (because our study spanned three years). We then formulated age-structured models to investigate whether survival rates were influenced by (1) the degree of vegetation cover; (2) flooding; or (3) interactions between vegetation and flooding.

We used an information-theoretic approach (AIC) for model selection (Burnham and Anderson 1998). We used the median $\hat{c}$ goodness-of-fit procedure approach to estimate the over-dispersion parameter ($\hat{c}$) (Cooch and White, 2011). The over-dispersion quasi-likelihood parameter indicates the degree of inadequacy of the fit of the model to the data; that is, the relative strength of evidence of the model. Following estimation of $\hat{c}$, we adjusted the model output using the variance inflation factor ($\hat{c} = 1.23$). We determined the sensitivity of the model rankings to $\hat{c}$ by incrementally decreasing $\hat{c}$ (White *et al.,* 2001). This showed that the order of models (i.e. ranked support) did not change with changes in $\hat{c}$. We ranked models by comparing ΔAIC_c (the difference between the lowest AIC and AIC from the set of models), and we used normalised AIC weights to evaluate the relative strength of evidence of models (Burnham and Anderson, 1998).

Results and Discussion

The 2010-11 "wet-season" (December-March) in tropical northwestern Australia was one of the longest and wettest ever recorded in the area (1090.1 mm of rain compared with the 42-year mean for Lake Argyle of 650.5 mm: BOM 2011). Flooding of natural and regulated riverine systems was extensive (Department of Water, 2011): the volume of Lake Argyle rose to more than double the usual wet-season maximum (from 10,763,000 ML to 22,087,740 ML: Water Corporation, 2011; Fig. 1a).

This increase in volume (thus the water level) drowned about half of the shoreline vegetation mats ($F_{2,45} = 7.14, p = 0.002$; *post hoc* Fisher's PLSD test, $p < 0.05$ for August 2011 vs both previous surveys; trend similar in all study sites $F_{8,27} = 0.38$, $p = 0.92$; Fig. 1b), the preferred habitat of hatchling crocodiles. Coincident with the disappearance of the vegetation mats, recapture rates ($F_{1,224} = 17.06$, $p < 0.001$; Fig. 1d; also see below) and growth rates ($F_{2,159} = 4.12$, $p = 0.02$; Fig. 1e) of hatchling crocodiles (at nine months old by August 2011) were much lower than recorded in previous years (compared with the nine month old hatchlings in 2009 and 2010).

Was the effect on crocodile viability a result of habitat degradation, or a more direct effect of other mechanisms? Hatching success of eggs was unaffected, because all eggs in this population generally hatch by late November (Somaweera et al. 2011b), a trend also observed in 2010. Dispersal into other areas is unlikely, because the steep banks surrounding the sites caused the lake to 'expand' vertically but not horizontally, and water did not spill over the banks of the lake in any of these sites. Predation is unlikely to have increased, because the deeper water presumably provided more opportunities for hatchling crocodiles to escape from predators. The lack or reduction of vegetation also enabled approaching the crocodiles more readily for size estimation and capture.

The putative role of shoreline vegetation mats in the crocodile decline can be tested with a spatial comparison. If shoreline vegetation mats are critical to hatchling survival, decreases in crocodile numbers should have been greatest in areas of the Lake that experienced the greatest reduction in vegetation mat coverage. Our analysis showed exactly that pattern: areas that retained more vegetation also retained more hatchling crocodiles after the flood in August 2011 ($r^2 = 0.41$, $F_{1,14} = 9.65$, $p = 0.008$; Fig. 2a) and in sites where vegetation was less affected, hatchlings had a higher mass ($r^2 = 0.32$, $F_{1,4} = 5.67$, $p = 0.03$; Fig. 2b)**.** No marked hatchlings were re-caught at two sites which experienced heavy loss of floating vegetation.

Our MARK analysis supports these results and suggests that changes in habitat characteristics affected both survival and recapture probabilities of freshwater crocodiles (Table 1). The best supported model was one in which survival rates differed among age classes and were lower in the post-flooding capture periods, and were affected by the amount of remaining vegetation. In all three "remaining vegetation" categories (low, medium and high), survival rates of three year old crocodiles were higher than those of one and two year olds, but survival was lower in all age classes after the floods. In this model, recapture probabilities were higher for hatchlings ($\boldsymbol{p} = 0.77$, SE = 0.04) than two ($\boldsymbol{p} = 0.60$, SE = 0.05) or three year olds ($\boldsymbol{p} = 0.39$, SE = 0.04), and recapture rates were age invariant during the two periods post-flooding ($\boldsymbol{p} = 0.55$, SE

= 0.05). The second best supported model was one in which survival and recapture rates were age-dependent. In this model, survival rates of hatchlings (= 0.53, SE = 0.03) were lower than those of one year old (= 0.75, SE = 0.04) or two year old animals (= 0.88, SE = 0.03). As expected, recapture probabilities of hatchlings (***p*** = 0.74, SE = 0.03) were higher than those of one (***p*** = 0.61, SE = 0.04) or two year old (***p*** = 0.40, SE = 0.03) animals, post-flooding.

In most tropical freshwater ecosystems, crocodilians are the largest aquatic animals, and it might be considered they would exhibit little vulnerability to flooding. In contrast, this study shows that unusually severe events of monsoonal flooding can significantly degrade crocodile habitats and subsequently high rates of crocodile mortality. Vegetation mats are a distinctive but fragile component of tropical riparian ecosystems, critical for many native species (Hill *et al.*, 1987). The vegetation mats are vulnerable to trampling by invasive herbivores (buffalos), which result in the mats detaching from riverbanks and being flushed out to sea during monsoonal floods (Hill *et al*., 1987) or which allow saline penetration upriver, killing the vegetation (Whitfield *et al*., 2006). Overgrowth by invasive water-weeds also may kill many mats (Adams *et al.*, 2002). Our results suggest that even in the absence of these threats from invasive species, the flooding due to increasingly extreme monsoonal events may imperil this distinctive habitat type, and the native species that depend upon it.

Acknowledgments

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33. Whitfield, A. K., R. H. Taylor, C. Fox, and D. P. Cyrus. 2006. Fishes and salinities in the St Lucia estuarine system - a review. *Rev. Fish. Biol. Fisher*. 16:120.Table 1. Ranking of candidate crocodile survival and recapture models investigating the effects of age structure, vegetation, and floods. The table shows number of parameters (*k*), change in QAICc compared to the best-ranked model (ΔQAICc) and model weights (*wi*) (see Methods for explanation). The capture-mark-recapture data set included encounter histories of 712 individual crocodiles.

Table 1. Ranking of candidate crocodile survival and recapture models investigating the effects of age structure, vegetation, and floods. The table shows number of parameters (*k*), change in QAICc compared to the best-ranked model (ΔQAICc) and model weights (*wi*) (see Methods for explanation). The capture-mark-recapture data set included encounter histories of 712 individual crocodiles.

Survival	Recapture	K	?AIC_c	w_i
age$_3$ + vegetation + flood	age + flood	16	0	0.546
age	age	6	0.76	0.373
age	age + flood	7	4.94	0.0463
age + vegetation	age	12	6.00	0.027
age + vegetation + flood	age	15	9.00	0.006
age + vegetation	age + flood	12	13.60	0.000
age + vegetation + flood	age + vegetation + flood	24	16.06	0.000

!

Fig. 1. Annual changes in the water level, habitat condition and the survival rates and growth rates of hatchling Crocodylus johnstoni in the northern portion of Lake Argyle, Australia. High rainfall in the 2010/2011 wet season increased water levels (a) and reduced the percentage of shoreline margined by vegetation mats (b). After the floods, the sightings of hatchlings were lower (c), recapture rate of marked hatchling crocodiles was lower (d) and the surviving hatchlings were in lower body weight than in previous years (e). The dash line marks the start of the floods. Error bars show SE.

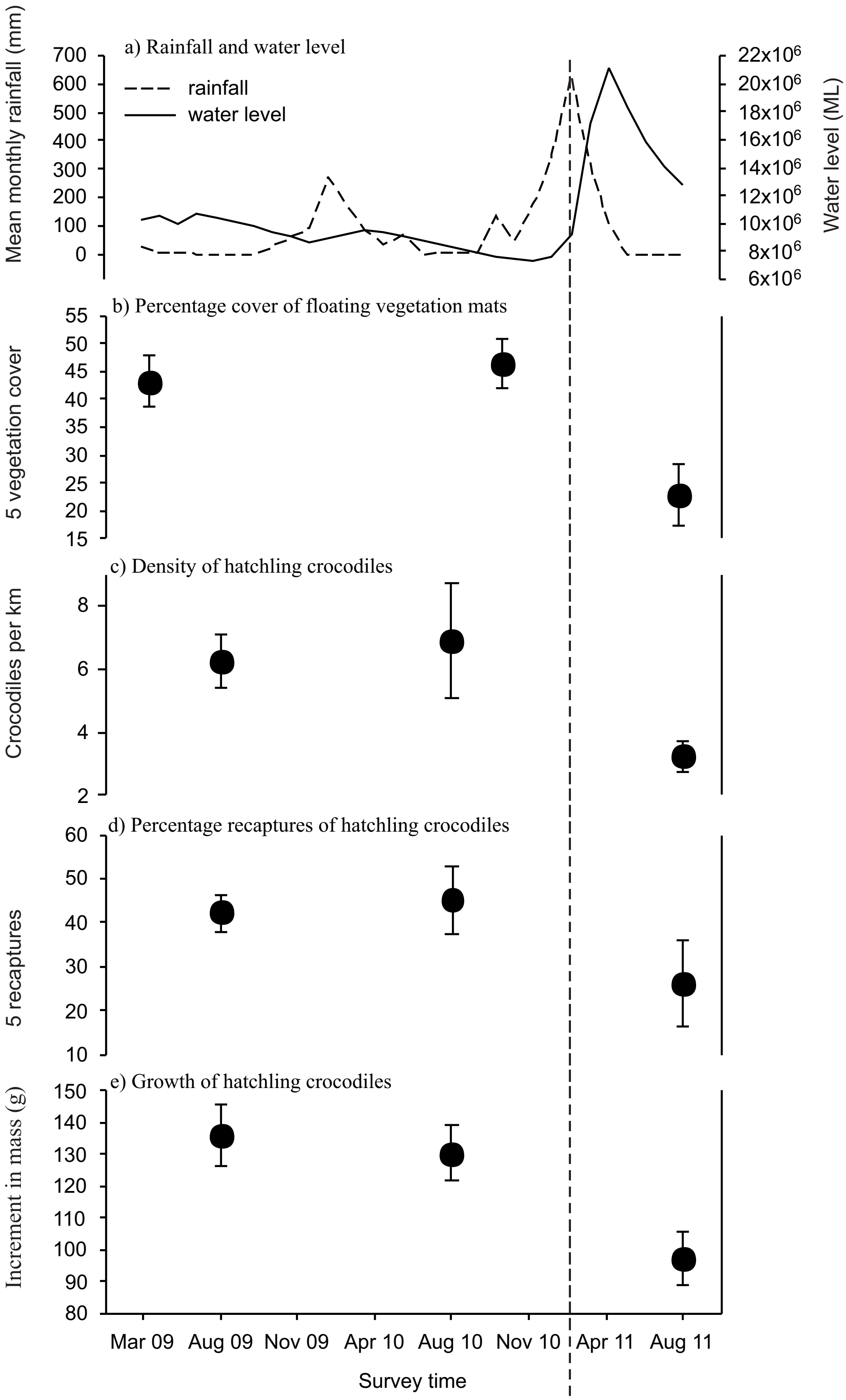
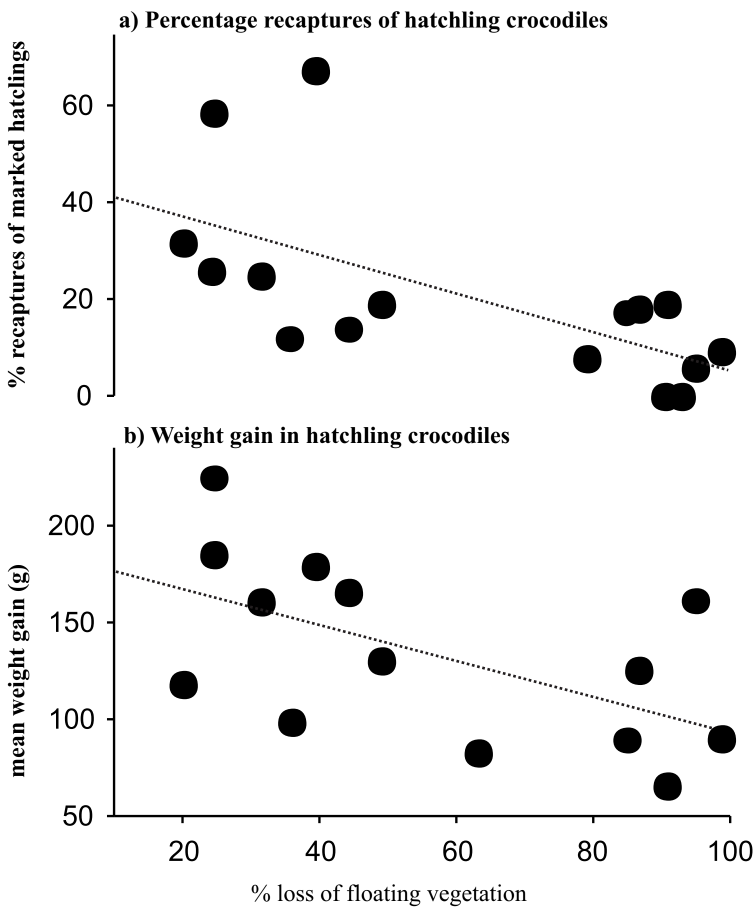


Fig. 2. Correlations between loss of floating vegetation, recapture rates, and body sizes of hatchling Crocodylus johnstoni at Lake Argyle, Western Australia. Areas that retained more vegetation also retained more hatchling crocodiles after the flood in August 2011 (a). In the sites where shoreline vegetation was less badly affected, young crocodiles were heavier (b). The "% loss of vegetation" refers to changes in the proportion of shoreline area with aquatic vegetation between November 2010 and August 2011.



Basking behaviour of saltwater crocodile in Bhitarkanika Wildlife Sanctuary, Odisha

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Crocodilians are a highly advanced group of reptiles. They are large, aquatic carnivores with skin covered with scales and bony scutes. Reptiles are cold blooded animals, meaning that they do not maintain a constant body temperature. But some reptiles exercise a degree of thermoregulation by either physiological or behavioural mechanisms. When temperature drops lizards, snakes and crocodiles bask in the sun to achieve the desired body temperature; once this thermal level is attained they will divide their time between sun and shade to maintain it. The direct effect of temperature influences the animal behavior to considerable extent. Basking is a regular and common habit of crocodiles. By following a strict daily pattern of alternating periods in the sun, in the shade and in water, they are able to maintain a body temperature of 250C varying by only a few degrees either way. The basking behavior of SaltwaterCrocodile and its functional significance is essential for the proper management of the crocodilesin India.

The basking behavior of wild population of Saltwater or Estuarine Crocodile (*Crocodylus porosus*) was carried out in Bhitarkanika Wildlife Sanctuary, Odisha from October 2012 and March 2013. Observations were made in crocodiles, basking along the river banks and creeks by boat. Hourly record of the temperature of bottom and surface water, soil and atmosphere along with the position of individual crocodile were made during the study period. Pearson's co efficient of correlation was calculated to measure the relationships between various temperatures and various kind of basking patterns. The difference between the time spent for basking by adults and juveniles were discussed in detail.

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Acute effects of freeze dried crocodile bile on male Sprague Dawley Rats

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Abstract

Crocodile gall bladder is an important traditional medicine. Previous studied suitable processes in crocodile gall-bladder preservation for value added product was freeze-dried. The result showed that could sublimate to be gold finely powder which make it easy to capsule if combine with rice starch powder. However, freeze dried crocodile bile for healthful doesn't have science report about toxicity of crocodile bile. For high efficacy of crocodile bile product, acute effects of freeze-dried crocodile bile were performed on male Sprague Dawley rats. The result showed that morbidity and mortality have not found any in treatment 300 mg/kg group of rats. Because of recommendation dose in human is 25 mg/60kg/day, there is very less than in the rat treatment. These revealed that freeze dried crocodile bile is appropriate for product development to be supplementary food in the future.

Introduction

Freshwater or Siamese Crocodile, *Crocodylus siamensis,* is an economic animal in Thailand. The minor products of crocodile are internal organs such as bone liver, gall bladder, *etc*. They have more demand for improving human health found in the traditions of many Asian cultures. In traditional medicine, animal parts and derivatives have been used e.g. tiger bone, rhino horn, gland from musk deer, bear gall bladders (Picheinsutthorn and Jeerawong, 2003). For treatment of a range of complaints such as fever, hemorrhoids, conjunctivitis and liver diseases, bear gallbladders and bile products are use. Animal bile including bear bile and snake bile has high amounts of bile acids. The ursodeoxycholic acid (UDCA), an ingredient in bile bear, can be successfully used to cure certain liver problems and dissolution of gallstones (Feng *et al*., 2009). Crocodile bile pill, a form of crocodile bile product is used as an asthma traditional Chinese medicine combination product (Irwin, 2001). In Thailand, Siamese crocodile internal organs are waste material in slaughtering industry. Although their bile has advantage in traditional medicine, a lot of crocodile gall bladders are useless per year. Moreover, general style of the preservation is naturally drying such as sunlight exposure, natural wind drying, *etc*. With these drying methods, the un-safety of the product about bacterial and fungal contamination has been found. For adding value to the bile product, Chaeychomsri *et al*. (2009) was studied the suitable processes in captive Siamese crocodile galls preservation and its bile product. The proper preservation process and crocodile bile product development has been done and registered as a Kasetsart University's innovative property (Thai patent application No. 0901001231, 2009). Recently, Siamese crocodile bile provides significant insight into the anticarcinogenic action on human cholangiocarcinoma cells (Song *et al*., 2012; Kang *et al*., 2012). However, it has no report about toxicity of the crocodile bile. In this study, we prepared freeze-dried product of Siamese crocodile bile, investigated the acute effects on male Sprague Dawley rats. The out put of this study will provide basic data of sub-chronic and chronic study for the crocodile bile product development and may support efficacy and value-adding of this freeze-dried crocodile bile product.

Materials and Methods

Collection of gall bladders: One hundred of captive Siamese crocodile (*Crocodylus siamensis*) gall bladders were collected from Rungtaweechai Crocodile Farm, Don Toom District, Nakhonpathum Province, Thailand.
Crocodile bile powder preparation: Process for dried crocodile bile production of Thai patent application No. 0901001231, Kasetsart University (Chaeychomsri and Siruntawineti, 2009) was performed as following. The gall bladders without fat tissue outside were surface sterile with 70% ethyl alcohol and the crocodile bile were collected in tray and freeze-drying using freeze dryer (Lyomaster, USA). The freeze-dried bile was powdered by graining at sterile condition. The crocodile bile powder was kept at 4^{o}c until use.

Laboratory animals: The Animal Ethics Committee of Kasetsart University, Thailand approved the use of laboratory animals in this study. Nine Spraque-Dawley males were purchased from The National Laboratory Animal Center, Mahidol University, Salaya, Thailand. The rats were randomly divided into 3 groups, each comprising three rats. Male

Sprague Dawley rats were divided into 3 groups: - Group I: the control rats; Group II and Group III that the crocodile bile powder was oral administration to rats at 300 and at 2000 mg/kg body weight, respectively. Rats were housed individually in hanging wire-mesh cages in a room with a controlled temperature of 25-29°C and a 12:12-h light-dark cycle with 30-70% relative humidity. Animals were allowed unlimited access to food and distilled water. Daily food and water intakes and body weights were recorded weekly for 14 days. The animals were observed for mortality or any signs of abnormalities periodically during the first 24 hours and twice daily for 7 days.

Results and Discussion

After rats were fed freeze-dried crocodile bile at 300 mg/kg/day, no treatment related signs of toxicity or mortality and no weight loss were detected in any of the animals during 14 days. However, at dose of 2000 mg/kg/day of crocodile bile, it was observed that the food and water intakes reduction and body weight lose within 7 days (Figure 1 - 2). Moreover, the death of Group III rats appeared. The acute toxicity result showed that morbidity and mortality were not found in treatment of 300 mg/kg body weight dose. As recommendation dose of crocodile bile in human is 25 mg/60kg/day, the doses used in this study are very low. However, a synthetic bile acid mixture that mimicked the bile acid composition of the snake (*Naja naja atra*) bile has short-term toxicity in rats (Yeh *et al*., 2003). The results demonstrate dose safety of freeze-dried Siamese crocodile bile. These revealed that freeze dried crocodile bile may appropriate for supplementary food product development.

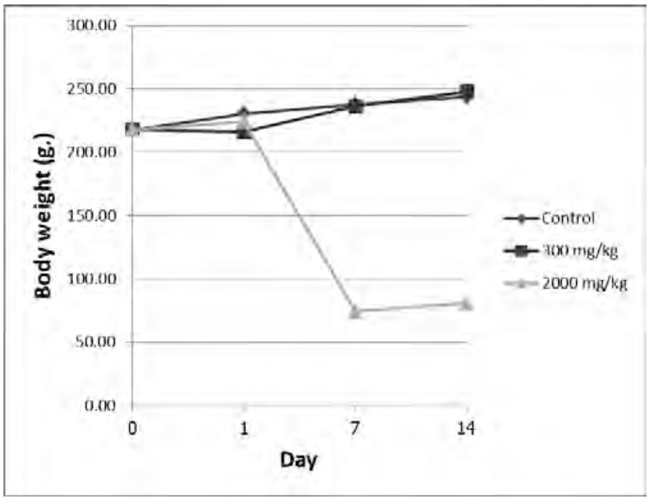
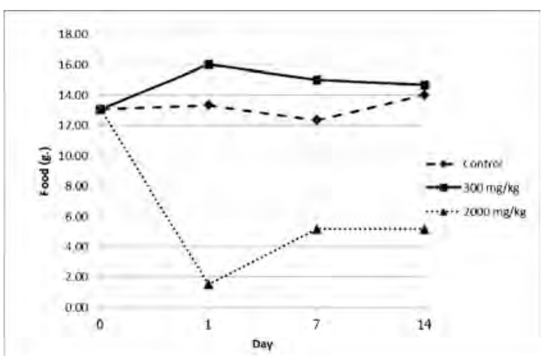
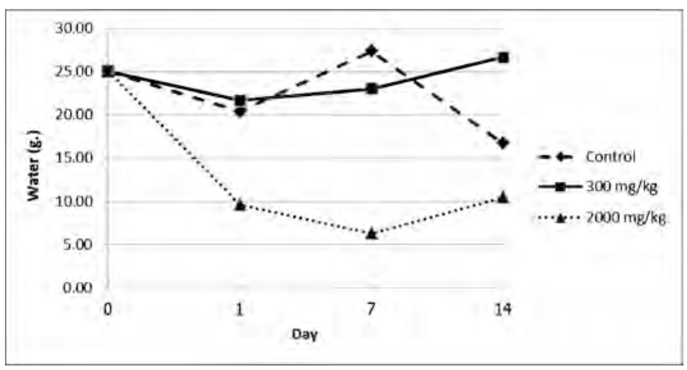


Figure 1. The body weight of experimental rats in Group I (control group), Group II (the rats treated with crocodile bile powder at 300 mg/kg body weight) and Group III (the rats consumed crocodile bile powder at the dosage of 2000 mg/kg body weight). These values were recorded weekly for 14 days.





(A) **(B)**

Figure 2. Daily food (A) and water (B) intakes of the control rats (Group I), the rats treated with crocodile bile powder at 300 and 2000 mg/kg body weight (Group II and Group III, respectively). These values were recorded weekly for 14 days.

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Efforts to re-established Philippine crocodile *(Crocodylus mindorensis)* wild population in Southern Philippines

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A tri-partite crocodile conservation agreement between the Department of Environment and Natural Resources Protected Areas and Wildlife Bureau, the Silliman University and JKMercado & Sons Inc. was implemented in April 2006. Adult captive-bred *Crocodylus mindorensis* was released in semi-wild environment for conservation breeding at Pag-asa Farms, Kapalong Davao Del Norte without supplemental feeding. This was made through the effort of Crocodylus Porosus Philippines, Inc in their commitment towards the conservation of *C. mindorensis* including the facilitation for the release of captive-bred animals into the wild. Outcome of the program have resulted into a soft released re-introduction of Philippine Crocodile at the Lungaug Creek, Bgy. Katipunan, Sto. Tomas, Davao Del Norte in July 2009 and the benign soft-released introduction in Siargao Island Protected Landscape and Seascape in March 2013 which contributed to the considerable increased on Philippine Crocodile wild population. Conservation initiatives on the released of this threatened species in Southern Philippines is documented and presented.

The ecology and distribution of crocodiles in the Mahamavo wetlands of north west Madagascar

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The Nile crocodile, *Crocodylus niloticus*, is the sole surviving member of Madagascar's historically speciose megafauna and its only large predatory species. The ecology of Nile crocodiles has been relatively well documented throughout its range on continental Africa however their ecology remains under studied in Madagascar. As is the case with the majority of other populations on the island, very little is known about the crocodile population in the rivers and wetlands of the Mahamavo water shed. Here we present distributional and preliminary ecological data based on two seasons of research during the dry season in the wetlands of Mahamavo, north-west Madagascar. We also provide an insight into human-crocodile conflict in the area based on opportunistic observations and the initial findings of a social science investigation. Current indications are that crocodiles in Madagascar have undergone an island-wide decline as a direct result of illegal harvesting of wild animals and habitat destruction. Our research reveals that even crocodile populations in relatively isolated areas do not remain unaffected by the drivers of this decline.

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A new distribution record for the Philippine Crocodile (*Crocodylus mindorensis*, Schmidt 1935)

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Abstract

The presence of the Philippine Crocodile in isolated highland geologic depressions in locality Seven Lakes, Barangay Ned, Municipality of Lake Sebu in South Cotabato Province, Mindanao Island at altitudes 740-840 m ASL was documented for the first time in November 2012. This new distribution record is significant because all records of the species before this date pertain to altitudes lower than 700m above sea level. Description of crocodile artifacts, population status, community perceptions and importance to species conservation is presented and discussed.

Introduction

The Philippine Crocodile or Philippine Freshwater Crocodile (*Crocodylus mindorensis*) became known to science on the basis of skulls supposedly from the island of Mindoro in 1929 and were described as new species in 1935 by K.P. Schmidt of the Field Museum of Natural History in Chicago (Schmidt 1935). Knowledge on the distribution of this highly endangered species rest on the survey works of Charles A. Ross of the Smithsonian Institution/World Wildlife Fund Philippine Crocodile Project (Ross and Alcala 1983). The results of the Project led to the conclusion that *Crocodylus mindorensis* is one of the most threatened crocodilian species in the world with an estimated population of 500-1000 individuals existing in the wild throughout its range (Ross 1982).

Endemic to the Philippine Islands, this crocodile is likely to be found widespread throughout the country and is now actually found in inland freshwater habitats as remnant populations in north-eastern Luzon and central to southern Mindanao (Pontillas, 2000; van Weerd 2000; Pomares *et al*. 2008). Records on the occurrence in southern and northernmost islands indicate that the species exist in isolated populations on small islands with minimal habitats (Manalo 2008). In many instances, populations in central Philippine or Visayan Islands as well as in southern and central Luzon have been locally extinct (Ross 2008).

Populations of *Crocodylus mindorensis* in lowland rivers, lakes, marsh habitats, small isolated island (Ross and Alcala 1983; Oliveros *et al.* 2005) was investigated by naturalists in the country. By adding together the Cordillera Central, Abra Province, Luzon Island, Philippines as new locality and altitudinal record of this species in 2002 (Manalo 2008), the crocodile researchers have been challenged to re-evaluate potential crocodile habitats on the basis of altitudinal limitation in this supposed lowland species. Continued population reduction, decline in area of occupancy, and extent of occurrence and/or quality of habitat (IUCN 1996) have served as a challenge to searching for the species in viable habitats.

The Philippine crocodile is considered to be a severely threatened species needing conservation action with only estimated 100 adults believed to be surviving in the wild around the country (Ross 1998).

In November 2012, reports of crocodile hunting for local consumption prompted a survey in highland of Southern Mindanao, as part of the diversification program of Crocodylus Porosus Philippines Inc. (CPPI) in partnership with the DENR-Protected Areas and Wildlife Bureau (PAWB) of the Department of Environment and Natural Resources (DENR), Philippine Crocodile Rescue and Breeding Center (PCRBC), and the Environment and Livelihood Organization for Advancing Development. The main purpose is to obtain information on the presence and status of crocodiles in isolated wetland depressions and seasonal lakes of Lake Sebu, South Cotabato, southern Mindanao.

Methods

On 22-26 November 2012, a number of isolated geologic depressions such as highland crest and inundated basins (n=18) in freshwater wetland habitat of Seven Lake (word originated from "*Saving Lakes*"), Barangay Ned, Municipality of Lake Sebu, South Cotabato were investigated for the presence of crocodiles. Geographic coordinates and altitude were obtained by handheld GPS receiver (GARMIN *etrex* Summit HC).

Crocodile specimens from crocodiles slaughtered by locals in 2007 and 2009 were examined and photographed. Intact morphological characteristics that are visible for the basis of species identification were cautiously digitally drawn using CorelDRAW ver.11 2002 to reflect available distinguishing features. Scale counts were analyzed following Brazaitis (1971), Ross (1982), and Ross and Alcala (1983) with notes on the description of Schmidt (1935). Modified morphometric cranial indices by Hall (1989) adapted from Iordansky (1973) were used to describe and compare relative skull measurements. Due to scarcity on comparable works or ratios for estimating the body length from head length for palustrine or small crocodile species, Bellairs (1969) formula [Body length = 4.39 + (7.49 x head length)] for *Crocodylus niloticus* were used for our specimen.

Standard spotlight survey method was conducted to further assess the presence of remaining crocodiles in viable habitat. Rapid assessments of sites were adapted from Davies and Giesen (1991) set of preliminary ecological value and viability criteria. Current distribution in places known to have reported sightings, verified reports and secondary information by the local inhabitants were documented. Species awareness campaign particularly on the general importance of wildlife conservation with emphasis on crocodiles, habitat, behavior and its conservation was opportunistically conducted with key informant interviews.

Results

Twenty one highland crest and inundated basins or small lakes were visited and were examined the habitats for the existence of Philippine crocodiles. About 38% (n=8) of reported lakes have reports on crocodile sightings from 2007-2010.

Sun-dried skins from an adult and a juvenile crocodile were displayed in the residences of their captors, Mr. Enrique Besa and Mr. Ama Gugo respectively (Fig. 1). The skull from the adult crocodile, in the possession of Mr. Trivetth Tupas, was collected by the research team through the authority of the Protected Areas and Wildlife Bureau of the Department of Environment and Natural Resources. These crocodiles were supposedly captured in Pugwan Lake (6°17'10.2"N, 124°26'19.6"E; 798 m ASL) and Pangalman Lake (6°18'03.3"N, 124°25'14.9"E; 753 m ASL), both of which are part of a land reform settlement (Presidential Proclamation No. 550 of 1969) that is permanently inundated. The area had been subjected to logging operations previously, and was converted into agricultural land that produced slightly turbid surface water draining towards a larger adjacent lake.

Figure 1. Mr. Rainier Manalo of CPPI, Dr. Cayetano Pomares of USM (left), local informant Mr. Trivetth Tupas (center) with sun-dried skin and skull of an adult crocodile taken from Lake Pugwan in 2009; and Mr. Ama Gugo with Dr. Cayetano Pomares, Mr. Rainier Manalo with sun-dried skin of a juvenile crocodile (right) taken from Lake Pangalman. Lake Sebu 2012.

A local informant led the team to an area in Lake Pugwan where nests were located in 2007 and 2009. The area is located on the sloping areas of the marginal upland forest on the northeastern side, situated about 25 m uphill from the water's edge. It was recorded at a slope of 40° at an elevation of 801 MASL. This nesting site is characterized as mixed secondary and primary forest and karsts limestone formation. Parts of the lake were converted into farmlands utilizing surface water for agriculture. The nests were located approximately 10 m away each other, albeit laid in different years. Interviews revealed that local residents collect crocodile eggs for food.

Description of crocodile specimens - The dorsal scalation of the adult hornback skin from Lake Pugwan comprised of 17 transverse dorsal scale rows, 10 dorsal midbody scale rows (PC 10-15), and ossified dorsal armor. The condition of the skin did not allow counting of the ventral scale row, but the ventral scales were relatively large. In Lake Pangalman, the sun-dried hornback skin (76cm dorsal length) of a juvenile crocodile was inspected. It comprised 18 transverse dorsal scale rows, 10 dorsal midbody scale rows (PC 9-14), 23 large ventral scale rows from the cloaca to the thoracic collar, and ossified dorsal armor. The animal was estimated to be around 1.1 m long.

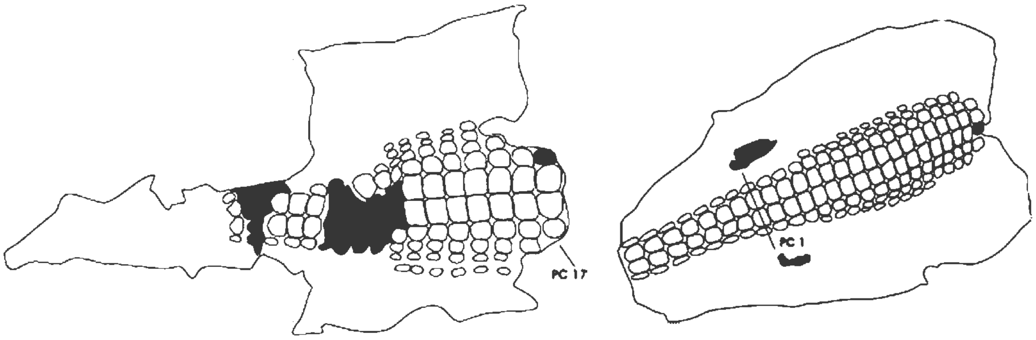

Figure 2. Sketch of a sun-dried skins from an adult (left) and a juvenile (right) crocodile taken from Lakes Pugwan and Pangalman respectively. Lake Sebu 2012.

Both sun-dried skin specimens (Fig. 2) had incomplete caudal scale rows and lacked nuchal shield cluster (PC 19-23) and post-occipital or occipitals (PC 24-26).

The skull showed a massive structure, distinctively broader and short snout of prominent maxillary angulation, prominent lachrymal groove, antorbital or maxillary ridge high and abrupt laterally, pronounced festooning of maxillary teeth, more rounded premaxillary with 5 teeth sockets, palatine-pterygoids suture nearly transverse and the length of maxillary symphysis is shorter than the length of premaxillary symphysis (MXS<PXS). Results on the relative growth of the examined skull specimen from Lake Pugwan (Table 1.) did not differ ($\mathcal{X}^2 = 4.758$, 8df, $P > 0.05$) with the relative growth range class mark of *C. mindorensis* skulls examined by Hall (1989). Two of the nine indices had conformed within the specified character size range of *C. mindorensis*.

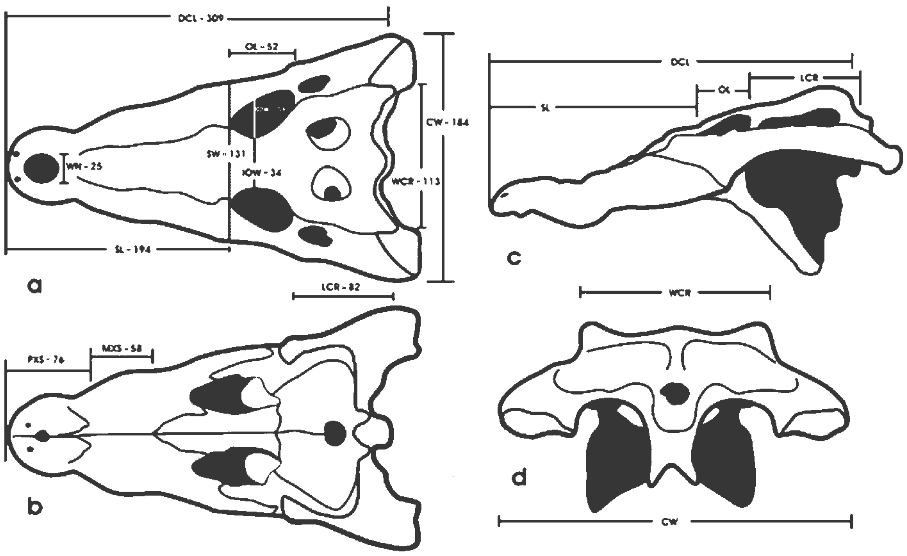

Figure 3. Dorsal (a), palatal (b), lateral (c), and posterior (d) view of skull specimen from Lake Pugwan, Bgy. Ned, Lake Sebu, Philippines showing measurements taken. DCL = dorsal cranial length, CW = cranial width, SW = basal snout width, SL = snout length, IOW = minimal interorbital width, OW = maximal orbital width, OL = maximal orbital length, LCR = length of postorbital cranial roof, WCR = posterior width of the cranial roof, WN = maximal width of external nares, PXS = length of premaxillary symphysis, and MXS = length of maxillary symphysis. 1mm.

* DCL = dorsal cranial length; RWST (relative width of snout) = (basal width of snout x 100)/snout length; RLST (relative length of snout) = (snout length x 100)/DCL; RCW (relative cranial width) = (cranial width x 100)/DCL; RWI (relative interorbital width) = (minimal interorbital width x 100)/maximal orbital length; RLR = (relative length of postorbital cranial roof) = (length of postorbital cranial roof x 100)/posterior width of cranial roof; ROL = (relative orbital length) = (maximal orbital length x 100)/ DCL; ROW = (relative orbital width) = (maximal orbital width x 100)/ maximal orbital length; RWN = (relative width of external nares) = (maximal width of external nares x 100)/ DCL snout length. (*adapted from Hall, 1989*).

Table 1. Comparative relative growth skull indices by Hall (1989) and Lake Pugwan skull specimen.

Character	*Crocodylus mindorensis* relative growth skull indices* by Hall (1989)			Lake Pugwan Skull Specimen
	Mean ± SE	Range	*Class Mark*	
DCL	227.7 ± 20.6	140-387	263.5	309
RWST	57.5 ± 1.0	51.9-66.3	59.1	67.53
RLST	63.3 ± 0.6	59.2-66.4	62.8	62.78
RCW	46.4 ± 1.4	43.9-49.8	46.85	59.55
RWI	53.1 ± 3.5	34.5-70.5	52.5	65.38
RLR	76.8 ± 1.1	71.2-84.2	77.7	72.57
ROL	15.8 ± 0.4	13.4-18.4	15.9	16.83
ROW	76.1 ± 2.0	65.9-91.3	78.6	69.23
RWN	19.2 ± 0.7	16.7-23.1	19.9	21.74

Based on skull measurements (Fig. 3), information on relative growth (Hall 1989), and total length estimate method of Bellairs (1969), the specimen was determined to be a *Crocodylus. mindorensis* of around 2.358 m total length (head length= 30.9 cm). Results on the dorsal scale patterns, palatine structure, cranial morphology and geographic location identify the animal to resemble the Philippine Crocodile.

Habitat structure and population status - Surveys of 21 of the more than one hundred highland crests and inundated basins or small lakes revealed no crocodiles, including 8 lakes where crocodiles were reportedly sighted between 2007 and 2010. Rapid site assessments on lakes with reported sightings revealed that a total of 3 wetland scored high on both ecological value and viability (Fig. 4). Among these are Lakes Ubodan, Pugwan and Pangalman, that are partly forested or partly in natural catchment condition. Majority of the reported sites have high ecological value.

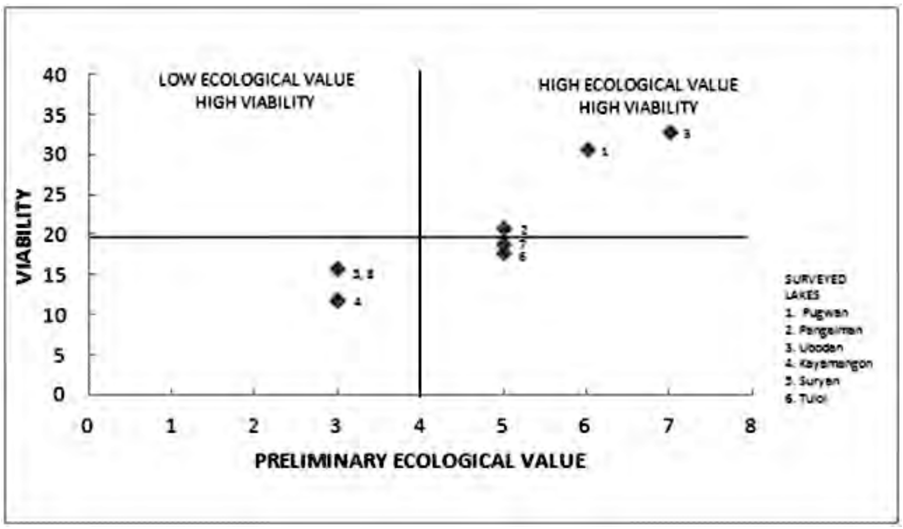

Figure 4. Scatter diagram of preliminary ecological value vs. viability (adapted from Davies and Giesen, 1991) of lakes with reported sightings in Seven Lake, Lake Sebu.

Highest value obtained by Lake Ubodan (6°18'10.8”N, 124°25'34.8”E; 792m ASL) is partly contributed by clear and greenish surface water habitat combined with layers of shrub and marsh associated vegetation (Fig. 5). Peripheral vegetation cover was partly surrounded by lower montane marginal forest in the western part while other areas adjacent to lake shore were herbaceous swamp and agricultural lands. The vicinity is composed of karst topography that is sparsely vegetated by dipterocarp trees, ferns, mosses and vascular plants associated with karst habitat.

Figure 5. Landscape of Lake Ubodan (left), Pugwan (center), and Pangalman (right). Lake Sebu 2012.

A further spotlight survey of Lake Ubodan in Seven Lake, Bgy. Ned, Municipality of Lake Sebu, revealed 7 or 8? eyeshines of non-adult crocodiles congregating at the shallow water's edge. These populations were presumed to be an extant population of Philippine Crocodiles. (There is a need to capture live crocodiles to confirm their identification as Philippine Crocodile.)

Combining the results of these preliminary surveys with interviews of key informants, there is an estimated 18 *C. mindorensis* (11 adult, 7 non-adult) in the 5 inundated basins of Seven Lake in Lake Sebu, between 740 and 840 m ASL.

Community awareness and perception - The presence of crocodiles locally known as *K'wangkug* (a T'boli local language for small crocodile living in lakes) is a common knowledge to the indigenous people living in the highland of Lake Sebu. Local residents of the study site recognized only one type of crocodile, describing it as small in size, with a yellowish back and white belly. Locals are aware that the lush vegetation of their wetland habitats contributed to the abundance of species in isolated lakes in the past. They are very much aware on the specific location where crocodiles appear to thrive. The remote and farthest community of Lake Sebu was converted to settlement sites a mono-crop plantation. Habitat conversion extends up to margins of the lake, and crocodiles are exposed for curiosity and target shooting.

Residents understand that the crocodiles are wary and do not attack humans. This behavior is characteristic of *C. mindorensis*. This behavior contributes to the locals' interest in crocodiles, including their utilization as a protein source. These hunting practices have resulted to the decline in the crocodile population and thus fewer interactions with humans. However, the common misconception about crocodiles generally showing aggression to humans and their livestock still persists.

Discussion

Since 1935, when K.P. Schmidt described *Crocodylus mindorensis* as new species, knowledge on the distribution on this species was limited on the localities presented by Ross and Alcala (1983) in their first and only comprehensive study on the distribution of Philippine crocodiles. Ross (1984) signifies that there is an insufficient knowledge on their preferred or required habitat. Philippine crocodile remains to inhabit minor pockets of habitats and none appears to be protected (Messel *et. al.*, 1992).

Basic understanding on the distribution in their natural habitat was mostly restricted in lowland freshwater habitat. An update on the status of crocodiles in the Philippines (Ortega *et.al.*, 1994) has recorded wild population in Busuanga Island. While the addition of an extant population of *C. mindorensis* in San Mariano, Isabela, Luzon Island and Pulangui River, Bukidnon, Mindanao Island (Pontillas, 1999) was documented from the works of U. Frederick Pontillas in his attempt to determine distribution, abundance, and population genetics of Philippine crocodile based on known distribution by Ross and Alcala (1983).

In summary, the Philippine Crocodile is considered to be a lowland species found in freshwater (rivers, lakes, marshes, small isolated island) habitats as remnant populations in north-eastern Luzon in the wetland pockets of Northern Sierra Madre foothills and several micro habitats in coastal towns of Isabela, Cagayan (van Weird, 2000), Dalupiri Island (Oliveros *et. al.* 2005 and Ross, 2005), and the presumed stronghold population in Ligawasan Marsh Game Refuge and Bird Sanctuary in Southern Mindanao (Pomares *et. al.* 2008). These localities have contributed to the significant picture of the distribution of this rare species and researchers have not done fieldwork on their possible presence in areas of high elevation.

In this paper, the analysis on crocodile specimens from the highlands of Lake Sebu, Mindanao Island revealed that the sun-dried skins and skull resemble those of *C. mindorensis*. Both sun-dried skin specimens had 17-18 transverse dorsal rows that matched with the scale character by Schmidt (1935), Ross and Meyer (1983), and Hall (1989). Cranium morphology measurements did not differ with the results on *C. mindorensis* relative growth of skull by Hall (1989). Total length estimate of around 235 cm. based on skull specimens taken in Lake Pugwan is within the size range estimate of

288-326 cm. (Ross and Alcala, 1983), 3.5 meters largest captive individual examined by Ross (1984), and slightly longer than the 217 cm. adult female crocodile captured and released in Caucauayan Creek, Dalupiri in 2005 (Oliveros *et. al*. 2005).

These results imply that the presence of *C. mindorensis* in this highland habitat of Lake Sebu on Mindanao is a new locality and altitudinal record (740-840 m ASL) for the Philippine Crocodile.

Our new finding on Mindanao and the occurrence of *C. mindorensis* in the Cordillera Central, Abra Province (Manalo, 2008) show that the Philippine Crocodile can thrive in lowland freshwater riverine and palustrine habitat to high altitude permanent and seasonal ponds including floodplain lakes. The existence of *C. mindorensis* in highland crest/isolated geologic depressions or small lakes in the vicinity of Lake Sebu, Southern Mindanao is a significant discovery as new locality and altitudinal record (700-850m ASL) of this species explored from 2002 to 2012. Owing to the presence of this species in two different biogeographic regions, suggested that altitude is not a limiting factor in the population distribution of Philippine crocodile. Messel *et. al*. (1992) noted that *C. mindorensis* are scattered on Mindanao and a few other islands in southern Philippines.

Conclusion

The existence of this supposedly "lowland" species in the highlands of Lake Sebu in southern Mindanao and in Cordillera Central, Abra Province, Luzon Island (recorded in 2002), suggests that altitude may not be a constraining factor when searching for potential habitat of this species. This can be considered as one of determining factors for their dispersal across terrestrial landscape. Historically, the Philippine Crocodile probably had a wider altitudinal distribution on various Philippine islands, large and small.

Recommendations

1. The highland central area of northern Luzon, Samar and Leyte and central Mindanao highland ridge along the provinces of Bukidnon warrants further fieldwork.
2. Higher elevation wetland ecosystem must be considered for re-assessment as potential Philippine Crocodile habitat.
3. In order to determine the original distribution of Philippine crocodile in the wild, historical distribution must be evaluated for species-habitat connectivity without considering the altitudinal limitation. (Try to include more pictures to illustrate details of habitats.)

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Mugger crocodile (*Crocodylus palustris*) status and situation in Iran

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Abstract

Small population of Mugger crocodiles distribute in southeastern part of Iran, in sistan & Baluchestan province. The area is known as the western most global range of the species. The main characteristic of the population is that has been divided to several sub-populations and being scattered. As a management option, the main part of crocodile habitats has been designated as "protected area" and "International wetland site". The crocodiles occupy vast range of natural and artificial water bodies as their habitats. Crocodiles use any available resources as food like fish, birds, dogs and villager's livestock but they are mainly dependant on fish s. One of the most specific and important behaviors of Mugger is burrowing which is mostly used as refuge, even by the hatchlings. Any evidences indicating of nesting in the burrows not found in the studies. Migration or movement between habitats in different distances is another considerable behavior of Muggers which provides potential threat for the crocodiles that have to pass through roads resulting in death by car strikes. Fortunately, as a unique situation in the world, there is no hunting on crocodiles in Iran and local people based on their cultural beliefs respect crocodiles and never harm them, although they have very close contact with crocodiles. Drought and flooding remain as the main natural threats for the crocodiles. In the last consensus conducted in May 2012, totally 326 crocodiles directly were counted, but seems that the number should be more.

Distribution of Muggers in the region

Small population of Mugger crocodiles distribute in southeastern part of Iran, in Sistan & Baluchestan province. The area is known as the western most global range of the species. The population seems to be isolated and it has been divided to several sub-populations as well as being scattered in the area. Their habitats are along three main rivers of the area: Sarbaz, Kaju and Bahukalat and their related headwaters and ponds. Some part of this area with an extend of about 465000 ha due to its importance as crocodile habitat designated as "protected area" 1971 named Bahukalat and in 1982 renamed to "Gandou" protected area. Gandou is the local name for the crocodiles in the area. The main distributional area of Mugger in Iran starts from Sarbaz and southeastern part of Nikshahr along Kaju River which joins to Sarbaz River in its way to the sea. Sarbaz River renames to Bahukalat after the village with same name. Although Kollany village and its pond is are near Govater Bay which are considered as end of crocodile range in Iran, there is no evidence that Iranian crocodile enter saltwater. Some part of the area according to importance for diverse fauna and flora, especially bird species, designated as 19th international wetland (Ramsar site) in 1999 Named Govater by & Hur-e-Bahu with an area of 75000 ha. The site consists of riverine and estuarine wetlands of the lower Sarbaz River, including permanent freshwater pools and marshes, mangrove swamps and intertidal mudflats, and also the sandy beach of the adjacent Gulf of Oman coast in the extreme southeast of Iran (Persian Baluchestan) to the border with Pakistan. The distribution are of the crocodiles in the country was supposed to be limited to mentioned areas but further surveys reveals that there are some crocodiles along Nahang River and related water bodies in n north eastern part of Gandou protected area. The river runs along Iran-Pakistan border and finally enters to Pakistan. In the old Persian literatures Nahang has defined as “Crocodile”. The population in Nahang and some parts close to the national border in Gandou area seems to be shared populations with Iran and Pakistan.

The main characteristic of the mugger populations in Iran is that they are very scattered in their range and not limited to only the natural water bodies, even found in the artificial ponds inside the villages. In normal situation and availability of water the crocodiles move between the existing habitats. The population has been divided to several sub-populations along the main rivers and existing habitats. Human activities like construction of dams also have caused forming of sub-populations too. According to the extend of the area and the situation, the relation between sub-populations and also populations of Iran and Pakistan crocodiles seems to be very rare. In Gandou area there are some habitats in border area in which seems that crocodiles move between countries.

The crocodile's habitats

Mugger crocodiles occupy two main “Natural” and “Artificial” habitats in the area and seem that they use all available suitable water bodies.

The main natural habitats are small or large ponds with deep enough water as well as vegetation cover along the rivers. Most of these ponds have similar characteristics providing suitable habitats with very thick vegetation along and sandy banks and some have depth of more than 6-7 meters. Generally, crocodiles avoid from shallow and running parts of the rivers.

Different types of artificial water bodies play essential role as crocodile habitats too. Most of this type is small or large ponds beside or in the villages that are constructed by the people for rain water storage. Dams in different sizes and capacity which are constructed by the people or government are another example for the artificial habitats, in which Pishin dam with more that 170 million m^3 is the most important one in distribution area of crocodiles. The same situation do exists along Kaju River in Zirdan Dam.

Regardless of the negative effects of the dams, it seems that according to the specific situation of the area and prolonged droughts, they play very important role for the crocodile populations by providing reliable habitats.

Main habits

The most specific and important behavior of Mugger is Burrowing. The burrows are used as refuge to avoid heat during hot and or even cold hours of day and may be other purposes. The behavior is observed in different conditions and forms that seem to be related to the habitat. They leave the tunnels at night and wander the area to search for food (Mobaraki 1999). In some occasions two burrows were found close together but not obvious if they are used by one or several specimens (Mobaraki 2002).

In another occasion in Djor pond at the end part of Bahukalat River 5 burrows were observed along an almost dried pond with a length of 200 m. In 2 of the burrows we could observe crocodiles inside and surprisingly could find one hatchling inside one of them, but it remains unclear if it is a kind of care provided by parents or the hatchling itself could find the refugee. Some observed burrows had 1-2 meters length but most were lengthy more than 4 meters. In artificial ponds in the villages burrowing is usual too.

Movement of crocodiles between the habitats is another quite usual recorded behavior in the area. Movement between the habitats seems to be for searching of new habitat. Based on the observations, this behavior seems to be more usual with juvenile crocodiles. But unfortunately this behavior appears to be as threat for the crocodiles as when they have to cross the roads car strike causes death for them. We have recorded several times killed crocodiles in different life stages in the roads (Mobaraki &Abtin 2007). This has been observed on hatchlings to in which a dead hatchling found on the road heading to river on the other side. Considering that most of the crocodile habitats are close to villages, crocodiles pass through the houses in their movements, causing some fear to people. In rainy seasons, as most of the ponds have water, short distance movements of the crocodiles between the ponds are more usual. In Pishin Dam pond which the rocks and stones prevent from digging burrows, the crocodiles use the water leading tunnels as refugee in dry season and lack of water release from reservoir and numbers of tracks are evident inside the tunnels.

Contact with local people

Numerous ponds inside the villages are a potential factor increasing close contact between local people and crocodiles. More over in some parts, most of the villages and human settlements are by or close the rivers and natural pond. This feature explains that all the time local people and crocodiles lived in close relation. It is worthy to explain that all the ponds are visited many times during the day by the people, specially the ladies and children, for daily usages. With so close contact of crocodiles and the local people, the most important factor that prevents from any harm to crocodiles is the cultural and religious believes and respects of the people. In Baluchistan due to water shortage, the crocodiles are respected as water living creature as existing of crocodiles would mean existing of water. Despite of such a close contact, direct Human-crocodile conflict is very rare and the crocodiles attack the people or even swimming children in the ponds. More over, there is not ant exploitation and harvest on crocodiles and the people not only never harm the crocodiles but also prevent the others too. This feature is unique in all crocodile habitats all around the world providing a suitable potential for conservation measures.

But the main problem is that crocodiles usually attack the livestock of the villagers causing economic loss for the people. The number of these attacks according to distribution pattern of crocodiles is considerable which annoys the people. The attacks are sometimes very severe when there is a very large crocodiles in a small pond with small amount of food making the crocodile nuisance. There is compensation program for the people conducted by Department of Environment offices but some times it is not in time and enough. There is a plan to expand the program to provide more support for the people. In some occasions the nuisance crocodiles are removed from the village by DOE guards. In general, the nuisance crocodiles are a potential problem which bothers the local people but in most cases the crocodiles captured and translocate to another habitats which could be safer and in less contact with people.

Number of Muggers in Iran

After years of change in the area caused by drought, flooding and construction of dams along the rivers, and a lack of reliable information on size of the Mugger population, a survey program was conducted over a 10-day period in May 2012. A key feature of the program was that local people, in cooperation with DOE, were engaged directly in the survey activities after training. Crocodiles were counted by direct observation during the day and night. Most available habitats were visited at night, and spotlights used to locate and identify crocodiles.

Potential habitats along the Nahang River were excluded, as well as some remote ponds in the area, due to uncertainty of water availability at the time of survey. Forty-three (43) different survey sections were visited during the survey period, from Firooz Abad pond near Rask and following the Sarbaz and Bahookalat Rivers to Djoor, close to Govatr Bay, as well as the existing artificial ponds and reservoirs in the area. Some parts of the Kajo River were also included. These areas reflected a total survey distance of about 150 km. Except for river mainstreams and ponds associated with them, other important habitats visited were artificial ponds and reservoirs close to villages mainly in "Gando Protected area" (around 465,000 ha).

A total of 326 crocodiles was observed, with Pishin Dam Reservoir (120 crocodiles) and Shirgovaz Regulatory Dam Reservoir (35 crocodiles) reporting the highest counts. Most crocodiles were juveniles or adults, with almost all crocodiles in Pishin Dam Reservoir being of large size (Mobaraki and Abtin 2013).

Main threatening factors

The most effective threats for Mugger crocodiles come from natural threats rather than anthropogenic ones. As mentioned generally there is respect for crocodiles and no one harm or exploits them. But the natural threat of "drought" and Flooding" cause the most important loss for both the crocodiles and their habitats. The periodicity of the factors has not been studied, but from time to time these factors impose some destructions to the crocodile population. Flooding is rarer than the drought and is in in a short period but the drought usually takes long time and we have experience of prolonged drought for 5 years. Hatchlings and juveniles receive the most mortality but even dead adults have been observed. In some occasions flooding destroys most of the nests and lack of water due to drought causes death for most of the hatchlings in one year.

Natural predators like the different species of the reptiles (Bengal monitor lizard) and mammals (Fox, jackal, Mongoose) and large water birds (herons) remain as potential threat for the nests and hatchlings too.

The most evident and may be direct effect of human activities which cause mortality for Muggers is caused by car strike on the roads constructed in the crocodile distribution range (Mobaraki and Abtin 2007). Crocodiles in their movement have to pass the roads and as the most movements re in the night hours, some of them die striking with the cars. Agriculture is the main activity of the local people and its development provides some problems for the crocodile habitats in which development of Banana farms is more effective.

Conservation status

Crocodiles are listed as an “Endangered Species” in Iran and are legally protected. There was a fine of 32 million Rls for illegal killing and capture of a crocodile but the fine increased to 100 million Rls in March 2013. Fortunately there is high potential for the conservation of crocodiles in Iran as the local people respect them as culturally important and never hunt or harm them.

Considering these situation and need for conservation activities "national management plan for the Mugger crocodile population in Iran" prepared and submitted to the related bodies for proper planning and implementation (Mobaraki and Abtin 2008). The budget for the activities is supposed to be secured by DOE and any other international supports would be welcome. The plan consists of 4 main approach and several activities defined for each one which the main items are:

1- Research works and complementary studies
2- Conservation of the crocodiles in the natural habitats
3- Captive breeding
4- public awareness / Education and Ecotourism

In the past years two centers in Dargas and Rikokash have been established for the purposes of rehabilitation, short period keeping of nuisance crocodiles and rearing/reproduction of some crocodiles. There are plans to expand the facilities as farm as well as research center for the crocodiles in the country. Local people are engaged in these centers too. Regular surveys and research works are being conducted all year long on crocodiles and the needed data on their biology and ecology are collected.

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Figure 1: Natural habitat of Mugger crocodiles along Sarbaz River

Figure 2: Basking Mugger at the middle part of a natural pond (A.Mobaraki)

Figure 3: Two burrows close to each other in a artificial pond, Djor (A.Mobaraki)

Figure 4: An artificial pond in Djor village

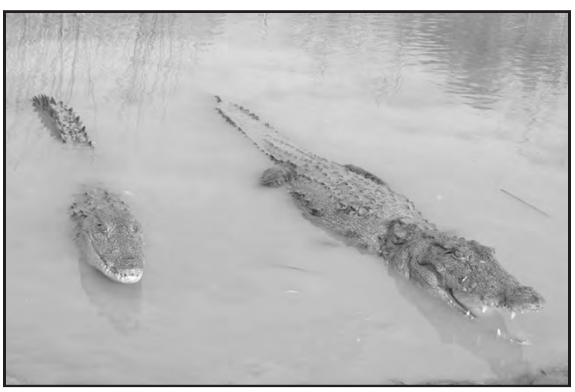

Figure 5: rearing Muggers in Riko Kash center (E.Abtin)

Ecology and conservation of crocodiles in Mesangat Lake, east Kalimantan, Indonesia

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Mesangat Lake in East Kalimantan is home to breeding populations of two crocodilian species: *Tomistoma schlegelii* and *Crocodylus siamensis*. Formerly a forested wetland, the area has been heavily logged since 1970s and further damaged in fires in 1997-98. Several invasive plant species, including *Eicchornia crassipes* and *Salvinia cucullata* now clog up the waterways and the area started undergoing conversion to palm oil plantation in 2008. In 2009 the agricultural development was suspended with an area of 6,000 hectares proposed for conservation. Research surveys focussing on the ecology of endangered species were started, facilitated by local NGOs: initially Yayasan Ulin (Ironwood Foundation) and currently YASIWA (Equator Conservation Foundation Indonesia). The data gathered are being used to implement a long-term conservation management plan for the area and gain more insight into the ecology of *T. schlegelii* and *C. siamensis* in the wild. To date the surveys conducted over three field seasons have provided information on the distribution, range, habitat partitioning and breeding seasons of both crocodile species inhabiting the area. Diet analysis of juvenile *T. schlegelii* and *C. siamensis* revealed no significant differences in their prey choice. Further distribution surveys and nest protection programme involving the local communities in Mesangat will help monitor and manage the species in the area. (Financial support: SSC/CSG Tomistoma Task Force, ZGAP, EAZA, Kölner Zoo, Dortmund Zoo, Virginia Aquarium

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Recent scenario of mugger (*Crocodylus palustris*) population in three districts of Gujarat State, India

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Abstract

A study was carried out in two years (from January 2011 to December 2012) to find out the recent scenario of muggers in the two districts namely Vadodara and Kheda District (now known as Kheda and Anand). These are one of oldest mugger populations in the state. Total 51 water bodies were surveyed in the three districts of Gujarat State, in addition to the 80 km long river stretch of Vishwamitri. Direct sightings of 334 muggers, which include 171 (51%) large and adults (> 2 m), 102 sub-adults (1 to 2 m) and 61 juveniles (<1 m) were recorded from 31 water bodies and the 80 km long river stretch of Vishwamitri. The maximum of 252 muggers were recorded in Vadodara District, followed by 49 in Anand and the least of 33 muggers were noted from Kheda District. However the secondary information and local reports reveal the fact that at least 470 muggers exist in these three districts of the state.

Introduction

The Marsh Crocodile or Mugger (*Crocodylus palustris*) is one of the common, widely spread and most adaptable crocodilian species in India. This species is categorized as nationally 'Vulnerable' subsequent to an assessment following IUCN criteria for threatened species and has the highest legal protection in India as it is listed in Schedule I of the Indian Wildlife (Protection) Act 1972.

During the early seventies, while the Mugger populations in India were reported to decline (FAO, 1974), same trend was recorded in Gujarat State. But whatsoever population survived in the state, was notable as compared to other parts of the country. The few published reports indicated, that the mugger population then was found in four areas namely Sayaji Sarovar (Vadodara District) (Oza, 1975), Gir forest (Junagadh District), Surrounding Barda Hills (Jamnagar District) (Joseph at al, 1978; Whitaker, 1978; Whitaker and Andrews, 2003), and a high density population in a small river stretch of River Sabarmati, near Barsan-Baroda (Kheda District) (Acharya, 1949), in Gujarat. There are few recent publications on the mugger surveys from these three districts (Vijaykumar, 1997), which show few water bodies of Kheda, Anand and Vadodara districts to contain a small number of muggers. Moreover, most recent publications on details of muggers of River Vishwamitri were available too (Vyas, 2010a; 2010b & 2012).

Therefore a study was carried out for two years from January 2011 to December 2012 to find out the recent scenario of muggers in the two districts namely Vadodara and Kheda District (now known as Kheda and Anand). These inhabit one of oldest mugger populations in the state, which survived in the state, after pre-independence and before the declaration of the Indian Wildlife Preservation Act-1972.

Study Area

All the water bodies (WBs) of various sizes from 0.4 sq. km to 20 sq. km of three districts namely Kheda, Anand and Vadodara were explored for the study, including 80 km long river stretch of Vishwamitri and urban sewage pits (**Fig. 1**). The districts; Kheda and Anand (earlier part of Kheda District but after 1998 Anand was separated from Kheda district) are located on south-eastern banks of down streams of River Sabarmati and are well known for their agro produce of crops including tobaccos, pulses, rise and wheat, and large areas irrigated by Mahi Irrigation Project.

Therefore most of the water bodies are interlinked/ connected with irrigation canal network. Vadodara district is situated in between two large perennial Rivers; River Mahi and River Narmada, mainly known for its industrial and agricultural area. A small non perennial river namely River Vishwamitri-Dhadhar flows through the district and transverses the highly populated urban city of Vadodara.

Methodology

All the WBs of three districts was extensively explored to find out the mugger habitats on the basis of direct visual clues and inquiries with locals. These habitats were visited repeatedly in different seasons and the animals were counted as per age groups/ various sizes. The counting methods applied were day count method and night count method (applied only in specific areas where vast differences were observed in between reports and day count results). The direct sighting and indirect evidences as foot print, feces, egg shells and burrows to mark the presence and absence of the species. During the visits, the habitat was assessed; information about livestock predation by the species, conflict, rescues, translocation and the breeding activity of the species was collected. Additionally, interviews the staff of forest department, wildlife enthusiasts, and local people were carried out, to know the perception of locals towards the species; especially those locals who dwell within a close proximity of WBs. Then the threats were identified, on the species and its habitat, from the study.

Results

Water Bodies Survey: Total 51 water bodies were identified and surveyed, including 15 WBs of Kheda, 16 WBs of Ananad and 20 WBs of Vadodara District, Gujarat State, in addition to the 80 km long river stretch of Vishwamitri which was extensively explored. Of which 10, 9, and 12 WBs of Kheda, Anand and Vadodara, respectively were noted with the presence of the species (Table 1: Appendix1).

Table 1: Water bodies of three districts of Central Gujarat State

Area	No. of Water bodies Surveyed	No. of Water Bodies species
Kheda Dist.	15	10
Anand Dist.	16	09
Vadodara Dist.	20	12
Vishwamitri River	80 km	
Totals	**51**	**31**

Mugger Counts: Total 334 various sized muggers were noted by direct sighting, which includes 171 (51%) large and adults (> 2 m), 102 sub-adults (1 to 2 m) and 61 juveniles (<1 m), recorded from 31 various water bodies and the 80 km long river stretch of Vishwamitri. The maximum of 252 muggers were recorded in Vadodara District, followed by 49 in Anand and the least of 33 muggers noted from Kheda District. However the secondary information and local reports reveal the fact that at least 470 muggers exist in totality in these three districts of the state (**Table 2**).

Table 2: The various sizes of muggers sighted in water bodies of three districts of Central Gujarat State (excluding the 31 muggers reported from Ajwa Sarovar, Vadodara)

Area	No. of WBs with species presence	Number of Muggers Sighted			Total Crocs	Reports
		Juvenile (<1 m)	Sub-Adult (1 to 2 m)	Adult (>2 m)		
Kheda	10	05	11	17	33	072
Anand	09	10	20	19	49	089
Vadodara	12	02	08	12	22	028
Vishwamitri R	80 km	44	63	123	230	250
Totals	**31**	**61**	**102**	**171**	**334**	**439***

Breeding: The breeding activities were recorded in total 11 water bodies by direct and indirect evidences. Empty egg shells, hatchlings and juveniles were recorded at six WBs of Kheda namely; Vaso, Tranj, Tranhaja (canal), Heranj-Chokadiya, Hernaj Gam Talaw and Nagrama. Few nests and hatchlings were recorded at Deva and Malataj village ponds of Anand District. Good breeding performance of the species was observed in year 2012, with few nests on a small river stretch of Vishwamitri, behind the Zoo (2011 & 2012: 1 nest), near Kalaghoda (2 nests: 2012) and in the down streams near Kothavada village (2011 & 2012: 1 nest each years). Nest pit and empty egg shells noted at Kodarvaya and at Chhipwad Ponds situated in the middle of Padra Town in Vadodara District.

Table 3: Number of muggers rescued from the human habitation in Years 2011 and 2012 from three districts of Gujarat State, India

Area	Year 2011	Year 2012	Total
Kheda Dist.	02	2	4
Anand Dist.	03	3	6
Vadodara Dist.	32	29	61
	35	34	71

Rescues, Conflict and Attacks: Most of the mugger population was found in and around human vicinity, hence invariably causing panic and conflicts for the locals. The local NGOs or forest staff provides rescue service for such crocs in conflict. They immediately rush to the location, on call and seize the animal, then releasing it back in nature as per the directions of the local forest officials. Such mugger rescue incidents were observed in all three districts. Total 71 incidents of mugger rescues from human habitation (**Table 3**) were noted, of which 61 cases were recorded from Vadodara, only (**Fig. 2 & 3**). Total 11 croc attacks (9 fatal and 2 non-fatal), including 10 from Vishwamitri-Dhadhar River System, Vadodara District and single from Kheda District were recorded within two years (**Table 4**). Figures also show that of all the Croc attacks, seven incidents on male victims and four attacks on female victims.

Threats: Numerous direct and indirect threats were observed on the species, including water pollution, encroachment on habitat, habitat loss, and river bank development. Very recently three incidences recorded at Vadodara involved dead/killed crocs found on a railway line (a 195 cm long animal) and on the road (a 90 cm long juvenile and an adult 210 cm long). Routes of transport also are a direct threat on the species. Few incidences about poaching and pet trading were also registered as legal cases filed against culprits and poachers.

Conclusion

Total 51 water bodies were surveyed in the three districts of Gujarat State, in addition to the 80 km long river stretch of Vishwamitri. Direct sightings of 334 muggers, which include 171 (51%) large and adults (> 2 m), 102 sub-adults (1 to 2 m) and 61 juveniles (<1 m) were recorded from 31 water bodies and the 80 km long river stretch of Vishwamitri. The maximum of 252 muggers were recorded in Vadodara District, followed by 49 in Anand and the least of 33 muggers were noted from Kheda District. However the secondary information and local reports reveal the fact that at least 470 muggers exist in these three districts of the state. This census indicates that not only has the mugger population flourished, but also has extended its distribution area, much enlarged than that noted in the last census. Earlier records show, there were only 8 and 5 muggers, in the four and three water bodies of Kheda (including Anand District) and Vadodara District, respectively, excluding nine muggers from the River Vishwamitri, upto the city limits. (Vijaykumar, 1997).

The mugger population of River Vishwamitri has increases well in the last two decades (**Figure 4**), especially within the limits of Vadodara City (Vyas, 2010b; 2012). It is also one of the most notable examples and a subject requiring intensive research, of a mugger population surviving and flourishing in an urban sewage. And on the other hand numbers of human-crocodile conflicts have risen in the entire river basin areas, and cannot be ignored or left un-attended.

The overall scenario of mugger population from these three districts; Kheda & Anand and Vadodara was observed distinctly, in terms of the habitat. The crocs of Kheda and Anand survive in fresh water and communal water bodies with rural agricultural landscape, establishing an ideal example of man-animal co-existence. And most of the crocs of Vadodara, especially from River Vishwamitri survive in polluted sewage water, in the core of urban landscape.

The HCC (Human Crocodile Conflict) has increased in last two decades to alarming levels. Past data of crocodile attacks (Vyas, 1998; 2005; 2010a & 2012) recorded from certain parts of Vishwamitri-Dhadhar river system was also accompanied with mitigation measures suggested (Whitaker, 2008). The question that persists is whether these suggestions were accepted and implemented by the authority or not. As a matter of fact, total ten incidences of HCC in the last two years have occurred in the river basin area and eight of these (5 males and 3 females victimized) were fatal. Of the many causes behind HCC, the foremost causes are unavailability of basic facilities for poor people from rural area, large sized of muggers found in human vicinities, lacuna of proper action by forest department and lack of co-ordination between authorities and local NGOs.

There exist several threats on the mugger population, which are generally recorded in even other parts of India, except the direct threat of roadways and railway traffic. This minor threat was earlier recorded in the area (Vyas and Bhavsar, 2009; Vyas, 2012). However, an urgent action plan is needed for the species management. Awareness and education programs are required to avoid the negative impacts which are bound to occur in the minds of laymen. Otherwise our conservation mission might face a failure.

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Table 4: Details of mugger attacks recorded in different parts of study area during years of 2011 to 2013, Gujarat, India

No	Date	Attack	River System	Victim's Sex (Age) /	Activity of the Victim	Location / Details	Geo-coordination	Name of victim / Remarks
1	13 April 2011	Fatal	Vishwamitri	Male (28)	River crossing	Vadsar, Vadodara City	N 22 15' 05.63" E 73 10' 01.30"	Amrut Bhaliya
2	17 April 2011	Fatal	Vishwamitri - Dhhadhar	Female	Washing clothes	Kothawada, Padra	- -	Aminaben Yakub Diwan
3	22 May 2011	Fatal	Vishwamitri - Dhhadhar	Male (15)	River crossing	Kotada, Padra Goraj, Muni Asharam	- -	? -
4	28 May 2011	Non Fatal	Dev River	Female (21)	Washing clothes	Waghodia	N22 20' 02.3" E 73 27' 56.1"	Krishnaba P. Rana
5	6 June 2011	Fatal	Dhhadhar	Male (45)	Sand collection	Virjay Village, Padra	N22° 5'25.61" E72°59'48.15"	-
6	21 Aug. 2011	Fatal	Vishwamitri	Male (22)	River crossing	Khalipur, Vadodara	N22°12'24.30" E73° 9'34.63"	Navin Narnbhai Rathodiya
7	29th Sep 2011	Fatal	Dev River	Male (52)	Bathing	Nr. Goraj, Waghodia Muni Asharm,	N22 20' 01.95" E 73 27' 56.45"	Dilip J. Joshi
8	8th Oct. 2011	Non Fatal	Vishwamitri	Male(40)	Bathing	Near Sama bridge, Vadodara City	N22°20'17.46" E73°12'17.44"	Ravaji J. Mali Leg cached
10	29 sep 2012	Fatal	Village Pond	Female (17)	Washing	Kodar-vaya, Jarod, Waghodia	N22 25' 20.41 E73 23' 8.68"	Koushalya k. Vasava
11	25 Oct. 2012	Fatal	Dev River	Female (11)	Washing clothes	Nr. Goraj village, Waghodia	N22 20 07.52 E73 28' 58.46"	Tejal C. Parmar
12	3rd March 2012	Non Fatal	Village pond	Male (10)	Watching animals	Traj, Matar, Kheda	N22°40'19.60" E72°38'34.23"	Jaimin J. Parmar,

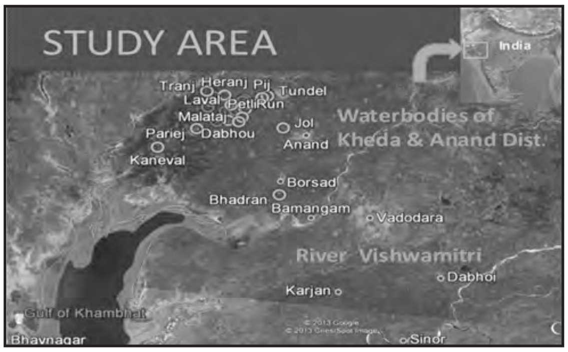

Figure 1: Map of study area showing locations of River Vishwamitri and water bodies of Kheda, Anand and Vadodara Districts of Gujarat, India (Courtesy Google earth).

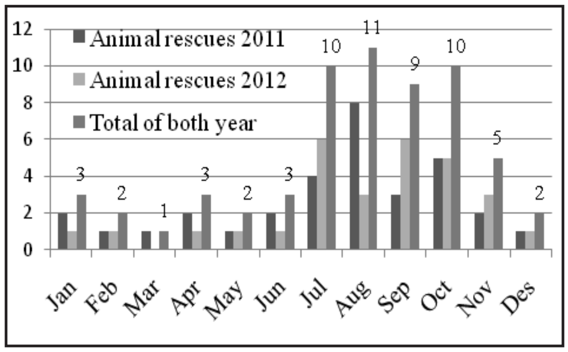

Figure 2: Pictograph showing rescued Muggers in various months from Vadodara City, Gujarat, India

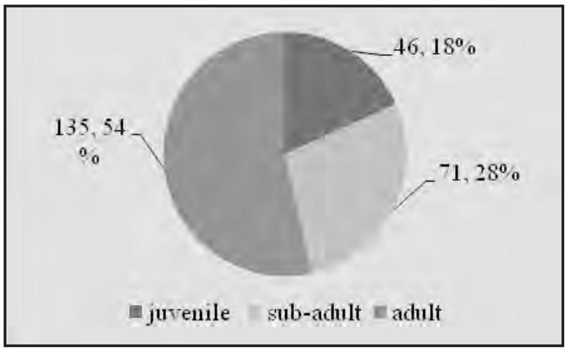

Figure 3: The pie-chart showing various sized muggers rescued from Vadodara City, during last two years.

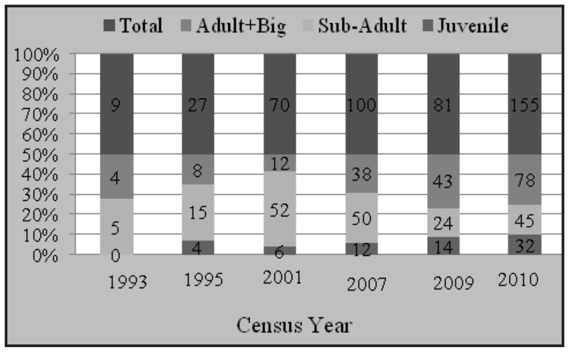

Figure 4: The pictograph of mugger population data of last two decades from River Vishwamitri within the city limit.

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Appendix 1: Details of Water bodies of Kheda, District, Central Gujarat, India

No	Water body	Go-coordination	Area of WB	Juvenile	Sub-Adult	Adult	Total Sightings	Muggers reported	Use of WB
1	Dundel, Nadiyad	22°40'34.36"N 72°49'15.11"E	1.0	0	0	0	0	0	Common usual Fish Farming
2	Pij Kapil, Nadiyad (2WB)	22°40'8.00"N 72°48'25.61"E	1+1=2	0	0	0	0	2	Common usual
3	Vaso Talaw, Nadiyad	22°39'24.32"N 72°45'21.28"E	1.0	0	1	1	2	5	Common usual
4	Ramsarovar, Vaso, Nadiyad	22°39'3.16"N 72°45'3.37"E	1.0	0	0	0	0	3	Common usual
5	Gangapur, Nadiyad (2WB)	22°38'36.59"N 72°46'38.42"E	0.4+0.6 = 1.0	0	2	0	2	3	Common usual
6	Tranj, Matar	22°40'19.60"N 72°38'34.23"E	2.8	0	0	2	2	16	Common usual Fish Farming
7	Pariej, Matar	22°32'44.51"N 72°37'0.43"E	9.0	1	2	3	6	6	Reserved Irrigation WB
8	Nr. Kans, Tranhaja, Matar	22°38'20.23"N 72°39'31.76"E	2.9	0	0	2	2	5	Common usual
9	Heranj-Chokdiya, Matar	22°40'0.25"N 72°41'39.10"E	3.6	1	2	3	6	12	Common usual Fish Farming
10	Heranj, Gam Talav	22°39'38.37"N 72°41'41.60"E	1.2	1	1	1	3	4	Common usual
11	Nagrama	22°37'4.49"N 72°38'59.66"E	4.5	2	2	5	9	15	Common usual Fish Farming
12	Machhiel	22°39'26.17"N 72°40'5.41"E	0.9	0	1	0	1	2	Common usual Fish Farming
			Total	**5**	**11**	**17**	**33**	**72**	
		Details of Water bodies of Anand District, Central Gujarat, India							
1	Deva-vant, Sojitra (3WB	22°37'13.36"N 72°44'5.91"E	1+1.1+ 1.2=3.3	9	11	10	14+14+2= 30	40	Common usual Fish Farming
2	Malataj, Sojitra	22°34'53.58"N 72°44'58.61"E	1.25	z1	2	3	6	30	Common usual
3	Dabhou, Sojitra Twin WB	22°35'2.20"N 72°43'4.47"E	1.7	0	1	0	1	2	Common usual Fish Farming
4	Petali, Sojitara	22°35'55.11"N 72°45'25.61"E	0.5	0	0	1	1	2	Common usual
5	Run, Sojitara	22°37'37.72"N 22°37'37.72"N	0.5	0	0	0	0	1	Common usual
6	Laval-Deva, Sojitara	22°38'10.07"N 72°43'7.26"E	1.1	0	2	2	4	4	Common usual
7	Bhadkat Deva, Sojitara	22°36'47.54"N 72°42'16.22"E	0.9	0	0	0	0	1	Common usual
8	Sejava-Deva Sojitara	--		0	0	0	0	1	Common usual

9	Maghrol, Sojitra	22°34'32"N 72°40'56"E	1.5	0	2	1	3	3	Common usual
10	Jol, Anand	22°34'35.20"N 72°53'0.88"E	0.6	0	1	1	2	2	Common usual
11	Kaneval, Tarapur	22°27'52.28"N 72°31'12.87"E	9.7	0	0	1	1	2	Reserved Irrigation WB
12	Bhadran, Borsad	22°21'9.81"N 72°54'8.27"E	0.5	0	1	0	1	1	Common usual Fish Farming
			Totals	**10**	**20**	**19**	**49**	**89**	

Appendix 1 Continue: Details of Water bodies of Vadodara District, Central Gujarat, India

No	Water body	Go-coordination	Area of WB	Juvenile	Sub-Adult	Adult	Total Sightings	Muggers reported	Use of WB
1	Opp. Talaw, Sarnej, Savli	22°29'2.95"N 73°24'39.42"E	1	0	0	3	3	4	Fish Farming
	Talaw, Sarnej, Savli	22°29'10.47"N 73°25'0.58"E	1	0	1	0	1	3	Fish Farming
2	Talaw Rajpura Savali	22°29'41.78"N 73°25'4.37"E	1	0	0	1	1	4	Fish Farming
3	Ajawa, Vaghodia	22°23'11.0" N 73° 23' 00.8"E	19.0	0	0	0	?	Not Surveyed	Potable Water Illegal Fishing
4	Kodarvaya, Vaghodia	22°25'24.22"N 73°23'10.93"E	1.5	0	1	3	4	4	Common usual Fish Farming
5	Karmasiya, Vaghodia	22°24'42.10"N 73°24'49.13"E	0.6	0	0	1	1	2	Common usual
6	Kamlapura Vaghodia	22°25'2.76"N 73°23'57.96"E	1.1	1	0	0	1	-	Common usual
7	Sim,Kamlapur Vaghodia	22°25'13.64"N 73°24'25.49"E	0.8	0	1	0	1	-	Common usual
8	Timbi, Vaghodia	22°18'52.88"N 73°17'11.80"E	7.0	0	1	0	1	-	Common usual Irrigation
9	Padra Town, Padra	22°14'11.33"N 73° 5'12.55"E	0.7	1	1	1	3	4	Common usual
10	Sim Talaw, Ghayaj, Padra	22°12'48.85"N 73° 5'49.99"E	0.7	0	1	3	4	4	Sewage Pond
11	Masar, Padra	22° 7'12.42"N 72°54'34.22"E	1.1	0	1	0	1	-	Common usual
12	Vadadala, Savali	22°28'30.82"N 73°18'52.95"E	5	0	1	0	1	3	Common usual Fish Farming

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Crocodile attacks in Sri Lanka

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Abstract

Sri Lankans living in rural and some urban areas risk attack by venomous snakes, elephants, buffaloes, bears and crocodiles. Some of these instances of human-animal conflict culminate in hospitalization with minor to severe injury, some are left with permanent disability of varying degrees and some result in fatality. A total of 177 cases of crocodile attacks by the mugger (*Crocodylus palustris*) and the saltwater crocodile (*Crocodylus porosus*) were investigated. Of the 177 attacks 148 (84%) of the victims were male, 27 (15%) were female and in 2 cases the gender was not recorded. The circumstances of the attacks were that 113 (64%) of the cases happened while the victim was bathing/washing, 38 (22%) while fishing and the rest during other miscellaneous activities. In the present investigation 50 (28%) of the cases were fatal and in 7 of these cases the body was not recovered. As a preventive measure against human-crocodile conflict (HCC) many techniques have been employed. Of these the traditional crocodile excluding enclosure (CEE's) has been used in the country for over 100 years and is recommended as a means for protecting both humans and crocodiles.

Introduction

Most Sri Lankans living in rural areas risk attacks by venomous snakes, elephants, buffaloes, bears and crocodiles. Some of these incidents of human-animal conflict culminate in hospitalization with minor to severe injuries, some are left with disabilities of varying degrees and some culminate fatally. As regards snakebite earlier studies indicated that approximately 65,000 people were being bitten by snakes annually, of which around 600 died (de Silva, 1976; de Silva and Ranasinghe, 1983). The present number of fatalities due to snakebite envenoming has reduced due to management of snakebite patients with antivenom serum. More recent official hospital reports indicate around 60 deaths for the year 2008, however, if we include an estimate for cases that have not been reported or not reached the medical statistician, we can assume that about 100 people die annually due to snakebite. Human-elephant conflict currently results in approximately 50 human deaths and 150 elephant deaths annually. Although during the past decade an average of only 2 deaths per year have occurred due to crocodile attacks these receive considerable media publicity.

Conflict between humans and crocodiles is probably as old as the human race and the fossil record shows that our ancestors were being attacked over one million years ago. The National Geographic News published on February 25, 2010 reported on fossil evidence of hominid bones with crocodile bite marks. These bones had been discovered in 2007 in Tanzania's fossil-rich Olduvai Gorge, a site that was home to early humans and to the 1.84-million-year-old crocodile species, dubbed *Crocodylus anthropophagus*, which means "eater of humans" in Latin. The oldest human skeletons discovered during archaeological excavations in Sri Lanka are around 37,000 YBP. These have not been investigated to see whether there are any crocodile bite marks present. However, there are several ancient traditional medical works in the country that include medicaments for crocodile bite. Perhaps, one of the first to include such medicaments is the *Sārārtha Sangrahaya,* written by the physician King Buddhadāsa around 337-365 AC (de Silva and Uragoda, 1983). It records the application of a mixture of three kinds of ginger onto crocodile bite wounds. Additionally, there are also impressive historical reports of crocodile attacks in the country. The Great Chronicle of Sri Lanka, the *Mahāvamsa* (recent part is known as *Cūlavamsa* (1:70.4) records the presence of large populations of crocodiles as well as the fact that people knew of fatal crocodile attacks. It also records that the army of King Parakkramabahu (1153-1186 AC) could not pass the deep waters at Yatthikanda and Dumbara due to man-eating crocodiles (Geiger, 1929). Wickramasinghe (2001) records that during the reign of King Rajasinghe the 2nd (1629-1687 AC) there had been many crocodile attacks around Gal-Oya. The king himself took his royal spear and thrust it into a man-eater in that river, and the crocodile submerged with the spear. Seeing this, one of his generals dived into the water, killed the crocodile and brought back the king's spear for which bravery he was rewarded immensely (Wickramasinghe, 2001). Additionally, we see that many Europeans who visited Sri Lanka over the past few centuries and who wrote about the country included some accounts of the reptiles, especially the snakes and crocodiles, in their works. The following are a few accounts of crocodile attacks recorded in these publications, which indicate that HCC has been occurring in the country for several centuries. These references are listed chronologically:

- Saar (1672) records the abundance of man-eating crocodiles he encountered in Negombo.
- Baker (1853) reports of accounts of crocodiles attacking animals and humans

- Le Bruin (cited in Suckling 1876) tells of a crocodile that had devoured at least 32 people at different times.
- Clark (1901) states that every year a number of men, women and children are killed by crocodiles.
- Julius (1907) reports that many native women have been seized when coming to draw water, and dragged down and eaten by crocodiles.
- Haughton (1916) reports of shooting two specimens measuring 5.57 m and 5.62 m in length at Kantali reservoir (Eastern Province). Until 1928 it had been dangerous for boatmen to dangle their limbs in the water of this reservoir as crocodiles had accounted for a number of human lives.
- An anonymous reporter (1924a) relates that at Hikkaduwa a 10 feet 8 inches long crocodile had attacked and eaten several humans. Another anonymous reporter (1924b) tells of a different man-eater at Hikkaduwa that was fifteen feet long and had attacked humans and cattle and been subsequently shot.
- Deraniyagala (1939) reports that the Government Agent of the Southern Province had informed him that a crocodile at Palatuva, Matara in Nilwala River had killed between 10-12 humans over a period of 20 years. It had been shot on 14th June, 1927. It is of interest to note that when the present author conducted his first survey of the Nilwala River in 2008 there were still some recent fatal crocodile attacks reported from Palatuva (de Silva, 2008). Furthermore, Deraniyagala (1939) also reports that the Government Agent of the Eastern Province had informed him that between 1900 and 1925, fifty-three humans had been devoured by crocodiles in Batticoloa district and nine in Trincomalee.

The above are just a few examples from a vast array of past literature on crocodile attacks in the country, indicating the severity of the HCC problem. If we take a rough calculation of the number of crocodile attacks that had been reported from Julius (1907) to Deraniyagala (1939), it is possible to estimate that approximately 150 humans could have died from crocodile attacks in the country during a period of approximately 30 years. During this period most aquatic systems of the country had large populations of both species of crocodile and this was before the large scale hunting of crocodiles for the skin trade.

Methods

Information on crocodile attacks was collected from the grass-root level government officers known as Grama Niladhari (= village headmen) as they are informed of any sudden deaths, from local police stations, field contacts, hospitals and information from printed media. Localities were visited and information regarding the attack was recorded on a structured survey form either from accounts given by the victim's family or friends, or if alive direct from the victim. In most cases, the exact place on the particular watercourse where the incident took place was visited, a GPS reading recorded and photographs of the location taken. Photographs of the injuries sustained by living victims and, in a few cases, of the dead person were taken where permission was granted. We noted that the best source of information on other crocodile attack victims was from people who had been attacked by crocodiles themselves. A preliminary survey was conducted on the human-crocodile conflict (HCC) in Matara in 2008. Subsequently an island-wide survey was conducted from 2009 to March 2013. During the survey, we also received information of 21 cases of crocodile attacks which took place between 10 and 29 years ago.

Survey findings

The case histories of 177 people from various parts of the island who had been attacked by crocodile in the last ten years were collected. Of these, 146 (83%) attacks were by the mugger (*Crocodylus palustris*) and 31 (18%) by the saltwater crocodile (*Crocodylus porosus*). Details of these crocodile attacks are given below. In the present study, 50 (28%) of the cases ended fatally, and in 7 (4%) cases the body was not recovered although people had witnessed these attacks and seen the crocodile taking away the victim.

Pattern of crocodile attacks

Brief details of the pattern of crocodile attacks are given below:

Gender of the victims: Of the 177 victims, 148 (84%) were male and 27 (15%) were female. The gender of 2 cases was missing from the record.

Occupation of the crocodile attack victims: The occupation of 120 victims out of the total 177 crocodile victims was recorded and indicates: 38 (32 %) fishermen; 49 (41 %) farmer / labourers; 6 (5 %) housewives; 21 (18 %) children and 6 (5 %) others. In the last category there was one captain of the armed services.

Activity of the victim during the crocodile attack: A majority 113 (64%) were attacked by crocodiles while bathing/washing (Figure 1). This was followed by fishing 38 (22%) (Figure 2). The rest were grouped as miscellaneous activities, as people living along rivers and streams and in the vicinity of tanks, rivers, marshes depend on these water bodies for their domestic needs e.g. drinking, and livelihoods like harvesting aquatic or semi-aquatic edible and non-edible plants.

Did the victim shout for help: Of 73 records, 49 victims shouted for help.

Status of the victim when attacked: Of 88 records, 38 victims were alone when the crocodile attacked, and in 50 cases the victims were either with a companion or with a child.

Was the victim aware of the existence of crocodiles even before the attack: Of 104 victims who responded 94 (90%) knew beforehand of the presence of crocodiles in the particular water source they were using.

Did the victim use the same place, undertake the same activity and at the same time: Of 124 people who responded 80 (65 %) had been using the same spot at the same time to carry out the same activity (bathing or washing etc) over a period.

Type of treatment sought after attack: Of the 101 victims who answered this question, 89 (88 %) had sought western treatment, whereas only 12 victims reported seeking traditional medicine. However, we observed that many yet seek and practice religious and sorcery in case of crocodile attacks.

Was the particular crocodile killed after the attack: Of 81 responses, 37 % stated that they believed the offending crocodile had been killed.

Crocodile attacks on farm and pet animals: In addition to humans we were informed that cattle (25 cases) and dogs (12 cases) had been taken by crocodiles.

Conclusion and recommendations

Data of 177 cases of crocodile attacks have been collected by the authors. However, based upon information received from various parts of the island, there were other crocodile victims that we could not investigate due to lack of time and the difficulty in visiting remote villages. As regards the offending species, 146 (83%) were by mugger crocodiles (*Crocodylus palustris*). This high percentage could be due to the fact that the mugger is widely distributed across virtually the entire dry zone plains in rivers, streams as well as in man-made aquatic ecosystems, such as the 10,000 odd tanks or reservoirs, agricultural canals, agro-wells and streams. All these aquatic ecosystems are widely and daily used by the people living in the dry zone plains for their everyday needs as well as for agriculture, plantations and for farm animals (Figure 1, 2). Additionally, with the exponential increase of human populations due to large-scale agricultural and human settlement projects over the past half century, the number of humans and livestock using natural water bodies in the dry zone of Sri Lanka has increased significantly. Water bodies in these areas are also inhabited by mugger crocodiles (*Crocodylus palustris*), the top predators of the ecosystem. This sharing of an essential, but a limited resource has resulted in an increase of HCC (Somaweera and de Silva, 2013). Furthermore, the traditional crocodile excluding enclosures are not used in the dry zone. Thus, it is natural there will be more mugger attacks when compared to the saltwater crocodile (*Crocodylus porosus*) attacks which numbered 31 (18%). It is, however, possible that there are more saltwater crocodile attacks which we have not investigated.

When considering these statistics we should note that in 2010 an approximate population of 1500 to 2500 mugger crocodiles was estimated to exist in Sri Lanka (de Silva and Lenin, 2010). More recently during the CSG Red Listing sessions conducted by James Perran Ross, during the 22nd Working Meeting held in Sri Lanka (May, 21-23, 2013) a population of 3500 wild mugger was arrived at by the assessors. This discrepancy can be explained as being due to several locations with healthy mugger populations being included in the new data that were not included in the previous estimates. In the present study, 50 (28%) attacks ended fatally. When these bodies were recovered after between a few hours to 1 or 2 days later, many parts of the body were missing. It was evident that the offending crocodile or crocodiles had devoured parts of the body rather than being eaten by fish or terrapins. In the present study the body of 7 (4%) victims was not recovered, although people had witnessed the victim being attacked and dragged away by a crocodile. In these cases the family, relations, friends and villagers joined in the search for the body, together with other relevant authorities (like police, Dept of Wildlife Conservation and NGO's) but without success.

The Male:Female ratio of crocodile victims in the present study was 6:1. A majority 113 (64%) were attacked by crocodiles while bathing/washing. This was followed by fishing 38 (22%). This result contrasts with a HCC study in Zambia where of 127 crocodile attacks in the Chiawa Game Management Area Zambia, 63% were fatal and the majority of attacks (54%) targeted fishermen as they fished from canoes (Wallace, 2010). Here it should be noted that freshwater fishery industry in Sri Lanka is increasing and has caused a major threat to the crocodiles of the country. The authors came across several incidents where the crocodiles which got entangled in fish nets were killed. The other circumstances where people got attacked were grouped as miscellaneous activities, as people living along rivers and streams and in the vicinity of tanks, rivers, marshes depend on these water bodies for their domestic needs e.g. drinking, bathing, washing and livelihoods like harvesting aquatic or semi-aquatic edible and non-edible plants.

Two significant finding of the study were:

1. That of 104 victims who responded 94 (90%) knew beforehand of the presence of crocodiles in the particular water source they were using. In fact some stated that their parents and grand parent knew of the

presence of crocodiles in the particular watercourse.

2. Of 124 people who responded 80 (65 %) had been using the same spot in the river/tank/stream at the same time to carry out the same activity like bathing or washing etc over a period of time.

Although the majority (90%) of the victims were aware of the presence of crocodiles in the particular aquatic habitat before they were attacked, all used words such as “I used to see it on the opposite bank”, or 'it was minding its own business' or “I never expected it to attack me”. Also several victims informed us that the crocodile had watched them for several weeks. This suggests that the people were not aware of the behaviour of crocodiles and had underestimated their intelligence. It is now well known that crocodiles follow the behavior and movements of the prey (human or animal) it is targeting for days before attacking. Another vital fact that emerged from the accounts related by crocodile attack victims and witnesses, was that they were repeating the same act (bathing, washing, fishing etc) at the same place and same time. Furthermore, of 88 records, 38 victims were alone when the crocodile attacked, and in 50 cases the victims were either with a companion or with a child. This indicates that the crocodile will target if the victim is alone or with one companion and not when there are several people bathing and splashing water and shouting.

During our survey we also observed and were informed that farm animals such as cattle, buffalo, goat and dogs regularly used the same spot for drinking and that these animals attracted crocodiles. The present study showed that the legs 45 (47%) of victims were the most vulnerable body part the crocodile attacked (Figures 3, 4), followed by the arms, 25 (19%) (Figures 5, 6). There were four cases where the buttocks were attacked (Figure 7) and in 12 cases the trunk including the chest was attacked (Figure 8).

When inquired whether the crocodile dragged the victim, ninety-eight (93%) victims stated that they were dragged into the water by the crocodile. One lady (43 years old) who sustained grievous injuries in the upper thigh had been dragged about 50 m away from the place she was bathing. When the crocodile attacked 67% of the victims had shouted for help while been dragged, perhaps the other could not shout for help as they would have been shocked or chocked with water.

Prevention of crocodile attacks

There is evidence from Sri Lanka to show that vulnerable people living close to crocodile habitats have taken various steps to protect themselves from crocodile attacks (de Silva, 2011, 2013). These traditional methods are:

1. Use of 'Crocodile Repellents' whereby herbal mixtures are put into the water. When the mixture disperses it is supposed to deter crocodiles from coming into that water (de Alwis, 1948; de Silva, 2011, 2013). At the present time experimental work on this herbal mixture is in progress.
2. Charms or an occult practice is believed to afford protection from crocodile attacks when recited in the prescribed fashion (Gnanaloka, 1954; de Silva, 2011, 2013). These forms of protection are now seldom used. Crocodile charmers are still popular in Borneo where man-eating crocodiles are common (Ritchie and Jong, 2002). It is of interest to note here that in the pearl fisheries of the early British period, the government had engaged the services of 'shark charmers' to protect the divers harvesting pearl oysters from shark attacks (Cordiner, 1807; Tennent, 1861).
3. Another well known protective method perhaps used from the 15th century AC is the crocodile t**alisman, where a g**ranite stone is engraved with charms and a talisman is placed in the water where people and farm animals frequent (Figure) (de Silva, 2010, 2013; Rohandheera, 2007).
4. People living along the Nilwala River in Matara which has been known for several centuries as a hotspot for saltwater crocodile attacks have been using highly practical and safe physical barriers**:** Crocodile Exclusion Enclosures (CEE). These enclosures are known in Sri Lanka as '*kimbul kotuwa'* (in Sinhala *kimbul* = crocodile and *kotuwa* = enclosure or pen). Traditional crocodile exclusion enclosures are constructed of thick kitul palm (*Caryota urens*) planks or long hard wooden poles firmly driven into the river bed, the two ends of the enclosure abutting the banks (Figure). In the recent past (2007), enclosures have been fashioned using metal rods and wire mesh (Figures) (de Silva, 2008, 2011, 2013). Additionally the Disaster Management unit of Matara has already installed 30 odd metal CEE's along the Nilwala river and some tributaries of it.

Though the effectiveness of the simple traditional crocodile excluding enclosure (CEE's) has been shown (de Silva, 2010, 2011; Somaweera and de Silva, 2013) all attacks took place where there was no CEE earlier, but the worse was, the few recent fatal cases (2011, 2012 and 2013) the victims have been bathing just few meters away from the CEE. This indicates the shear carelessness of the people. The recent (2012) fatal case of an 18 year old girl attracted wide media coverage as apparently the personal CEE they had installed had several wooden poles missing for some time and the crocodile entered through the gap and attacked and killed the girl.

All traditional and the newer metal enclosures studied had only 3 sides fenced, being open to the bank. In a previous report, the author has recommended that an ideal CEE should be fenced on all four sides, with an entrance door from the land side that should be kept closed when the enclosure is not in use (de Silva, 2008). This is to prevent crocodiles that wander about on land at night accidentally entering the enclosure and remaining inside the CEE's. We came across 2 incidents (Tissamaharama and Matara) where a crocodile had come into a three-sided CEE (de Silva, 2008; Somaweera and de Silva, 2013).

There are two other preventive methods adopted in recent times - Crocodile excluding fences (CEF) and the installation of warning signboards. The CEF is installed at places where crocodiles stray into domestic compounds in the night, usually to attack pet animals or poultry. This has resulted in the construction of "crocodile fences" made of metal to protect domestic property (de Silva, 2008). Drawing attention to dangers by means of warnings on signboards would be a simple and important step in any preventive strategy. However, it has been observed that warning signboards are not generally displayed, even at the many tanks and rivers where several crocodile attacks have taken place in the past.

Killing and Translocation

During our survey we received reliable information that several crocodiles have been killed after attacks by the family, friends and villagers. In one instance, after a 5 year old boy was killed the father and his friends have killed approximately 5 crocodiles inhabiting that particular stream. In Matara, Nilwala River some villagers have put poisoned baits and approximately several crocodiles have been seen floating in the river few days later. The Department of Wildlife Conservation has translocated several saltwater crocodiles (mainly from Nilwala River) over the past decade. These have been released in National Parks belonging to the department; however, these are mainly mugger habitats.

Recommendations

As a result of our island-wide survey of selected habitats of mugger (*Crocodylus palustris*) and saltwater crocodile (*Crocodylus porosus*) together with inquiries into incidents of attacks on humans at these locations, several important and interesting observations have emerged. These need to be taken into account for future planning and for conducting awareness programs. According to the accounts of crocodile attack victims and witnesses, it appears that crocodiles have observed people engaged in their water-based activity, like bathing and washing clothes, over a period of time before an attack. This would imply that, at least some attacks, were not the result of a casual encounter with potential prey, but the culmination of a hunt at a spot where prey was known to gather. Based on our findings the following actions should be progressed:

1. Intensive awareness programmes among vulnerable populations. Inform them if possible not use the same place, same time and same action, if possible, if not to take extra precautions. If a crocodile is observed around the place where they bathe/wash they should not underestimate its intelligence - it is possible that it is planning to attack.
2. Installation and maintenance of physical protective structures such as 'crocodile exclusion enclosures' (CEE) and 'crocodile-fences'; and
3. Installation of warning sign boards in danger prone areas.
4. Educate as to the importance of crocodiles in our aquatic ecosystems
5. Killing or translocation of offending crocodiles is questionable as shooting or capturing any specific 'man-eater' is questionable. Australian studies (Caldidicott et al., 2005) indicate that there is no guarantee that the crocodile responsible for the attack can be captured. In addition, incidents of translocation of supposed 'man-eaters' into wildlife sanctuaries is known in the country (N. Atapattu, personal communication, 2008). However, the 'homing' capability of crocodiles is now well known (Read et. 2007). In this case perhaps the best is to install a CEE or keep the animal in a zoo or a crocodile farm.

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Figure 1. People bathing/washing in a tank


Figure 2. Tank fishing.


Figure 3. Leg attacked by crocodile


Figure 4. Upper thigh attacked by crocodile


Figure 5. Arm attacked by crocodile


Figure 6. Arm attacked by crocodile


Figure 7. Buttocks attacked by crocodile


Figure 8. Trunk / chest attacked by crocodile

Photographs : Anslem de Silva

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Discovery of a 2nd fossilized tooth of an extinct crocodile from Sri Lanka: Preliminary report

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Abstract

The first fossilized crocodile tooth from Sri Lanka was secured by P. E. P. Deraniyagala in July 1939 in gem sand in a gem pit at an approximate depth of 12 feet in Tunhiriya vila, Gönapitiya, Kuruvita, Sri Lanka. In March, 2013, a second undamaged fossilized crocodile tooth was discovered at a depth of 5 m from the same Pleistocene bed at Kuruvita village.

Introduction

Crocodilians had their evolutionary beginnings more than 250 million years ago in the early Triassic (Seymour *et al*., 2004). The oldest known fossil of a modern crocodilian is about 125 million years old (Brazaitis and Watanabe, 2011). The British Museum of Natural History (1922) reports of possessing several extinct crocodile species in their collection including a large collection from the Pliocene Siwalik formations of India that contained a snout of a colossal extinct gavial *Rhamphousuchus crassidens* which might have attained a length of about 16 m.

Deraniyagala reports that on 17th July 1939 a fossilized crocodile tooth fragment was secured from a gem pit in Tunhiriya Vila, Gonapitiya, Kuruvita (Deraniyagala, 1953, 1958). The tooth was discovered at a depth of 12 feet. Another gem pit in the vicinity yielded hippopotamus and rhinoceros fossils in the same degree of mineralisation as the crocodile tooth. In March 2013 the authors secured another fossilized crocodile tooth from the same Pleistocene bed, close to the location where Deraniyagala collected his fossilized crocodile tooth. The present communication is a preliminary discussion on these 2 fossil crocodilian teeth.

Materials and methods

The fossil tooth fragment collected by P. E. P. Deraniyagala in 1939 is held at the National Museum, Colombo, registered No. F. 28 (Figure 1). This second, undamaged fossilized crocodile tooth (Figures 2 and 3), was discovered at a depth of 5 m in March 2013 at Korawakwila, Edandewela, Kuruwita, Ratnapura. It is at the present time with one us (KA) and will be eventually deposited in the National Museum. Measurements of the fossil teeth were taken with veneer calipers Valley dial caliper, Valley Industries, USA.

Discussion

According to Deraniyagala (1958), the fossilized crocodile tooth fragment (Figure 1) had been along with the teeth of an extinct Rhinoceros, and within the same bed, in a close by gem pit had yielded fossil fragments of an extinct hippopotamus and rhinoceros. Deraniyagala (1953) considered that this fossilized crocodile tooth belonged to an extinct crocodilian. Furthermore, as this tooth was more slender with a more re-curved apex when compared with the teeth of the two extant species of the country, he considered that it 'might belong to a new species which might eventually be named *Crocodylus sinhaleyus'* (Deraniyagala, 1953, 1958). This tooth fragment (Figure 1) when we measured was 45.3 mm in height and 14 mm wide at the broadest place, this was slightly less than the measurements given by Deraniyagala, as according to the museum staff it has got slightly damaged. Deraniyagala (1953, 1958) estimated that this particular tooth had belonged to a crocodile measuring approximately 12 feet or more in length. He further reports that at the time of writing the only crocodile species known from Kaluganga close to Ratnapura, about seven miles southeast of Kuruvita is *Crocodylus porosus* (the Saltwater crocodile). *Crocodylus porosus* is still known from the river Kalu, but is uncommon.
Deraniyagala (1958) postulates that during the 3rd interglacial about 1,50,000 B. C. there had been large natural lakes around Ratnapura that supported large mammals and proposed the term *Ratnapura fauna* for these extinct fauna, as most of the Pleistocene fossils found in Sri Lanka were embedded in the gem gravels or alluvial deposits of the Ratnapura area. According to Deraniyagala (1958) and Manamendra-Arachchi and Adikari (2011), these fossils of extinct fauna resemble closely the extinct Indian *Shivalik fauna*. The extinct large mammals of Sri Lanka include two species of

rhinoceros (*Rhinoceros sinhaleyus* and *R. kagavena*), a hippopotamus (*Hexaprotodon* [=*Hippopotamus*] *sinhaleyus*) and a gaur (*Bos gaurus sinhaleyus*). Radiocarbon dates are not yet available for the two crocodile teeth fossils but thermo-luminescence dating is available for the extinct *Rhinoceros sinhaleyus* with a range of 80,000 (± 20,000) years before the present (S. Deraniyagala, 2004; Manamendra-Arachchi et al., 2005; Manamendra-Arachchi and Adikari, 2011). Here it is of interest to note that the first crocodile tooth fossil was found in the vicinity of the extinct rhinoceros fossils which "were of the same degree of mineralization" (Deraniyagala, 1953). Thus, it is possible that the particular crocodile tooth (Figure 1) is of the same age.

Some measurements of the second fossilized crocodilian tooth (Figures 2 and 3) are: the maximum height, 79.39 mm; maximum width (horizontal) of root, 23.55 mm; maximum height of root, 64.36 mm; maximum crown height, 24.48 mm; maximum crown width, 14.45 mm. The tooth is generally "S" shaped. It was collected by K.M. Premawardhana in a gem pit, approximately 5 m below the surface at Korawakwila, Edandewela, Kuruvita, Ratnapura in March 2013. This fossil was in the same Pleistocene bed at Kuruvita that Deraniyagala (1958) found his specimen. Ours, however, is complete and in a well preserved state (Figures 2 and 3) when compared to the sample collected by Deraniyagala which was a fragment and badly damaged (Figure 1). As regards the tooth collected by Deraniyagala, he states that if the tooth is reconstructed it would probably measure 95 mm in length (Deraniyagala, 1953, 1958).

Considering Deraniyagala's (1958) postulation that during the 3rd interglacial there had been large natural lakes around Ratnapura that supported large mammals, we could assume that this extinct crocodile would have been a lake species that lived alongside large aquatic and marshland mammals like hippopotamus, rhinoceros, water buffalo and gaur. Today there are no natural lakes in Sri Lanka, the main inland waters being the several thousand man-made reservoirs, known as 'tanks' the building of which commenced around the 6th century BC.

Detailed work on these fossil crocodile teeth as well as on geologic and climatic changes, events that took place like drying up of the large lakes and other possible causes for extinctions is underway, hence this preliminary account.

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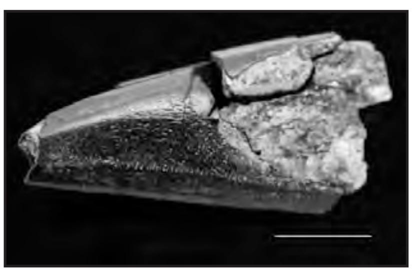

Figure 1. Fossil tooth fragment collected by Deraniyagala

Figure 2. Second Fossil tooth

Figure 3. Second Fossil tooth

Photographs : Kelum Manamendra-Arachchi

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Preliminary observations of some nesting strategies of *Crocodylus palustris* in Sri Lanka

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Abstract

Data on nest selection sites of the mugger crocodile *Crocodylus palustris* in Sri Lanka is predominantly based on anecdotal observations and date as far back as Parker's report in 1880. During the ongoing island-wide surveys of crocodiles we observed 41 mugger nests. These egg-laying sites indicate that the mugger uses three distinct strategies to lay eggs. Our observations complement the limited information available on the reproductive habits of the mugger in Sri Lanka. We observed a few nests alongside busy roads and human habitations.

Introduction

Whitaker and Whitaker (1984) provide a fairly comprehensive paper on the reproductive biology of the Indian Mugger. Reviewing the available literature from Sri Lanka that refers to or includes notes on the reproductive habits of the mugger, we see that the mugger selects a variety of places to lay its eggs. Parker (1880) is perhaps the first to report on the selection of sites used by the mugger to lay eggs, followed by Abercromby (1913); Deraniyagala (1930); Phillips (1941); Somanader (1941); de Silva (2013); de Silva et al., (2013) and Rathnasiri et al., (2013). Data from the present study give a fairly good picture of some mugger strategies in selecting a nesting site and other associated reproductive patterns. Our report of the mugger laying eggs alongside busy anthropogenic areas is perhaps the first report for the country.

Methods

The observations were investigated by the authors separately and opportunistically during the years 2003 to 2013 in many areas of the country. Additional data received from colleagues and some officers of the Department of Wildlife Conservation are also included.

Results, discussion and recommendations

According to our own data as well as from the available literature pertaining to Sri Lanka, the sites in which the mugger has selected to lay her eggs can be grouped under the following.

Table 1 Distribution of the sites selected by the 41 muggers to lay eggs

Site selected to dig the nest	No. observed	No. recorded in literature	Total
1. Sandy place on tank bund	16 (39%)	5 (Clark, 1901; Deraniyagala, 1939; Somanader, 1941; Phillips, 1941 and Gabrial et al., 2013)	21 (44 %)
2. As above but with a close by guard burrow	4 (10%)	1 (Parker, 1880)	5 (10%)
3. At the entrance of the burrow	17 (41%)	1 (Abercromby, 1913).	18 (38%)
4. Anthropogenic habitat	4 (10%)		4 (8%)

Selection of the site to excavate the nest

The above data suggest that the favourite or most widely selected (44%) nesting site by the mugger are item 1, sandy places in tank/river or stream banks without much scrub vegetation, with no decaying vegetation, with dappled sunlight, close to water and where few people or buffalo/cattle come. (Fig. 1, 2) This site is recorded by Parker (1880), Abercromby (1913), Deraniyagala (1930); Phillips (1941); Somanader (1941) and de Silva (2013).

As regards the next most widely selected (38%) place to dig the nest is (item 3) in front of the mugger burrow entrance, Abercromby (1913) was the first report this from the country. However, as regards item 2, the method where the nest is dug on a sandy bank with a nearby guard burrow, (Fig. 2) we have observed this strategy in two completely different scenarios: nest on a bank with a guard burrow inside forest, at a place not accessible to humans or buffalo/cattle, while the other was in fairly busy anthropogenic habitat in Tissamaharama (south east) and Kekirawa (north central province). (Fig. 3) Perhaps the possible reason in a forest could be protection from predators such as jackal, wild boar, wild cats and monitor lizards. However, crocodiles living in/around human habitats may be explained due to Human-crocodile co-existence observed in some areas in Sri Lanka, for example at Godadora Ela (irrigation canal) in Tissamaharama, where large muggers come to compounds to bask, nest and make burrows. One of the first to report this was Clark in 1901 that '…bathing unconcernedly in a tank with the heads of half-a-dozen of these brutes showing above the surface only a few yards from them'. Whitaker and Whitaker (1989) state: 'Today the traditionally amicable relationship between man and mugger can rarely be illustrated in India; muggers are too scarce. In Sri Lanka, however, there are many places where people bathe in "crocodile infested waters" without fear'. I can add that there are still some areas in Sri Lanka where people live virtually side by side with the mugger. Whitaker's (1989) comment that the 'mugger is a more "socially acceptable" species of crocodile" is interesting. However, we have not as yet observed using rock caves/crevices in far off secluded places as reported by Abercromby (1913).

A clearer idea of the reproductive cycle of the mugger and its general reproductive strategies will give us a better picture for devising both appropriate conservation measures and the necessary data to put in place robust protection for crocodiles and humans.

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Figure. 1

Figure. 2

Figure. 3

Photographs : Anslem de Silva

A Preliminary study on human crocodile relationship in Urubokka Oya, sothern province of Sri Lanka

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A preliminary study was conducted to assess the impact of humans on crocodiles and vice versa along the Urubokka Oya / Maha Oya (oya = river) in Humbantota District, Sothern Province of Sri Lanka. This river provides good habitats with both rocky and muddy river banks and muddy shallow water. The river mainly flows through paddy cultivated lands and villages. Approximately 250 person hours were spent in the field over a period of six months from October 2012 to March 2013 to assess the relationship between humans and crocodiles. General area surveys and questionnaire were used as tools of data collection. No crocodiles were captured during the study. In average ~3 individuals of Mugger Crocodile *(Crocodylus palustris)* were recorded in a given field day, with total body length (TBL) ranging from ~0.3m to ~3m. No written record was found of humans been killed by crocodiles of this river or vice versa. One verbal record was found about a crocodile which have killed two humans in 2001 and the animal was captured by the officials of Department of Wild Life Conservation. During the last twelve years 9 crocodile attacks were recorded with 2 deaths, 3 major injuries and 4 minor injuries. However 12 crocodile (TBL: ~0.3m to ~5m) deaths were recorded with 4 been killed by shooting, 5 been killed by beating and 3 juveniles found in an adjoining agricultural well killed by some chemical probably a pesticide. Altogether 8 crocodiles (TBL: ~0.6m to ~4.5m) have been captured and 3 have been handed over to Department of Wild Life Conservation. Out of the other five, 2 (TBL: ~1m) have been released to Kalametiya Bird Sanctuary and there are no record about what happen to the other 3 captured crocodiles. According to this survey it is prominent that there is a developing human crocodile conflict along Urubokka Oya and it will increase as the human population grows. Therefore there is a need of a much in-depth study in order to have better management plans.

Key Words: human crocodile conflict, Urubokka Oya, conservation, Sri Lanka

The status of the mugger crocodile (*Crocodylus palustris*) inhabiting the Wilpattu National Park, Sri Lanka

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Wilpattu National Park (WNP) is the largest national park in Sri Lanka and spans an area of 365,000 acres (148,000 hectares). Large saucer shaped water bodies known as Villus that fill up and consists almost entirely of rain water is a unique geographic occurrence at Wilpattu and is the basis of the name which translates to 'Lake District'. The present status and distribution of crocodiles within the park is not known as there were no detailed studies carried out in recent times especially in the last ten years when the civil conflict was at its peak. The park is now open since the conflict ended in May 2010. The preliminary survey to ascertain the status of crocodilians at WNP was conducted during August 2011. During which period 27 Villus were investigated during the day and at night 14 villus were surveyed using eye-shine technique. The counts were carried out from the bank in both instances. The day counts revealed 27 crocodiles the while night counts revealed 50. Six burrow sites were discovered and examined. The two river systems that border the park in the North and South, the Modaragam Aru and Kala Oya respectively were well watered. Both systems were not adequately surveyed. However a nest site in Kokmutai by the Modaragam Aru was discovered on 7th September 2011 with 13 egg-shells scattered, nine hatchlings and a guard burrow. The nest site was surveyed. Some of the hatchlings were captured and measured. It was the first recorded Mugger nest sighting reported from WNP. Due to the prevalent dry conditions of the time, most Villus had considerably shrunk in size and many had dried up completely. Despite the fact that no overland migrations to the two rivers were witnessed during the study it was thought to be the likely reason for the low counts from WNP. It is recommended that a further annual cyclical study be conducted to better ascertain the carrying population of crocodilians in the park and verify the possibility of the inter villu and villu to river migrations during the dry season.

Treatments and medical management of hook engulfed saltwater crocodile *(Crocodylus porosus)*

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Abstract

The saltwater crocodile *(Crocodylus porosus*) also known as the estuarine or Indo-Pacific crocodile, and the largest of all living reptiles. As well as the largest terrestrial and riparian predator in the world. Due to anthropogenic activities and involvements to natural habitats numbers of these crocodiles are declining. According to the observations during t6he last 3 years a trend was build up by the affected people of the area to use hook to trap crocodiles. As such they use iron hooks anchor trap hooks with a dead bait of a dog or a cat or some ox meat. At the engulfing process this iron anchor or hooks penetrate to laryngeal area of throat or esophagus. If animal trap it cable connected with that hook hunters pull the animal and may be kill or allow to animal for die with several days. This inhumane process people use clearly for killing the animal not for capture. Some crocodiles die immediately after engulf due to damage indirectly to aorta. Other animals stay several days and ultimately they were dying due to starvation and other sevior traumatic injuries and complications. Traumatic injuries and other complications were aggravated due to struggling immediate after engulfing of hook. These incidents were increasingly reported during the few years; the areas where crocodiles and human deaths were occurred. In this paper two cases were taken in to consideration which a hook engulfed crocodiles and some observations in the process of medical management.

First case the crocodile was 10feet long average body weight 600kgs was recorded find out with hook engulfed from area at Beruwala. Animal was depressed, externally several wounds over body surface. Cable connected with hook was already visible externally. The first step was to sedate the crocodile by using Ketamin Hydrochloride. However after examine the animal it was find condition of animal is not suitable for sedation. Later it was decided to remove the hook by manual restraining. Wooden plate with central hole and iron bar square apparatus use as a mouth gag. This was facilitated specialy for this purpose. Stretch the mandible and upper jaw by use ropes and fix the wooden plate in between two jaws. Insert hand through the mouth gag to throats and inspected the severity of the damage. It was a anchor hook with two sharp edges at two directions. Both two edges were deeply penetrated to ventral and part of the proximal edge of the esophagus. It was very hard attempt and very difficult process to remove the hook, reason was if remove one hook simultaneously other edge of hook entangle. The design of hook very hard to remove both edges at the same time and if try to remove simultaneously increase the damage of surround tissues. About 20 minutes tried to remove the hook which failed. Meanwhile crocodile was died. After the death the surgical procedures followed to reach to place by ventrally thoracic opening. Incised the skin and muscle layers of thoracic area ventrally parallel to hook engulfed area. Opened the xipoid cartilage and access to place. It was evident a seviorly traumatized tissues around there and already necrosed.Sevior bleeding lesions also observed. Due to primary struggling of hook engulfing all the tissues around the area was damaged and with the time it was necrosis.

Second case was saltwater crocodile captured by people in Ragama area which was suspected of victim for one human death. It was trap with a designer hook which consists with bunch of hooks complicity 3 hooks fixed in to three different directions. The animal was captured by Department of Wild Life Conservation and brought to the zoo. At the time of arrival it was a depressed and 4 inch long deep wound was found on the head which was suspected that that cause by an axe. Given Dexamethasone 20ml, Cyanocobalamin 25ml, long acting Penicillin 30ml, Hydrocortisone succinate, deep intramuscular.Localy dressed the head wound. Same procedures perform as earlier case and try to remove hook by manually. But after heavy manipulation within 30 minutes remove the hook. During the process the crocodile died. The caercas was open it in necropsy revealed sevior damageoccured due to engulfing of hook. Suspected human hand and foot bones already find out from stomach content of crocodile. Those were sent for further forensic investigation.

According to these two cases it was observed manual manipulation and attempt to remove hooks were not successful and it could damage the surrounding tissues furthermore. Surgical attempts are non practicable with post operative care. Always hooked engulfed crocodiles were very week and dipressed.Their prognosis was very poor due to extensive damage to throat. According to this cases the recommendation is first inspect the engulfed hook and level of penetration by manually. If minor attachment to tissues can remove the whole hook manually. If it is a strong attachment do not try to remove whole hook manually. However to save the life of the animal it may be possible to cut the cable connected to the hook from its deepest end inside the crocodiles body.Reamaining iron hook inside the throat or esophagus wall can be settled in it as it is. For control of the infection of surround tissues can give Long acting Penicillin and as anti inflammatory Flunexin maglumate intramuscularly

Preliminary observations of *Balantidium* infections in marsh crocodile in Jaffna Peninsula

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The mugger or marsh crocodile *(Crocodylus palustris)* has been recorded from many locations in the country with a majority from Yala and Wilpattu National Parks in large rivers, marshes, reservoirs and tanks in the low country dry zone and also from Jaffna Peninsula. Parasites of crocodiles in Sri Lanka have not been studied previously. Faecal samples were collected from muggers in Jaffna peninsula in November 2012. Each sample was divided into two and few drops of formalin was added to one portion and the other was kept either in a cooler at 4^0C or at room temperature (27-33^0C) until analysis. Samples were brought to the lab and processed by modified salt floatation followed by morphological identification using the light microscope. A total of 21 faecal samples were analysed from two locations in Jaffna namely, Ampan and Sarasalai. All the samples were positive for *Balantidium* cysts. The intensity of infection varied among the individuals with extremely high cyst counts from some individuals. DNA studies are underway to identify the *Balantidium* species. Although the presence of cysts of *Balantidium* has been recorded from faecal samples of crocodiles and alligators in commercial closed farming systems in other countries, this study provides first record of *Balantidium* infections in *Crocodylus palustris* of Sri Lanka.

Current conservation status of *Crocodylus porosus* from Borupana Ela and its hinterlands in Moratuwa, Sri Lanka

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Crocodylus porosus (CP) is the largest reptile species distributed in the coastal belt and its environs of Sri Lanka. This species is categorized as Lower Risk/Least Concern (version 2.3) under the IUCN Global Red List, and Endangered (B2ab iii) in the 2012 National Red List of Sri Lanka. Despite it being locally common in some regions in the island, data on general behavior, feeding and reproductive habits and also the genetic and morphological variation within the species in Sri Lanka is not well known. The data in this abstract are based on opportunistic field observations made by the authors for 37 days (~6 hrs/ day) from February 2012 to March 2013 in Borupana (Kospelana Bridge to Borupana Bridge). This study area covers less than 1000 hectares and falls within the western province (647'39.72" to 650'17.26" N and 7953'09.00"to 7954'48.31"E), at an elevation of 1-2 m above sea level. Surveys were conducted both during day and night and flashlights were used at night. Specimens accidentally caught in fishing nets were also examined. Whenever possible specimens were taken from fishermen to determine their sex, weight and obtain measurements and released at the same habitat. We also interviewed villagers using a written questionnaire. Furthermore basic environmental parameters were collected at locations, where specimens were collected.

During the survey we were able to record a total of 41 individuals (29 through fisheries by-catches and 12 direct observations). Out of the 29 specimens, eight were killed by fishermen for consumption. These individuals ranged from 14-180 cm (SVL) and weighed 0.08-53 kg. According to questionnaire surveys administered on villagers between 21 to 60 years in age (n=84), 96% of them believed that CP have no importance and should be killed; 89% has killed at least one CP in Borupana; 74% has eaten CP meat and 45% has eaten CP eggs. Contrastingly, among villagers below 20 years in age (n=53), 81% believed CP to be of importance thus should not kill; 86% not killed even a single CP in Borupana; 82% not eaten CP meat and 88% not eaten CP eggs as additional food source.

Borupana is a local 'Hot Spot' for CP and there is a healthy population in different size classes and good habitat for nesting. But few threats were noted: Karadiyana massive garbage dumping area is close to this site (potentially emitting toxic chemicals to the water), and several industrial factories dump their waste to Borupana Ela (7.2 to 7.9 ph level). Water temperature at ~30cm depth fluctuates between 29.3 to 30.8 C at night time and between 30.1 to 31.6 C during day time. Three fatal attacks from CP have been recorded from the area over the last ten years and eight other attacks have taken place. Five large individuals were removed from this location and translocation to Bundala, Yala and Lunugamwehera areas, which are inhabited by muggers. Education and awareness workshops for the villagers were also conducted over the last year.

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Discovery of a 4th century AD perforated crocodile tooth ornaments from Sri Lanka

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Abstract

The first discovery of perforated crocodile tooth ornaments among 41 drilled tooth artifacts belonging to eight vertebrate species uncovered during standard archeological excavation procedures conducted at the Jethawanarama monastic site, Anuradhapura are discussed. These perforated tooth ornaments could possibly have been used as a necklace, arguably worn by a hunter. It is possible that the particular hunter who had killed these animals would have made a vow and placed these hunting trophies on the offering altar to lord Buddha averring that he will not commit such actions in the future.

Introduction

The wearing of various parts of animals such as bird feathers, mammal and reptile bones, shells, coral, horn, ivory and animal teeth as ornaments by man is known over several thousand years BP from many parts of the world (Vanhaeren *et al*., 2006). Royalty, chieftains and commoners would all have worn these during religious, sorcery, folk, fertility and agricultural rituals, during hunting (possibly as a protection or to get more game) and other activities. From Sri Lanka drilled shells of marine and freshwater molluscs and shark teeth have been discovered from different parts of the island, which are dated from 3,800 to 38,000 YBP (Deraniyagala, 1992; Perera, 2010; Manamendra-Arachchi and Adikari, 2012). However, there is no previous evidence of drilled crocodile teeth from the country. Thus we report for the first time the discovery of the drilled teeth of probably a marsh crocodile (*Crocodylus palustris*), along with the drilled teeth of at least 8 other vertebrate species uncovered during the Jethawanarama monastic site excavations.(Fig. 1) The present communication is mainly concerned with the crocodile teeth (Figures 2, 3, 4,5)

Material and methods

Forty-one drilled teeth artifacts belonging to at least 8 vertebrate species (there were 7 unidentified teeth fragments) were discovered during standard archeological excavation procedures conducted in 1984 at the Jethawanarama monastic site (Table 1 and 2). These were found buried in front of the offering table of the Northern Wahalkada or Ayakeya which is situated between the stupa and the entrance (Figure 1).

Table 1
The 41 Drilled Teeth artifacts

Vertebrate Species	No of drilled teeth
Crocodylus palustris (Mugger crocodile)	2 (and fragments of another 8)
Herpestes spp. (Mongoose)	6
Canis familiaris (Dog)	10
Prionailurus viverrinus (Fishing cat)	2
Melursus urisinus (Sloth bear)	1
Panthera pardus (Leopard)	3
Dolphin sp.	1
Hystrix indica (Porcupine)	1
Unidentified perforated teeth	7
Total	41

Table 2

Morphometric details of a perforated crocodile tooth

	Tooth sample 1	Tooth sample 2
Registered no	I.314 / A / NAY, Northern Ayakeya, 1984.9.24	I.314 / A / NAY, Northern Ayakeya, 1984.9.24
Total height	31.35 mm	27.17 mm
Base width	10.03 mm	8.76 mm
Base thickness	8.75 mm	6.91 mm
Outer diameter of the drilled hole	3.10 mm	2.91 mm
Inner diameter of the drilled hole	2.91 mm	2.62 mm

Discussion

Perhaps the oldest evidence of drilled vertebrate teeth ornaments we have to date is from Europe and goes back to the Paleolithic era. These ornaments were discovered during excavations at Come Sauniero, France (Castel *et al*., 2002). However, perforated marine mollusc shells are much older (1, 35, 000 to 1, 00, 000 YBP) and have been discovered from Israel and Algeria (Vanhaeren *et al*., 2006). Archaeologists consider these to be some of the oldest known drilled ornaments to be worn by humans. In Sri Lanka the perforated shells of aquatic (marine and freshwater) molluscs worn by prehistoric (Mesolithic) man between 3,800 and 38,000 YBP have been discovered from Fa-Hien cave at Bulathsinhala, Batadombalena cave at Kuruvita and Pothgul lena at Alawala, (Deraniyagala, 1992; Perera, 2010; Manamendra-Arachchi and Adikari, 2012). The oldest of these drilled shells from approximately 38,000 YBP, discovered from Batadombalena (cave), Kuruvita had been worn by the prehistoric man known as Balangoda man (Deraniyagala, 1992; Perera, 2010).

Though the use of perforated teeth ornaments had commenced during the Neolithic Period in European countries (Castel *et al*., 2002), no such artifacts have as yet been discovered from Sri Lanka. However, the discovery of 41 perforated teeth belonging to at least eight vertebrate species from the 4th century AC in Sri Lanka is important in several ways:

1. This is the first discovery of perforated terrestrial vertebrate teeth, especially that of the crocodile.
2. These would have been possibly used as a necklace or kept as hunter trophies.
3. Given the precise location of the find it is credible to believe that the particular hunter who had killed the animals had made a vow and placed these hunting trophies on the offering alter averring that he will not commit such actions in the future.

Of the 8 vertebrate species represented in this series, the crocodile probably accounts for the most damage to humans and their farm animals. As both of the crocodile species (*Crocodylus palustris* and *C. porosus*) of the country are known to attack and occasionally kill humans (de Silva, 2010, 2011) several precautionary measures were taken by vulnerable people to protect themselves (de Silva, 2011). In many instances the offending crocodiles were killed and a good and convenient memento would have been a crocodile tooth. In the past animal ornaments were usually worn mainly by village elders, hunters or a person who held some government position as an object of prestige or as hunting trophies or as a protective talisman.

It is still the common practice of many hunters to keep a memento of the animals they kill (shoot). It is note worthy that even today many pay hundreds of rupees for one hire of elephants tail, the elephant should be a wild one, that means no human have got on to its back. Usually these are worn as ring and are considered a good luck charm and a protection. Similarly, parts of the wild boar are considered a protection against witchcraft. We still see modern men wearing wild boar tassels, leopard or bear claws mounted in metal pendants (Figure 5).

It is highly possible that these perforated animal teeth found at Jethawanarama would have belonged to a hunter and were used as a protective talisman, a sign of a professional hunter, for prestige, to get more game or worn during some folk ritual.

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Figure. 1

Figure. 2

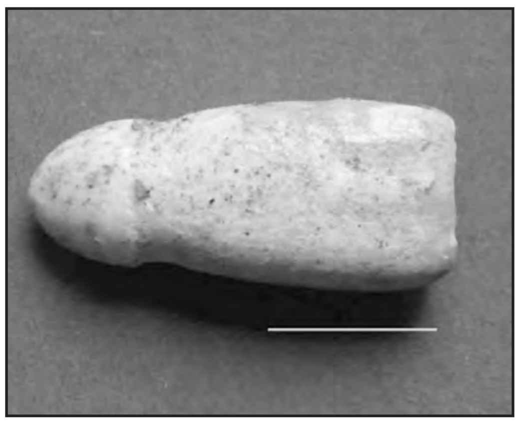

Figure. 3

Figure. 4

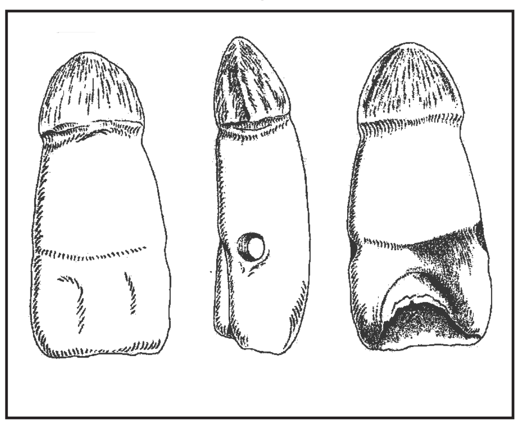

Figure. 5

Photographs : Kelum Manamendra-Arachchci

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Mugger burrows: preliminary investigations into the unique tunnels excavated by *Crocodylus palustris* in Sri Lanka

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Abstract

Approximately 200 *Crocodylus palustris* (Mugger crocodile) burrows were observed at 26 different localities in Sri Lanka between 2002 and 2013. As some burrows were inaccessible due to high water levels, preliminary investigations were conducted of 103 of these. Two main types of burrows observed during field work were: the 'shelter' burrow, the burrow with egg nest near the mouth and the 'guard' or 'defense' burrow. The former is used during the hot dry season when its aquatic habitat is drying or dried, and the mugger virtually aestivates in the low temperature inside the chamber of the burrow. The 'defense' or the 'guard' burrow is used to stay closer to the nest and protect it from potential predators. The guard burrow is usually first made by the female after selecting an appropriate site. The average height and width at the entrance of the mugger burrow, the depth or the length of the burrow and the temperature inside the burrow were recorded. Of the 103 burrows, 42 were deemed 'active' with either muggers present inside or with signs of recent use. Some anecdotal reports of mugger burrows in Sri Lanka spanning the years 1880 to 2013 are highlighted.

Introduction

A burrow is defined as a 'hole in the ground dug by certain animals for shelter or defense'. Many of the crocodilians of the world dig burrows or tunnels (Bihui, 1990; de Silva, 2010; Rathnasiri, 2011; Rathnasiri et al., 2013; Steubing and Lim, 2004; Vijaykumar, 2000; Whitaker et al., 2007). Among crocodilians, *Crocodylus palustris* is well known for its burrows or tunnels (hereafter referred to as the Mugger Burrow = MB). They are used by muggers under various circumstances, such as a refuge for resting, thermoregulation, aestivation during prolonged drought and protection from natural predators and humans. Some are dug for guarding the nest (Parker, 1880; de Silva et al., 2013) and in these the nest is situated near the mouth of the burrow (de Silva et al., 2013; Rathnasiri 2011; Vijaykumar, 2000).

Crocodilian species found in the tropics use the burrow to survive the effects of drought and extreme heat. However, the Chinese Alligator (*Alligator Sinensis*) and the American alligator (*A. mississippiensis*) that range above 30º N where temperatures fall below freezing use the burrows as refuges from cold winter temperatures (Whitaker et al., 2007). For Sri Lanka, Deraniyagala (1939) reports that with the onset of a drought period, muggers feast on frogs and shoals of fish exposed by diminishing water. In this manner, they accumulate a fat reserve preparatory to aestivation either in burrows or under rocks deep in jungles.

Sri Lanka and Gujarat, India are two of the best places to observe MB's. In Sri Lanka they are popularly know as *kimbul gé* (*kimbul* = crocodile, *gé* = house) by the villagers. Approximately 200 mugger borrows were observed in various parts of the island, of which investigations were conducted in 103 burrows or tunnels (de Silva, 2010; Rathnasiri 2011; Rathnasiri et al., 2013). The other burrows could not be investigated as when we visited the water level was high and the burrows were submerged or there was difficulty in approaching the burrow.

In Sri Lanka we observed two main types of MB's during our field work: the 'shelter' burrow, and the 'guard' or 'defense' burrow the burrow. The former is used during hot dry season when its aquatic habitat is drying or dried, and the mugger virtually aestivates in the low temperature inside the chamber of the burrow. The latter type: 'guard' or the 'defense' burrows, we observed 2 varieties guard/ defense burrows. The typical guard burrow is usually first made by the female after selecting an appropriate site (see de Silva et al., 2013 in this publication) after which the female digs a pit to lay eggs few meters away and above the guard burrow. The other is she digs a 2 to 2.5 m burrow and dig a pit to lay the eggs at the mouth or slightly inside the burrow, thus the mother stay closer to the nest and protect it from potential predators. Thus, we see that in Sri Lanka the mugger use two versions of guard burrows. We observed in a few burrows that muggers, including hatchlings, can sometimes group together in a single tunnel, (de Silva, 2010; Rathnasiri 2011; Rathnasiri et al., 2013). Mugger's grouping together in a single tunnel is also recorded from India (Vijaykumar, 2000). Some details of the mugger burrows that were investigated are given below and in Table. 1.
The following are the available anecdotal reports of MB's from Sri Lanka spanning between 1880 and 2013:

1. W. K. Parker (1880) is the first to document from notes provided to him by one S. Waitialingam of a 'guard burrow'. He reports that the mother first makes a large hole for herself to live in during the day in order to watch her eggs.
2. A. F. Abercromby (1913) reports of crocodiles laying eggs in a deep hole in a bank.
3. K. W. S. Mitchell (1925) reports of an interesting account of digging out a crocodile from a 30 ft. long burrow on land.
4. P. E. P. Deraniyagala (1936) reports of the U-shaped mugger burrow found in riverbanks.
5. Whitaker and Whitaker (1984) referred to mugger burrows in Sri Lanka.
6. Brady Barr (2002) mentions initiating investigations in *C. palustris* of selection of burrow sites, mapping of burrows and their biological significance, and the thermoregulatory role burrows play in the biology of the mugger crocodile.
7. R. Whitaker et al., (2007) reports more details on MB in the Bundala National Park, Sri Lanka.
8. Anslem de Silva (2010) reports some details of 26 MB mainly from the North Central province.
9. G. W. R. P. Rathnasiri (2011) reports details of 18 MB from the Udawalwe National Park.
10. Rathnasiri et al. (2013) reports briefly of 105 MB from several locations in the country.
11. Adrian R. Gabriel (2013) reports on six MB from the Wilpattu National Park.

However, this study is the first detailed paper on the MB of Sri Lanka.

Methods and material

From the year 2002 up to 2013 approximately 200 MB's belonging to the three types were observed at 26 different localities in the country (north from Jaffna to south Bundala, Yala). As some burrows were inaccessible due to high water levels, we were able to conduct preliminary investigations in only 103 of them. MB's were investigated at different times during the day by the survey team. A measuring tap was used to take measurements of the height and width of the entrance of the MB. The depth of the burrow was taken by fixing several 1 m long plastic tubes with sockets, a 15 m nylon cord was passed through the tube and fixed to the first pole (Figure 1) so that pole could be pulled back. A digital thermometer was fixed to the first tube to take the inside temperature (Figure 2). Once the plastic rod hit the end of the tunnel, it was kept there for 5 to 6 minutes after which it is was pulled back rapidly (Figure 3) and the temperature immediately noted. The ambient temperature as well as the temperature at the entrance of the MB was taken. Compass orientation of the entrance and the GPS location was recorded. Digital images of the burrow entrance and sometimes inside, as well as how far it was from water, soil type, vegetation around and above the burrow and threats to the burrow were taken. All data were recorded in a structured survey form,

Results, conclusions and recommendations

According to Whitaker and Whitaker stream-dwelling mugger's use tunnels as year round residences, preferring embankments with heavy root systems (Whitaker and Whitaker, 1989). In Sri Lanka we observed similar MB in Yan Oya (stream), tanks and with heavy root systems, also some with small roots (Figures 4) The mugger uses its snout and the forelimbs to dig the burrow. Once it has dug up to its body length, the hind limbs and the tail are used to push the soil back out from the tunnel. One of us (PR) observed a mugger breaking roots jutting into the tunnel. However, the time taken to dig the entire tunnel is not known, however, it is possible that a crocodile could dig a burrow within a few days. Whitaker and Whitaker (1984) referred to mugger burrows in Sri Lanka and India (Gujarat and South India) and noted that yearling, sub-adult and adult mugger all dig burrows. At Yan Oya we observed 35 MB in a row about 3 to 10 m apart (de Silva, 2010 ; Rathnasiri , 2011), Mobaraki (2002) reports observing two burrows close to each other in Iran.

The average height and width at the entrance of the mugger burrow were 43.16 cm (range 20-90 cm) and 80 cm (range 29-154 cm), respectively. The depth or the length of the burrow varied from 100-1100 cm with an average of 310 cm. Most of the deepest MBs (ranging from 800-1100 cm) were observed at Yan Oya (N 7° 25´ 32.5´´ and E 80° 27´ 31.4´´). The temperature inside the burrow was usually about 3 to 10 ºC less than the outside temperature. A chamber where the crocodile rests was present in 94 (90%) burrows. Of the 103 burrows, 42 (40%) were deemed 'active' with the presence of a mugger (Figures 5, 6).

Burrows at three different heights above water level; 5-10 m up the bank, at the water level and at the middle of the bank between water level and the top have been observed in the Gir Forest, India (Vijaykumar, 2000). In Sri Lanka we have observed at the bottom of the bank and around mid bank. This may be as all banks that we investigated during the study was less than 5 m tall. Gupta and Srihari (1990) who studied mugger burrows at Bhorsaindan Sanctuary, India reports that burrow utilization was greater in winter months when temperatures dropped to 11º C. Shekar (1993) reported two to six muggers in the same burrow in winter months at this Sanctuary. However, in Sri Lanka in the dry zone plains where the muggers inhabit the temperature does not go below 24º C, and there are no winter or summer seasons, thus use of the burrows as refuges from cold does not arise.

The height and width of the burrow entrance (Figure. 3) and the depth and temperatures at burrow surface and inside the burrow of an earlier study in the North Central Province (de Silva, 2010) are given in Table 1.

Table 1. Some measurements of mugger burrows

	Number	Minimum	Maximum	Mean	Std. Deviation
Burrow height (cm)	21	30	75	49.52	11.237
Burrow width (cm)	22	54	142	83.91	22.209
Burrow depth (m)	20	2	12	5.82	2.939
Ambient temperature (oC)	16	24	38	29.89	4.703
Surface temperature (oC)	18	23	33	26.92	2.871
Inside temperature (oC)	18	19	30	24.28	2.600

(Source: A. de Silva, 2010)

The number of MB in a particular area does not equate to the number of muggers present in that particular locality. Romulus Whitaker (personal communications to AdS, 2011) who has worked in India, Sri Lanka and many other countries stated that in one place in Gujarat where he counted 19 burrows there were over 100 muggers. Similarly, Vijaykumar (2000) reports that he observed only 58 burrows at Hiran dam where around 200 muggers exist and he assumes that muggers will group together in a single tunnel. This indicates that only some dig tunnels. Furthermore, Whitaker (in lit.) informed that 'there is mixed information as to how many crocodiles will go into one burrow. A big male will probably occupy a burrow and not allow others in. Smaller muggers may stay in a big burrow previously made by a bigger mugger. There are variables of all kinds that no one has yet quantified'. During our survey we once observed an adult (possibly the mother) with 15 hatchlings (counts made by eye-shine technique) in one burrow (Figure 5 & 6).

Threats to Mugger Burrows

Illegal sand mining was seen taking place close to burrows (Figure 7). We also observed the barricading of the entrance of MB with poles and the fixing of a noose when the mugger was inside (Figure 8.) (de Silva, 2010). Additionally, we saw that during the renovation of tank bunds MB were being destroyed.

Conservation and eco-tourism

Sri Lanka is at the present time known as the world's hotspot for the mugger crocodile. Several international film companies (National Geographic, USA, BBC, Discovery, Animal Planet, etc) have produced and released TV documentaries about the mugger on channels the world over. Thus, some people would like to see the famous mugger burrows, and they could be used in eco-tourism (de Silva and Lenin, 2010). We feel that many would like to see the multi-purpose unique burrows made by an ancient group of reptiles of the world.

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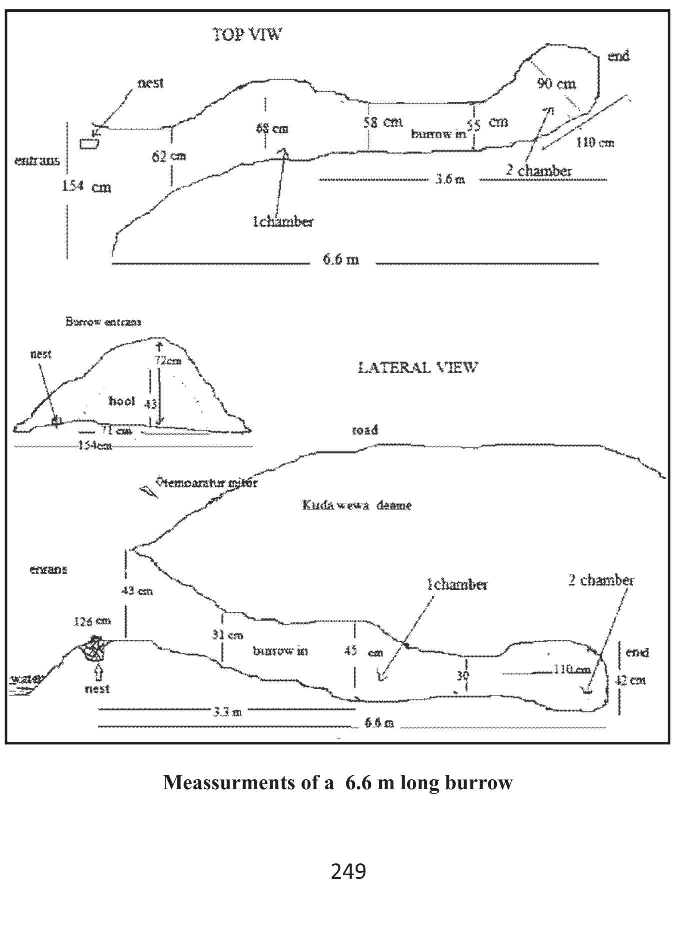

Meassurments of a 6.6 m long burrow

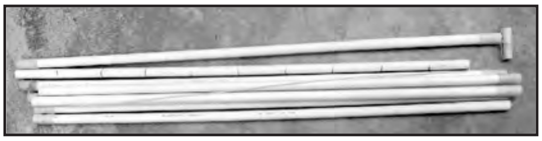

Figure. 1

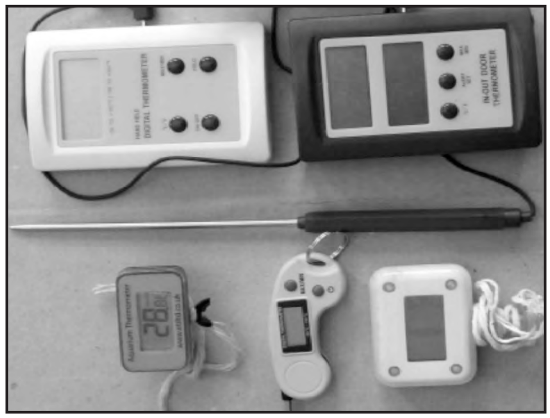

Figure. 2

Figure. 3

Figure. 4

Figure. 5

Figure. 6

Figure. 7

Figure. 8

Photographs : Anslem de Silva and Pradeep Rathnasiri

Human- crocodile conflict in Nilwala River: a social science perspective

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Interactions between humans and crocodiles in the Nilwala River were present for centuries. However, during the past decade a total of 15 fatalities were recorded and eight crocodiles were killed in response to the four human attacks, as food and for protection last year. Therefore this interaction has gradually progressed in to a conflict. The main objective of the study was: Understand the root cause of the humancrocodile conflict and find out the barriers to overcome the problem and propose recommendations to conserve crocodiles and enhance human well being in Matara. A structured questionnaire of 32 questions was developed to assess the knowledge, attitude and practices of people, additionally potential solutions developed were also included in the questionnaire. Awareness programs to schools and local government officials were also conducted. A total of 66 individuals were interviewed in six Divisional Secretariats. Majority of the respondents did not have proper knowledge about crocodiles as reported in previous studies. Sand mining was found to be a major cause of the issue changing the river physically, geologically and chemically (18 %, n=66 as per respondents). 26 % believes that a sudden population rise as the main reason for recent attacks. 68.1 % (n=66) use the river throughout the day for all purposes (42 % (n=81 responses)). 36 % believe that croc watching tours will not benefit community. 26.2 % (n=126 responses) believed more crocodile exclusion enclosures must be built and19% (n=126 responses) proposed alternate water source as solutions. Majority (86%, n=66) believe that public showers are useful and (61 %, n=66) are willing to adopt a new lifestyle without the use of the river if an alternate water source is given. A list of short term and long term rational solutions were formulated based on this study. Each numbered according to its priority. Both long term and short term solutions must be implemented imminently.

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Population assessment and status of salt water crocodiles (*Crocodylus porosus*) in Bellanwila- Attidiya Sanctuary, Attidiya, Sri Lanka

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Abstract

The study was conducted in a waterway within the Bellanwila - Attidiya Sanctuary. The canal was sectored in to two parts and was surveyed from Jan 2013 to April 2013 on randomly selected dates.. 31 individual sightings were recorded. 14 (45 %) and 17 (55 %) crocodiles were recorded in sections 1 and 2 respectively. The population density of crocodiles in the area is 5.3 (Based on the day maximum number of encounters were recorded: day 3, n=10) and the population density in Section one and two were 3.6 (n=4) and 7.79 (n=6) respectively. Average sightings per day were 6.2 day^{-1} (2.1hr^{-1}). Three (10%) hatchlings, one (3 %) juveniles, 2 (6 %) sub adults, 10 (32 %) adults and 15 (48 %) EO was recorded. 26 (84 %) were found in canals and five (16 %) in the lake. 15 (48 %) were found in shallow water near bank, six (19 %) was found in open waters and 10 (32 %) aquatic vegetation near bank.

Introduction

Two species of crocodiles: the Mugger or Marsh crocodile *Crocodylus palustris* Lesson, 1831 and the Saltwater or Estuarine crocodile *Crocodylus porosus* Schneider, 1801 are reported from Sri Lanka. The saltwater crocodile (*Crocodylus porosus*) is a highly threatened reptile in Sri Lanka existing in only a few locations that consists of proper habitat for it to thrive in. It is categorized as Endangered in the 2012 National Red List according to its distribution within the island (MOE 2012). It has only a few favoured natural habitats left, and presently most of these habitats are being cleared, altered and under pressure by human activities. The numbers of the saltwater crocodiles has been greatly reduced in Sri Lanka whereas it is more abundant in other parts of its range (de Silva, 2008). This reduction is mainly due to killing of crocodiles for its skin and mean, destruction of habitat and destruction of nesting sites.

Crocodylus porosus occur mostly in coastal areas such as Bentota, Negambo, Bolgoda, Muthurajawela, Matara, Kumana & Trincomalee. However, populations are found in Nawala and Etul Kotte (Deraniyagala 1939; Samarasinghe DJS. Pers.Obs). The present study reports the status and population of *Crocodylus porosus* within a selected area in the Bellanwila-Attidiya Sanctuary.

Study site

BAS is situated within the upper catchments of the Bolgoda river basin. The core study area is roughly 12 km x 0.5 km (nearly 372 ha), at a mean elevation of 0.6 m above sea level.

BAS area lies at the intersection of 6° 48'-52'N and 79° 52'-56' E (IUCNSL & CEA, 2006; Maduranga, 2005). This area is situated within the low country wet zone and has a tropical monsoonal climate (Gunatilleke & Gunatilleke, 1990). Mean annual temperature is approximately ~28o C and average annual rain fall for the study area is about 2800 mm (CEA / Euro consult, 1993). The study was conducted in a waterway within the Sanctuary. The canal was sectored in to two parts: Section one (1.11 km): Bellanwila - Attidiya Wild Life Department office (6˚ 50' 14.41" N 79˚ 53'28.61" E) to Attidiya Bridge (6˚50'40.46"N 79˚53'05.31"E); Section two (0.77 km): end of section one to 200 m away from Kawdana Bridge (6˚50'18.46"N 79˚52'45.57" E). Section one is relatively less exposed to human pressure than section two. Manmade structures such as houses, buildings are less encountered in section one,

Methodology

The two sections were surveyed from Jan 2013 to April 2013 on randomly selected dates. Eye shine surveys were conducted for five days (From 1930 h to 2230 h) and visual encounter surveys were conducted for four days during daytime. All surveys were conducted by foot, sampling both sides of the canal equally. Hatchlings <0.35, Juvenile 0.35-1 m, sub adult < 2 m, 2 m< as adults (Webb et al., 2010; Webb & Manolis 1989). Eyes only counts were recorded as EO. Habitats were divided into three: Canal, land and lake. Microhabitats were identified as: shallow water near bank, Open waters and among aquatic vegetation.

Results

31 individual sightings were recorded throughout the study period. 14 (45 %) individual sightings of crocodiles were recorded in section one and 17 (55 %) were recorded in section two (Figure 1) during the study period. The population density of crocodiles in the area was 5.3 km^{-1} (Based on the day maximum number of encounters were recorded: day 3, n=10). The population density in Section one 3.6 km^{-1} (n=4) and 7.79 km^{-1} (n=6) in section two. Average sightings per day were 6.2 day^{-1} (2.1hr^{-1}). Three (10%) hatchlings, one (3 %) juveniles, 2 (6 %) sub adults, 10 (32 %) adults and 15 (48 %) EO was recorded. 26 (84 %) were found in canals and five (16 %) in the lake (Figure 2). 15 (48 %) were found in shallow water near bank, six (19 %) was found in open waters and 10 (32 %) aquatic vegetation near bank (Figure 3). Eichhornia sp. was observed to spread throughout the canal mainly in section 1 during the last two days of the survey (Figure 4). A reduction of encounters was evident due to the spreading of water hyacinth (n=7, encounter rate: 1.4 day^{-1}). Several exist points of waste material (Unknown chemicals) from nearby factories were observed.

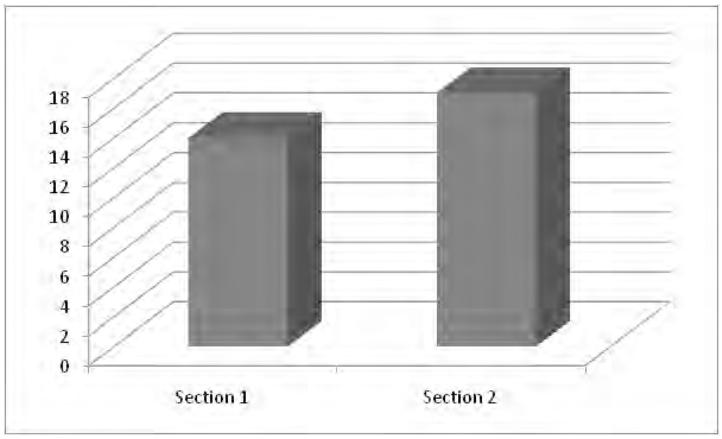

Figure 1. Total number of individuals recorded in Section 1 and 2.

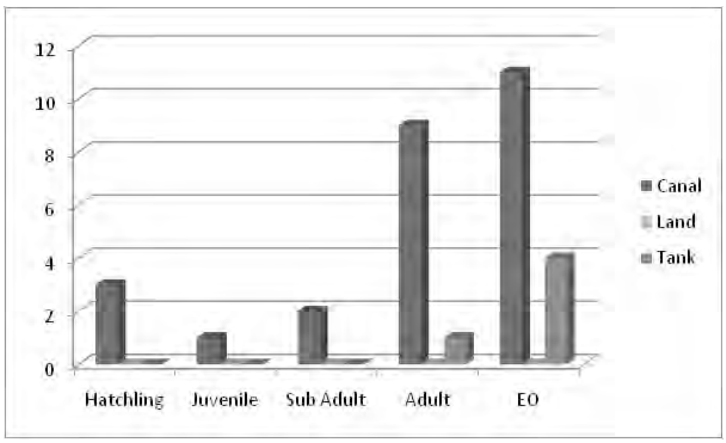

Figure 2. Habitat Selection and Age Class.

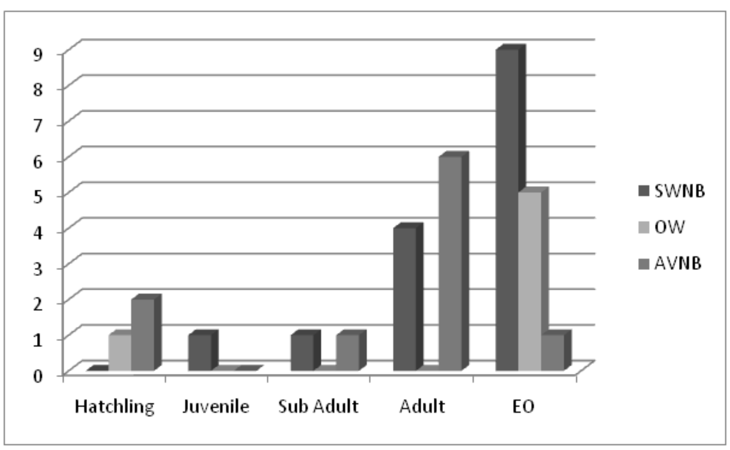

Figure 3. Micro Habitat Selection and Age Class. (SWNB: Shallow water near bank; OW: Open warers; AVNB: Aquatic vegetation near bank).

Discussion

BAS currently under massive anthropogenic pressure due to recent urban development strategies, unauthorized construction of houses, garbage dumping together with dumping of hazardous waste by nearby factories to the canal and the spread of the invasive aquatic plant water hyacinth (Figure 5 & 6). The population density in Section two is much higher when compared with section two 7.79 km^{-1} (n=6) and 3.6 km^{-1} (n=4) respectively. Section two has more anthropogenic pressure than section relatively, but the canal expands in with and one area is regarded as a high security zone, yet there are signs of dumping of waste material in to the canal.

Although crocodiles are highly adaptive to most environments, the amount of chemicals released into the canal, low flowing rate of water thus accumulating of hazardous chemicals could have a bad effect towards the crocodiles inhabiting this area. These chemicals and other toxins mix into the water especially at the beginning of the monsoon season and many large fish and water monitors are often observed dead. As crocodiles are also scavengers they could be devouring these dead carcasses, which could in return pose adverse health risks.

It is recommended that a proper mechanism is developed to remove water hyacinth periodically, and stop dumping of garbage and other hazardous waste material into the canal immediately. This could put pressure on the current population of crocodiles and suppress their distribution further inland to Weras ganga and Kiri Matta area where crocodile are present. Another threat identified was fishing using nets by villagers. Although humans do not use the canal for bathing purposes, they use the canal to harvest *Ipomoea aquatica in section one.* These people could face a threat by crocodiles.

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Figure 4. Study Area.

Figure 5. Water hyacinth spread throughout the study area.

Figure 6. Waste material and garbage dumped to the canal.

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Preliminary study on attitudes, knowledge and practices (KAP) of villagers towards conservation of crocodiles (*Crocodylus palustris*) in Ethimale Tank of Uva Province

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Abstract

A survey was formulated to study peoples' attitudes, knowledge, practices and risk perceptions towards survival of crocodiles *(Crocodylus palustris)* in the Ethimale tank at Moneragala district. A pre-tested structured questionnaire was used to collect data from 47 residents including fisherman and villagers, those who utilize the reservoir daily. The questionnaire included information on the crocodiles, their habitat and behaviour, importance and current practices of villages which affects survival of crocodiles. Knowledge and attitude were measured using knowledge and attitude indices. Data analysis was carried out by Microsoft Excel. As observed by the villagers, the number of crocodiles drastically reduced after 1983, with the damage occurred to the tank bund. Villagers practiced mass killing of the crocodiles and some were migrated to surrounding tanks in Ethimale. Intentional killing of yearlings and trapped crocodiles in fish nets and destruction of eggs to control their population, use of floating nets for fishing that attract crocodiles and illegal consumption of crocodile eggs and flesh were identified as the major threats for the survival of the crocodiles at present. Major problem for the villagers is the economical damage caused by crocodiles, by feeding on the fish catch and damaging the fishing nets. There are no incidences on direct crocodile attacks to human. Moreover, it was noted that the villagers possess moderate awareness on crocodiles including their behavior, measures to escape once a crocodile had attacked, and their importance as a part of the ecosystem. Around 40% provided positive responds on crocodile based eco-tourism, if enough protective measures are followed. Though, the need for conservation of the crocodiles is identified by the villagers (71%), their precedence for living does not allow practicing conservation measures. Hence, it can be concluded that crocodiles are under threat in the area and conservation initiatives need to be taken immediately to prevent them from extinction.

Introduction

The largest wild mugger crocodile (*Crocodylus palustris*) population inhabits in Sri Lanka, especially in inland reservoirs, tanks, river (Stacy and Whitaker, 2000). However, habitat destruction and fragmentation due to population growth leads to reduce the mugger crocodile population from their natural habitats. Ethimale reservoir which located in Moneragala district is known to occupy considerable number of mugger crocodiles. Area of the reservoir is 1850 acres and used for inland fisheries extensively. Therefore, it may cause a threat to the survival of crocodiles which inhabit the reservoir. Hence, this study was formulated to study peoples' attitudes, knowledge, practices and risk perceptions towards survival of crocodiles (*Crocodylus palustris*) in the Ethimale tank at Moneragala district.

Methodology

Knowledge, Attitude and Practices (KAP) of respondents towards crocodiles were assessed using a pre-tested structured questionnaire. Data were collected from 47 residents including fisherman and villagers, those who utilize the reservoir daily to understand the nature of interaction of residents with crocodiles.

Knowledge and attitude were measured using knowledge and attitude indices. Knowledge was measured by collecting information on the crocodiles, including approximate size, breeding pattern, their habitat, behaviour, importance and folk believes. Current situation of human crocodile conflict (number of crocodile attacks, damage incurred and reaction towards offending crocodile) and practices of villagers which aggravate the conflict were assessed based on the observations and information gathered from respondents. Attitude of the respondents were assessed based on the solutions suggested by them to solve the human crocodile conflict. Furthermore, their attitude on the necessity of conservation initiatives for crocodiles was evaluated. Finally, the potential to use crocodile based ecosystems for eco-tourism was studied. Data analysis was carried out by Microsoft Excel.

Results & Discussion

According to the observations of the respondents, there are around 70 to 100 crocodiles inhabit the reservoir and average length of an adult crocodile is 6-7 feet. Their habitat is shallow water less than 10 feet. Respondents have observed the crocodiles on the ashore specially during morning (6-7 a.m.) and evening (6-8 p.m.). Furthermore, they migrate away from the human territory during November to February where the highest rainfall was experienced in this area. Breeding is taking place predominantly during the dry season (August) and they lay eggs in the sandy tank bunds. People have seen foot long hatchlings during September and October. Major predators for hatchlings are *Varanus bengalensis* (Monitor) and *Varanus salvator salvator* (Water monitor).

Among the respondents, the major group who interact with the crocodiles were fishermen, representing 80% of the sample. Though, there are no incidences on direct crocodile attacks to human, economical damage caused by crocodiles (by feeding on the fish catch and damaging the fishing nets) was identified as the major problem for the fishermen. Conversely, fishermen use floating nets for fishing which attract crocodiles to the fish catch aggravating the conflict. As observed by the villagers, the number of crocodiles drastically reduced after 1983, with the damage occurred to the tank bund, due to migration and mass killing of crocodiles. At present, intentional killing of yearlings and trapped crocodiles in fish nets, illegal consumption of crocodile eggs and flesh were identified as the major threats for survival of them and consequently the population is declining day by day.

Though, the need for conservation of the crocodiles is identified by the respondents (71%), their precedence for living does not allow practicing conservation measures. However, 60% of fishing community suggested that immediate actions should be taken to solve the problem and one of their major suggestions was capturing and translocation (Figure 1).

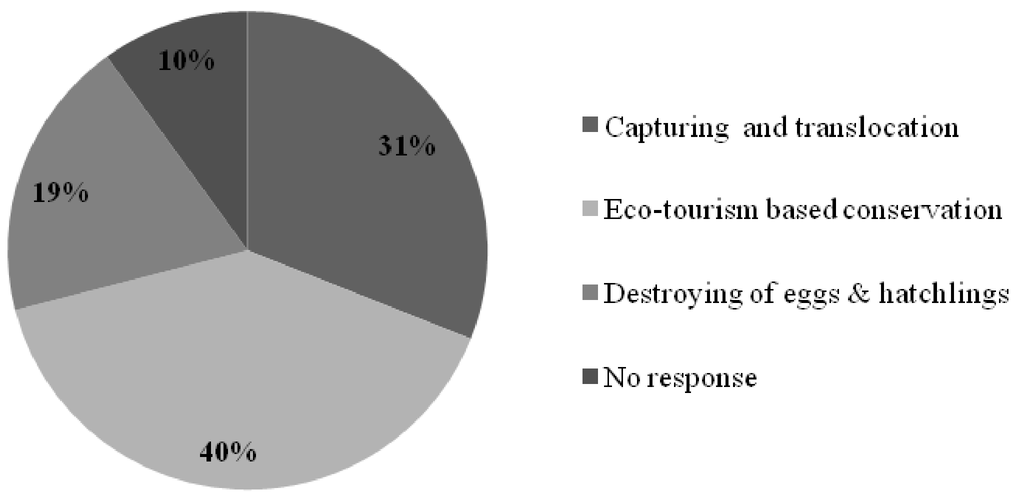

Figure 1: Proportion of responses to solve the human crocodile conflict in Ethimale tank

Around 40% provided positive responds on crocodile based ecotourism, if enough protective measures are followed. Since, both parties are mutually benefitted, this can be identified as a potential measure to solve the human crocodile conflict.

Conclusion

It can be concluded that crocodiles in Ethimale tank are threatened by the human activities, and conservation initiatives need to be taken immediately to prevent them from extinction. Since, the villagers possess a positive attitude towards conservation of crocodiles there is a possibility to implement a conservation strategy.

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Preliminary observations of the status of crocodiles and peoples attitudes towards crocodiles in the northern province of Sri Lanka

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Most of the northern parts of Sri Lanka are poorly investigated for crocodiles during the past half a century due to over 30 years of civil conflict in the north of the country. However, there are reports of the presence of the mugger dating back to 1852. As such, a study was designed to investigate the status of crocodiles inhabiting the Northern Province which is a part of the ongoing crocodile survey of Sri Lanka. The Northern Province consists of 5 administrative districts namely Jaffna, Kilinotchchi, Mullativu, Vavuniya and Mannar. Each district was visited several times and preliminary investigations were carried out from May 2010 to January 2013. These investigations were carried out first to check for crocodiles and then to assess the knowledge and attitude of people regarding crocodilians by administered a structured questionnaire. The presence of crocodiles were checked by investigating the scats, foot prints, drag marks during the day and night counts using 'eye shine' technique. Approximately ten tanks and part of the Jaffna estuary were investigated in Jaffna of which evidences such as foot marks, osteoderms and scats were collected. During the survey period we did not come across any crocodile bite victims in Jaffna district. However, in Vauniya several crocodile bite victims were interviewed and mugger burrows were also observed in two tanks. In Mannar, muggers including both live and killed specimens were observed. Examinations of exhumed adults from Mannar island indicated people do not eat crocodile flesh in Mannar island, where as around Giants tank many crocodiles have been killed for flesh. In Jaffna out of 71 people interviewed, 86% had no idea of the importance of crocodiles, 21% aware of crocodiles and said crocodile killing were done because of attacks and 14% said they would not support conservation initiatives towards crocodiles. Our preliminary investigations suggest that there is an appreciable mugger population in many unexplored areas of the Northern Province. However because of the resettlement activity in this part habitat reduction and crocodile kills are noticed. Thus it is felt that the people must be informed about the important ecological roles played by crocodiles as well as to install crocodile exclusion enclosures for the people to carry out their routine activities.

Using traditional knowledge to minimize human-crocodile conflict in Sri Lanka

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With the exponential increase of human populations due to large--scale agricultural and human settlement projects over the past half century, the number of humans and livestock using natural water bodies in the dry zone of Sri Lanka has increased significantly. Water bodies in these areas are also inhabited by mugger crocodiles (*Crocodylus palustris*)- the top predators of the ecosystem. This sharing of an essential, but a limited resource has resulted in an increase of 'Human-Crocodile Conflict' (HCC).

Traditionally (and till present day), Crocodile Excluding Enclosures (CEEs) have been used by people in the southern wet zone of the island where humans frequently use waters inhabited by saltwater crocodiles (*C. porosus*). CEEs are simple devises where three sides are fenced with wooden poles. However (surprisingly), CEEs are not in use in most parts of the dry zone where large populations of muggers exists and pose a serious medical concern through attacks (minor to grievous, including deaths) annually.

This study fulfilled three objectives: 1) it identified three regions covering over 10 villages with a considerable HCC and, with the help of the communities, introduced and installed CEEs to physically segregate the two components humans and muggers; 2) undertook two 'Knowledge Attitude and Practice' surveys, one pre construction and the other six months post-construction (100 participants each) to measure the success and understand limitations; and 3) conducted concurrent awareness programmes to upraise the understanding of crocodiles among the lay public.

The study indicates that building physical barriers to segregate the two components and concurrent development of a positive attitude towards crocodiles through awareness programmes are effective actions in reducing the HCC in Sri Lanka. The results show that there is a significant increase in the frequency and duration of use of water resources by villages and also a positive attitude change towards crocodiles. No crocodile attacks on humans or killing of crocodiles by humans were reported from the areas since the CEEs were installed, where as three crocodile attacks (one fatal) and at least seven crocodile deaths have been reported the year before.

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A view on saltwater crocodile *(Crocodylus porosus)* captured from anthropogenic habitats in western province, Sri Lanka

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Abstract

Over the past few years there has been a dramatic increase in the media attention to humans and domestic animals that have been attacked by Salt water crocodiles. Although it has not received equal attention, many Salt water crocodiles have also been killed by humans. In-between there are many instances that crocodiles were captured from the residential areas and relocated to suitable habitats with the involvement of the Dept. of Wildlife Conservation (DWC) and other conservationists. Among the 16 specimens captured by the DWC during the past 2 years, 14 were males. Among these animals, there was one instance where the crocodile died due to the wounds caused by a hook, which was used to hunt the animal using bait by the locals. There have been several reports of this occurring elsewhere, and the animals have died before rescue was possible. The other crocodiles that were captured were released back to the National Parks such as Yala and Bundala and to sanctuaries such as Muthurajawela.

Introduction

The Saltwater Crocodile (*Crocodylus porossus*) also known as Salties or Estuarine crocodiles. The Salt water crocodile is one of the 23 species belonging to family Crocodylidae. Globally distributed in a wide area, this species is considered as the largest species of the Crocodiles (Deraniyagala, 1936,Ross,1989; Alderton,1991,). It is also the world's largest living reptile in terms of mass. Adult males can reach sizes of up to 6 meters (20 feet) with possible reports of exceptionally rare individuals of nearly 7 metres (23 feet). However, the largest confirmed individual was measured as 20.7 feet (6.3 metres) taking into account partial tail loss (Whitaker, R & Whitaker, Z: 1998)

They are recorded in South and South-East Asia, Northern parts of Australia, Philippine Islands, Papua New Guinea, Solomon Islands, Vanuatu and Palau (Alderton,1991; Stuebing et al., 1994). There are many instances that even 9m crocodiles have also been reported in the latter part of the 19th century.

Female Saltwater Crocodiles reach sexual maturity at lengths of 2.2 to 2.5 m (10 to 12 years old). Males mature later (3.2 m, at around 16 years old). Females on average lay 40 to 60 eggs (this can range from 25 to 90) in mound nests made from vegetation (usually grasses and vines) and mud. Breeding territories are usually established along tidal rivers, creeks and freshwater areas. These are normally constructed between the months of November and March during the wet season, but this varies slightly geographically. The mound helps to insulate the eggs from temperature extremes, hides them from predators, stops them from dehydrating, and also serves to raise the eggs above the ground to minimize the risk of flooding.

Background

Within the last few years there has been many instances that the humans, live stocks and dogs were attacked by the Salt water crocodiles. It was revealed by a survey done in 2010 associating more than 100 water bodies that about 130 persons were attacked with 35 fatalities. About 80 per cent of them were attacked while they were bathing and washing clothes in tanks. Conversely over 50 crocodiles were killed by the locals in revenge and as a measure to prevent future attacks. In 2011, there had been 25 deaths due to crocodile attacks, in the island but in 2012, it was very few. However both parties of crocodiles and humans are affected by these incidents.

Western province, in Sri Lanka is the most urban region and still records crocodile in residential areas each year. All these records are of the Salt water crocodiles. The Dept. of Wildliffe conservation and other groups of concervationalists involve in capturing the crocodiles with the help of the public . It is a good trend that the public is engaging in reporting the authorities and even capturing them unharmed to hand over to them. However it is still reports that few crocodiles killed by humans using baits.

Earlier there are incidents that the crocodiles were shot to death. Since the leagal issues came in to paly the method of killing the crocodiles is changed. The most common way is using a dead dog or beef as the bait. There was one instance reported, that two hooks joint as a "Y" with a cable to hunt the crocodile. When the crocodile got caught, it was managed to free itself from one hook by pulling. The wounded crocodle was captured by the DWC, and trired to remove the swallowed hook. Unfortunately the crocodile died due to septic wounds and it was revealed in the post motum, the internal organs such as the lever and the intestines were torn while the crocodile was trying to escape. Other method of killing crocodiles are poisoning them, or beating them to death after capturing them using traps.

Captured Areas

Ten individuals were captured from Weres ganga (canal) and other water bodies attached to it. Three crocodiles were captured inside the houses and which were also closer to the canal. There was one instance that the crocodile was caught in fishing net and another was found stucked in a drain (Chart:01) , (Map:01)

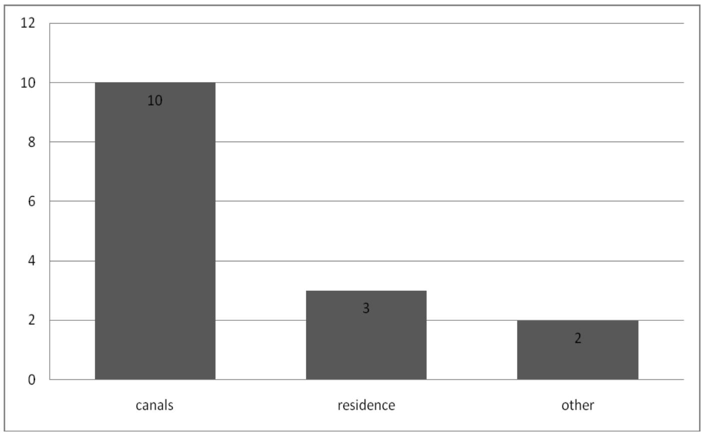
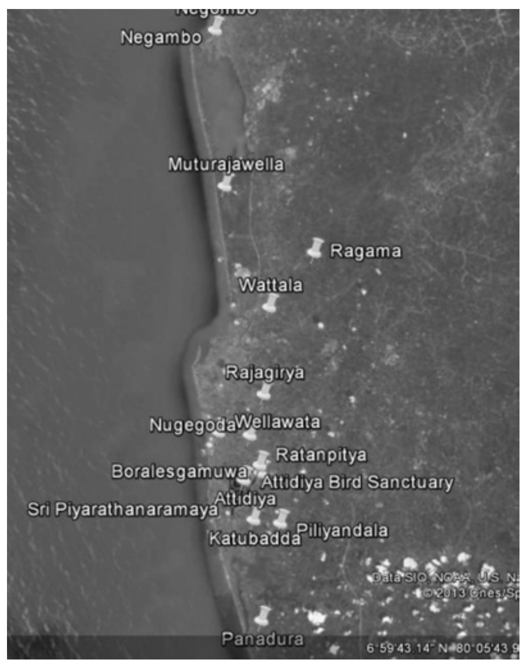


Chart 01 : The Habitat Types That The Crocodiles Were Captured.

From the 16 specimens those were captured and released, 14 were males and only 2 were females. This situaton can be justified as a territory issue since Salt water crocodile is a very terrestrial species. Sub adults males may be chased away by the larger males and due to scarcity of food sources; they may tend to attack humans and livestocks.

Suggestions

Relocating the animal is not the ideal solution to solve the human-crocodile conflict. It only brings out a temporary releaf to the affected people. The Western Province of Sri Lanka belongs to the low land wet zone. If an animal is relocated, that new habitat also should belong to low land wet zone. Muthurajawela is a suitable habitat for Salt water crocodiles. Since the land area of Muthurajawela is not sufficient enough to accommodate many larger crocodiles, due to territory problems it is not the first option of the DWC to release the crocodiles. There is a need of a proper relocation area for the captured crocodiles. Not only a crocodile's sanctuary, but also a rehabilitation center for crocodiles also needed. . The distance from the capturing area should also be considered when transporting the crocodile. Many crocodiles captured had wounds and were treated in the National Zoo. Some of the crocodiles released were handicapped ones, which made it more vulnurable for them to survive in the wild. Specially Yala and Bundala, the National parks situated in the dry zone, has a very large population of Marsh crocodiles (*C. palustris*). On the other hand, Bolgoda river and Muthurajawela marsh lands can provide suitable habitats, but urbanization and the land size restrict the number of Salt crocodiles can live in the area (Chart:02).



The locations which the crocodiles were captured. (Map :01)

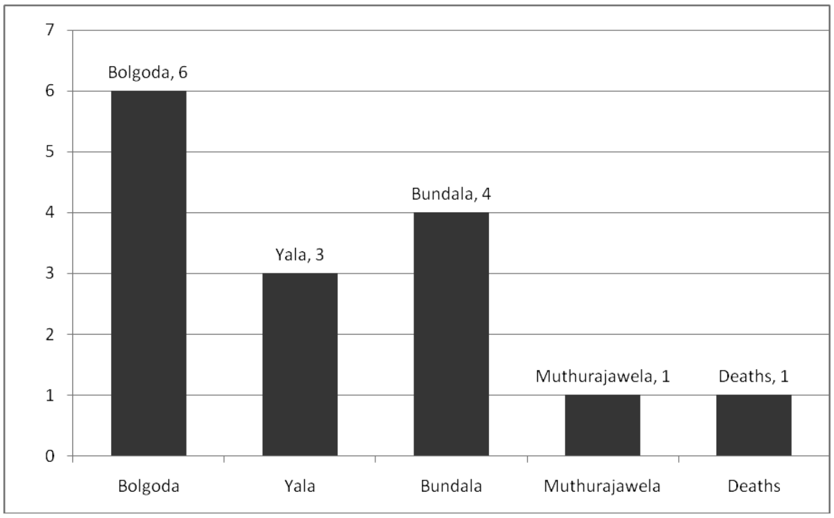


Chart 02: The Locations The Crocodiles Were Released

Since there had not been proper researches done on the home range of male and female crocodiles it is essential that these kind of investigations to be done. It is important using modern tracking techniques for this purpose. Tagging of the captured and relocated crocodiles can be easilly done .If those individuls can be monitored valuable informatin can be gatherd about the behavior   of these animals, or whether they were really able to survive in their new habitat. More data is needed of both sexes, not only the captured animals, but also the other crocodiles in wild habitats and of different sizes.

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Challenges for current Red List assessments for Crocodilians

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The IUCN Red List is the definitive global evaluation of threatened species. Most crocodilian Red List assessments date from 2002 and re-assessment of the status of many crocodilians is overdue. Species categories and criteria are based on IUCN Red List categories and criteria version 3.1 (2001) and conducted by teams of CSG species experts coordinated by the Red List Authority. Since 2012, new assessments have been completed on two species and are underway or planned for six more. The completed assessments must be reviewed by CSG members and steering committee and approved by the Chairman, then submitted to IUCN for inclusion in the updated list.

Changing crocodilian taxonomy driven by new genetic and morphology studies provide a challenge for assessments. Recent work indicates a number of currently recognized species probably include cryptic species not previously recognized. There is sound evidence that the populations of *Crocodylus niloticus* occurring in western and central Africa are distinct at the species level (Hekkala et al 2011). *Osteoleamus* is now thought to include *O. tetraspis*, a revived *O. osborni* and possibly a third unnamed taxon (M. Eaton pers comm. and in prep.). *Mecistops cataphractus* appears to be two taxa (M. Shirley pers comm. and 2013) and the division of *C. noveaeguineaea* first suggested by Phil Hall and Andy Ross (Hall 1989) is supported by genetic information (Gratten 2003). Doing global Red List assessments of currently recognized species may obscure or conflate different conservation status of cryptic taxa. However, current legal protections such as CITES and national laws may be destabilized by premature changes of unrecognized or informal taxa. To address this, the CSG Red List authority is in discussion with species experts, taxonomic experts and Red List staff to ensure orderly modification of the list of species for Red Lists assessment. To begin, we have added the new, west African *Crocodylus* to enable drafting an assessment of that taxon separate from *C. niloticus* of eastern and southern Africa.

Additional challenges to assessments are generated when the uncertainty of data allow different interpretations of status. For example, a recent assessment of *C. palustris* proposed its Vulnerable status based upon recent decline. However there is uncertainty about the population size (mature adults worldwide). If that number is less than 2,500 and the species is thought to be in decline- it might qualify for Endangered under criterion C 2 a i, However if they are not declining or if the adults population exceeds 2500 then the status is Vulnerable A 2acd (IUCN 2001). Resolving this uncertainty by a consensus 'best estimate' of population numbers will allow finalization of this assessment.

Assessments undertaken since the last CSG Working Meeting 2012 are summarized here:
Crocodylus siamensis **CR-Critically Endangered A2 cd**. Reduction in population size ≥80% over the last three generations (75 years) inferred due to c. decline in area of occupancy and d. actual levels of exploitation.
Tomistoma schlegelii **VU A 2 c**. **Vulnerable** Populations have been reduced, by over 30% in the past 75 principally due to continuing loss and fragmentation of swamp forest and many documented populations are small, fragmented. The change to Vulnerable reflects a more accurate assessment based on survey data which was not available at the time of the first assessments (CSG 2000).

Crocodylus mindorensis **CR A2 c d**. **Critically Endangered**, declines in the last 75 years. In final review**,** *Crocodylus palustris* **VU or EN??** -. Under review**,** *Crocodylus niloticus* (East and southern Africa) in progress*, Crocodylus sp. Nov* (west and central Africa) in progress*, Osteoleamus tetraspis* in progress*, Mecistops cataphractus* in progress

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Captive populations of Tomistoma in Taiwan

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There are 77 individuals (18 males and 59 females) of Tomistoma,*Tomistomaschlegelii*, in seven different units in Taiwan. Among them, Longqun Crocodile Farm, Chaiyi has largest captive population including 15 adult males and 28 adult females. The body size of Some males Tomistoma in Longqun Crocodile Farm may exceed six meters, maybe the largest captive individuals in the world. Taipei Zoo signed an agreement with Longqun Crocodile Farm to cooperate the conservation of Tomistoma. We successfully sampled 12 individuals and analyzed their genetic diversity. Five haplotypes were found among 12 samples, at least three haplotypes are different from the previous studies. The serious problem of captive population of Tomistoma in Taiwan is ageing, most of them are near 30 years old.

Plastination of crocodiles for veterinary education

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Historically taxidermed specimens were used to demonstrate reptilian morphology. In the 1970s plastination techniques to replace tissue fats and water by liquid curable polymers were developed by Gunther von Hagens. Once hardened, these specimens retain the anatomical characteristics of the original specimen but do not decompose or smell. Consequently we routinely use plastinated specimens to teach reptilian gross anatomy. To plastinate small crocodilians we follow the methodology based on using the specifically developed silicon polymer Biodur S10 (von Hagens, 1985). Here specimens are kept in fixative for at least four weeks to ensure tissue stabilization. This is followed by dehydration using ascending concentrations of acetone at -25°C to remove tissue water. Next, fats are removed by solvents, acetone or methylene chloride, at room temperature for a short time. Then the specimen's volatile solvents are replaced by submerging the specimen in a miscible curable silicon polymer (S3) bath under a vacuum starting at 7.5 mm Hg which is increased slowly over 3-4 weeks to 0.5 0 mm Hg. A subsequent fixation period of >24 hours at standard pressure for tissue relaxation is recommended. The specimen is removed from the silicone bath and allowed to slowly warm up to 25°C with as much silicone inside the specimen as possible to limit shrinkage. Minor changes to limb positioning can be done at this stage. Subsequently, the specimen is placed in a curing gas (S6) atmosphere to facilitate polymer reactions and ultimate hardening of the specimen. Regular removal of excess silicone is necessary. Drying in a closed tank afterwards is essential. Overall we have found that plastination produces excellent robust specimens that students can handle with little chance of damaging them.

Teaching anatomy and histology of crocodilians

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In Europe and North America current veterinary graduates have a broader range of employment opportunities, many of which include wildlife, than ever before. This has been driven, in part, by the marked increase in the personal ownership of exotic pets of which reptiles are a significant component. The demands for excellent veterinary care for this diverse group of animals had grown commensurately. Consequently the need for the inclusion of basic anatomical and histological training of non-domestic animals including reptiles, birds, amphibia and fish has grown dramatically for our current veterinary medicine undergraduates. To accommodate this demand our Institute of Veterinary Anatomy at the Freie Universitaet in Berlin, has introduced a compulsory course for our undergraduates to study the functional morphological characteristics of these groups of animals including crocodilians. The course curriculum involves gross anatomical studies of skeletal and plastinated specimens as well as histological specimens prepared by our institute. The characteristics of the crocodilian musculoskeletal, digestive, urinary and reproductive systems are each covered in depth. Details of cardiovascular and pulmonary systems, sense organs, skin, hematology, as well as radiography are also explored. Powerpoint presentations are based on only a few books and journal articles on anatomy and histology of crocodilians as such literature is limited. A few websites provide additional information on specific aspects of crocodilian anatomy. Whenever possible we endeavour to have our students gain experience with live crocodilians held in veterinary clinical institutions as well as by excursions to zoological institutes.

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Chemical composition of Siamese Crocodile (*Crocodylus siamensis*) egg yolk

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Abstract

The 23 unfertilized crocodile eggs were collected from captive mature female Siamese crocodiles. The yolks were separated and freeze-dried before analysis of their chemical composition, including fiber, fatty acids, amino acid profile and the inorganic substances as potassium, phosphorus, selenium, vitamin-D3, and vitamin-E. The results of chemical composition were discussed. The fresh and freeze-dried egg yolks were studied for their protein patterns compared with hen and duck egg yolks. These protein samples were separated by SDS-PAGE in condition that containing beta-mercaptoethanol reducing agent. The optimal concentration of polyacrylamide in the separating gel was 7.5% (w/v). The SDS-PAGE protein pattern of crocodile egg yolk was different from hen and duck egg yolks. In addition, there was no difference in protein pattern between the fresh- and freeze dried- crocodile egg yolks. The crocodile egg yolk contained major proteins in 233, 110, 88, 78, 66, 47 and 35 kDas. These findings can be useful as crocodile egg database for sustainable uses and value added as functional food in the future.

Introduction

Siamese crocodile (*Crocodylus siamensis*) is an important economic animal in Thailand. The crocodiles lay high eggs per year which 40% are unfertilized eggs. Only 10% of this unfertilized egg was consumed. In order to evaluate the potential use of unfertilized Siamese crocodile eggs as a source for human and animal food products, their yolk fraction was studied on chemical composition and protein pattern. The data from this study may be guide lined for value adding of crocodile egg in supplementary or functional food industry.

Materials and Methods

Egg samples: Twenty three of captive Siamese crocodile (*Crocodylus siamensis*) unfertilized eggs were collected from Rungtaweechai Crocodile Farm, Don Toom District, Nakhonpathum Province, Thailand. The three of hen (chicken) eggs and duck eggs which purchased from Luang Suwan Vajokkasikij Egg Farm, Kasetsart University and a supermarket (Tesco Lotus Supermarket, Nontaburi branch, Thailand), respectively, were used in protein pattern analysis. The eggs were kept at 4°C in a refrigerator until used.

Egg yolk preparation: The eggshells were broken by hand, the white fraction was manually removed and the yolk was collected into microtubes using syring. These yolk fractions were prepared in two parts (fresh and freeze-dried parts) for protein pattern analysis. The remaining of crocodile egg yolk was weighted and then freeze-dried using freeze- dryer (Lyomaster, USA). After drying, the dried crocodile egg yolk was weighted, kept in sterile container and stored at 4°C for its chemical composition analysis.

Chemical composition analysis: The freeze- dried crocodile egg yolk was determined for its chemical composition as following. The total carbohydrate, protein (factor 6.25), saturated fatty acids, unsaturated fatty acids and cholesterol were examined by principle analyses of Thai Compendium of methods for food analysis, 1st ed. 2003. The tested inorganic substances as potassium, phosphorus, selenium, calcium, vitamin-E, -D3 (by principle analyses of Thai Compendium of methods for food analysis, 1st ed. 2003) were determined. The amino acid profile was analysed by Gas Chromatography/ HPLC (In house method based on J. Assoc. Off. Anal. Chem. Vol. 72. No.6. 1989)

Protein pattern analysis: Hen yolk (HY), Duck yolk (DY), Crocodile yolk (CY) and Freeze-dried CY (CYF) were homogenized with a homogenizer (Omni, USA.) at low speed for 30 seconds. The homogenates were diluted (1:100) with water and aliquot for Sodium Dodecyl Sulfate-Polyacrylamide Gel Electrophoresis (SDS-PAGE) - sample buffer containing beta- mercaptoethanol reducing agent. SDS-PAGE was used for protein separation with separating gels (7.5%) and stacking gels (4%) at a constant current of 20 mA using a Compact-PAGE apparatus (Atto, Japan) followed by Coomassie Brilliant Blue R250 (CBB) staining. The protein patterns were recorded by gel document system (Gel Doc XR System, BioRad., USA). The protein band molecular weight was determined and compared using Quantity One 1-D Analysis Software. (BioRad, USA).

Results and Discussion

The mean width and length in centrimeter of Siamese crocodile eggs used in this study were 4.67 and 7.94, respectively. In addition, the mean weight of crocodile eggs yolk was 61.47 grams. The chemical composition of freeze- dried crocodile yolk was shown in Table 1. The high amount of vitamin- E and phosphorus were found in Siamese crocodile egg yolk (14.11 mg/100 g and 1,209 mg/100 g, respectively). The CY has high nutritive value more than hen egg yolk such as Oleic acid (HY~10.78 g/100g sample) Vitamin D3 (HY~5.4 ug/100g sample) and Glutamic acid (HY~1970 g/100g sample) (Mamara and Donald, 2003). But the CY has higher cholesterol than hen yolk (424 mg/100g) (USDA nutrient database, 2007). Amino acid profile of the yolk tested by Gas Chromatography/ HPLC was shown in Table 2. The top five amounts of amino acids were Glutamic acid (4665.37 mg/100g), Serine (4062.57 mg/100g), Aspartic acid (3595.95 mg/100g), Leucine (3247.37 mg/100g) and Arginine (2349.82 mg/100g), respectively. Amino acids in the least three amount were Tryptophan (495.07 mg/100g), Methionine (832.36mg/100g) and Cystine (852.29 mg/100g), respectively.

Table 1. The chemical composition of Siamese crocodile egg yolk

Substance	Amount	Unit
Carbohydrate	9.61	%
Protein	43.78	%
Cholesterol	855.57	mg/100g
Unsaturated fatty acid		
Palmitoleic acid (C16:1)	2.02	g/100 g
Oleic acid (C18:1,cis-9)	12.57	g/100 g
Linoleic acid(C18:2,cis)	5.61	g/100 g
Erucic acid (C22:1)	0.50	g/100 g
Docosahexaenoic (C22:6n3)	0.07	g/100 g
Saturated fatty acid		
Myristic acid (C14:0)	0.15	g/100 g
Palmitic acit (C16:0)	10.19	g/100 g
Stearic acid (C18:0)	1.88	g/100 g
Fiber		
Insoluble Dietary Fiber	32.71	%
Soluble Dietary Fiber	1.80	%
Dietary Fiber	34.51	%
Potassium	485.45	mg/100 g
Phosphorus	1,209	mg/100 g
Selenium	0.47	mg/100 g
Vitamin- A	14.11	mg/100 g
Vitamin- D3	87.38	mg/100 g

The crocodile egg yolk was determined for it protein pattern by SDS-PAGE in the separating gel was 7.5% (w/v). The results demonstrated its protein (CY/ CYF) pattern was different from hen (HY) and duck (DY) egg yolks (Figure 1). However, the protein patterns between the fresh- and freeze dried- crocodile egg yolks were not difference. The crocodile egg yolk contained major proteins in 233, 110, 88, 78, 66, 47 and 35 kDas. Chicken egg yolk presents protein bands at 105, 83, 79, 60-70, 46, 32 kDas that are apo-HDL, γ-livetin, apo-HDL, γ-livetin, apo-HDL, Phosvitin and apo-HDL, respectively (Amanda *et al*., 2009). A crocodile egg yolk protein band with molecular weight of 47-kDa had molecular weight closely to hen egg yolk phosvithin protein. However, the crocodile egg yolk proteins need to be analyzed with high advanced proteomic methods for more information. The results in this study demonstrate the protein and amino acid identities of Siamese crocodile egg yolk. These may be useful for the egg yolk value adding and functional food application.

Table 2. Amino acid profile of Siamese crocodile egg yolk

Amino acids	Unit (mg/100g)	Amino acids	Unit (mg/100g)
Alanine	2190.19	Lysine	2089.13
Arginine	2349.82	Methionine	823.36
Aspartic acid	3595.95	Phenylalanine	1639.56
Cystine	852.29	Proline	1931.87
Glutamic acid	4665.37	Serine	4062.57
Glycine	1376.26	Threonine	1874.88
Histidine	1016.29	Tryptophan	495.07
Isoleucine	1221.44	Tyrosine	1620.77
Leucine	3247.73	Valine	1486.52

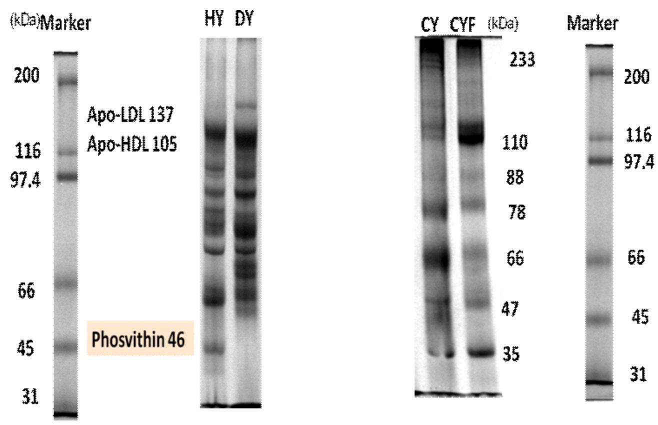

Figure 1. Egg yolk fraction protein patterns of hen yolk (HY), duck yolk (DY), Siamese crocodile yolk (CY) and freeze-dried CY (CYF). kDa: molecular weight in kilodalton ; Marker: Protein standard marker

Acknowledgments

We appreciate Rungtaweechai Crocodile Farm and Wani Thai Limited Partnership for unfertilized Siamese crocodile eggs and technical assistance. P.P. & M.K. were granted fby Department of Zoology. P.P. was supported by grants of Science Achievement Scholarship of Thailand (SAST) and Faculty of Science- Undergraduate Special Problem Matching Fund.

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Protein pattern and amino acid profile of Siamese Crocodile (*Crocodylus siamensis*) egg white

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Abstract

Siamese crocodile (*Crocodylus siamensis*) has been considered as an economic animal of Thailand. The mature female lays 20-50 eggs per year which 60% of total eggs are fertilized and 40% are unfertilized eggs. Egg is a good source of proteins and amino acids. However, data of protein in Siamese crocodile eggs has been limited. For guidelines on the usage of unfertilized crocodile egg white in the future, twenty-three crocodile eggs were collected and determined protein pattern and amino acid profile. The results revealed that Glutamic acid was the most abundant in crocodile egg white (6776.76 mg/100g), followed by Aspartic acid (5291.08 mg/100g), Serine (4768.03 mg/100g), Leucine (4602.48 mg/100g) and Lysine (3277.45 mg/100g). The three minor amino acids are Tryptophan (561.87 mg/100g), Methionine (988.52 mg/100g) and Histidine (1386.67 mg/100g). The protein patterns were studied by sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) in the condition that containing mercaptoethanol reducing agent. The concentration of polyacrylamide in the separating gel was 7.5% (w/v). The SDS-PAGE patterns of fresh crocodile egg white were not difference with freeze-dried process, which showed six bands of protein with molecular weight 231.8, 175.4, 135.5, 91.3, 65.1 and 37.2 kDas.

Introduction

The commercial products of crocodile such as skin, meat, internal organs, blood, *etc*. In Thailand, freshwater Siamese crocodile (*Crocodylus siamensis*) is an economic animal. Only 60% of the crocodile eggs ever hatch. The remaining infertile crocodile eggs have not been use. Eggs have well known to be a good source of high-quality proteins, completely has essential amino acids especially in egg white. Due to a lack of research on nutritive value of Siamese crocodile egg, the protein pattern and amino acid profile of the crocodile egg white were studied for its utilization.

Materials and Methods

Egg samples: Captive Siamese crocodile, *Crocodylus siamensis*, 23 unfertilized eggs were collected from Rungtaweechai Crocodile Farm, Don Toom District, Nakhonpathum Province, Thailand. Chicken eggs (n= 3) and duck eggs (n= 3) which purchased from Luang Suwan Vajokkasikij Egg Farm, Kasetsart University and a supermarket (Tesco Lotus Supermarket, Nontaburi branch, Thailand), respectively, were used in protein pattern analysis. All eggs were stored at 4°C in a refrigerator until used.

Egg white preparation: After using hand for eggshell breaking, the egg white part was manually removed by syring into microtubes. The fresh and freeze-dried parts of white fractions were prepared for protein pattern analysis. Moreover, the crocodile egg white was weighted and freeze-dried in a freeze- dryer (Lyomaster, USA). The freeze- dried crocodile egg white was weighted, kept in sterile container and kept at 4°C until chemical composition analysis.

Protein pattern analysis: Homogenization of chicken or hen white (HW), duck white (DW), crocodile white (CW) and freeze-dried CW (CWF) were performed using homogenizer (Omni, USA.) at low speed for 30 seconds. The homogenates were diluted (1:100) with water and aliquot for Sodium Dodecyl Sulfate- polyacrylamide gel electrophoresis (SDS-PAGE) - sample buffer in reducing condition with beta- mercaptoethanol. Protein separation was done by SDS-PAGE (7.5% separating gels and 4% stacking gels at a constant current of 20 mA) with a Compact-PAGE apparatus (Atto, Japan). The gel was stained with Coomassie Brilliant Blue R250 (CBB) and protein pattern was observed via a gel document system (Gel Doc XR System, BioRad., USA). The molecular weight of protein bands was analysed using Quantity One 1-D Analysis Software. (BioRad, USA).

Results and Discussion

In this study, Siamese crocodile eggs had 4.67 cm mean width and 7.94 cm length. The mean weight of crocodile eggs white was 31.69 g. Amino acid profile of the white examined by Gas Chromatography/ HPLC was shown in Table 1. Glutamic acid was the most abundant in crocodile egg white (6776.76 mg/100g), followed by Aspartic acid (5291.08 mg/100g), Serine (4768.03 mg/100g), Leucine (4602.48 mg/100g) and Lysine (3277.45 mg/100g). The three minor amino acids were Tryptophan, Methionine and Histidine, which was 561.87 mg/100g, 988.52 mg/100g and 1386.67 mg/100g, respectively. The quantity of major amino acids in crocodile egg white were lower than hen egg white (FAO, 1970) which comprising of Glutamic acid (10,890 mg/100g), Aspartic acid (6,090 mg/100g), Serine (6,070 mg/100g), Leucine (6,800 mg/100g) and Lysine (4,640 mg/100g). The crocodile egg white was determined for it protein pattern by SDS-PAGE in the separating gel was 7.5% (w/v). The protein patterns of fresh and freeze-dried crocodile egg white were similar, but were different from hen and duck egg white when analyzed by electrophoresis, SDS-PAGE. The crocodile egg white showed 6 bands of protein with different molecular weight with hen and duck white, which have 3 and 2 bands respectively (Figure 1). However, the protein patterns between the fresh- and freeze dried- crocodile egg whites were not difference. The SDS-PAGE protein patterns of crocodile egg white showed 6 bands of protein with molecular weight 231.8, 175.4, 135.5, 91.3, 65.1 and 37.2 kDas. These results suggested the variation of protein between species that probably due to the role of proteins are differ. However, the crocodile egg white proteins need to be analyzed with high advanced proteomic methods for more information. The present study has provide a database of protein in Siamese crocodile egg white which can provide indications as to directions for further research in value adding of the unfertilized crocodile egg.

Table 1. Amino acid profile of Siamese crocodile egg white

Amino acids	Unit (mg/ 100g)	Amino acids	Unit (mg/ 100g)
Alanine	2963.68	Lysine	3277.45
Arginine	1970.87	Methionine	988.52
Aspartic acid	5291.08	Phenylalanine	2177.18
Cystine	2395.50	Proline	2860.67
Glutamic acid	6776.76	Serine	4768.03
Glycine	2282.39	Threonine	2886.39
Histidine	1386.67	Tryptophan	561.87
Isoleucine	1427.61	Tyrosine	1906.35
Leucine	4602.48	Valine	2212.61

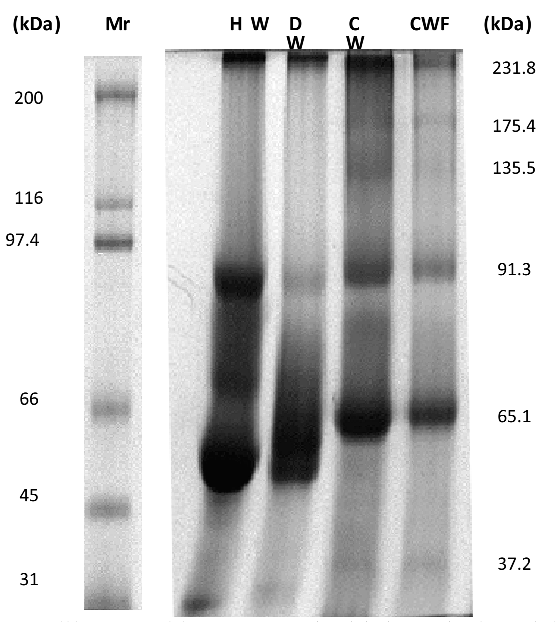

Figure 1. Protein pattern of Siamese crocodile egg white compared with hen, duck and freeze-dried crocodile egg whites. Egg white fraction protein patterns of hen white (HW), duck white(DW), Siamese crocodile white (CW) and Freeze-dried CW (CWF). kDa: molecular weight in kilodalton ; Mr: Protein standard marker

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We appreciate Rungtaweechai Crocodile Farm and WaniThai Limited Partnership for unfertilized Siamese crocodile eggs and technical assistance. M.K. & P.P. were support by a grant from Department of Zoology. P.P. was granted by Science Achievement Scholarship of Thailand (SAST), and Faculty of Science-Undergraduate Special Problem Matching Fund.

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Living with crocodiles for sustainable use and management of agro-pastoral dams in Benin: a hope or a scope?

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Nile crocodiles make themselves at home in agro-pastoral dams where they share the dam ecosystem services with local communities. This research aims at assessing how do stakeholders frame the presence of crocodiles, what institutional changes are needed to improve human-crocodile interactions, and how do crocodiles use their habitat. Using a comparative case study design in three villages in Benin, we reflected on an interactional framing perspective to answer to the two first questions. Data were collected from 2009 to 2012 through interviews and Focus Group Discussions. Regarding crocodile habitat use, the three agro-pastoral dam waters were sampled in different seasons and analyzed in the laboratory for the physico-chemical and microbiological parameters. All the spaces visited by crocodiles were featured by observations and interviews. Results showed that the dams were used for multiple purposes. This involved diverse stakeholders with different interests, backgrounds, knowledge, and assumptions. In addition, the dams were the main habitat for crocodiles. The stakeholders involved in the dams framed crocodiles as a main constraint jeopardizing their livelihood because they predated valuable fish species and livestock, destroyed fishing material and the dam infrastructures, and injured mainly children and women. Moreover, the dam water became polluted because the levels of physico-chemical parameters exceed the standards for human and livestock. The dams were also polluted by harmful bacteria (Coliforms, feacal streptocoque, *Escherichia coli,* spore of *Clostridium, Salmonella typhi, Salmonella typhimurium, Salmonella enteritidis,* and *Campylobacter jejuni).* Spaces visited by crocodiles included riparian forest, yam farms and vegetable plots, household heaps, human habitations, schools, and churches. The study suggests that researchers from both social and biological sciences should develop collaborative efforts, use direct observations, measurements and communication tools for evaluating management actions that allow humans living with crocodiles for sustainable management of agro-pastoral dams.

Rituals and symbolism for crocodiles in Goa

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The mugger (*Crocodylus palustris*) is a widely distributed crocodilian species in India. Crocodile worship is a common practice in many parts of India like Dhudhmogra (Mandvi) and Devlimadi (Songadh) in South Gujarat, Vidharba (Maharashtra) and 24 Parganas of West Bengal. A similar practice of worship is also seen in two villages of Ponda Taluka of North Goa district of Goa state for the Mugger (*Crocodylus palustris*).

A small population of the mugger, locally known as 'mange', is confined to a short mangrove-studded stretch of the Kumbarjua- Banastari Canal in South Goa. The Adil Shah of Bijapur introduced crocodiles here, in the 15th Centrury, as deterrents against enemy soldiers. In Goa, one sees an age-old prayer ceremony, of uncertain origin, practiced by the people of Durbhat Wadi village who strongly believe that the animal protects their village.

The legend states that when the village paddy fields were flooded with adjacent sea water, the villagers attempted to pacify the sea by worshiping the crocodiles which were numerous at that time. Every year on the day of the new moon in January, which coincides with the commencement of threshing of harvest paddy, the ceremony of '*Mannge Thapnee' (Clay Crocodile molding)* is performed. The villagers understand that their veneration may not be reciprocated, and so they avoid direct contact with the animal and offer their devotions to a crocodile made from silt. The villagers believe that it is because of their worship that the crocodiles never cause any harm to them or attack their families.

But is this enough? The sightings of the animal have reduced in the past 1year with a few cases of conflict reported recently, and the habitat also seems to be facing the pressures of urbanization and industrialization.

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Bio-logging science: a mechanistic approach to understanding Gharial *Gavialis gangeticus* (Gmelin, 1789) ecology

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Abstract

The study was conducted in Hastinapur Wildlife Sanctuary, Uttar Pradesh between October - November 2009. We attached data loggers with a newly developed time-scheduled release system to 2 captive-reared Gharial. Multi sensor data logger and the digital still-picture logger were deployed to record swim speed, diving behavior, ambient temperature, stroke frequency, body angle and the surrounding environment. While, the acceleration data logger was deployed to record diving behavior, ambient temperature and head movements that may relate to prey capture. The system released the loggers from the Gharial 24 hr after deployment, and allowed us to retrieve the loggers via VHF radio signals. The results obtained though at nascent stages elucidate the underwater behaviour and fine-scale movements of Gharial in the wild. Further modifications in the experiment [Technological and the use of large sample size] can contribute towards better understanding, consequently helping in the improved conservation management of the species.

Key words: Data-logger, Acceleration, Dive, Gharial, Conservation.

Introduction

Bio-logging can be defined as 'the use of miniaturized animal-attached tags for logging and/or relaying data about an animal's movements, behaviour, physiology, and/or environment' (Rutz & Hays 2009). Bio-logging technology allows researchers to take measurements from free-ranging animals as they move undisturbed through their environment (Bograd *et al.* 2010). The approach is suggested to have emerged in the 1940s when a capillary depth gauge was attached by Pers Scholander onto a harpooned whale to gather information about the cetacean's maximum diving depth (Naito 2004) hence, bio-logging science could thus be >60 year old. Kooyman (1965) first used the data-logging technique by developing a time depth recorder (TDR) to study the diving physiology of Weddell Seals *Leptonychotes weddellii*. Length of the data was limited to one hour, but this was the first device used to obtain detailed information on underwater activity of a marine animal. By 1975 improvements in the TDR made possible the recording of the diving activity of Fur Seals *Callorhinus Ursinus* and Weddell Seals *Leptonychotes weddellii* over 14 days (Kooyman *et al*. 1976) and later in 1981 for > 3 months. With the emergence of microprocessors that made possible miniaturization and the logging of several additional variables with the incorporation of appropriate sensors, the range of application extended considerably to various marine animal species (e.g. Wilson & Bain 1984, Naito *et al*. 1989, Watanabe *et al*. 2008 and Sato *et al*. 2009). Research on reptiles has largely focused on Sea Turtle. For e.g. Migratory patterns and feeding grounds of post-nesting female Hawksbill Turtle *Eretmochelys imbricate*tagged on the Yucatan Peninsula, Mexico have been described by Cuevas *et al.* (2008). McClellan & Read (2009) have demonstrated the use of sonic and satellite telemetry to determine the vulnerability of juvenile Green Turtle *Chelonia mydas* to incidental capture in an artisanal gill net fishery off the coast of North Carolina, USA.

Figure 1. Gharial *Gavialis gangeticus* Critically Endangered Crocodilian.

The Gharial *Gavialis gangeticus* is an endemic, river dwelling crocodilian of the North Indian subcontinent, whose wild populations have been depleted throughout much of its former range (Ross & Magnusson 1990 and Chowfin & Leslie 2013). The total breeding population of the species in the world is now estimated to be less than 200 individuals making it a critically endangered species (IUCN 2007). The species is listed as Schedule I under the Indian Wildlife (Protection) Act, 1972. Gharial are both taxonomically and structurally unique; being the only living representative of a once well-represented family and that having the most attenuated snout of all crocodilians. It is interesting to note that name Gharial is derived from *ghara*, an Indian word for *pot* because of a bulbous knob (*narial excrescence*) present at the end of their snout. The *ghara* also renders Gharial the only visibly sexually dimorphic crocodilian. Present day conservation threats mainly include habitat destruction, depletion in prey bio-mass and retaliatory killings by fishermen who consider Gharial as competitors for the same resource *i.e* fish.

Study area

Kukrail Gharial Breeding Centre, Lucknow (Uttar Pradesh)

Kukrail reserved forest, which covers an area of 2000 ha is located 12 km away from the State Capital i.e Lucknow (Fig. 2a). It was established as the Gharial Breeding Centre in 1976 in order to rear and release the captive Gharial into the wild to revive the depleting population of the species (Singh *et al*. 1999). These captive reared Gharial are released into Rivers Chambal, Ganga and its perennial tributaries i.e Sharda, Ghagra, Girwa and Ramganga. The Centre also runs the captive breeding programme on turtles.

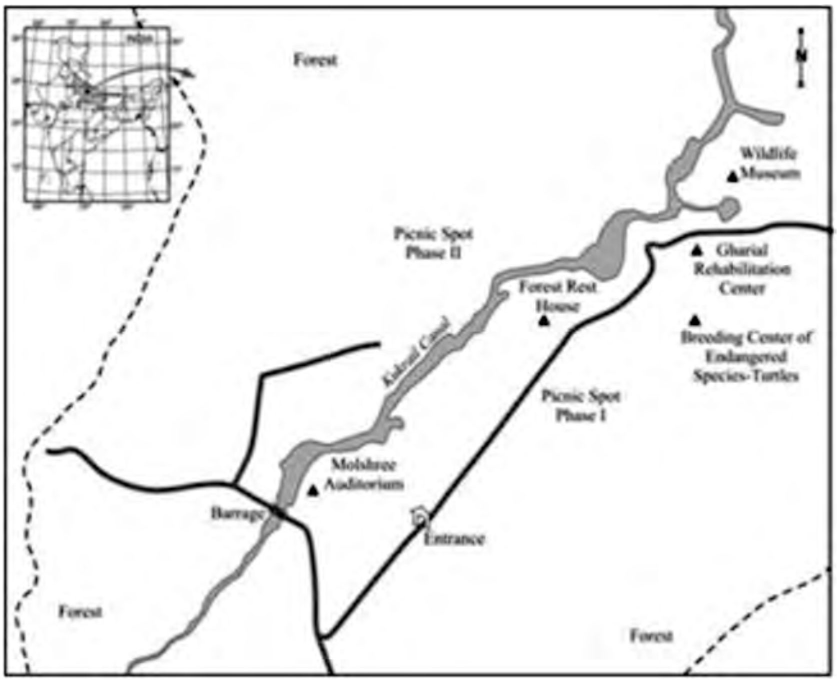


Figure 2a. **Kukrail Gharial Breeding Centre, Lucknow (Uttar Pradesh)**

Hastinapur Wildlife Sanctuary, Meerut (Uttar Pradesh)

Hastinapur Wildlife Sanctuary (28°46′ and 29°35′N Latitude and 77°43′ and 78°30′E Longitude), which was established in 1986 in the Indo-Gangetic plains (Fig. 2b). The Sanctuary encompasses an area of 2073 km^2 representing about 0.2% of the total geographical area of the Gangetic grasslands. The area of the Sanctuary mainly falls under five districts of Uttar Pradesh namely Muzzaffarnagar, Bijnor, Meerut, Ghaziabad and Jyotibafuley Nagar (Noida). Altitude of the area ranges between 130 and 150m above sea level. Three distinct seasons are recorded; winter from October to mid March, followed by summer from mid March to mid June and monsoon starts in mid June and continues till September. May and June are the hottest months when the temperature reaches about 45°C; December and January are coldest and the temperature can fall near to 0°C. The annual precipitation is about 1200mm. The vegetation of the Sanctuary can be classified into three main types - tall wet grasslands in low-lying areas that remain inundated for most parts of the year; the short wet grasslands remain dry from mid winter to the onset of the monsoon, and the dry scrub grasslands on raised grounds amidst the Ganga and on highland, also known as 'Khola' (Nawab 2000). A diverse fauna exists in the Sanctuary which makes this area a biodiversity hotspot in the Gangetic plains.

Methodology

The study was conducted between 26 October 2009 and 30 November 2009 in two phases. In Phase I the study was conducted at the Kukrail Gharial Breeding Centre in captive conditions and in Phase II the observations were made under wild conditions.

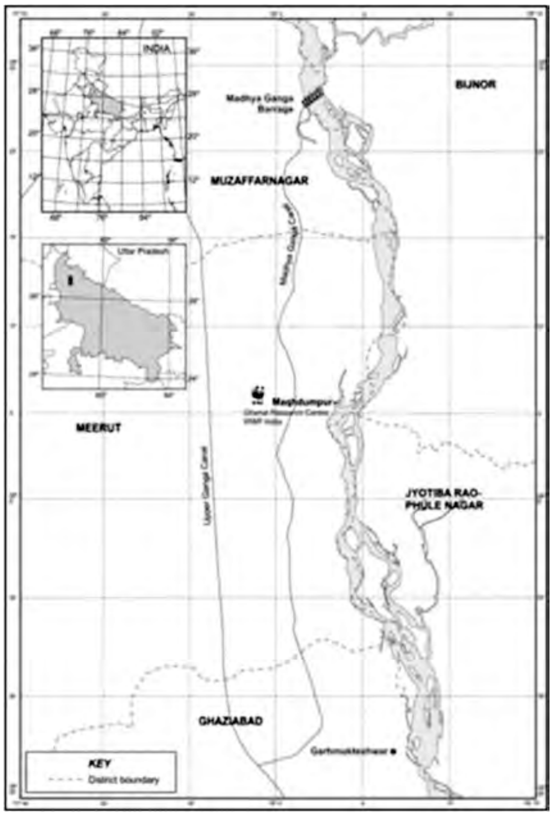


Figure 2b. **Hastinapur Wildlife Sanctuary, Meerut (Uttar Pradesh)**.

Instruments used

(i.) A multi sensor data logger (W190L-PD3GT) (Fig. 3). This weighs 92 g in the air and is 22 mm in diameter and 124 mm in length. It records swim speed (1 sec), depth (1 sec), 3-axes accelerations (32 Hz) and temperature (1 sec).

(ii.) An acceleration data logger (W190L-D2GT) (Fig. 4). This weighs 18 g in the air and is 15 mm in diameter and 50 mm in length. It records depth (1 sec), 2-axes accelerations (32 Hz) and temperature (1 sec).

(iii.) A digital still-picture logger (DSL190-VDTII). This weighs 73 g in the air and is 22 mm in diameter and 138 mm in length. It records 1M pixel picture every 5 seconds.

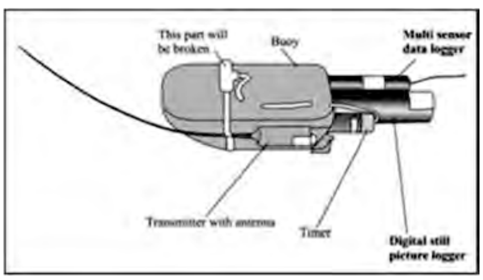


Figure 3. Multi Sensor Data Logger and Digital Still-Picture Logger with a buoy (281g in the air).

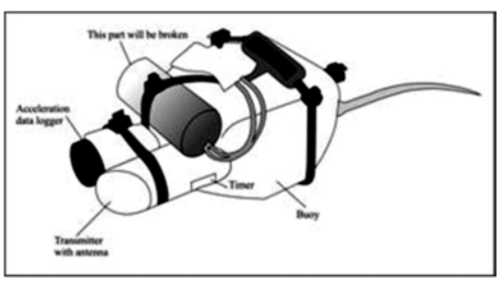


Figure 4. Acceleration Data Logger with a buoy (71g in the air).

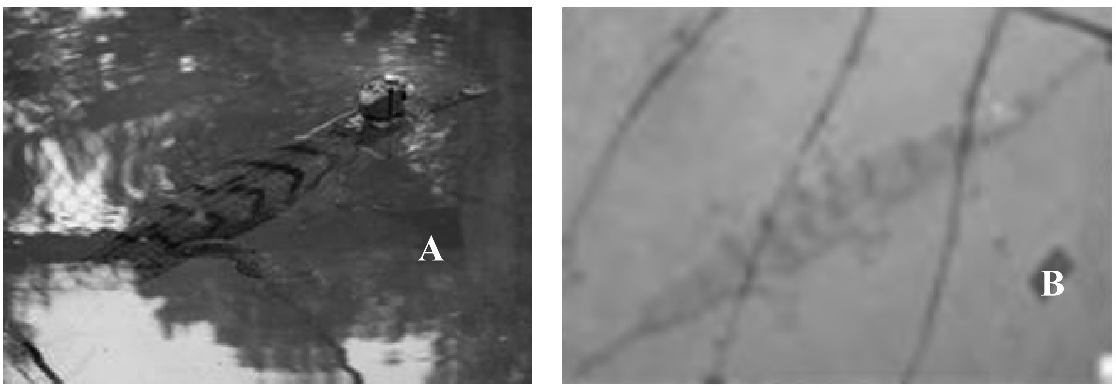
Deployment of bio-loggers

Captive Gharial were used to establish the method of deployment of bio-loggers. The multi sensor data logger and the digital still-picture logger were fixed with a buoy “larger device” (281g in the air) and deployed on the back at the junction of double crest whorl and single crest whorl of the sub-adult animal to record swim speed, diving behavior, ambient temperature, stroke frequency, body angle and surrounding environment. The cable tie was passed through the holes grilled into the scutum (dead cells) and the device was fixed. The acceleration data logger with a buoy “smaller device” (71 g in the air) were deployed on the head at the depression of the skull notch of the juvenile animal to record diving behavior, ambient temperature and head movements that may relate to prey capture. Both the devices were composed of the data loggers, buoy, VHF transmitter, timer and cables. Epoxy glue did not work for the skin of the Gharial. Silicone glue seemed to be effective at first glance, however, part of the plastic mesh got unstuck. The unstuck part was then fixed using cyanoacrylate glue “Loctite”. The mixture of the silicone glue and cyanoacrylate glue worked well for attaching the mesh on captive animals.

Monitoring and Observations

Time series data of movements: Under experimental conditions at Gharial Breeding Center at Kukrail, Lucknow; Uttar Pradesh

Acceleration Data Logger with a buoy (71g in the air) was deployed on the juvenile male Gharial [A] (Body mass = 6.4 kg; Total body length = 133 cm) and the Multi Sensor Data Logger and Digital Still-Picture Logger with a buoy (281g in the air) was deployed on the sub-adult male Gharial [B] (Body mass = 12.5 kg; Total body length = 162 cm). The animals were in good health condition.4 hr timers were used to detach the devices from the animals during the experimental study at Kukrail. The instrumented animals were released into the experimental ponds and their underwater behavior was observed. When the timers got activated in the water, it made a 'low' sound. The animals resting at the bottom of the pond reacted to the sound and swam, however, no abnormal behavior was observed.



According to the acceleration data, juvenile Gharial rested for most of the time at the bottom of the experimental pond (Fig. 5a). Fluctuation with large amplitude in acceleration was recorded prior to the detachment of the device, the juvenile Gharial might have been disturbed with the surrounding noise but showed no abnormal behaviour (Fig. 5b). The timer was activated at 14:39 hr and the device got detached from the animal.

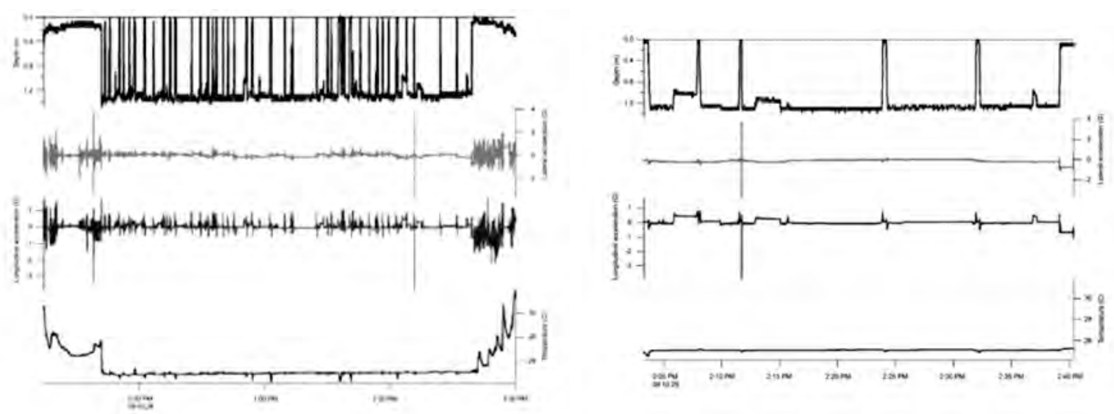


Figure 5a. Figure 5b.

Sub-adult Gharial repeated resting dives and shallow water swimming. The propeller of the logger did not rotate well, which indicates that the swimming speed was lower than the stall speed of propeller (0.2 0.3 m/s) (Fig. 6a). When the timer got activated and the device got detached at 20:16, the animal reacted to the low sound and swam for 30 sec and then stopped and rested at the bottom of the pond showing no abnormal behaviour (Fig. 6b).

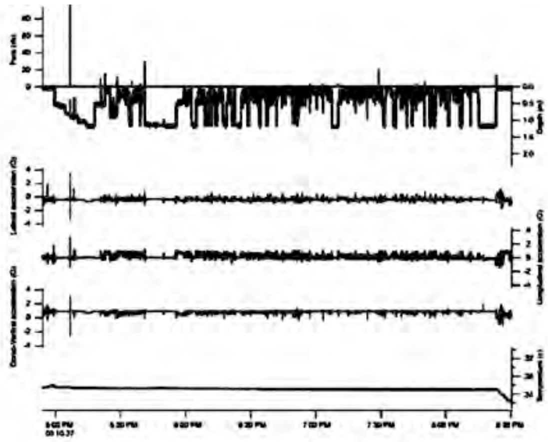


Figure 6a

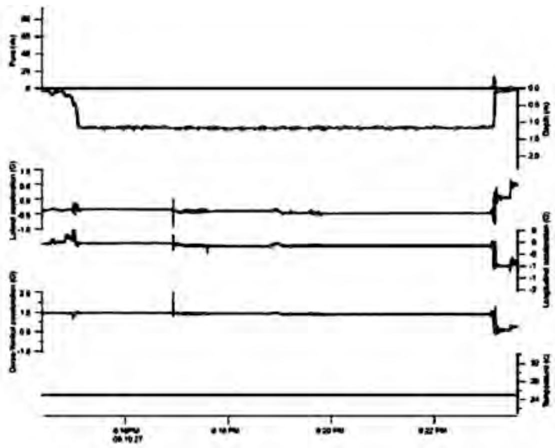


Figure 6b

Time series data of movements: Under wild conditions at Hastinapur Wildlife Sanctuary (Meerut) Uttar Pradesh

Juvenile male (Body mass = 6.4 kg; Total body length = 133 cm) and Sub-adult male (Body mass = 12.5 kg; Total body length = 162 cm) were released into the wild (River Ganga) at Hastinapur Wildlife Sanctuary. The methodology established for the deployment of the bio-loggers under captive conditions was used. The system released the loggers from the Gharial 24 hr after deployment, and allowed us to retrieve the loggers via VHF radio signals. The instrumented animals were released at 12:17 hr and at 12:55 hr respectively on 30 October, 2009.

Juvenile Gharial recorded repeated dives and the deepest dive depth was 1.4 m. Increase in ambient temperature was gradual; however it decreased abruptly, this indicates that the animal sometimes came out to bask on the land (Fig. 7a). Lateral and longitudinal accelerations indicate activity of the animal during dives, when the animal was at the surface, activity was higher in comparison when the animal was diving (Fig. 7b).

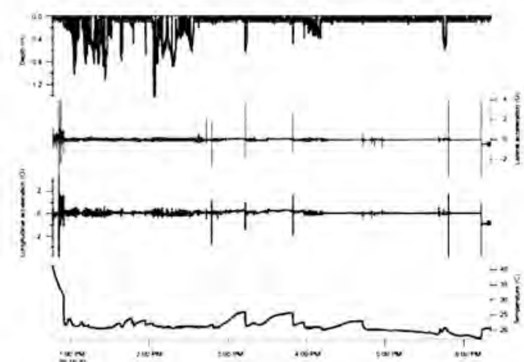


Figure 7a.

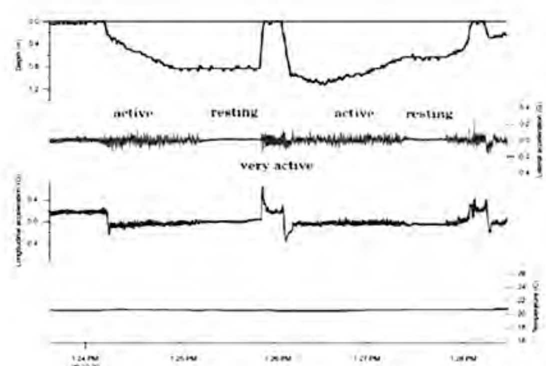
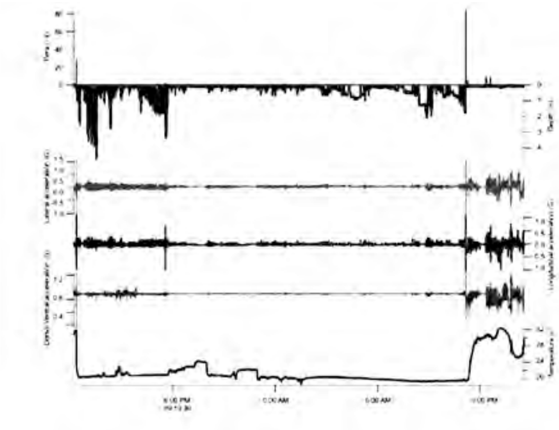


Figure 7b.

Sub-adult Gharial recorded repeated dives and the deepest dive depth was 4.7 m. Ambient temperature recorded to increase gradually, but it decreased suddenly which ndicates that the animal occasionally came out for basking. The propeller did not rotate well during the period of deployment, this could be because; the swim speed of the animal might have been lower than the stall speed of the propeller (0.2-0.3 m/s) or the suspension in the river water might have affected the stall speed (Fig. 8a). The animal was inactive in some dives. Dive durations of the inactive dives were usually long, longest dive duration recorded was 40 minutes (Fig. 8b). Stroking movement in the deepest dive (4.7 m) was different from those in the typical dives. It stroked in the descending position only, this suggests that the animal had positive buoyancy during the deepest dive and ascended using the positive buoyancy. There is a possibility that the Gharial might change the inhaled air volume in relation to the dive depth.



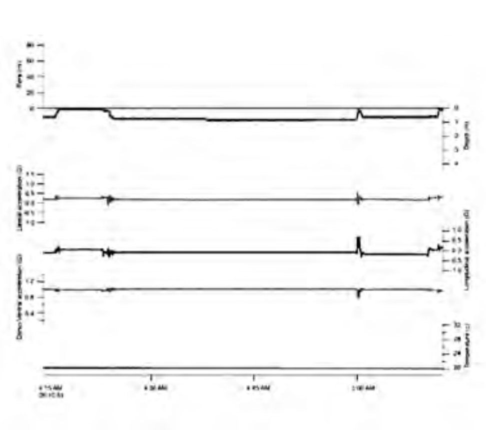
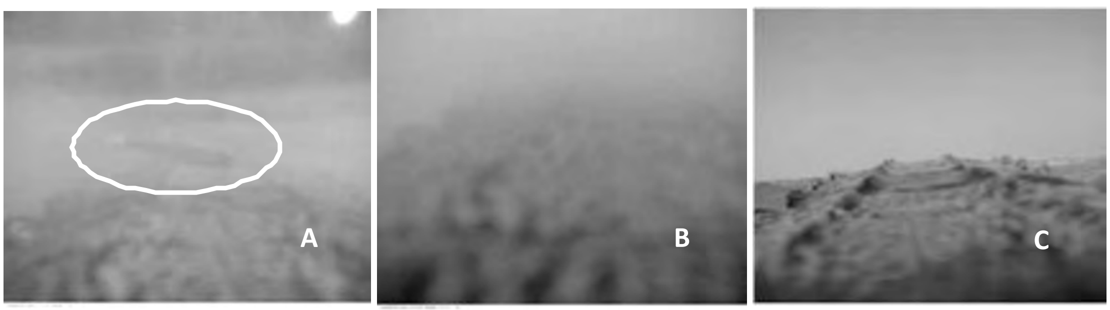


Figure 8a.   Figure 8b.

Still picture

The camera was deployed on the sub-adult Gharial released in the river and 14507 pictures were recorded (1 M pixel every 5 sec.). Fish was recognized in some pictures [A], most pictures were not clear [B] and when the animal came out for basking the picture recorded were clearer [C].



Understanding Gharial behaviour and way forward

The results elucidate that Gharial may have capacity of long dive. The sub-adult Gharial dove for more than 40 min (this is concluded from the 24 hr data collected). Time series data can also describe how often Gharial haul-out on the land. Present study indicates that Gharial can swim in darkness when they dive deeper than 1 m in Ganga River. This raises a question of how the animal captures its prey underwater or do they always feed on the surface waters?

In the present model (PD3GT, 22 mm in diameter), it was difficult to measure swim speed by the propeller as its diameter was small. 3MPD3GT logger is available and can be tried, the diameter of the logger is 28 mm and the stall speed is also better than the present model used.

Results indicate that camera does not work well under water in River Ganga. Although pictures were possible at the surface and on land but the recording period was prolonged. The present model can be modified with a depth sensor that can activate the functioning of the depth trigger for taking pictures.

The need is for larger data sets and on experiments on more number of individuals, this shall contribute towards better understanding of the underwater behaviour of Gharial under natural condition, consequently helping in the improved conservation management of the species.

Acknowledgements

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Embryogenesis of crocodilian skin

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Crocodilian skin functions primarily as a mechanical, osmotic and thermal protective device. This study examined the chronological development of skin in embryonic through to hatchling, Estuarine (*Crocodylus porosus*) and Australian freshwater (*Crocodylus johnstoni*) crocodiles. Eggs of each species were incubated under appropriate conditions then sampled over time until hatching. Following histological processing skin was examined using light and electron microscopy. In the first trimester a simple squamous then columnar epithelium surmounts a quickly differentiating dermis consisting primarily of irregular collagen bundles. Early in the second trimester scale formation became evident above a loose dermal layer surmounting a thicker dense dermis. Melanocytes were evident in the epidermis and melanophores in the dermis. In the final trimester the epidermis increased in its cellular complexity with tough β keratin over the presumptive scales and soft α keratin in interscalar areas. The underlying loose dermis remained relatively static in its development but the dense dermis increased in its thickness dramatically. At hatching melanophores were common in the flank and back dermis of both species. Birefringent chromatophores were present in the flank and back dermis of *C. porosus* but not *C. johnstoni*. Chromatophores were absent from the belly skin of both species. Polynomial relationships for total; epidermal, dermal and skin thickness were developed to describe incubation development. All were linear except for total epidermal thickness in *C. porosus* where initial slow development to day 21 was followed by a 10 fold increase to day 27 then slow growth to day 41 and again rapid growth until hatching. This study provides an insight into possible times for the manipulation of incubation to improve skin quality in crocodilians

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Crocodiles in Sri Lanka threat and protection?

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Introduction

Sri Lanka is home of two crocodilian species: the mugger or marsh crocodile, *Crocodylus palustris* and the estuarine or saltwater crocodile, *Crocodylus porosus*. The Sri Lankan populations of both species are threatened, although there are numerus national parks and crocodiles have been specifically protected there since 1938 through the Fauna and Flora Protection Ordinance.

Clearly the management of crocodile populations in the wild and the protection of their habitat on Sri Lanka is not a success story. Publications from hundreds of years ago reported crocodiles on the island and such descriptions from the 17th and 18th centuries, and even into the19th century, indicate that crocodiles must have been quite numerous in some regions (Whitaker & Whitaker 1979).

The wild population status of *C. palustris* has changed dramatically in recent years, and the status of *C. porosus* is nothing short of catastrophic. A little more than 30 years ago, Whitaker & Whitaker (1979) estimated the total population of *C. palustris* on Sri Lanka at about 2,800 specimens (not including specimens of one year or younger). Two decades later, Santiapillai & De Silva (2001) and Das & De Silva (2005) estimated only 1,220 specimens left, or about 43 percent of the population that existed in the 1970s.

Even more critical is the situation with *C. porosus*. In the 1970s, Whitaker & Whitaker (1979) estimated the population along the southwestern coast of Sri Lanka at 250 specimens (not including specimens of one year or younger), and around the rest of the entire island only 125 more, for a total population of 375 saltwater crocodiles. This figure corrected the previous estimate made by Whitaker & Daniel (1978) of 500-750 specimens, reducing the number practically by half. According to Santiapillai & De Silva (2001) and Das & De Silva (2005) the current population of *C. porosus* on Sri Lanka is possibly no more than 300 specimens. During a recent study De Silva (2010) reported the observation of only 50 saltwater crocodiles ranging in length from 60 cm to 4.5 m

The decline in numbers of crocodiles has several causes. With *C. porosus* the main causes are hunting for meat and skins, destruction of nesting grounds, and urbanisation of coastlines. Construction of new roads contributes by giving humans access to once remote areas. Various recent studies (e.g. Porej 2004, Gramentz 2008a, 2008b) have indicated a definite negative correlation between crocodile numbers and the intensity of human activities, such as fishing and construction.

Distribution on Sri Lanka

There is hardly any precise information available about the past distribution and abundance of *C. porosus* on Sri Lanka. However, the presence of the species in the southwestern part of the island was mentioned by Kelaart (1852). He wrote that the species was commonly found in the large rivers of the island, including the Mutwal River near Colombo, and also it occurred in Southern Province.
Whitaker & Whitaker (1979) reported the presence of saltwater crocodiles in western Sri Lanka and along the southern coast in the rivers Bentota Ganga, Maha Oya, Kelani Ganga they determined that the principle remaining population of the species was restricted to this section of coast. Other previously large populations (Pottuvil, Batticola, Trincomalee and Mullaitivu) had already disappeared by the time of their investigation. This species has also completely disappeared from Jaffna Peninsula (Santiapillai & De Silva 2001). Other localities cited by Deraniyagala (1930) Chilaw, Puttalam, Colombo, Panadura, Bolgoda, Kalutara, Bentota, Gintota, Wakwella, Matara, Hathagala near Tongalla, and Trincomalee are all also along the western and southwestern coasts.

Whitaker (2004b) suggested that a reproducing population of *C. porosus* might still exist only in the swampy region of Muthurajawela, mentioned by Devapriya (2004) and Porej (2004). Gramentz (20081, 2008b) reports occasional successful nesting in the Bentota Ganga; De Silva (2008, 2010), from the Nilwala Ganga in the south. Recently crocodiles were confirmed on Mannar Island in nortwestern Sri Lanka, but the species to which it belonged could not be determined (Somaweera et al. 2004).

Santiapillai & De Silva (2001) believe that relatively abundant and secure populations of both crocodile species are currently found only in the two protected areas of Ruhuna National Park in the southeast and Wilpattu National Park in the northwest. They confirmed the presence of *C. palustris* at 105 of 113 studied localities; *C. porosus*, at only 33 both species were found at 25 localities in the parks. A very large mugger crocodile population lives in the already mentioned Ruhuna National Park, where De Silva (2010) observed 493 specimens.

Threat factors

Unfortunately it seems that because the crocodiles are protected in the nationalparks (which is unquestionably necessary), little or no importance is given to preserving crocodile habitat elsewhere on the island. In the past, the natural habitat of *C. palustris* was altered by the construction of water reservoirs and thousands of kilometers of artificial irrigation canals. This gave the crocodiles unnatural alternatives, and the ability to travel from one reservoir to another for this reason *C. palustris* is more widely distributed than *C. porosus*. Juvenile and subadult mugger crocodiles may also travel overland to colonise neighbouring areas of habitat. Saltwater crocodiles are much more dependent on the sea, and therefore much less likely to travel from one body of water to another.

Porej (2004) estimated the number of saltwater crocodiles in the Muthurajawela marshland to be 15 specimens. With increasing human activities and draining of wetlands, this area of crocodile habitat is steadily shrinking (Devapria 2004). Presumably very few large saltwater crocodiles are left on Sri Lanka, making the discovery of a 5.03 m specimen a couple of years ago all the more exciting. Captured on 24 February 2009 at Hendala, about 20 km north of Colombo, this large crocodile was taken to the protected Udawalawe National Park. In the past, crocodiles of this size were not uncommon. Older literature (see Deraniyagala 1939) mentions saltwater crocodiles on Sri Lanka measuring 5.25 and 6.6 m in length. Even in the national parks, crocodiles of this size are no longer found. The largest saltwater crocodile seen by Santiapillai et al. (2000) in Ruhuna National Park was only about 3 m long; the largest mugger crocodile, about 2.5 m. One recent large *C. porosus* of 4.5 m in length was reported by De Silva (2010).

Another indication of the serious threat to crocodiles on Sri Lanka is the current population structure. According to Cott (1961) and Graham (1968), a normal crocodile population should consist of mostly adults, with relatively small numbers of juveniles. The percentage of sighted adults accounted only for 7% when recent hatchlings are included and 11% without hatchlings. Both recent hatchlings and yearlings represented 40% of the sighted crocodiles. The other two immature size categories as well as adults were represented in 7% of the sightings (Fig. 1). Alltogether 93% of the counted crocodiles were immatures and only 7% were adults. According to Cott (1961) and Graham (1968) in an environment unaffected by human influences a normal crocodile population should be dominated by adults and juveniles should be represented in comparatively low numbers. However, the population in the area of the Bentota Ganga is strongly skewed towards hatchlings and yearlings. In Arnhem Land, Northern Australia, Messel (1977) reported that hatchlings accounted for 23.22% of *C. porosus* seen and 23.06% were one year old. Similar findings were published by Porej (2004) for the Muthurajawela marsh region, where juveniles and subadults made up 78% of the saltwater crocodiles sighted.

I do not believe that the distribution presented in figure 2 reflects the actual proportion of crocodiles in the different size classes. Instead I suppose that all but hatchlings and yearlings are biased from the behaviour of the crocodiles. Frankly, it seems possible that crocodiles from the age of about one year onwards develop a high degree of wariness. Probably because of the above mentioned causes.

Messel (1977), Webb (1977a) and Webb et al. (1977) reported an average egg number of 50.3 (range 40-62, n = 18 nests) in *C. porosus* nests. Therefore it is possible that even with relatively high mortality during incubation and shortly after hatch all hatchlings sighted and reported here came from just one and probably not more than two nests. This is also supported by the small number of reproducing adults and of what is known of the behaviour of the hatchlings. Webb (1977b) reported a strong site fidelity in *C. porosus* hatchlings for the first time period after hatch. After two months the majority of hatchlings (69%) were still within 0.5 km of the nest. However, Deraniyagala (1937) reported that in each of two nests from Maha Bellana (Western Province) only 25 eggs were found.

Due to the land use behind the mangroves with some little villages and residents, paddy fields and tracks following the course of the river it seems very unlikely that a nest would have remained unnoticed (especially when it would be guarded by a female). I rather assume, also because of the scattering pattern shown in figure 3, that the hatchlings are from one nest laid on an island. According to Webb (1977a) hatchling groups stay together for up to $2^1/_2$ months after hatching.

In the next size category (30-50 cm SVL, 1-2 years) considerably more downstream movement was found by Webb (1977b) and therefore the yearlings in figure 4 show a greater dispersion. However, the number of nests (season 2007) must have been also very few (possibly also only one or two).

The small number of sighted adult saltwater crocodiles is most probably due to their decimation. Another factor is undoubtedly that the adults have survived and grown large are those animals that have learned to be alert to intruders and remain mostly unseen. Senanayake (1995) reported that crocodiles on Sri Lanka are killed because of fear of attacks on humans and domestic animals. Also Santiapillai et al. (2000) and Santiapillae & Wijeyamohan (2004) emphasize the bad reputation that crocodiles have on Sri Lanka. Even 30 years ago, Whitaker & Whitaker (1977) saw that public education was needed. Also De Silva (2010) addressed the necessity of education of the people living and fishing in the Nilwala Ganga in Matara of the precautions they should take to prevent crocodile attacks and also why crocodiles and their habitats should be conserved. Nonetheless, today there is still not a single special protection program for crocodiles.

Porej (2004) reported that in the Muthurajawela marsh and Negombo lagoon region, mother saltwater crocodiles guarding their nests are still killed. When a nest is discovered by fishermen, they keep returning to the site until they find the mother and kill her. If the eggs are freshly laid when the nest is found, they are collected to be eaten. If the eggs are further developed, the nest is burned.

Devapriya (2004) mentions that in addition to collecting eggs, fishermen also kill crocodiles for meat and skins. This is partly associated with superstition some believe that eating crocodile meat will help cure asthma. Inquiries carried out by De Silva (2010) and its team revealed that some people have placed a piece of crocodile skin on the sole of the shoe as it helps to improve eyesight. The fat is also supposed to have medicinal properties, and crocodile meat is believed to be an aphrodisiac (Simon 1954).

Some methods by which saltwater crocodiles are captured have hardly changed since being described by Deraniyagala (1939). A hen or a dog or puppy is tied to a tree at the water's edge. Flapping wings, yelping, or splashing attracts the attention of nearby crocodiles. When a crocodile takes the bait and begins to roll, men throw spears at it, aiming for the weakly armored underside.

When fishermen in the Muthurajawela and Negombo region inadvertently catch juvenile crocodiles along with fish, they eat them just the same (Porej 2004). Devapriya (2004) reports that juvenile crocodiles can get caught in fish traps and drown. Nest destruction and the killing of juvenile and subadult crocodiles that get caught in fishing nests (where they sometimes drown) is also seen on the Nilwala Ganga (De Silva 2008). One fisherman told De Silva (2010) that he had killed five juvenile crocodiles that had been caught in his nets, and other fishermen had similar stories. For example, De Silva (2010) reported that on 30th January 2010 a crocodile which was caught in a fish net at Karawgaha tank was killed and eaten. Furthermore he reported that of twelve fishermen interviewed all except one killed the crocodiles which were trapped in fishing nets. One adult mugger of approximately 2 m length had severely beaten by the fishermen to take it from the net. The injured crocodile was left on the banks of the tank, but fortunately it was subsequently rescued and released after its recovery into another tank (De Silva 2010).

Also railway tracks are a threat to crocodiles when they lead through their habitat (fig. 9). De Silva (2010) reported a case of a large (ca. 4 m, 13 foot) saltwater crocodile which died on the spot after being hit by the train that was heading for Chilaw from Colombo.

Whitaker & Whitaker (1977, 1979) affirmed that if the saltwater crocodile is to survive on Sri Lanka, it would need a protected area where it could live without conflict with humans. Groombridge (1982) wrote that in addition to commercial hunting, mainly during the 1950s and 1960s habitat loss is the main threat to saltwater crocodiles. While De Silva (2010) pointed that the is “a good recovery and appreciable population of crocodiles (mugger) especially in some wildlife parks”, the “crocodiles outside national parks face many threats as they often get killed due to various human activities including the human crocodile conflict”.

Indeed there is currently not a single protected area for *C. porosus* in the most crucial southern part of Sri Lanka. Steel (1989) explains that protection measures for saltwater crocodiles are quite unpopular with local residents, who commonly consider the animals dangerous monsters. Officially, crocodiles have been protected in Sri Lanka for decades (see De Silva 2008). According to Whitaker (2004a), however, protection for *C. porosus* in India and on Sri Lanka exists only on paper; he considers it unlikely that the species will survive there.

Today, all of the coastlines and river mouths in the southwestern part of the island Moratuwa, Panadura, Kalutara, Bentota, Balapitiya, Ambalangoda, and near Galle are virtually free of saltwater crocodiles. Whether significant populations exist farther upriver or in inland lakes is not known. The discovery of yearlings, subadults and adults of the saltwater crocodile inhabiting the Nilwala Ganga in Matara was reported by De Silva (2010), which is an indication for a breeding population. The few remaining suitable areas of habitat are also in danger of being lost to urbanisation. A compounding factor is the threat caused by industrial and organic waste in the rivers. Devapriya (2004) concludes that these materials are harmful to the health of the crocodiles.

Saltwater crocodiles on the Bentota Ganga

The case of the Bentota Ganga will now be looked at more closely to illustrate the situation. The data presented here are partly based on a preliminary survey carried out from 23 to 26 November 2007 (day counts at these two days) (Gramentz

2008a) and a more comprehensive one carried out from 24 September to 9 October 2008 (four day and four night counts from 29 September until 9 October). The third night count had to be stopped after about 60 min due to engine problems. It was tried to time the counts with the dark phases of the lunar cycle as well as falling tides (what was only partly possible at the end of the survey). On each survey large areas of the Bentota Ganga were searched, one day time survey included the Kaluwamodera Ganga and in two day time surveys the Welipenne Ganga. Total search time was 37 hrs 55 min (23 hrs 5 min during the day, 14 hrs 50 min during the night).

All night counts could only be carried out up to a maximum turning point for safety reasons as groups of illegal alcohol (Arrack) producers were active along the river. So unfortunately night counts from upper parts of the Bentota Ganga are still lacking.

It was hoped to find some concentrations of recent hatchlings to limit the area which is still used and suitable for nests. According to Deraniyagala (1939) the peak of the nesting season along the coast of Sri Lanka is July and August and the hatchlings of this report are those very recently hatched.

Although it is a common practise not to include hatchlings in calculations of relative abundance because of their high rate of natural mortality they were included here in some calculations for comparison to other non-hatchling size classes.

Sizes of the crocodiles were estimated at closest range. Only three recent hatchlings were measured and released after a few minutes at precisely the same spot. Crocodiles up to 35 cm total length were treated as recent hatchlings and specimens up to 70 cm as yearlings. Other immature size classes were 0.70 1.50 m and 1.50 2.30 m (fig. 5). Crocodiles were counted as adults when their size was estimated from 2.30 m onwards (fig. 6). According to Webb & Manolis (1989) females reach maturity usually at a total length of 2.30 m. Therefore all crocodiles from that size onwards were considered being adults. 'Eyes only' (fig. 7) counts were treated as non-hatchlings (yearlings appr. >- 70 cm total length onwards). The crocodiles were counted from an outboard-powered boat with 15 hp engine at a cruising speed of about 3.1 to 3.6 miles/hour. During night counts the open water and the river banks were scanned by two persons with powerful torches. Once a crocodile was sighted its position was recorded using a GPS Garmin Geko 201 and approached so much so that it was possible to estimate its size. Size estimates as total length were made by two observers. In those instances (during night counts) where size estimates could not be made because the crocodiles were well hidden within mangroves and could not approached closer by boat were classed as 'eyes only' (EO).

Multiple 'eyes only' counts at the same location during different night surveys are assumed to represent the same specimens. Therefore, the 25 EO counts most probably represent a maximum of 15 individuals (fig. 7). Furthermore due to the habitat structure in which 'eyes only' counts occurred all were probably from immature crocodiles.

The numbers of crocodiles have been corrected when it was assumed that there were double or multiple counts of the same specimen. This was the case when a crocodile of the same size was located at the same spot or when after comparison of photos the spotting pattern on at least one flank/body side was found to be identical.

The Bentota Ganga has a length of about 55 km and its tributaries are predominantly the Welipenne Ganga, Pitugal Ganga, Pelawatta Ganga, Elpithiya Ela and Migaspithiya Ela. Beside these rivers the Kaluwamodera Ganga enters the Bentota Ganga close to its mouth. The Bentota Ganga and its tributaries are situated almost completely in the lowland wet zone of southwestern Sri Lanka. The original bank area of the river is dominated by mangroves.
Of a number of crocodiles belonging to different size classes their association to the bank structure was noted (counts represent sightings and not individuals). As can be seen in figure 10 A most hatchling sightings were found in close association with mangrove habitats. This association is slightly reduced in yearlings (fig. 10 B), but this type of bank structure is clearly of major importance in these size classes. As a side note one hatchling which was caught among mangroves was still busy swallowing a large shrimp. The presence of hatchlings during day and night in the water amongst mangroves and sometimes perched on small branches was previously documented and reported by Webb (1977a). So some aspects of hatchling behaviour at Sri Lanka were the same as at Arnhem Land, Northern Australia.

Deraniyagala (1930) described the saltwater crocodile from Bentota as a “man-eater”, but also notedthat the species had become rare on Sri Lanka. In 1955 he described the invalid *Crocodylus porosus minikanna* the subspecies name means man-eater in Sinhalese. *Crocodylus porosus* is considered by a number of authors as the largest recent crocodile species (e.g. Deraniyagala 1936, Daniel 1983, Groombridge 1987, Steel 1989), whereas the latter author and previously Bellairs (1969) discussed data of specimens with exaggerated lengths. On the average adults have a total length of 3.50 4.50 m (Brazaites 1974). Undisputedly there is a possible danger for humans by adult *C. porosus* (Pooley & Ross 1989, Neil 1971).

The number of crocodiles in Bentota Ganga has definitely been continually dropping for several decades. This may be due to their negative impact on the development of infrastructure and tourism, which are welcomed by the authorities. Until the 1970s, crocodiles were still relatively abundant at the river mouth where shorelines that have since been built up still had the same thick mangrove vegetation that is found in other river areas. The survival of saltwater crocodiles is strongly linked to the preservation of mangrove shore regions (Bustard & Choudhuri 1980). Today, saltwater crocodiles have completely disappeared from the immediate area of the river mouth due in part to past hunting, alteration of the shoreline, and current use for tourism, including a variety of recreational water sports (figs. 11 and 12) (Gramentz 2008a, 2008b).

The same is true of other regions along the southwestern coast of Sri Lanka. I was told that crocodiles have not been sighted in the Indian Ocean off the mouth of the Bentota Ganga “for ages”. Deraniyagala (1930) wrote that during the two years before his publication several of these crocodiles measuring 2-3 m were caught off the western coast at Kalutara, Panadura, and Moratuwa.

Most saltwater crocodile habitat consists of rivers affected by ocean tides, and colonised from the seas. The network of roads and human habitation in southwestern Sri Lanka makes it virtually impossible for these crocodiles to travel overland to find new waterways. It makes no difference how good conditions might be farther up the rivers. If the lower regions of the rivers are uninhabitable for crocodiles, their migration is severely restricted if not impossible. According to Deraniyagala (1936), saltwater crocodiles do not inhabit any inland waters on Sri Lanka. Due to hunting and destruction of nesting sites, populations in upriver retreats are becoming fragmented, with isolated subpopualtion consisting of ever-diminishing numbers of individuals.

Larger saltwater crocodiles measuring 1.5 m and more are still hunted and eaten in the catchment areas of the Bentota Ganga and the Welipenne Ganga. This is also reflected in the small numbers of sightings of crocodiles of this size. Since hunters know that killing crocodiles is against the law, the meat is sold secretly.

Crocodilians are still greatly feared in the Bentota Ganga. In the past there were a greater number of large specimens in the river, and there were more victims of attacks among the local residents. One example is the “Bentota Man-eater”, a crocodile that ate two people before it was killed. This may or may not be the same crocodile that was known as “White Face”, reported by Van De Bona (1996) and Karunathila Ka (1991). According to Deraniyagala (1939), the “Bentota Man-eater” had a total length of 2.5 m. According to Van De Bona (1996) the crocodile known as “White Face” lived in the tributary Welipenne Ganga, near Kuruduwatta, and had a total length of about 4.5 m.

In any case it is possible that in the past there were many large saltwater crocodiles in the Bentota Ganga that noticable scars on their heads, perhaps from missed attempts to kill them with clubs or spears whenever such a specimen was sighted, it may have been called “White Face”. Van De Bona (1996) wrote that especially fishermen tried to kill crocodiles in the Bentota Ganga whenever they could secretly, since doing so was against the law. Eventually a “White Face” was shot and killed.

It is noteworthy that despite these stories, the responsible local authorities haver never issued information to advise local residents on how to live in harmony with crocodiles in the river, nor have they posted any kind of warnings or fences to protect people and domestic animals form possible attacks. At least partly this negligence may have caused casualties which in turn may seem to justify i to kill the larger and more dangerous crocodiles.

The time when very large crocodiles were living in Sri Lanka is long gone. Possibly the largest saltwater crocodile ever killed in Sri Lanka was a specimen caught in Matara, which was about 6.70 m (over 22 feet) long (Clark 1971). In late October 2010 a local newspaper reported that a large saltwater crocodile (measuring either 4.2 or 4.8 m, depending on the source) had been killed in Mawilangathurai Lagoon by villagers from Kanthankudi (Batticaloa District) in eastern Sri Lanka for revenge, because it had supposedly eaten a fisherman.

It is difficult to say at what point and to what degree crocodiles are disturbed by human activities. In Bentota Ganga, near the towns of Aluthgama and Bentota, people are out on the water practically all day long. Tourists enjoy daytime water sports such as windsurfing, jet skiing, waterskiing, canoeing, speed boating, tour boating, and so on, until just before sunset. Shortly thereafter, the local fishermen begin their evening and nighttime fishing.

Large areas of the Bentota Ganga are used for extracting sand. On 4th October 2008 I counted a total of 39 boats out for this purpose just between 11:30 a.m. and 12:45 p.m., between 06°21'59.5” north latitude 80°07'49.1” east longitude and 06°23'41.5” north latitude 80°05'48.8” east longitude. During the same time, no crocodiles were sighted in this stretch of water. Although the habitat there seemed to be of suitable quality, the crocodiles had either moved away to other areas, or were keeping especially well hidden because of the disturbance.

During my first investigation on the Bentota Ganga in 2007, I twice saw a saltwater crocodile (presumably the same on both times) (fig. 8) of more than 2.5 m in length, in the shade under mangrove branches (Gramentz 2008a). The following year I was able to account for three saltwater crocodiles of just over 2.3 m (Gramentz 2008b). De Silva (2008) and his team also counted only three large specimens in the Nilwala Ganga these were possibly all longer than 3 m in length, and one possibly as much as 4.5 m long. According to Messel (1977), a great approach distance (to which a person can come before the animal will flee) is an indication of the intensity of hunting in the past. Where crocodiles were hunted, or are still hunted, the animals demonstrate an increased sense of alertness and caution with a longer approach distance. Two specimens (fig. 6) with estimated lengths of 2.4 m and 2.6 m allowed our boat to aproach to 50-60 m in the open water before diving (Gramentz 2008b). They surfaced after a couple of minutes, having moved farther away from the boat. Crocodiles of at least about 2 m in length with access to shoreline vegetation allowed approach to distances of only 4-5 m.

Since there are still some nests being produced, it can be supposed that there are more adult crocodiles in the Bentota Ganga than were sighted, although numbers are low. Bayliss et al. (1986) remarked that there are crocodiles, especially large ones, that are never seen. It may also be quite difficult to see even young crocodiles in areas where hunting pressure is great. Bustard (1986) reported that young *C. porosus* quickly lern to avoid approaching boats.

There is also a possibility that light pollution or photopollution (excessive or obtrusive artificial light) may have a negative effect on saltwater crocodile orientation. Brock (1960a) repeatedly observed crocodiles moving toward lights at night. Especially crocodiles in the lower reaches of the Kaluwamodera Ganga are subject to significant amounts of artificial light from houses, bridge illumination, boats, and even occasional fireworks. Lamps located directly along the shoreline that are kept on for the most part of the night could have a considerable impact on the behaviour of the crocodiles.

Natural predators

In addition to anthropogenic threats a natural threat for nests and hatchlings is possibly *Varanus salvator* which occurs in large densities in the area (Deraniyagala 1936, Daniel 1983, Gramentz 2008b) Whitaker & Whitaker 1978) consider water monitors a potential predator of *C. porosus* nests at North Andaman. Wilson (1971) observed a monitor digging out a crocodile nest at Sri Lanka. Also De Silva (2010) listed *V. salvator* as a predator of the eggs and he also mentioned mongoose (*Herpestes* sp.), wild boar (*Sus scrofa*), and golden jackel (*Canis aureus*) as predators of crocodile nests. The destruction of nests and feeding on hatchlings by *V. salvator* and other predators in already threatend crocodile populations has an even more significance.

Causes for conflicts between crocodiles and humans

Some crocodiles may abandon their sense of caution when potential food is at stake. On the Bentota Ganga, I observed observed a 1.9 m specimen on 30th September 2008 (20:42 hours) and on 6th October 2008 (19:25 hours) probably the same animal, even though the sightings were about 2.5 km apart (both on the same side of the river). In both cases meat scraps had been dumped near the water's edge in one place it was beef and goat meat left as part of a Muslim school's Ramadan festivities; in the other place, fish and chicken scraps from a weekly market. Both installations were strongly illuminated for a number of hours after sunset. It is possible that this individual is making a connection with the light and a possible food source.

One resident of a village along the Nilwala Ganga explained that in the past conflicts with crocodiles used to be quite seldom. However, since riverbanks are recently being fortified and built up, with money from tsunami relief funds, there are more crocodiles coming near the village, and conflicts have consequently increased. The structure of the banks has been changed to decrease the effects of tides on water level, and increase the amount of water available for crop irrigation (e.g. for rice paddies). Crocodiles are attracted to these areas that now have consistently higher water levels. At first the villagers were happy with the improved irrigation, but with time, as more crocodiles began to move in, their initial euphoria turned to distress. Of course the residents do not want to relinquish the new abundance of water, but they do want to get rid of the crocodiles whatever it takes.

Part of the blame for the bad reputation of crocodiles among the general public is sensationalist media reporting. One of my assistants remembered how a local newspaper had reported a bus accident 17 or 22 years ago. Full of passengers, the bus had gone off a bridge into the Kaluwamodera Ganga (a tributary of the Bentota Ganga). According to the report, the saltwater crocodiles living in the river had viciously attacked the people in the water. A friend of my assistant's, who lives directly on the river near the bridge, saw the accident. He said that there were indeed crocodiles in the water, but the dead and injured people were all victims of the accident, not crocodile attacks. But newspaper sell better with fantastic stories of crocodile attacks.

The Island (www.island .lk), a Sri Lankan online newspaper, reports nearly ten people killed by crocodiles every year in the Nilwala Ganga. However, this number is certainly an exaggeration. De Silva (2008) recorded a total of only eight deaths by crocodiles for almost an entire decade (1998-2007). Sensationalist, false reporting by local media naturally contributes to the persistence of the bad reputation of crocodiles in the public few.

De Silva (2010) found that of 131 investigated cases of human crocodile conflicts 37% of the people as reaction killed the offending crocodiles themselves. Sometimes family members and friends of the victim killed the crocodiles and in one incidence the father and friends have killed up to 4 crocodiles in revenge.

Recommendations and considerations

The recommendations listed below refer not only the main stream of the Bentota Ganga but to all waterways in the study area as side creeks and tributaries as for example the Welipenne Ganga.

1. At no time or place should nets be stretched from one side of a river across to the other side (fig. 14). Crocodiles that are inadvertantly caught in any fishing activities should be set free, not injured or killed.

2. Police boats should patrol the waters at irregular intervals throughout the day and night to curb illegal hunting.

3. Sand collecting (fig. 15) should not be allowed in areas inhabited by crocodiles.

4. Sand mining in the proximity of burrows of muggers should be stopped as it causes disturbance of the crocodiles. Whenever tanks have to be renovated or cleared this has to be done very carefully that no burrows are affected or even destroyed in the course of the process.

5. As disturbance is beside killing and habitat destruction a threat for the crocodiles as it keeps them away from a former inhabited area water sports such as jet skiing, waterskiing, banana boating, windsurfing, and speed boating should be completely prohibited. This would also be for the safety of tourists. Human casualties due to carelessness would turn the mind of the public against the crocodiles. An exhaustive report on measurements for the prevention of crocodile attacks was recently published by De Silva (2010).

6. At certain locations, especially where there is easy access to the water, signs should be posted, in Sinhalese (fig. 16) and English, warning of crocodiles and prohibiting swimming, The signs should help the people to perceive crocodiles as a normal part of life in these areas. Possibly not more than ten signs should be needed in the Bentota Ganga region.

7. Clearing of trees for firewood, and consequent destruction of crocodile nests, must be stopped in the Nilwala Ganga region (De Silva 2008).

8. Hotels and guesthouses should provide information brochures explaining the habits of saltwater crocodiles in the Bentota Ganga, and the importance of protecting them.

9. No more permits should be issued for new buildings or for adding on to existing buildings in the shore regions of the Bentota Ganga and Nilwala Ganga, for example. Illegal buildings should be torn down at the cost of the builder, and the shore should be be restored, as much as possible, to its riginal natural condition. To avoid further habitat destruction and reduce the potential for conflict between humans and crocodiles, boat traffic, and other disturbances, no more building should be allowed along the still largely intact shore regions of rivers and lakes.

10. All buildings and small villages near the banks of the rivers (including the Bentota Ganga) should be protected with fences on the side facing the water.

11. In all buildings close to the banks of the rivers the lamps should be screened.

12. Fireworks should be completely prohibited near rivers the noise probably disturbs the communication between crocodiles. On New Year's Eve Brock (1960b) noted a modification of the behaviour of his *C. niloticus* which was usually silent. After each bang of the fireworks the crocodile responded with one short and loud roar).

13. On railroad tracks leading through regions inhabited by crocodiles a speed limit should be maintained which is slow enough to stop the train to avoid accidents with crocodiles crossing or resting on the track.

14. The discarding of animal scraps from market, etc. into the rivers should be stopped.

15. Inland and off-shore fishermen must be emphatically informed that crocodiles are protected animals and should never be killed if they are caught inadvertantly. Should the crocodiles because of their size impose a threat to the fishermen the release should to be done by specialists. The safety of both humans and crocodiles has priority over material damages. A fund could be raised for compensation of damaged fishing gear for local people.

16. “Problem crocodiles” should not be simply shot they should be relocated.

17. There is a long time history of fishing in the Bentota Ganga. A number of human casualties resulted in the construction of the boats used for fishing. Therefore safer boats should be employed to reduce or at best prevent crocodile related human deaths and injuries. Many of the boats currently in use are narrow canoes with outriggers for support (locally named catamarans), the main body being shallow and completely open. A deeper, broader, and more enclosed boat type would be safer for transport and fishing.

18. Many shorelines in the remaining distribution of *C. porosus* in wester, southwestern and southern Sri Lanka are under enormous pressure from urbanisation. A complete suspension of construction in these areas is urgently necessary. A building-free strip of at least 40 m wide must be maintained along crocodile inhabited waters, with no access roadways to the shoreline. De Silva (2008) points out that a 20metre strip along shorelines is technically public land, and destruction of the mangroves there could easily by protected by law.

19. Porej (2004) states that mortality of eggs and juveniles must be reduced as a primary measure for the protection of the population of saltwater crocodiles in the Muthurajawela marshes.

If disturbance factors in the lower section of the Bentota Ganga are actually prevented in the framework of future conservation measures a problem could appear from natural movements by certain age classes. Webb (1977b) noted that rivers could lose crocodiles from the mouth particularly those in and above the two to three year old category. In fact in this study a specimen which was sighted closest to this area was approximately 1.90 m in total length (fig. 12). The distance from that sighting to the mouth of the Bentota Ganga is about 2.3 km. It is therefore possible that in this already depleted population at least some specimens from the Bentota Ganga leave the river for the Indian Ocean. On the other hand the mouth of the Kaluwamodera Ganga lies opposite the mouth of the Bentota Ganga into the ocean and the crocodiles also have the chance to enter this river.

The creation of a protected region for *C. porosus* in southwestern Sri Lanka is urgently necessary, and in my opinion this should at least encompass the Bentota Ganga and Madu Ganga as well as their tributaries. Any further land clearing or development for urbanisation, agriculture, or tourism in this area must be prevented.

Henle & Streit (1990) showed that nearly all reptile species, which became extinct due to influence of man within the last 2000 years were inhabiting islands. Due to habitat destruction and disturbances in the lower sections of rivers, the local population of *C. porosus* is more an "inland-species" with the same risk to become endangered. The trend of a diminishing population size which has been documented over the last decades clearly is directed towards a local extinction if not large scale protection measures are immediately initiated. Destruction of nests during clearing of vegetation in crocodile habitats was reported by De Silva (2010).

Future outlook and little reason for optimism

The status of both species of crocodiles on Sri Lanka is very bad. Already in 1971 the editor of the Sri Lankan journal Loris (vol. 12 (3):152) noted: "Crocodilians are threathened with extinction all over the world. In Ceylon this is true at least of the Estuarine crocodile (*Crocodylus porosus*)." And in fact saltwater crocodiles are actually on the brink of extinction in the Bentota Ganga and other rivers of southwestern and southern Sri Lanka the larger specimens, which were decimated by hunting in past years, are especially affected.

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Fig. 1: Relationship of sightings of immature and adult *Crocodylus porosus* (survey 2008).
A including recent hatchlings, B without recent hatchlings.

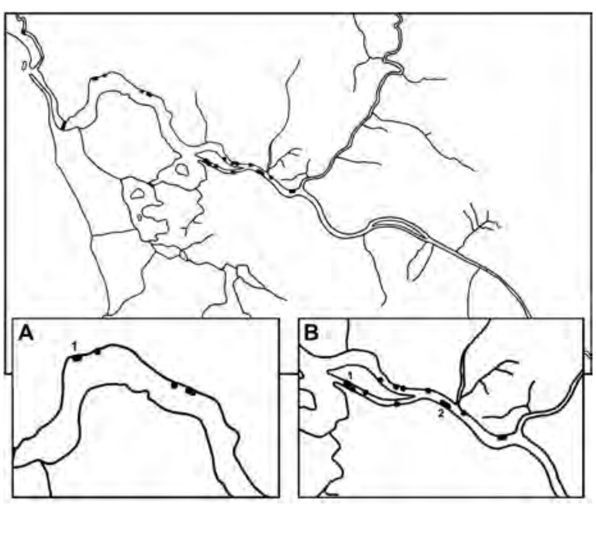

Fig. 2: Population structure according to sightings of *Crocodylus porosus* in the Bentota Ganga and Welipenne Ganga (survey 2008).

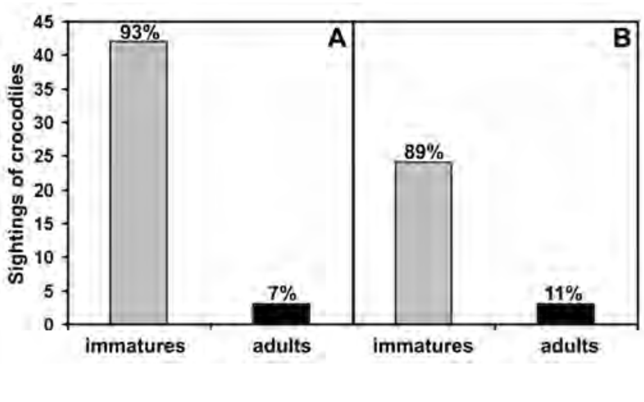

Fig. 3: Distribution of sighted recent hatchlings of
Crocodylus porosus (survey 2008).

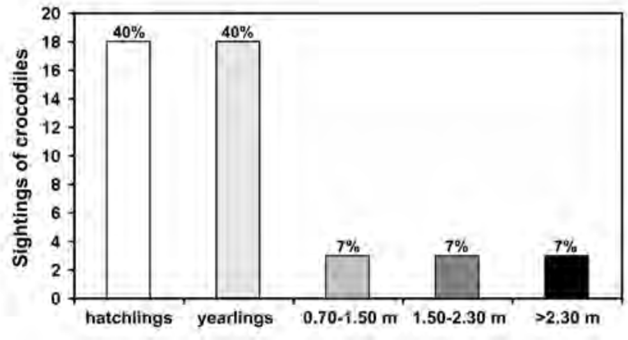

Fig. 4: Distribution of sighted yearlings of
Crocodylus porosus (survey 2008).

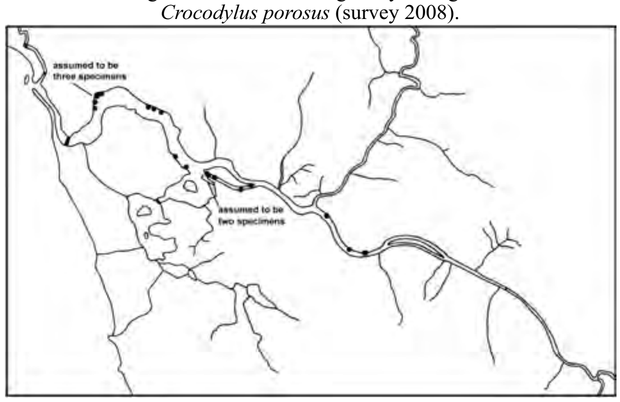

Fig. 5: Distribution of sighted *Crocodylus porosus*
of the size classes 0.70-1.50 m (○) and
1.50-2.30 m (●) (survey 2008).

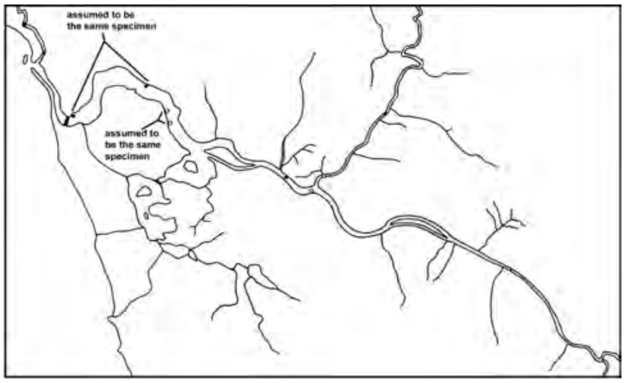

Fig. 6: Distribution of sighted adults of
Crocodylus porosus (survey 2008).

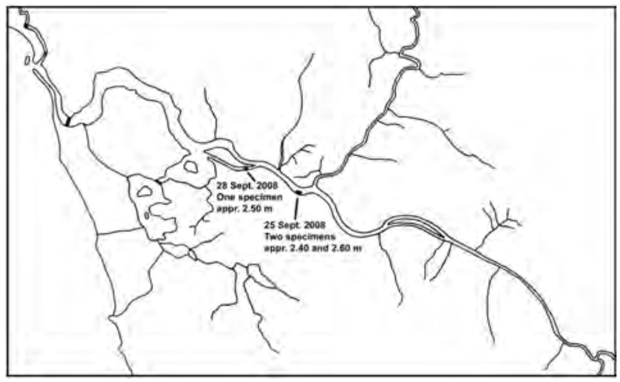

Fig. 7: Distribution of 'Eyes Only' counts
(survey 2008).

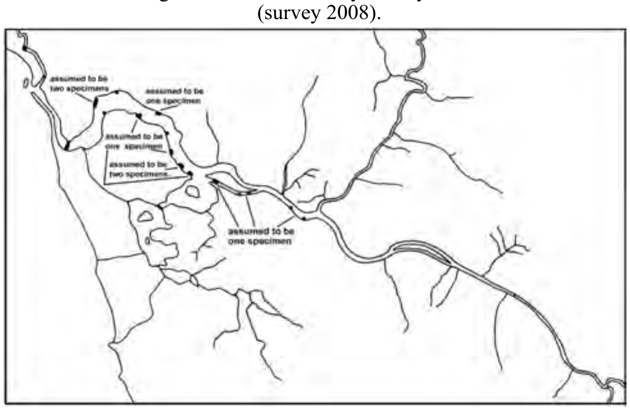

Fig. 8: Map of the most part of the study area of the
Bentota Ganga and localities of *C. porosus* during a preliminary
survey on 23rd and 26th November 2007.

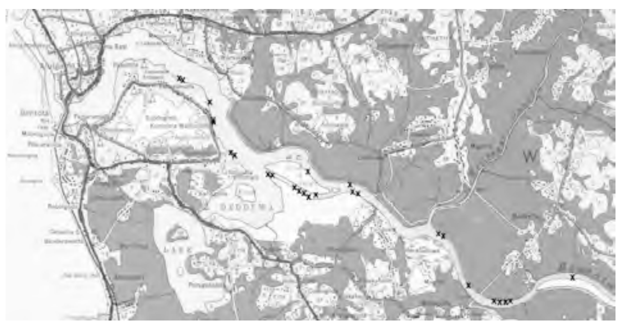

Fig. 9: Railroad bridge over a stream feeding the
Dedduwa Lake.

Fig. 10: Association of sighted hatchlings and yearlings of
Crocodylus porosus to bank vegetation (survey 2008).

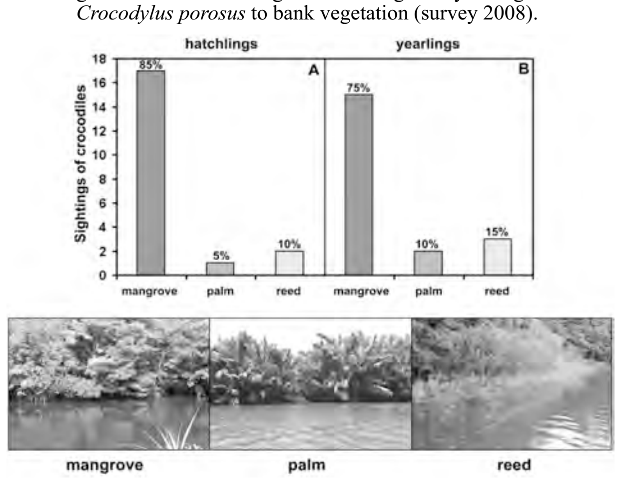

Fig. 11: Western part of the Bentota Ganga
with the position of hotel buildings.

Fig. 12: Examples of disturbances in the lower section
of the Bentota Ganga. A tour boating, B waterskiing,
C jet skiing, D windsurfing.

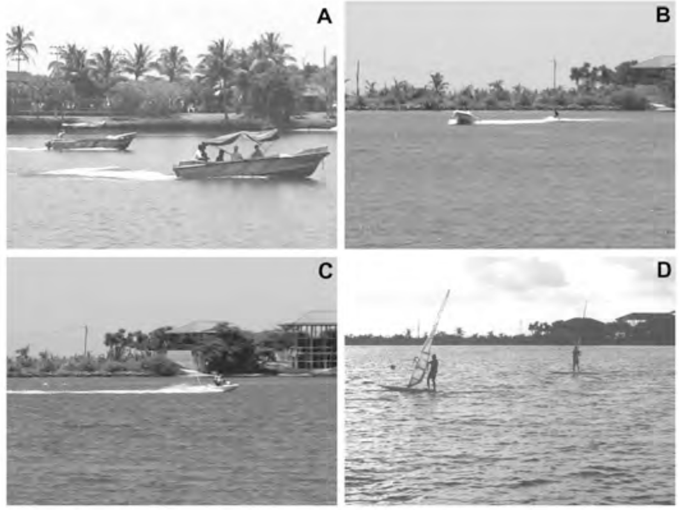

Fig. 13: Bentota Ganga and Welipenne Ganga showing
disturbances and construction sites along the Bentota Ganga.
A boat traffic, B water sports and diverse tourist activities,
C fishing net, D sand collecting, E sand collecting,
F motorway bridges.

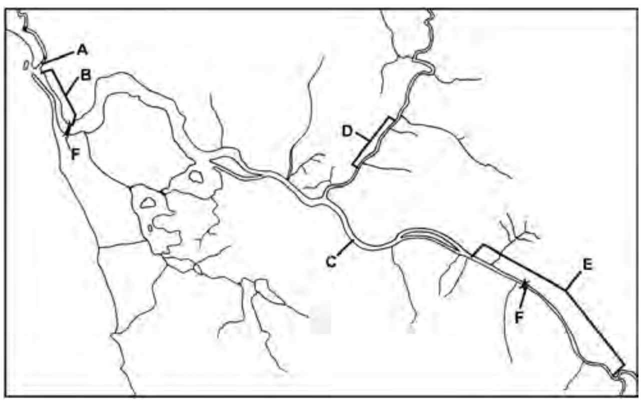

Fig. 14: Net stretched across the Bentota Ganga.

Fig. 15: Several boats collecting sand on the Bentota Ganga.

Fig. 16: Proposal for a warning sign (black letters and
graphics on ochre background) in Sinhalese saying:
"Attention. No swimming. Crocodiles in the water."

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Crocodile conservation programme in Odisha, India with special reference To saltwater crocodiles, *Crocodylus Porosus* of Bhitarkanika mangrove ecosystem.

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Abstract

Crocodilians were threatened in India due to indiscriminate killing for commercial purpose and severe habitat loss until enactment of the Wildlife (Protection) Act.1972. All three species of crocodiles (Gharial, *Gavialis gangeticus;* Saltwater crocodile, *Crocodylus porosus and* Mugger crocodile, (*Crocodylus palustris)* in the river systems of Odisha were on the verge of extinction by the 1970's. Crocodile numbers were few because of ever increasing human activity in the rivers and their other traditional habitats, and consequent reduction in the extent of habitable stretches. Also, because of the fact that survival rate of the crocodile hatchlings in nature is low, because of predation.

With initiation of the Government of India/FAO/UNDP Project "Crocodile Breeding and Management" a Crocodile Conservation Project was launched in 1975 in different States. The Gharial, *Gavialis gangeticus* and Saltwater crocodile, *Crocodylus porosus* conservation programme was first implemented in Odisha in early 1975. Subsequently the Mugger crocodile, *Crocodylus palustris* conservation programme was initiated, since Odisha has the unique distinction of having all the three species of Indian crocodilians. The Conservation and Research Centres were established by the Forest Department, Govt. of Odisha at Tikarpada in Satkoshia Gorge Sanctuary, Dangmal in Bhitarkanika Wildlife Sanctuary/National Park and Ramatirtha in Similipal Wildlife Sanctuary for Gharial, Saltwater crocodiles and Mugger crocodiles, respectively. The main objective of the crocodile conservation programme was to quickly multiply the population using the "grow and release" techniques. During the last three and half decades, the 'rear and rehabilitation' of crocodiles at various centres have been carried out successfully.

The Saltwater crocodile operation has been a successful one and the crocodile population in Bhitarkanika river system has gradually been built up. As per the Jan., 2013 census in the river systems of Bhitarkanika sanctuary, there were 1661 crocodiles including more than 200 adult crocodiles. This is a over 16 times increase of crocodile population during the three and half decades. More than 60 released female Saltwater crocodiles have bred successfully and are laying eggs in the wild. This is a 12 times increase compared to mid 70s with respect to availability of crocodile nests in the wild.

At present, Bhitarkanika holds the largest population of Saltwater crocodiles in the wild in comparision to all its distributional range in India. It is to be noted that about 80% of the total Indian *C.porosus* population are available in the Bhitarkanika river systems of Odisha state.

This paper deals with the "conservation success" of the crocodile conservation programme, especially the Saltwater Crocodile 'rear and rehabilitation operation' in the mangrove ecosystems of Bhitarkanika in Odisha, India.

Introduction

The population three crocodilian species in India as well as in Odisha critically reduced due to combination of poaching and habitat loss (Bustard,1974,1975; Daniel and Hussain,1975; Kar,1978, Kar,1978,81,89; Singh etal.,1984) by the seventies. Piecemeal efforts were being made from the sixties onwards to save the crocodile. On request of Government of India, FAO Expert Dr. H.R. Bustard was appointed by UNDP/FAO to study on the prospects of crocodile rehabilitation in the river systems in 1974 and based on his report and guidance a Crocodile Conservation Project was launched in 1975 in different States.

During 1976, survey of (i) Saltwater crocodiles and (ii) Gharial crocodiles was conducted in the river system of Bhitarkanika area and in the Mahanadi, respectively. The number of Salt-water crocodiles in Bhitarkanika area was estimated to be 95, including 34 adults. The number of Gharials in Mahanadi was estimated to be 8, including 4 adults. No detailed survey was, however, conducted for Mugger crocodiles at that time, although the species occurred at several places in the State. The breeding population of Mugger known at that time was in the Balimela Dam in Koraput district.

An adult basking Mugger crocodile on the river bank of Satkosia Gorge

The Crocodile Project started with the objective of building the population and to make up the natural losses by death and predation through rear and release operation. This involved collection of eggs from the nests as soon as these were laid, incubation and hatching of these eggs in hatcheries under regulated conditions of temperature and humidity, rearing the young juveniles, marking and release of the young crocodiles into Nature in protected areas, and assessment of the degree of success in restocking any protected area with crocodiles released from the hatcheries. To accomplish these tasks, 3 separate research units were established at Tikarpara, Dangmal and Ramatirtha for the Gharial, Saltwater Crocodile and the Mugger, respectively. At the Nandankanan Biological Park, captive breeding plans for all three species were pursued.

Management Objectives

The broad strategy adopted for rehabilitation of crocodiles was to protect them in their natural habitats, to rebuild the population quickly through captive breeding (rear and release), and to build up trained personnel for the job. The broad objectives of activities under crocodile project were the following.

(a) To protect the remaining population of crocodilians in their natural habitat by creating sanctuaries.
(b) To rebuild natural population quickly through 'grow and release' technique.
(c) To promote captive breeding.
(d) To take-up research to improve management. Some of the major research activities have been in the following directions.

- Interpretation of the various types of data collected during survey and census.
- Determination of parameters for maximum success in egg collection, egg incubation, hatching, rearing and release, including husbandry aspects on feeding, food conversion and growth.
    - Study of habitat features and population structure.
    - Study of behavioural biology including reproduction, thermo-regulation, feeding, water-orientation, locomotion etc.

(e) To build up a level of trained personnel for better continuity of the project through trainings imparted at the project-sites and through the erstwhile Central Crocodile Breeding and Management Training Institute, Hyderabad.
(f) To involve the local people intimately through the following:

- The development of a strong level of acceptance of the project by the people, by locating the projects in rural areas where people could both see and participate in the entire programme.

- Protect the immediate and long-term interests of fishermen who reside within the sanctuaries, and whose livelihood depends on fishing, by, if necessary, providing an alternative source of income that was not detrimental to the conservation aims.

Project Sites In Odisha

Gharial project at Tikarpada

At Tikarpada, Gharial eggs were obtained at different points of time from Narayani and Kali rivers in Nepal and Chambal sanctuary in Madhya Pradesh, Rajastan and Uttar Pradesh. The eggs collected from Mahanadi were infertile. Some hatchlings of Gharial were obtained from eggs incubated in Royal Chitwan National Park of Nepal and Katarniyaghat sanctuary in Uttar Pradesh. All Gharials reared at Tikarpada and those produced from captive breeding at Nandankanan zoo, numbering more than 700, were released in the river Mahanadi between Boudh and Katrang.

An adult male Gharial with prominent “Ghara”

One of the assessments of the rear and release operation in respect of Gharials was made during December, 1987 - January, 1988, when only 25 Gharials were found to be surviving in the entire stretch of the river Mahanadi and down stream of Hirakud Reservoir over a length of 400 Kms. In January, 2012 census, two males and three female Gharials were sighted / counted in and outside of the sanctuary, respectively. A study was carried out to assess the reasons for poor survival of the Gharial in Mahanadi. For increasing the Gharial population to more viable levels it is absolutely essential to minimize fishing and navigation at least on certain stretches of the river. It has been under consideration to rehabilitate Gharials in Mahanadi up-stream of Hirakud reservoir, and some stretches of the river Brahmani.

Mugger project

The Ramatirtha center, meant for Mugger crocodiles, initially started with eggs and juveniles of Mugger procured from Tamilnadu. Since 1984 breeding of Muggers and the release of young ones into the nature in Similipal have been carried out, and so far more than 600 crocodiles have been released in Similipal.

(a) Census was conducted to ascertain the population status of Mugger crocodiles in the prominent rivers / water bodies such as West Deo, Budhabalanga, Khairi and East Deo inside the Similipal. A total of 82 Muggers were counted during 2012 census. The census result indicated that the two stretches namely UBK-Patbil and Kandadhenu- Lower Barhakamuda of the West Deo river were holding above 60% of total muggers in about 15 km of the river. This is the situation / trend continuing since late 1980s during which regular monitoring of the crocodiles has been carried out.

(b) An isolated population of about 40 Mugger crocodiles are now available in the Ghodahad Reservoir, which is an important tributary of the Rushikulya river in the Digapahandi range of Berhampur (T) Division of the Ganjam district.

Saltwater Crocodile Project

At Dangmal in Bhitarkanika Wildlife Sanctuary/National Park, Saltwater crocodile ('Baula' is the Oriya term for Saltwater Crocodile) eggs have been collected locally; and young crocodiles have been released in the creeks and the estuaries; and more than 2300 crocodiles have been released in phases since 1977(Kanungo,1976; Kar, 1978; Kar, 1981,1984; Behura,1999; Chadha and Kar,1999; Singh et al, 1984;Mohanty et al,2004; Patnaik etal,2012)

Basking male Saltwater crocodile (*Crocodylus porosus*)

This operation has been reasonably successful and the crocodile population in the Bhitarkanika river system has gradually been built up. Above 70 released female Saltwater Crocodiles have bread successfully and are laying eggs in the wild.

The annual census conducted in the river systems of Bhitarkanika wildlife sanctuary in January, 2013 indicated that there were 1661 Saltwater crocodiles and the crocodile population is on increasing trend. The details about the census results are as under:

Comparison of census results (2005 to 2012)

Hatchlings (<50 cm)	Yearlings (50-90 cm)	Juveniles (90-180 cm)	Sub-adult (180-240 cm)	Adult (240 cm+)	Total
486	356	396	128	295	1661
(29.48%)	(19.28%)	(25.74%)	(9.28%)	(16.22%)	(100%)

A juvenile partial white crocodile with a normal coloured crocodile

Size class	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Hatchlings	681	657	503	538	538	519	531	489	486
Yearlings	290	283	368	343	375	373	377	320	356
Juveniles	169	197	259	231	264	298	304	427	396
Sub-adults	107	122	135	143	148	156	166	154	128
Adults	207	203	232	261	271	281	292	269	295
Total	1454	1462	**1497**	**1516**	**1596**	**1627**	**1670**	**1659**	**1661**

The highlights of 2013 winter census are

(a) Bhitarkanika holds twelve (12) crocodiles of about 16-18ft. length, four crocodiles of 18-20ft. length and three crocodiles above 20ft. length.

(b) The areas (main Bhitarkanika river from Khola to Pathasala, Thanapati creek, Mahinsamada creek, Suajore creek, Baunsagada creek, Kalibhanjadia, etc.) having higher concentration of crocodiles fulfills the following basic requirements for survival of this endangered reptilian species:

(i) Good mangrove cover / fringing mangrove vegetations.
(ii) A network of creeks and creek lets.
(iii) Stretches of undisturbed mud banks as favored basking/resting spots.
(iv) Less human disturbance.
(v) Little or no illegal fishing activities.
(vi) Hypo -saline condition of water in the creeks, and
(vii) Depth of water (minimum 2.0 m at the lowest tide).

From the census results, 2013 as well as from the population trend, it is seen that the Saltwater crocodile population in the river systems in and outside the Bhitarkanika sanctuary is almost stable.

Management in the wild

Since the prime objective of crocodile project is to rebuild their population in the wild, restocking the sanctuaries with captive reared crocodiles is an ongoing programme. The resident and released populations of crocodiles are periodically monitored and the trend of nesting is also assessed.

Protection of crocodiles is a round-the-year activity. Measure threats are from intruding fishermen using nylon set nets which is most harmful for young and adult crocodiles.

Because of occasional reappearance of crocodiles in their former habitat that is now shared by increasing human population, there are occasional instances of nuisance crocodile. Such crocodiles are generally captured and shifted to some other river/creek or are brought back to captivity after careful consideration of the case histories and field conditions.

In the Bhitarkanika deltaic area, there are six Gram Panchayats consisting above one lakh human population reside surrounding the National Park area. More than 40% of the resident human population daily depend upon the National Park area for their livelihood. They illegally enter in to the tidal rivers and creeks for fishing using fishing nets of various mesh sizes and length, and also they collect fire wood as well as house hold materials form the forest. At times they swim in the tidal rivers with the logs and even they use hand made polythene boats to ferry big rivers. In the process, the people are attacked by the resident large males. Most of incidences of the crocodile attacks on humans recorded in the National park happened due to illegal entry of the people either for fishing or fire wood collection. Evidences were there that the fishermen managed to kill large male crocodiles of 19-20 feet length by putting illegally strong nylon nets in the potential crocodile habitats of Bhitarkanika river system, and even they had axed the head portions of the crocodiles.

The State Wildlife Organisation is very much concerned and taking all possible steps to prevent human-crocodile incidents. It is now essential to bring up a 50 metre strip of mangroves along all the creek and river banks in and outside the National park , which will ensure a total separation of crocodiles from people and domestic live stock.

Captive breeding of crocodiles at Nandankanan

Captive breeding units on all the three crocodilian species have been established at Nandankanan Zoo (Acharjyo et al, 1996 a,b,c; Kar et al, 1998). Muggers bred at Nandankanan Zoo have also been released in Satkosia Gorge. Gharials bred for the first time in Nandankanan in 1980, which was a world record. Although Gharials have failed in establishing in Satkosia Gorge, Muggers have settled down well in this stretch of Mahanadi River. As per survey carried in January to March 2012 there are 91 Muggers in Mahanadi system

Research and training

In-house research has been conducted to standardise 'the rear and release' technique. Studies have been carried out to determine the appropriate method of population assessment, egg collection, egg incubation, hatching, and husbandry of the young crocodiles and various aspects of behavioural biology of the three species of crocodiles and their habitat features (kar and Bustard,1991;Kar and Patnaik,1998; Mohanty etal,1984). The baseline data on Indian crocodilians and their management has been possible because of over 300 publications produced from these conservation projects.

Training has been imparted to all field staff employed in the project to help them to discharge their duties efficiently. Local people have been trained on how to bring live food for the hatchling in the pools.

Contributions

All the three species of crocodiles have been saved from the brink of extinction, and many of their habitats have been brought under the protected area network of the state. The crocodile project that has since long come to a slow-pace in the

State has contributed immensely to develop the know-how and spreading of awareness. Study on the ecology and biology of the Saltwater crocodiles emphasizes the presence of mangroves to be the most important facet of environment for the crocodile species. Loss or depletion of mangrove forest causes either complete extermination of the population or draw the population to the verge of extermination. The climate and the mangrove ecosystem are the factors for survival of the Saltwater crocodiles. Future of the crocodiles can be secured with adequate protection of their habitats.

Apart from producing a large number of crocodiles in a short span, the Crocodile Project has contributed in various ways to the entire approach of wildlife conservation, research and training.

- Local people have been intimately involved in the management of crocodiles.
- Full time research personnel have been inducted into the wildlife wing to carry out research on crocodiles and other associated wildlife.
- Some important wetland sanctuaries have been created with crocodiles as the flagship-species.
- Active management of other wetland species began in conjunction with the crocodilians. These included the mangrove plants, marine turtles, freshwater turtles, monitor lizards, Gangetic dolphins, Irrawaddy dolphins, otters and other reptilian fauna.
- Along with the crocodile project there began an intimate overseas collaboration in the field of wildlife conservation, education and training.

Acknowledgements

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East African holotype in Colombo, Sri Lanka

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Abstract

The original subspecies *Crocodylus niloticus pauciscutatus* Deraniyagala, 1948, was from East Africa at Lake Rudolf (Lake Turkana) in Kenya and adjacent Ethiopia. It is based on a holotype, and its type description is compared with the newer (1974 and onward) CITES version of the same name. The type material of *C. n. worthingtoni* Deraniyagala, 1948, and *Crocodilus multiscutatus* Rüppell, 1826, from Kenya and Sudan respectively, is also discussed, and specimens from Egypt, Madagascar are mentioned, and Adanson's "Crocodile vert" from the Senegal River is illustrated. Various problems involved with counting the dorsal, ventral and flank scales in African mesorostrine crocodilians are detailed.

Introduction

Until 1974, the subspecies *C. n. pauciscutatus* was pretty much ignored, but when CITES recognized this species-group name it became more than a hypothesis that could be listed as merely a junior synonym of *Crocodylus niloticus* without subspecies, at least temporarily. Therefore I evaluate the specimen basis for this name, and examine the characters that were claimed to distinguish the original 1948 *C. n. pauciscutatus* as a taxon. My conclusion is that this name is available in zoological nomenclature. However, its type description was internally inconsistent and with a remarkably small sample, and the reason he called the Lake Rudolf (= Lake Turkana) crocodile as *pauciscutatus* withstands neither close scrutiny not larger sample sizes from the type locality. Some old information from Rüppell (1826) and Deraniyagala (1948) about the dorsal scales on the body and neck of Nile River crocodiles from Egypt and Sudan is relevant, as is also some Ross & Mayer (1983) and other data about Madagascar. Explicit and substantive references are made to photographs in Graham & Beard (1973) that are not reproduced here, but that book was reprinted in 1990 by Chronicle Books in San Francisco, California.

Discussion

In a paper published in Sri Lanka (then Ceylon), of which the section titled"Probable new races of Nile Crocodile" is an included short part (pages 30-31, & figure 2 on plate 12), Paul E.P. Deraniyagala (1948) routinely and deliberately designated holotypes "type" and paratypes. However, in the type description of *Crocodylus niloticus pauciscutatus* Deraniyagala, 1948, he designated only a holotype, and it was "Colombo Museum specimen No 1" which is "the skin of an adolescent from Lake Rudolf presented by Mr. A. L. Griffith, the Assistant Superintendent of Police, at Lodwar, Turkana district, East Africa" and 161 cm long (not the animal's total length, but rather that of the incomplete skin). The scientific name of the Lake Rudolf or Lake Turkana crocodile is based entirely on this headless hornback hide. It was clearly stated that the holotype skin "had been removed by cutting along the mid ventral line" and that its head and the distal part of the tail were missing (Deraniyagala, 1948). Less clear is the nature of the "two adult skins from Lake Rudolf made available to me [i.e., to P.E.P. Deraniyagala] by Mr. L. E. Whitehouse" which Deraniyagala examined in Kenya. The ventral scales of the two Whitehouse specimens were reported in Deraniyagala (1948), although partly worded incorrectly. His table 6 category "Number of transverse rows of belly scales" (sic) must mean the number of truly ventral scales in the transverse row at the level of the widest part of the belly (what I often call "midbody" or "midbelly"). Probably redundantly his table 6 "Abdominal transverse scale rows" (sic) category appears to mean the same thing. In any event, the Deraniyagala (1948) text data about there being approximately 20 single-crested caudal whorls appears to be based on specimen(s) other than the holotype, and there were two of them (columns A & B in his table 6) owned by Mr. Whitehouse, of which the tail was complete on only one (the column A individual). The collar-vent count on the holotype skin is unknown, and so also is the transverse count of truly ventral scales across the widest middle level of the belly. However, the "type-skin" was reported in his table 6, column C, to have 19 double-crested caudal rows in its dorsal armor. Separately it was also said in table 6, column C to have 16 transverse dorsal rows on the superior surface of the body, which is different from his text characterization that in this subspecies "the dorsal scutes are in fifteen transverse rows from the neck to the back edges of the thighs" (Deraniyagala, 1948), when actually it was only the Whitehouse individual with a complete tail (column A) that had 15 dorsal body rows. The other Whitehouse adult (col. B) and separately the holotype juvenile (col. C) both had 16 dorsal transverse rows on their "body" (as opposed to the neck and the tail). Thus, the holotype data in his table 6 (number of transverse dorsal scute rows = 16) contradicts his "fifteen transverse rows from the neck to the back edges of the thighs" but, in contrast, this same table 6 data does not contradict his later text characterization that in *C. n. pauciscutatus* “there are generally 15 or 16 transverse rows of dorsal scutes” on the body (Deraniyagala, 1948). In addition to examining three skins from Lake Turkana in Kenya, one of which was later deposited in the Colombo Museum, Mr. Deraniyagala (1948) also examined an unknown number (“several”) adult skulls, and as evidenced by his written description of the lower teeth and selected bones of the lower jaw, and his plate 12, figure C illustration, at least one of the skulls had its mandibles. Thus, because the holotype skin was headless, it is certain that all of the information concerning the head of *C. n. pauciscutatus* was based on other specimens which, although mentioned in the type-description, are not official paratypes of the name. Similarly not paratypes are the “three Lake Rudolf specimens now in the British Museum and numbered D. E. F. in Table VI” (Deraniyagala, 1948) which were examined by H.W. Parker at the BM(NH), and not by P.E.P. Deraniyagala. It was good scientific practice for Deraniyagala (1948) to designate a Colombo Museum specimen from Lake Rudolf as a holotype, while simultaneously not designating as paratypes the other Lake Rudolf material that was known to him (but not owned by him), and separately some Lake Rudolf specimens in London, England, reported to Deraniyagala only in words and numbers by Mr. Parker. The species-group name *Crocodylus niloticus pauciscutatus* Deraniyagala, 1948, is based in zoological nomenclature upon one unique and incomplete individual animal. Thus, Ross (2006) was technically wrong about there being belly scales data about a “type series of the name” (sic), because there was no belly scales data from the holotype (a type-series of 1) in Deraniyagala (1948). In Ross (2006) the two Whitehouse skins were mistakenly treated as paratypes, which they definitely are not. Despite my 2006 error, the basic Ross (2006) question remains unchanged about whether or not the two standard kinds of ventral scale counts on the holotype of *C. n. pauciscutatus* identify it correctly to subspecies in the old official identification manuals for CITES regulated crocodilians.

Separately there is a statement in Ross (2006) which alleged that the *Crocodylus n. niloticus* material that Deraniyagala (1948) distinguished as different from the Lake Rudolf crocodile was from “Faiyum, Egypt” (the Fayum). That assertion was based on information in the introduction to the paper, and I had overlooked two specimens of *C. n. niloticus* explicitly cited in the crocodiles essay as “an adult skin at the headquarters of the Southern Area Camel Corps at Assuan, and another at Wadi Halfa” (page 30 in Deraniyagala, 1948). These two are the skins that formed his southern Egypt (Aswan on the Nile) and northern Sudan (Wadi Halfa on the Nile) sample for comparison with the skins in Turkana, Kenya, at Lake Rudolf.

The Aswan and Wadi Halfa skins each had 17 dorsal transverse body rows according to counts made by Paul Deraniyagala himself at those places, or possibly from his own photographs. The difference between 17 dorsal body rows for these two Nile River animals (n=2), compared with the 15-16 that he counted on Lake Rudolf animals (n=3) was the justification for naming one of the two Lake Turkana skins with 16 rows as *pauciscutatus* meaning few scaled (16 on the holotype) compared with many scaled (17 transverse body rows). The latinized term for many scaled is “multiscutatus”, and both Aswan and Wadi Halfa are geographically located very near to the type-locality of *Crocodilus multiscutatus* Rüppell, 1826, which is the Nile River in northern Sudan (probably known to Deraniyagala indirectly through Boulenger's or someone else's synonymy listing). In his 1825 letter from Dongola, today the capital city of the state of Northern in the nation of Sudan, Eduard Rüppell (1826) asserted that there are two species of Nile River crocodiles in the Dongola (actually Sukkot or Soucot) region, which itself is located between the Nubian Desert and the state of Northern Kordofan. These two species were “*Crocodilus vulgaris*. Lin.” (today *C. vulgaris* Cuvier) and his own new *Crocodilus multiscutatus*. Both of Rüppell's species exhibited the same number of transverse dorsal rows on the body, namely 16 each. The reason that Rüppell (1826) employed the name “*multiscutatus*” was not to denote the number of transverse dorsal body rows (which is the same 16 in both of his Dongola taxa), but rather to denote a remarkably large number of scales within the individual transverse row across the animal at the midbody level (at or near PC-12) where the dorsal armor is its widest.

Thus, the name *C. multiscutatus* Rüppell reports a transverse count across the dorsal surface at or near PC-12 (“midbody”), while in contrast *C. n. pauciscutatus* Deraniyagala reports a lengthwise count of dorsal transverse rows located between but not including the neck and the tail, with the dividing line between body and tail being the transverse level of the rear edges of the thighs in Deraniyagala (1948), but Rüppell (1826) did not define where the body stops and the tail begins.

Given the coincidence that Rüppell (1826) said 16 transverse rows on the body for all of the *Crocodylus* in the Nile in northernmost Sudan, and Deraniyagala (1948) said 16 transverse dorsal body rows for his Lake Rudolf holotype, it becomes important to note that Deraniyagala's (1948) Turkana, Kenya, animals (n=3) were reported as 6 scales across at midbody when Deraniyagala (1948) said that in his *C. n. pauciscutatus* “the contiguous dorsal scutes are arranged in 3/3 longitudinal series. Ventrally the two median rows are noticeably larger than the others. The specimens examined were three skins and several adult skulls”. Thus, the 3/3 data is a generalization, as opposed to a direct report of the number of dorsal scales that are contiguous with each other as a transverse row at the widest level across the body on the holotype specimen. Clearly neither his ventral nor his dorsal scalation generalizations are direct reflections of the holotype, and all of his observations about the head, and his information about the maximum adult size of the crocodiles in Lake Turkana, is also not based directly on this holotype individual.

What Rüppell (1826) said about *Crocodylus* in the Nile River in northern Sudan is that some (namely *C. vulgaris*) have 6 scales across (presumably 3/3) at midbody, while others (namely *C. multiscutatus*) have 10 scales (presumably 5/5) in the corresponding transverse dorsal row. I do not understand exactly how Eduard Rüppell counted his 10 scales across the back, but I have seen 9 contiguous dorsals at or near the midbody level (actually in PC-12 only) in *C. niloticus* rarely (Ross & Mayer, 1983). Because Rüppell (1826) is a very obscure paper and printed in a difficult German typeface, it is almost certain that Paul Deraniyagala did not know that *C. multiscutatus* Rüppell referred to the breadth of the midbody carapace. Probably all that he knew (if anything germane) was that the type-locality of *C. multiscutatus* was the Nile River in northern Sudan (near Wadi Halfa and Aswan). He did not know that Rüppell (1826) had reported 16 transverse dorsal body rows on all of the crocodiles in the Dongola (Soucot or Sukkot) area.

The dorsal character said to distinguish *C. n. pauciscutatus* (defined as Lake Turkana) from *C. n. niloticus* (defined as Wadi Halfa and Aswan) does not work, unless Rüppell's definition of what qualifies for counting as a dorsal transverse row was different from Deraniyagala's. Further, when Deraniyagala (1948) said that "Mr. H. W. Parker informs me that three Lake Rudolf specimens now in the British Museum and numbered D. E. F. in Table VI, possess 16, 16 and 17 rows", he appeared to accept that data, and if so it too contradicts the simplistic dichotomy that 15 or 16 means Lake Rudolf, while simultaneously 17 means not Lake Rudolf. However, ambiguity at the thoracic and sacral ends of this lengthwise counting character casts doubt about the homology of different men's (Deraniyagala's, Parker's and Rüppell's) counts of the number of transverse rows crossing the body.

On whole animals the traditional method of finding the sacro-caudal juncture by the back legs sometimes arrives at the same result as the Ross & Mayer (1983) method, but not always. Other specimens such as flat skins and stuffed animals present special problems. There is a Ross & Mayer (1983) recommended way to find precaudal row #1 (PC-1) and caudal row #1, but it was not employed by Deraniyagala (1948), and it was presumably applied by neither Mr. Parker (in Deraniyagala, 1948) nor E. Rüppell (1826). The parsimonious presumption is that all of these men employed the same hind-legs definition for the division between the body and the tail, but it is unlikely that their specimens were all flat skins. The hind leg on a whole animal is presumably significantly different from the hind leg on a flat skin. If this is not true, then someone should demonstrate it. Also, exactly what the back edge of the thigh means needs clarification, because it is different at the juncture with the body, compared with further out along the femur.

In *Crocodylus niloticus* "there are 16 or 17 continuous rows of precaudal armor, with four to nine, usually six, scutes per transverse row at midbody. The median scute pair of the anteriormost thoracic row is often enlarged" (Ross & Mayer, 1983). However, table 1 in the same 1983 paper showed that rarely a result of only 15 dorsal body rows was encountered (PC-16 has a mode of 6, and a range of 0-6). Also I newly note that the Senegal River stuffed specimen illustrated as figure 1 in Ross (2012a) has an obvious and normal sized anteriormost thoracic row, and then anterior to it is a vestigial row that some people might count as a transverse body row present, while other people might consider it absent because the scales are so much reduced in size and number. It is just a pair of tiny scutes on Adanson's "Diasik" or "Crocodile vert" MNHNP 0.7524, and this ancestral transverse thoracic row can be seen near the extreme left edge of the photograph below (Figure 1) in the present paper.

There is a similar but more obvious anteriormost thoracic transverse row situation on a Lake Rudolf *Crocodylus niloticus* shown in a photo on page 62 of Graham & Beard (1973). This reduced and interrupted row is located between the shoulder blades and consists of a contiguous pair of median scales and also a detached smaller scale on the ends of a vestigial transverse row (reduced from 6 to 4 by internal deletions). On this individual Lake Rudolf or Lake Turkana animal there are three transverse rows of nuchals, but the description based on three skins in Deraniyagala (1948) indicates a nuchal cluster of two transverse rows. The posteriormost of the three transverse rows of nuchals is not obligatory in the Nile crocodile. Sometimes it is present to a variable degree, and sometimes it is completely absent. The Graham & Beard (1973) page 62 Lake Turkana crocodile has the posteriormost row of nuchals present as fully expressed scutes in a pair, and 2 is the maximum normally expected in this cervical row (PC-19) on this species.

There is a page 90 photo in Graham & Beard (1973) that shows the complexity of the osteoderms in the cervico-thoracic juncture region on another Lake Rudolf *Crocodylus niloticus*. There is good reason to question the simplicity of the dorsal scale counts on the body in Deraniyagala (1948) and also those in Rüppell (1826) and the majority of other more recent reports about the living northern African mesorostrine crocodilians.

It was implied in Deraniyagala (1948) that Lake Rudolf *Crocodylus* have a transverse space of unarmored skin separating their nuchals from their thoracic and body armor. This is true in the page 90 photo in Graham & Beard (1973), but apparently not so in their page 62 example which has its cervical and thoracic rows essentially continuous, and thus not separated from each other by a broad band of flexible skin at the cervico-thoracic juncture. The page 62 animal has PC-19 present as 2 scutes, but the thoracic row immediately adjacent and posterior to it is probably not PC-18, because table 1 in Ross & Mayer (1983) said that PC-18 has a mode of 0 and a range of 0 in *Crocodylus niloticus*. The anteriormost transverse thoracic row on this individual should (in theory) be PC-17. However, I would need to at least see the sacral region more closely, and better yet feel the perpendicularly outstretched femur bones of the hind limbs, and separately the iliac crests of the pelvis, to say for sure that PC-18 is not the body row in question.

Separately perplexing is the Deraniyagala (1948) dichotomy of "median rows of ventral scutes not enlarged" in *C. n. niloticus*, compared with "median rows of ventral scutes enlarged" in *C. n. pauciscutatus*. This character presumably refers to the median pair of scales in appropriate transverse rows, but in a picture on the bottom of page 246 in Graham & Beard (1973) the dimensions of the scales bordering the long-axis ventral midline of the animal do not look differentially enlarged compared with their neighbors. To the contrary, there is a remarkable degree of regularity (approaching three dimensional reflective symmetry) in "the two median rows" and their general region on at least the midbody part of the belly (see also the pages 118-119 photo in Graham & Beard, 1973). Based on experience, I do not characterize the belly scales as occurring in longitudinal rows, but rather as transverse rows only, and actually they are not truly transverse rows. The midline phenomenon along the length of the belly has an embryological complication and this makes it prone to anomalies. Therefore I prefer to perform the collar-vent count a full scale away from the midline (the Bronx Zoo method), once on each side to purposefully avoid the median pairs of elements, as explained in Ross (2012c).

There is an old and rare book by Karlheinz Fuchs in which Madagascan *Crocodylus niloticus* (his "Croco Mada" ventral skins) were alleged to exhibit a "double row of broad scales found along each side of the ventromedian line" and resemble the commercial skin of East African animals on the mainland (his "Croco Afrique" belly hides) in some ways. However, as documented in Ross (2012b), Mr. Fuchs (probably written in 1973) did not say that these especially broad pairs of scales are characteristic of *Crocodylus niloticus* in Kenya, nor in a tiny part of adjacent Ethiopia (nor a corner of South Sudan) at the northern end of Lake Turkana.

The fact that the number of transverse rows in the collar-vent count, and the maximum number of scales in a truly ventral row across the belly were reported for the two Whitehouse skins (presumably hornbacks, but not stated), but not the holotype skin (definitely a hornback) suggests that the ventral long-axis midline on "Colombo Museum specimen No 1" was damaged during preparation. It is unknown whether or not the cloacal oval is present, and peripherally there is ambiguity about whether or not any of its paws are present. The exact incompleteness of the holotype of *C. n. pauciscutatus* Deraniyagala, 1948, needs being explicitly reported, but it is known that the tip of its tail is missing after the 15th dorsal transverse row posterior to the sacro-caudal juncture, which in Deraniyagala (1948) was defined as the level of the back edges of the thighs. The level where the body stops and the tail begins is alternatively determinable the Ross & Mayer (1983) way for flat skins, stiffed animals, and on selected photographs. The results of the two (1948 and 1983) methods might be slightly different. If anyone has done scale counts on the Colombo Museum skin from Lake Rudolf, the method of identifying the sacrocaudal juncture in the dorsal armor deserves special and explicit explanation. Similarly the definitions employed in performing ventral counts on the belly skin should be noted (see Ross, 2012c). The Ross & Mayer (1983) dorsal armor method was designed primarily for whole animals that have their pelvic and femur bones inside them, and on which these bones can be manually felt through the skin and muscle. Unfortunately only one of the three Ross & Mayer (1983) ways of finding the sacro-caudal juncture works on flat skins and from specially detailed photographs.

In the two cited dorsal view photos in Graham & Beard (1973) it is difficult to see exactly which transverse row in the pelvic region is the first to slightly broaden, going posteriorly towards and onto the tail, and therefore I can not reliably locate the sacro-caudal juncture on these two photos. Thus, because the location of PC-1 is uncertain, it is impossible for me to assign a precaudal number to the anteriormost thoracic row. However, my best guess is that their page 62 animal has 17 precaudal rows present, and judging from the right edge where the hind leg had formerly been, my guess is that the third row from the bottom on the page 90 picture is PC-1, because after the body armor narrows and crosses the pelvis, it is this row that seems to slightly widen. If correct about PC-1, then the anteriormost thoracic row (with two median scales contiguous with each other) is PC-17. In this same page 90 photo the single vestigial osteoderm surrounded by flexible skin in the cervico-thoracic juncture region is unassignable to transverse row. It could be a remnant of the anteriormost thoracic row theoretically possible in the Crocodylia (PC-18), or alternatively a fragment from the posteriormost cervical row possible in the Crocodylia (PC-19).

It was recently said that in *Crocodylus niloticus* "the dorsal scales, which are not directly adjacent to the nuchals, are arranged in 6-8 longitudinal and 17-18 transversal rows" (Trutnau & Sommerlad, 2006). In my opinion it is a seriously misleading and major oversimplification to say that the dorsal body scales are arranged in longitudinal rows. Rather, what they intended to say is that there can be 6-8 longitudinal keel rows at the general midbody level, but always 4 at the pelvic level (PC-1 and PC-2), and often less than 6 at the anterior end of the thoracic series.

There was no definition of exactly where the body stops and the tail begins in Trutnau & Sommerlad (2006), except their figure 13 (and its corrected caption), which is very vague. Problematically, the Trutnau & Sommerlad (2006) assertion that 18 transverse rows are possible on the body in *Crocodylus niloticus* might (hypothetically) in some cases be true when the back-legs thigh level is employed as the method of finding the posterior end of the "body" as opposed to the tail, but in contrast it still remains true that the Ross & Mayer (1983) prediction is that, when defined by its vertebral correspondence, PC-18 is always absent or reduced to a single scale or less in the Nile crocodile species.

There are four color pictures (figures 142, 150, 359 and 360) alleged by Trutnau & Sommerlad (2006) to be *Crocodylus niloticus pauciscutatus*, but none of the four are explicitly animals from Lake Turkana. Three are "Masai Mara, Kenya" (near Lake Victoria, and far distant from Lake Rudolf) and one is just "Kenya" for locality. The Trutnau & Sommerlad (2006) distribution for their *C. n. pauciscutatus* included all of Kenya, but it was unclear in Deraniyagala (1948) about whether or not his *C. n. pauciscutatus* occurred anywhere other than Lake Rudolf, Turkana, itself. Paul Deraniyagala (1948) examined a specimen from Lake Victoria, but he did not say that Lake Victoria has the same subspecies of *Crocodylus niloticus* as Lake Rudolf. He did, however, suggest that Lake Baringo in Kenya's Rift Valley has a different subspecies (*Crocodylus niloticus worthingtoni* Deraniyagala, 1948), which was said to be small adult animals (which is unlike Lake Rudolf, Lake Victoria and elsewhere). Further, he noted that Mr. Parker's examination of the BM(NH) material from Africa (no details, but implicitly not Lake Rudolf) revealed 17 transverse body rows on eleven, and 15 transverse body rows on one. That 15 result is perplexing, but I interpret Deraniyagala (1948) as saying that the Lake Turkana crocodiles have fewer body rows than *Crocodylus niloticus* in Egypt, Sudan, and pretty much the rest of Africa, including Lake Victoria. His 17 rows data from the BM(NH) implies that Deraniyagala (1948) was not saying that Lake Turkana and everything south and west of it (such as Madagascar, South Africa and Senegal) is the*C. n. pauciscutatus* kind. Therefore I today consider the species-group name *pauciscutatus* Deraniyagala, 1948, restricted to its type locality. There is a figure 6c illustration in Ross & Mayer (1983) showing a *Crocodylus niloticus* from Madagascar (MCZ 12552) which lacks an narmored space clearly separating its nuchals from its thoracic scales. Concerning this phenomenon, Ross & Mayer (1983) said that "in some individuals, especially from Madagascar, a row of two scales intervenes between the thoracic and cervical armor. We interpret this as PC 19 on the basis of its being closer to the cervical than the thoracic armor, but this identification is not certain". Thus there are at least two places in Africa where the Trutnau & Sommerlad (2006) characterization that the nuchals are not directly adjacent to the dorsal body armor in *Crocodylus niloticus* does not always work. For reasons discussed in Ross (2012b, 2012c), it was a surprise to Andy Ross and me that *Crocodylus niloticus pauciscutatus* Deraniyagala, 1948, ever became a CITES regulated crocodilian taxon. It had not been actively employed between 1948 and 1974. Note that the bibliographic listing on page 256 in Graham & Beard (1973) is wrong about one detail. The pagination of the Deraniyagala (1948) paper is not pages 31-32, which are merely the crocodile part.

As an example of the status of *C. n. pauciscutatus* before 1974, the words "*pauciscutatus*" and "subspecies" and "Ceylon" are not in Graham & Beard (1973). Further, Deraniyagala's name does not appear in their text. Separately, although Baringo was mentioned as a lake (through which an explorer passed), Graham & Beard (1973) did not mention the Lake Baringo crocodile hypothesis (*C. n. worthingtoni* Deraniyagala, 1948). In Fuchs (2006) the identification character "Number of lateral scale rows" was defined on his page 16 as "The clearly visible longitudinal rows are precisely counted on the transverse row midway between the posterior rim of the collar and the anterior rim of the cloacal vent. Determination of the size, the degree of ossification and lengthwise keels". He appeared to be reporting the number of enlarged flank rows encountered at midbelly and midbody level, as opposed to the number of scutes within any individual flank row. Thus I interpret Fuchs (2006) as indicating 3 or 4 lengthwise rows of enlarged scales in the flank skin at midbody in his own expanded version of *Crocodylus niloticus pauciscutatus* from 1974, which theoretically should include the 1948 original. However, there are more than 4 scutes in each of the obvious two flank rows on the Lake Turkana giant on the book's covers and pages 186-187 in Graham & Beard (1973).

Because Fuchs (2006) was working from the belly going outwards onto the flank skin, his "outermost" flank row is the one farthest from the animal's long-axis ventral midline. About *C. n. pauciscutatus* he said "Number of lateral scale rows: 3-4 large scales, keels on the outermost longitudinal row towards the dorsal scutes. Granular scales irregularly scattered between the large scales". Indeed, in the Graham & Beard (1973) germane photo there is a strip of granular scales separating the contiguous dorsal armor from the dorsalmost flank row, and similarly a band of granular scales separating that proximal flank row from the slightly more distal flank row parallel to it, and further there is a lengthwise zone of granular scales distal to that second flank row. Separately this Graham & Beard (1973) covers and pages 186-187 crocodile has a few granular scales within each of its two obvious flank rows, separating some but not all of the scutes within each row from its neighbors in the same row. The Fuchs (2006) data about the number of lateral scale rows in *C. n. pauciscutatus* appears to me to not describe what I see on this individual Lake Rudolf animal.

Therefore, in an attempt to better understand the meaning of this Fuchs (2006) character, I looked at his "*Crocodylus suchus*" (sic) account on page 113, which says "Number of lateral scale rows: 4-5 large scales, keels more or less strongly developed on all scales. Granular scales scarcely exist, nowhere arranged in longitudinal rows" (page 130). The type locality of the *C. suchus* species employed by Fuchs (2006) was not Egypt, but mistakenly "Niger" meaning the Senegal River, and based on the "Crocodile vert" or "Diasik" specimen collected by Michel Adanson. As shown in my Figure 1, the MNHNP 0.2724 specimen collected by Michel Adanson at the Senegal River has one obvious flank row of seven individual scutes. This is not the Fuchs (2006) predicted 4-5 flank rows, and further there is a remnant of the lower row, but it is reduced to a short lengthwise ("longitudinal" in Fuchs, 2006) row of unkeeled small ("granular" in Fuchs, 2006) scales at the midbody and midbelly level. Clearly the Figure 1 Senegal River crocodile has one obvious flank row, and this is different from the obvious two rows in Lake Turkana, but traces of the second (lower) row can perhaps be seen when the Figure 1 photo is viewed closely, and when the viewer is looking deliberately for vestigial traces of this ancestral flank row.

Conclusion

The name *Crocodylus niloticus pauciscutatus* Deraniyagala, 1948, is based on a single specimen that is expected to be in the natural history museum in Colombo, Sri Lanka. The hypothetical differentiation of *C. n. pauciscutatus* from its implied *C. n. niloticus* (and other potential subspecies) involves dorsal and ventral scale counts in the neck and body region, and also the special and obvious flank row(s) on the lateral surface of the body. Expanding the data in Ross (2006), there are now additional reasons to believe that the crocodiles in Lake Turkana did not key to their species-group name in the old CITES identification manual.

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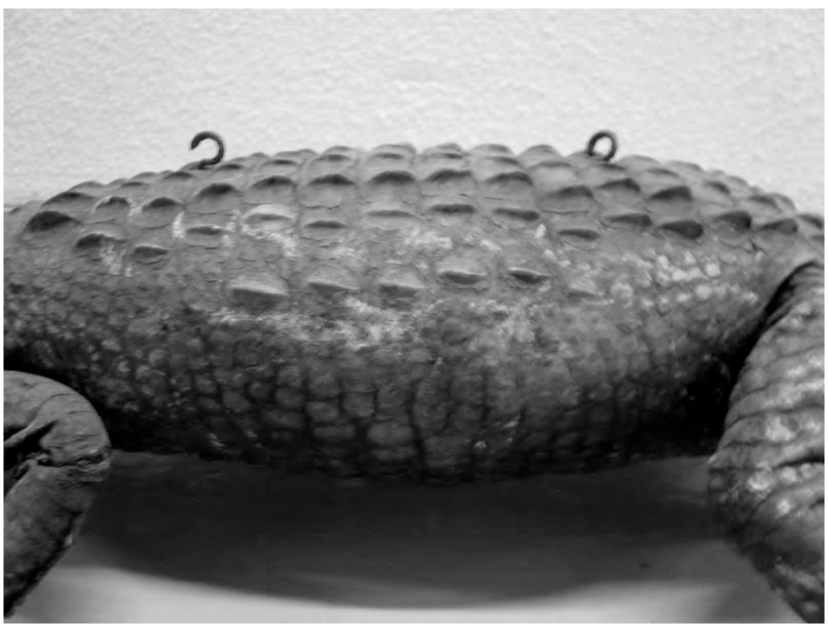

Figure 1. From the Senegal region, this mesorostrine African crocodilian (MNHNP 7524) has five or more really big flank scales, and these scutes are arranged in a single row. Photo by Ashley Pearcy.

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CSG Thematic and Working Group Reports

Human-Crocodile Conflict Working Group

1. Participants: Charlie Manolis (Chair), Christine Lippai, Erin Britton, Adam Britton, Colin Stevenson, Ashley Pearcy, Rob Gandola, Akira Matsuda, Raju Vyas, Tarun Nair, Phil Steele, Oswald Bracken, Rambli, Brian Wright, Brandon Sideleau, R.J. Rao, Hiran Goonewardene, Abhijit Das, Jigar Upadhyay, Snehal Bhavsar

2. Crocodile Attack Database: Adam Britton and Brandon Sideleau provided an update on development of an online database for crocodilian attacks (www.crocodile-attack.com).
   - A grant from Charles Darwin University (Darwin, Australia) will allow the website search engine to be developed.
   - The website is effectively a data gathering tool and will include elements such as Country Trends and will identify 'Hotspots'.
   - It is proposed that CSG members will be able to register and use the site. Initial access may be to summary tables and maps, but "deeper" access to the data will also be possible.
   - Brandon will send out a copy of the online form that people will be able use to submit attack data (injury/fatality on humans only).
   - The HCCWG will have the opportunity on comment on the website as it is being constructed.
   - Around $1100 per year will be required to maintain the database (eg hosting). Major upgrades of the site would require additional funding.
   - General agreement that would be a useful tool, although it was also recognized that data could easily be misinterpreted.

3. HCC Facebook and Google Groups: Following the Manaus meeting (2010), a HCC Facebook page and HCC Google Group were posted. Initial interest was good, but the initiative has subsequently faltered. Many people were not aware of the Facebook page. A link will be placed on the CSG website, and the sites monitored with a view to revitalizing them.

4. HCC Case Studies: The Chair indicated that people will be approached to provide information on specific case studies dealing with HCC and mitigation measures, for incorporation into the CSG website, with links to the Crocodilian Capacity Building Manual that is currently being developed.

5. Environmental monitoring**:** Ashley Pearcy raised the issue of whether environmental modeling could allow a level of prediction of HCC, and thereby allow mitigation to be more targeted.

6. 23rd Working Meeting: The Chair gave a summary of the proposed HCC session for the 23rd working meeting (Louisiana, May 2014).

At Plenary, the CSG Chair raised some concerns that an independent website on HCC, which aims to use data from CSG members, may be perceived as representing the CSG and the collective knowledge on conservation, research and management that it possesses. Enquiries for assistance with HCC issues may thus be directed to a website rather than the CSG.

Veterinary Science Group

This CSG Veterinary Science Group meeting gave the attending members an opportunity to meet to review and update the content of the report capturing the outcome of the meeting held in Manila 12 months ago. This was also a great occasion to connect and strengthen our relationships.

1. Worthwhileness of the CSG Veterinary Science group mailing list

In Manila the group concluded that it can be more true to its mission. Over the last 12 months the queries presented to the CSG-vet mailing list were met with limited but useful responses. The level of response can be described as adequate and we are thus still far from our aspiration of excellence. In Manila the group also decided to spread the word amongst herpetological groups, farming associations and zoological park associations that such the Veterinary Science group exists. The desired outcome is that as the offer of help becomes known, those in need will take advantage of it.

The update on this point is as follows

1.1. Matt Plummer, who is now in charge of a number of farming operations in Australia, has started promoting awareness amongst Australian farmers. Previous contact with individuals was met with some interest. Marisa Tellez contacted a number of American herpetological circles. Pablo Siroski, one of our active contributors on the web-based vet group, could not attend this meeting. Paolo Martelli had no update and Kent Vliet volunteered to take over his task of contacting AZA, EAZA and AAZ as he is already active on the AZA and EAZA. Background information and message was provided. Samuel Martin contacted the French Vet Zoo Association (AFVPZ) as well as other crocodile caretakers. We do not expect an immediate increase in demand for CSG-Vet input. We must continue to commit time to responding to the queries we receive.

1.2. On Charlie Manolis' recommendation, Paolo invited Cathy Shilton to join the Veterinary Science group. We are grateful and fortunate that that she has accepted with enthusiasm. Cathy immediately became an active member, already contributing very significantly to the Colombo workshop and meeting.

2. CSG Website

Over the last 12 months the following documents were added to the CSG website.

a. Necropsy procedures in English, French and Spanish translation - thank-you Samuel Martin and Luis Sigler.
b. Anesthesia literature references (up to 2010) - thank-you Anabelle Olsson.
c. Link to histopathology site.

3. Review the list of relevant research topics encouraged by CSG

These were areas of veterinary science and medicine that will benefit crocodilian medicine, conservation and biology. They were not revisited at the Sri Lanka meeting:

- anatomy
- immunology acquired and innate
- Stress: stress indicators, response to stress, stress monitoring, patho-physiological effects of stress
- epidemiology emerging diseases and biosecurity, including at international levels
- nutrition
- health assessment and screening in general and in the context of reintroduction following IUCN reintroduction specialist group
- croc specific veterinary training of managers and veterinarians in various areas.
- Behavior , medical and husbandry training of the animals
- husbandry and welfare, electric immobilization
- intellect, cognition
- endocrinology/reproductive physiology
- genetics
- physiology

4. Use of electro-immobilization

We had unanimously agreed on the following in Manila: *"Like every tool, electrical immobilization must be used by trained staff using well maintained equipment. To the best of our observations there are no reasons to consider that EI is more detrimental than manual capture to the individual or the group it is in. There is evidence that it less stressful to the animal (Franklin et al.). Studies are underway and more specific studies are encouraged."*

Update**:** One of our CSG-vet members, Dr. Silke Pfitzer, has completed a thesis titled "Physiological Parameters of Farmed Nile Crocodiles (*Crocodylus niloticus*) Captured Manually and by Electrical Immobilization". The thesis is being reviewed as we meet. The important issue of whether the electro-immobilization leads to unconsciousness was raised. See also point 5.

The following are pending and have been assigned

Topic	Action	Target
Veterinary procedures (general examination, sampling, medication etc.)	Samuel Martin Terry Cullen	May 2013, no update.
Literature resources	Kent Vliet Val Lance Paolo Martelli Charlie Manolis	Pending political and legal issues. We have been unable to progress on the issue of copyrights. It was decided that Kent will make available a list of his entire collection of papers, books and journals. We realize this will be challenging to search but it will have the merit of being freely and globally available for those motivated enough to use it.
Database of gross images of normal tissues and pathology with labels	Cathy Shilton	Cathy will add to the document used for the workshop showing a collection of necropsy photos. This will be posted as PDF and will offer a valuable resource for fellow vets. Furthermore Cathy will contact the WDA to see if a link specific for crocodilians can be shared.
Introduction techniques for new animals in captivity	Samuel Martin Terry Cullen Geoff McClure	May 2013, document prepared by Geoff, under review.
Parasite database Xcel format	Marisa Tellez	December 2012. Subject to publishing issues. Very likely to be made available by CSG meeting in 2014.
Manual for parasite collection/preservation by Marisa Tellez	Marisa Tellez Paolo Martelli	Had been lost in the mail, is now available and will be published shortly.
Share information on histopath database technicalities to facilitate adding material	Paolo Martelli	August 2012. The website owners are no longer available for further uploads but existing database will persist. We have not located a university that will allow scanning and posting for free.
Facilitate movement of histopathology slides in and out of the USA	Terry Cullen	Update next CSG meeting, 2014
Scientifically sound study on effect of various electrical parameters on crocodiles subjected to EI	Marc Merchant	Pending review of Dr. Silke Pfitzer's thesis to refine needs, see below

5. Present and assign tasks for the capacity building group

5.1. Euthanasia/killing methods. Paolo presented a draft that was reviewed collectively.

a. Stunning by shooting or captive bolt followed by pithing. At this moment electrical immobilization is assumed to cause unconsciousness as in other species. However no specific data exist in crocodiles to support this so an important caveat is placed on pithing after immobilization that the crocodile must appear to be unconscious (unresponsive and unaware) before pithing.

b. Also refer to the document by the expert panel on humane euthanasia of reptiles to choose methods suitable for crocodilians (the document is biased towards pythons).

c. Pithing without stunning is not a humane method of euthanasia or culling and should be discouraged. However the group is well aware of how common this practice is and of cultural and legal differences. Also stunning a medium or large crocodilian without proper equipment may not be possible, in which case it is preferable to swiftly carry out pithing without stunning than to attempt traumatic destruction of the brain repeatedly. We encourage CSG members to increase awareness that this practice is not ideal and should be replaced with one of the above.

d. Bleeding without pithing is not acceptable by any standard. Pithing is an absolute requirement and should be done in the unconscious animal. We encourage CSG to work towards building awareness

Method	Acceptability
Captive-bolt pistol	Alone or with a subsequent method to ensure death (pithing) if the brain is not immediately destroyed.
Blow to the head with a hard implement	In combination with a subsequent method to ensure death (pithing) if the animal is only stunned.
Decapitation	With a subsequent method to ensure death (pithing or blunt trauma).
Shooting	With a bullet appropriate for size of the animal and in line with relevant legislation, training and safety protocols (effective, quick and humane). Particularly in conjunction with spinal severance and pithing (used on crocodiles). When the distance between the animal and the shooter is minimized in order to reduce margin for error for "missing" the brain.
Pithing	After prior stunning (captive-bolt or blow) or decapitation and as method to ensure death.
Cervical Dislocation, if performed in the correct size animal (<200 g)	With proper technique and followed by another procedure to ensure death.
Injection	Depending on the context and the experience/training of the person (e.g. veterinarian, researchers).

Good questions that arose from this discussion are:

1. Can we recommend voltages, frequencies and length of usage for electro- immobilization? No we cannot at this stage. It is a field that needs further scrutiny. In domestic animals it has been shown that higher frequencies do not lead to unconsciousness and cause pain. Data is lacking in crocodilians.
2. Is an electrically immobilized animal unconscious and can E-I be used as stunning method prior to pithing? Studies in food animals show that effectiveness, pain and unconsciousness are a function of frequency, voltage and duration. Such studies are lacking in crocodilians.

5.2. Share with the capacity building committee what are the (web) resources or resources that the members use. Links can be added to the CSG website. It was clear that none of us was really clear as what the capacity building referred to. We will seek further guidance from Ashley Pearcy.

6. Other matters

6.1. With Chris Banks, to request people maintaining adult or breeder *C. mindorensis* to submit a 'floor plan' and photo/s of their breeder pen design with comments on the behavior/compatibility of their animals. Submissions will be collated to ascertain any features of pen design that will affect breeding. All submissions will be acknowledged and presented at the next CSG working meeting in 2014. This initiative will be included in a database - it should be noted that there is no current 'studbook'. This has been completed, was presented by Geoff McClure in Negombo and was added to the Manila Proceedings.

6.2. The crocodile husbandry challenge - to design self-cleaning accommodation for 50 2-year-old crocodiles. Proposals will be presented at the 2014 CSG meeting.

7. Any other matters

Workshop at the Colombo Zoo: attendance was approximately 100 participants of all boards in contrast to the intended 25-30 vets and wildlife officials only. As a result the workshop turned out rather different from what we had intended. However we are not disappointed at all and the feedback from the workshop has been overwhelmingly positive, with most people finding it useful and wanting more workshops. Lessons learnt are: A well-managed registration, a clearer description of the workshop scope and content and a proper assessment form.

The group unanimously would like to see workshops included in future CSG working meetings. The following areas where identified as useful to seasoned or beginning professionals and students alike. This list is not exhaustive:

- veterinary techniques
    - general exam
    - special examinations
    - anesthesia
    - surgical techniques
- translocation and transport of large crocodilians
- field biology techniques
    - measurements
    - stomach flush
    - marking and identification
    - bleeding
    - population and nest surveys
- captive rearing techniques
    - egg handling
    - care of hatchling
    - slaughter
- methods of capture in different situations and good restraint practices
    - on land
    - in water
    - from boat
    - trapping

Mark Merchant and Marisa Tellez will do their best to organize a 4-hour workshop on field biology at the CSG meeting in 2014. This is very short notice but hopefully it will be possible. Most likely it will include measurements, capture from a boat, bleeding, etc.

CSG Tomistoma Task Force

Participants: Bruce Shwedick (Chair), Colin Stevenson, Kent Vliet, Jen Brueggen, Szu- Lung Chen, Paolo Martelli, Rambli Ahmad, Oswald Braken Tisen, Tarun Nair, Nirmal Kulkarni, Shakthi Sritharan, Fabian Schmidt, Akira Matsuda, Agata Staniewicz, Samuel Martin, Gowri Mallapur

1. Meeting started with introductions, first by CSG-TTF chairman Bruce Shwedick, about his involvement with TTF and a brief history. TTF was initiated in Gainesville Florida in 2002. Since then several people have held the post, starting with Grahame Webb, then Ralf Sommerlad, and followed by Rob Stuebing. The other attendees introduced themselves and their interest in the group or work related to Tomistoma.

2. Bruce Shwedick committed to remaining in the position of Chair for as long as is needed.

3. The recent TTF report to the Steering Committee will be published on the CSG website, together with the complete

minutes of the meeting.

4. The aim of the TTF will be to now move its main focus of attention to Asia.

5. Updates from the last meeting. Re finances, the TTF has a fund of $US45,000 available. Recently, a Night for the Crocs fund-raising event resulted in just over $US7100.

6. Revised draft assessment: This has been completed and the consensus after consultation with CSG experts is to move Tomistoma to "Vulnerable". The CSG review is awaited. Colin Stevenson mentioned that this review was initiated because more information is available since the last assessment. Paolo Martelli raised the question that seeing more animals and greater accessibility may mean more encroachments and pressures.

7. The TTF website will be integrated into the CSG's website (www.iucncsg.org), and key portions will be translated into Bahasa Malay, Bahasa Indonesian, Japanese and Chinese.

8. Recommendations from 2008 Tomistoma Workshop will be updated and re-circulated among the TTF core members and to participants of today's meeting. Those CSG members with specific interests and expertise will be given an opportunity to take on responsibilities. These recommendations are divided into three areas: Captive Husbandry, Field Research and Developing Partnerships for Conservation.

9. Few points to consider were put forth to the attendees
   a. Quick Surveys: Region wide rapid assessment surveys

   b. Could the existing *C. porosus* 3M Program in Sarawak be helpful for the monitoring and conservation of Tomistoma?

   c. What is the best way to facilitate activities in Asia-suggestions included working with Singapore Zoo that has supported CSG-TTF efforts in the past, as well as Zoo Negara and Taipei Zoo. Promote Tomistoma awareness and conservation issues through lectures at museums, local community organizations, businesses and social events.

   d. The Tomistoma Task Force has been comprised primarily of CSG members from outside of the range states. Bruce Shwedick suggested setting a 10-year goal by which the activities and conservation efforts of the CSG-TTF would by conducted primarily by CSG members and/or others from within the range states.

10. General Discussions

Oswald Braken (Sarawak Forestry Department): The main governmental issues in Malaysia/Sarawak are economic and social. How will funding for work come? With the involvement of the CSG and increased people involvement the work profile can be augmented. The governmental priority for Tomistoma is currently low is as there is no economic benefit from this crocodile and there are no serious HCC issues. One of the positive suggestions for Tomistoma would be for people to be able to see it in its habitat.

Agata: It is currently hard to find people in Indonesia interested in studying crocodiles. Currently there is some local interest in studying fish and some associated parameters.

Colin asked about the outcome of the workshop in Thailand in 2008. Did anyone from the Range State seem promising?

Bruce has had recent and on-going discussions with Fernando Potess of the PRCF about initiating a long-term conservation project in West Kalimantan. CSG-TTF is currently awaiting a revised proposal.

Bruce: The CSG Executive Committee met with him have suggested to send a delegation to universities in that region on a " fact finding " mission which could culminate with a governmental meeting in Jakarta. The delegation would include Bruce and possibly Charlie Manolis. This mission would also attempt to identify potential students that could receive funding through the CSG Student Grant Program.

Kent Vliet: Applauded the Chairman and the vision and forward thinking. He mentioned that it is important to identify a diverse range of partners, not only universities, museums, government authorities, but established conservation organizations like WCS, CI & FFI. Their help could be essential due to their familiarity in which to speed the process of finding partners and understanding political situations and ramifications.

Kent also suggested that the CSG-TTF should continue to raise funds as a nucleus to establish its roots and grow. Maybe this fund raising activity can be handed over to the zoo community.

Hosting an IUCN meeting is very powerful in making ones presence felt and to evoke a response from the government. Kent also suggested that Sarawak host a full working meeting of the CSG with Government officials from Range States. This contributes to a significant increase in government awareness and availability of funding opportunities from range countries.
The pros and cons of a full meeting versus a regional one were also discussed. The impact of a full meeting is much greater and there is much greater worldwide attention. The larger meeting can lead into a series of smaller regional specific, target-based meetings

Oswald: Government of Sarawak has a grant for organizing programs with international participation in conferences. This will need a guarantee of international attendance. In 2014 in Borneo a program on *C. porosus* is planned and an additional day for Tomistoma workshop can be added easily. This is planned for the mid-year. The response from the attendees at this meeting was positive. It is important to have local and regional experts at this meeting.

Imanul Huda from West Kalimantan has been proposed for new membership to the CSG. Samuel Martin mentioned an individual from Sumatra who has a gibbon rescue centre and very unique methods for doing surveys and monitoring local wildlife. Samuel to facilitate communication.
Non-traditional methods for survey of Tomistoma should be considered, such as stationary surveys being used by Mark Auliya, Agata S. and Jeff Lang currently. Camera trapping works better for *C. siamensis* which came to the traps with rats and near nests. Agata currently uses canoes due to the topography of the area in question in Lake Mesangat. Another suggestion was to use video-equipped drones with high-resolution video and GPS.

Secondary information about Tomistoma from fishermen is sometimes received. Rob Stuebing has initiated a small reward program for local fishermen who do not collect Tomistoma eggs for food and allow successful hatching.

Paolo mentioned that he believed it was essential to separate science and conservation.

Colin: It is important to tie in with other organizations working in that area.

Kent: Meld with the other IUCN specialist groups in the area and share resources. Aid with materials and small grants.

Jen Bruggen spoke about her experience at an eco lodge in Kalimantan on their trip to an Orangutan Reserve. She observed 11 animals during the day and two at night. The river they traveled on had an orangutan reserve on one bank and a palm oil plantation on the other.

Some alternative survey techniques: Recording of vocalization/infra sounds. Losing equipment is a hazard. Acoustically distinct characters may be identified.
A rangewide GIS project to make detailed distribution maps of habitats that had historically housed crocodiles was suggested. This can help assign priority to habitat and increase communication among people across boundaries.

The meeting attendees provided their contact information in order to continue these and other Tomistoma related discussions in the future.

Zoos Group

Participants: Kent Vliet, Jen Brueggen, John Brueggen, Fabian Schmidt, Geoff McClure, Colin Stevenson, Gowri Mallapur, Shakthi Sritharan, Alex Meurer, Mark Merchant, Sally Isberg, Cathy Shilton, Matt Plummer, Nikhil Whitaker

Brief History
Six years ago the Zoos and Community Education thematic group was created with the intent of building a community of zoo professionals from within the CSG. However, there has not been a lot of forward momentum of the group. A Google listserv was created to encourage conversation among the international zoo professionals, which includes mostly North American and European zoos. Communication from Latin American and Australian zoos has been less frequent, and from Asian and African zoos has been rarer still. Currently, there are about 40 members on the Google listserv. The group was split into two separate groups in 2012: Zoos; and, Public Education and Community Participation.

Communication within the group includes *in-situ* and *ex-situ* crocodilian conservation projects, as well as enclosure design, breeding, behavior, etc. within the zoo community to the improvement of crocodilian husbandry and management.

Action Plans
1. Build membership within the group, especially from Asian and African regions.
    a. Current members should strongly consider recruitment of new members from other zoos that could be relevant to significant contributions to crocodilian conservation.

b. Could there be a better way to communicate than the Google listserv?
c. Members are required to have Google accounts in order to receive the e-mails, however this is a simple registration.

2. Long-range goals, such as contributions to the CSG. Need ideas and discussions.
3. There will be a special half-day session devoted to zoos at the CSG meeting in 2014.
    a. The primary theme will be the contribution and impact of zoos to crocodilian conservation.
    b. Contributions to all aspects of crocodilian biology (behavior, anatomy, reproduction, veterinary science, etc.) achieved by research and observations under captive care can also be highlighted.
    c. At least 6-8 speakers. We must identify these speakers and topics by the end of summer 2013 to report to Mark Merchant for scheduling purposes.
    d. Presentations may consist of several 15 minute allotments, with perhaps a few 30 minutes or longer.
    e. Care will be taken ensure that North American speakers do not dominate the time, but to have presentations from a wide range of speakers from many represented regions.
    f. A strong selection process will be used to select presentations versus posters.
    g. Design the presentations and schedule, so as to not discuss similar ideas and projects.
    h. Presentations would ideally be grand projects and commitments and highlight the many ways that the zoo community contributes to *in-situ* conservation and the biology of crocodilians.
    i. How much money is directed towards conservation from the zoo community? Many zoos and private groups make contributions to support international projects. We need to try to quantify this. Colin Stevenson (Madras Crocodile Bank Trust) says he may be able to put this together.
    j. Conservation projects supported by the zoo community tend to emphasize more critically endangered species, rather than species that are valued for commercial uses. So this may be one important element to the theme of the workshop.
    k. Is there need for a zoo workshop committee to organize this event? We will see. Kent does not wish to plan it all.
    l. Mark Merchant offered ideas such as the financial contributions of zoos to conservation and research, reintroduction programs, as well as the behaviors observed within zoos that have added to the general knowledge of crocodilians.

    It is important for keepers to realize they can offer these kinds of contributions to the crocodilian scientific community, including reproductive physiology and husbandry.

The group engaged in a discussion of the standards of space for husbandry, as this had been a topic brought up in the CSG Steering Committee meeting; Kent was continuing to draft a statement in collaboration from Perran Ross, Alex Meurer and Paolo Martelli. A short statement was made for the response of the CSG to international inquiries. To be presented at the end of the meeting in Sri Lanka.