Crocodile Specialist Group of the Species Survival Commission

CROCODILES

Proceedings of the 23rd Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of IUCN – The International Union for Conservation of Nature - convened at McNeese State University in Lake Charles, Louisiana, USA May 26-30, 2014

(Unreviewed)

2014

IUCN

The World Conservation Union

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The Crocodile Specialist Group

The Crocodile Specialist Group (CSG) operates under the auspices of the Species Survival Commission (SSC) of the IUCN (International Union for Conservation of Nature). The CSG is a worldwide network of biologists, wildlife managers, government officials, independent researchers, representatives of non-government organizations, farmers, traders, tanners, manufacturers and private companies actively involved in the conservation, management and sustainable use of crocodilians (crocodiles, alligators, caimans and gharials). The financial affairs of the CSG are managed through a legal entity, the International Association of Crocodile Specialists Inc. (IACS).

The CSG members in their own right are all experts in some aspect of crocodilians. Together they have the skills needed to assess conservation priorities, develop plans for research and conservation, conduct surveys, estimate populations, provide technical information and training, and to draft conservation programs and policies. The CSG Executive keeps its members updated on international events with crocodilians, conducts reviews of national programs, and tries to track and prioritise issues in forums such as CITES, that encourage legal trade and discourage illegal trade. CSG Working Meetings are generally held every two years.

Forward

The biology of the American alligator, and the various state programs consolidating their conservation, management and sustainable use, are arguably more advanced in the USA than they are in any other country, with any other species. The USA have been true pioneers in applying science to all aspects of alligators, and crocodilians around the world have benefited from the insights and experience gained. Hence it was with great pleasure that the 23rd Working Meeting of the IUCN-SSC Crocodile Specialist Group was held at McNeese State University, in Lake Charles, Louisiana, USA (26-30 May 2014).

Louisiana has played a particularly important role in alligator research, and much of it has been done by or in cooperation with Rockefeller Wildlife Refuge. This refuge has a unique and innovative history. In 1913, Edward Avery McIlhenny, a naturalist and businessman, with the assistance of other philanthropists, purchased around 86,000 acres of marsh in Louisiana. The following year the land was sold to the Rockefeller Foundation, which eventually donated it to the State of Louisiana. The Deed of Donation stipulates, among other terms, that the property must be maintained as a wildlife refuge, and that any revenues generated from the property must stay on the refuge. In 1920 the marsh was declared the Rockefeller Wildlife Refuge.

The role the McIlhenny family, of Tabasco Sauce fame, has played with alligators in Louisiana is simply amazing. Not only did Edward McIlhenny write a great book on alligator biology (1935), but he engineered the land acquisitions and set the conditions demanding long-term commitments to wildlife research. Without the foresight of the McIlhenny family, crocodilian research and management around the world would not have advanced as much as it has.

One of the key alligator researchers from Louisiana was Ted Joanen, a true research pioneer and retired biologist with the Louisiana Department of Wildlife and Fisheries' Rockefeller Wildlife Refuge. He worked in collaboration with Larry McNease on most research publications. Ted and his work were formally recognized at this CSG meeting with two outstanding Research Awards in Sustainable Use Management. A proclamation from the Louisiana State University (LSU), where Ted completed his master's degree, established the "Ted Joanen Outstanding Research Award in Sustainable Marsh Management". LSU graduate students will be eligible for annual grants to further studies and research focused on marsh and sustainable use management. Ted's bachelor's degree *alma mater*, Southeastern Louisiana University (SELU), presented him with an endowed Professorship to further studies in sustainable marsh management and conservation of wetlands. Dr. Chris Beachy, head of the SELU's Biology Department presented the award on behalf of the university and benefactors.

This was extraordinary recognition by Louisiana officials and by those involved in alligator harvesting, ranching, farming and trade, of Ted Joanen's four decades of commitment to the management of alligators and marsh as renewable natural resources. Ted was also a CSG pioneer, involved in the first meetings (1971). His commitment to 'finding ways to keep the marsh wet and wild' is a lesson for all of us.

The 23rd Working Meeting was well attended by some 363 participants from 38 countries, making it the most highly attended CSG meeting ever. Once again a great diversity of research results was presented, providing a wealth of information on crocodilian conservation, management, sustainable use and general biology. Special thematic sessions conducted at the Working Meeting examined Human-Crocodile Conflict, the Impact of Zoos on Crocodilian Conservation and Biology, Genetics/Systematics and Biochemistry/Physiology.

None of this would have been possible without the generous financial support provided by donors, particularly McNeese State University, who provided the venue, accommodation, meals and functions, either free or at a highly discounted rate. CSG member Mark Merchant and his team worked tirelessly to make the meeting the great success it was.

The Working Meeting was preceded by a CSG Executive Committee meeting (23 May), and a meeting of the CSG Steering Committee (25 May), which as usual, was open to all participants. The Steering Committee addressed a wide range of current CSG issues and priorities, particularly, the current situation in Madagascar and Colombia, concerns about the activities of the Responsible Ecosystems Sourcing Platform, preliminary outcomes of the Ethiopia review, and establishment of a CSG Leadership Program.

The Proceedings of the 23rd Working Meeting of the CSG will once again be a unique compendium of current information on crocodilian research, conservation, management and sustainable use. It will serve as an important reference source for CSG members and non-members with an interest in crocodilians.

SUMMARY OF THE MEETING

The 23rd Working Meeting of the IUCN-SSC Crocodile Specialist Group was held in Lake Charles, Louisiana on the campus of McNeese State University. The meeting was attended by 363 participants, representing 43 countries. Scientists with interests in farming and ranching, industry trade, ecology, conservation, physiology, genetics, and biochemistry gathered to discuss a wide array of topics.

The working meeting was preceded by a meeting of the Steering Committee on Sunday, May 25th. The Steering Committee meeting was attended by at least 106 conferees. During the meeting, Chairman Grahame Webb bid farewell to members that had passed away during the past year, announced changes to the Steering Committee, and discussed several issues that needed to be resolved. In addition, proposals to host the next meeting in 2016 from Argentina, Cambodia, and South Africa were considered.

A **B**

A. Steering committee members were treated to a classical Cajun pig roast (coshon de lait) at the McNeese State University Alumni Center.
B. But first, Professor Grahame Webb toasts the Committee with a toast of Apple Pie, a local favorite drink.

The meeting was rich with social events, the first of which was an Opening Welcome Social held in the McNeese State University Grand Art Gallery. The event was attended by Randy Roach, (Mayor of Lake Charles), Dr. Phillip Williams (President of MSU), and Dr. Jeanne Daboval (MSU Provost). The event was used to showcase the brilliantly-detailed scratchboard art crocodilian images of Mr. John Agnew.

A **B**

C

A/B. The Sunday night Welcome Social, held in the Grand Art Gallery, featured the amazingly detailed crocodilian scratchboard art of special guest John Agnew. **C**. Lake Charles Mayor Randy Roach was present to welcome our guests to Lake Charles.

A packed house filled the Memorial Gym at McNeese state University all week for the 23rd Working meeting of the IUCN-CSG

A broad spectrum of topics were discussed during the five-day working meeting, including special session concerning current industry topics, zoological contributions to crocodilian conservation, crocodilian reproduction, and a special session concerning the possibilities of splitting some species in to multiples based on emerging genetic data. Thanks to Don Ashley Kent Vliet, Carlos Pina, and Perran Ross for organizing the Industry, Zoo, Reproduction, and Crocodilian Species sessions, respectively.

During the first day of the meeting, the Industry Committee made a special presentation to Ted Joanen for his ground-breaking work in the 1960s and 1970s, during which he studied the natural history, feeding and nesting ecologies of the American alligator. His studies served as the basis for the development of the world's first crocodilian sustained use management program, and the development of an industry that is worth hundreds of millions of dollars worldwide. Today, Louisiana unarguably serves as a key leader in the area of crocodilian sustained use and management. The Chair of the Department of Biological Sciences at Southeastern Louisiana University in Hammond, Louisiana, was present to announce development of the Ted Joanen Endowed Professorship. This research award will be presented to a student each year, in Ted's name, to further crocodilian research and conservation work.

A **B**

A. Department of Biology Head at Southeastern Louisiana University, Dr. Christopher Beachy (Left), presents the Professorship to Ted Joanen **B**. (right to left) Ed Froelich, Ted Joanen, Professor Grahame Webb, Alejandro Larriera.

A **B**

A, Special guest Dr. Peter Brazaitis delivering his presentation about the history of the CSG, entitled "An anecdotal history of the CSG: The early years". **B**. Ted Joanen speaking about the "History of Alligator

Conservation in Louisiana". These presentations set the theme of the meeting, "Crocodilian Conservation: A Lesson in History"

Another presentation, to 10-year old student Karin Ebey, was made during the first day. Karin has, for the past three years, asked that friends and family not give her birthday gifts, but give her the money that they would have spent on gifts. She then has sent the money to the CSG to be used for crocodilian conservation. What an incredible act of conservation from a remarkable young lady!

Karin Ebey receiving her award from CSG Chair, Professor Graham Webb.

A. The infamous Proyecto Yacare harem, and their fearless leader, enjoy the food, beverages, and science at the Wednesday night poster session. (L to R) Soledad Moleon, Gisela Poletta, Alejandro Larriera, Evelyn Lopez, Virginia Parachu, and Agu Latorre **B.** Don Ashley, Val Lance, Catherine Lance, and Pamela Ashley.

The 2014 CSG auction was held Thursday night. With nearly 200 donated items donated by CSG attendees, this auction raised a record $14,743, to which the Executive Committee decided will be applied to crocodilian conservation in West Central Africa. Many thanks to auctioneers Joe Wasilewski and Carlos Pina for their added entertainment value and for prying some much money from the conference attendants. The host organizing committee would like to thank all of those that donated items to the auction.

A **B**

A. Several hundred auction items displayed on tables for CSG members to view before the auction.
B. Auctioneers Joe Wasilewski and Carlos Pina work the crowd and raise and enormous sum of money ($14,743) for crocodilian conservation in Africa.

The Castillo Award to presented to Steve Platt for his many years of tireless work with Siamese crocodiles (*Crocodylus siamensis*) in southeast Asia, and with Morelet's crocodiles in the Yucatan region. It is fitting that Steve is from Baton Rouge, Louisiana.

2014 Castillo Crocodilian Conservation award winner Steve Platt (left) with CSG chair Professor Grahame Webb.

Very early on Wednesday morning, everyone was awakened by the thunder, lightning, wind, and heavy rains that dumped approximately 8 cm of rain in 3 hours. However, the 8:30 am session started on time….the show must go on!!!

A **B**

C

A. Contraband Bayou overflows its banks. B. the torrential rains turned the campus into Lake Mcneese.
C. Bruce Schwedick swimming to the meeting?

Every night, after the social functions and hospitality suites closed at the meeting, the assembly moved down the street to Coolers, which quickly became the iconic watering hole for the late night CSG parties. We filled the bar every night, to the delight of owner Cody Cahanin.

A

B

A. Giant Colombians (Robinson Botero-Arias) and tiny Mexicans (Luis Sigler)) catch up on old times, enjoy the friendly atmosphere and music at Coolers.
B. Cuban delegate Toby Ramos with Cooler's owner Cody Cahanin
C. CSG 2014 attendees fill the outdoor porch at Coolers

A **B**

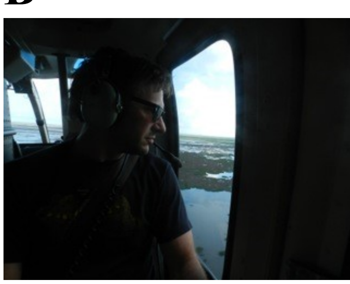
C

A. Cake: 2 meter alligator mother defending nest. **B.** Whole alligator roasted in a Cajun microwave
C. Meeting participants enjoy Cajun favorites: crawfish, alligator, ettoufe, and bread pudding to name a few.

On Saturday, May 31, 100 international guests were treated to a field trip to the historical Rockefeller Refuge in Grand Chenier, Louisiana. Guests were issued their own farmed alligator that was measured, weighed, tagged, and transported into the marsh on airboats for release. Guests were allowed the opportunity to tour the Rockefeller research facilities, ride in a 5 m boat some eight km to see the Gulf of Mexico, and ride in a helicopter to view the refuge from the air. Tremendous thanks are owed to the dedicated Louisiana Department of Wildlife and Fisheries staff, and other volunteers, of Rockefeller Refuge for providing this fantastic opportunities for our CSG guests.

A

B **C**



A. An armada of airboats at Rockefeller Refuge awaits CSG guests. **B.** Participants are shuttled in and out of helicopters for a bird's eye view of the refuge. **C**. Releasing farm-raised alligators.


23rd Working Meeting of the IUCN
Crocodile Specialist Group
Crocodile Specialist Group
McNeese State University, Lake Charles,
Louisiana, May 26th-30th, 2014

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An Anecdotal History of the CSG: The Early Years

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As I sat there in front of the crocodilian exhibit in the Reptile House of the Bronx Zoo in New York, I observed the gathering of luminaries who had come together to talk about saving crocodilians. There seemed to exist among those present a significant volume of the then-known information about crocodilians. That was March 15, 1971.

Crocodile specialists

The roster of specialists assembled for that first meeting (Fig 1) had come from around the world. Not all were recognized scientists from academia, but all were specialists in their own right: Anthony Charles (Tony) Pooley, a Park Ranger and conservationist from the Ndumu Game Reserve, Zululand, represented South Africa. His behavioral observations and captive breeding of African crocodiles were some of the earliest. Max Downs, a Senior Ecologist from the Wildlife Laboratory, Papua New Guinea, developed a program for crocodilian management as early as 1966. The author (PB), Reptile Department, Bronx Zoo, NY, USA, specialized in crocodilian identification and husbandry and developed sexing techniques for crocodilians (Brazaitis, 1969); Prof. Angus A. d'A. Bellairs, University of London, UK, was an evolutionary biologist and anatomist. Dr. Robert Bustard, Research School of Biological Sciences, Canberra, Australia, and Food and Agriculture Organization specialist with the United Nations, was a consultant for crocodile management programs in India. Dr. Hugh Cott, Selwyn College, Cambridge, UK, was a zoologist. His observations on the ecology of the Nile crocodile in Uganda and Northern Rhodesia in 1961 included one of the earliest assessments of the economic status of crocodilians (Cott, 1961). F. Wayne King, Curator of Reptiles, Bronx Zoo, a conservationist, organized the 1st. CSG meeting. Prof. Federico Medem, Instituto Roberto Franco, Villavicencio, Colombia, was an extraordinary field biologist and specialist on South American crocodilians. His voluminous publications on crocodilians remain legendary (Medem 1955, 1981, 1983) (Fig 2). Ms. Moira A. G. Warland, Executive Officer, IUCN, Morges, Switzerland, represented IUCN. Mrs. Clare Hagan, CEO, Hagan and Co., NY, an eminent fashion designer, represented the exotic leather industry. Her insights into the crocodile leather industry would prove invaluable in developing functional conservation strategies. Utai Yangprapakorn and his son Charoon were from the Samutprakarn Crocodile Farm and Zoo, Thailand. The farm had a long history of successful crocodilian breeding and skin production. Robert (Bob) Chabreck, Louisiana State University, Cooperative Research Unit, Baton Rouge, Louisiana, USA, had developed a sexing technique for alligators (Chabreck, 1963). James H. Powell, a journalist and public relations expert, was an Explorers Club adventurer. He was one of the first to survey and report on the status of Mexican crocodiles. Rene Honegger, curator, Zoo Zurich, was an expert on the captive breeding of reptiles.

Fig. 1. Participants, 1st meeting of the IUCN Crocodile Specialist Group at the Reptile House at the Bronx Zoo, NY. March 1971. Top row, left to right: Anthony Charles (Tony) Pooley, Max Downs, Peter Brazaitis, Prof. Angus A. d'A. Bellairs, Robert Bustard, Hugh Cott, F. Wayne King, Federico Medem. Bottom row: Moira A. G. Warland, Clare Hagan, Utai Yangprapakorn, Robert (Bob) Chabreck, James H. Powell, Charoon Yangprapakorn and Rene Honegger.

Fig. 2. Federico Medem, Instituto Roberto Franco, Villavicencio, Colombia, conducted the first comprehensive field surveys of South American crocodilians in 1973, later published in two volumes (Medem, 1981, 1983).

Nineteen papers covering a range of crocodilian issues, status and husbandry were presented over the three-day meeting (Crocodiles. Proceedings of the First Working Meeting of Crocodile Specialists, 1971).

The origins of the IUCN Crocodile Specialist Group (CSG)

It was no surprise that the New York Zoological Society (NYZS), now the Wildlife Conservation Society (WCS), had hosted the first working meeting of the International Union for the Conservation of Nature and Natural Resources (IUCN) Crocodile Specialist Group. The New York Zoological Society had a long history of wildlife conservation, and crocodilians had been a special interest of the first curator of reptiles, Dr. Raymond L. Ditmars (Ditmars, 1913) (Fig. 3), and has remained a Society conservation focus since 1898 (Brazaitis and Abene, 2008). In the US, as early as 1907, President Theodore Roosevelt, a Zoological Society supporter, had put a public face on the need for the conservation of natural resources and wildlife in a speech before the National Editorial Service.

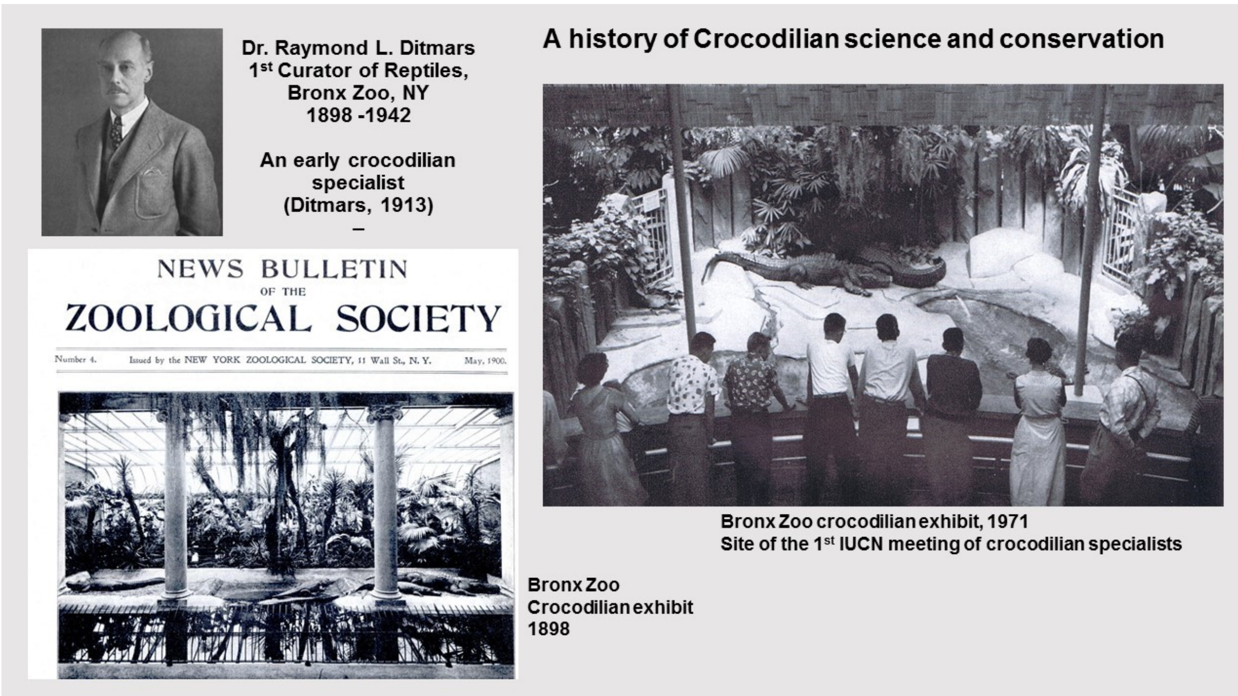

Fig. 3. Reptile house at the Bronx Zoo, 1898 crocodilian exhibit. Crocodilian exhibit in 1971 at the time of the 1st meeting of the CSG.

The years leading into the1970s were on many counts the darkest for wildlife. The 19TH and early 20th century culture of indiscriminate and unbridled abuse of nature and natural resources for a wide range of human wants found many species marching on the road toward extinction. Some had already reached that destination. Crocodilians were universally disliked and considered to be dangerous vermin. They would have a very long journey to travel from near-extermination to preservation.

Nearly all of the crocodilians were experiencing some threats to their existence, particularly those species that had skin suitable for making fashionable leathers. The pace of extermination had increased its cadence for crocodilians with advances in new and improved technologies. By 1920, reliable outboard motors carried hunters into the most remote crocodilian habitats. Air cargo carriers had proliferated after 1945 and World War II, as an army of trained pilots and war-surplus cargo planes could quickly bring raw skins from remote airports to global markets.

The decimations were not going unnoticed. A global concern for the future of wildlife and the environmental quality of the planet itself was awakening. The creation of the IUCN Crocodile Specialist Group has its roots in a global strategy (Fig.4). The United Nations Educational, Scientific, and Cultural Organization (UNESCO) was founded in 1945 out of concern for peace and respect for human rights through education, science and culture. The human tragedies of World Wars I and II had left an indelible mark on society. The IUCN, founded in 1948 in Fontainebleau, France, had also emerged with a strategy of balancing the safeguarding of nature while answering people's needs.

The two entities came together in 1959 when UNESCO invited IUCN to prepare a list of nature parks and reserves. At a meeting of IUCN members in 1963, a resolution was adopted that would become the basis for an international treaty, the Convention on International Trade in Endangered Species of Wild

The origins of the IUCN Crocodile Specialist Group and the nucleus of crocodilian conservation and management

1945 The United Nations Educational, Scientific, and Cultural Organization (UNESCO), founded

1948 The International Union for the Conservation of Nature (IUCN), founded

1959 UNESCO invites IUCN to prepare a list of nature parks and preserves

1963 IUCN adopts a resolution that would become the basis for an international treaty, the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES)

1969 At the 33rd meeting of the IUCN Species Survival Commission (SSC) in Bonn, Germany, the decision was made to **create the IUCN Crocodile Specialist Group (CSG).** The CSG becomes the international advisory group for the management and conservation of crocodilians in a strategy of sustainable utilization

1971 First meeting of Crocodile Specialists at the Bronx Zoo, NY

1973 (12 February) 80 nations participate in negotiations to outline the provisions of CITES in Washington, DC.

1975 CITES comes into force

1987/1994 CITES, universal tagging requirements for crocodilian skins and hides

Fig. 4. Timeline to the creation of the IUCN CSG and parent organizations.

Fauna and Flora (CITES), often referred to as the Washington Convention. The scientific and environmental preservation communities were well aware of the impact the coming of CITES would have on all aspects of wildlife conservation and the global trade in animals, plants and their derivatives, and in determining which species might survive and which might perish. CITES would draw on a wide range of scientific interests for counsel and expertise. In August 1969, the IUCN Species Survival Commission (SSC) had recognized the plight of crocodilians. Fourteen of the 21 known crocodilian species were considered to be threatened with the possibility of extinction. At the 33rd. meeting of the IUCN SSC in Bonn, Germany, the decision was made to create the IUCN Crocodile Specialist Group. Thus, the CSG became, by definition, the international advisory entity for all matters concerning the conservation and management of crocodilians. CITES provisions would reflect the recommendations of the IUCN CSG. It was in this atmosphere that the first CSG meeting took place.

On 12 February 1973, 80 nations participated in negotiations to outline the provisions of CITES in Washington, DC. However, CITES would not go into effect until 1975, when ratified by 10 participating countries. Once ratified, CITES would oversee international trade in wildlife, and the fledgling organization, the CSG, formed in March 1971 at the Bronx Zoo, would go on to become an example of success.

Over the ensuing years, the CSG would be chaired by eminent scientists (Fig. 5). Dr. Hugh Cott would assume the first chairmanship in 1971, followed by Dr. F. Wayne King, 1973-1978; Dr. Howard (Duke) Campbell from 1979 to 1981; then Dr. King from 1981 to -1989, when the chairmanship would be assumed by Prof. Harry Messel. Dr. James Perran Ross was named to the position of Executive Officer in 1990. Dr. Grahame Webb would assume the chairmanship in 2004, and remains chairman to the present time.

The governance of the CSG become more formalized but decentralized in 1988 with the creation of a CSG Steering Committee and the appointment of vice chairs, representing the five worldwide crocodilian producing regions. The Steering Committee would become the governing entity within the CSG. Correspondents would replace invited memberships and CSG participation became open to any interested party.

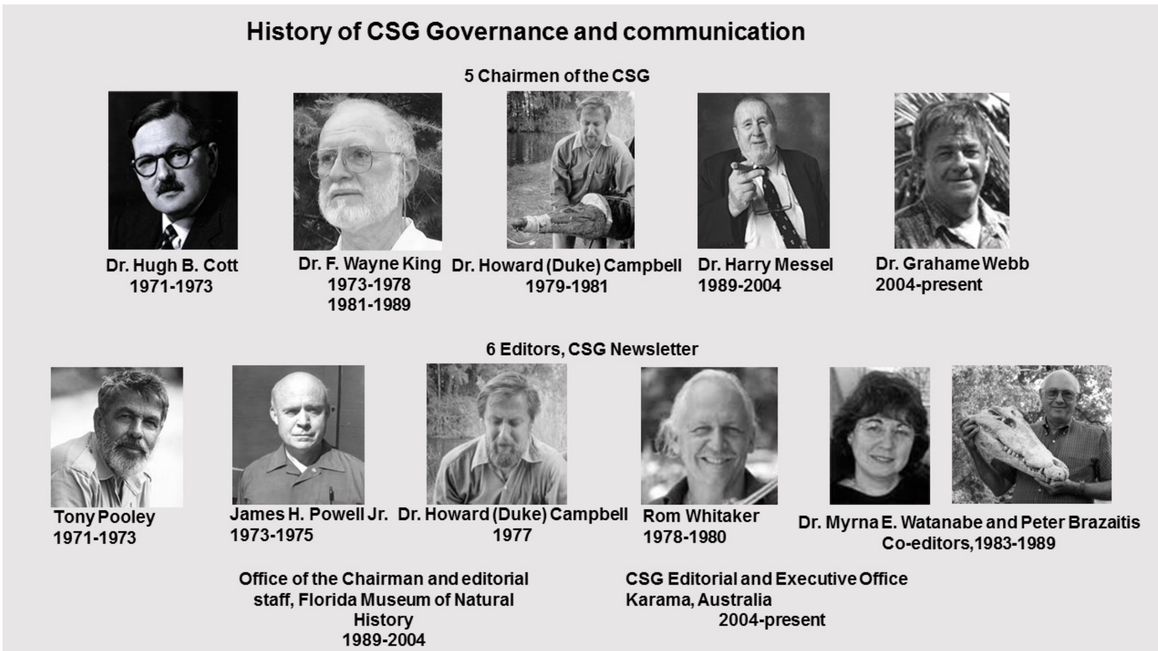

Fig. 5. Timeline of IUCN Chairmen and Editors of the IUCN CSG Newsletter.

Communication among crocodilian specialists and programs was an important element within the CSG. Tony Pooley would become the editor of the first CSG Newsletter in 1971. James H. Powell, Jr., followed from 1973 to 1975. Dr. Howard (Duke) Campbell held the editorship in 1977. Rom Whitaker held it from 1978 to 1980 and Peter Brazaitis and Myrna Watanabe assumed the editorship from 1983 until 1989. The chairman's office took over editorial tasks until 2004, when the editorship of the CSG Newsletter moved with the chairman to the CSG Editorial and Executive Office in Karama, Australia.

Specialist Group meetings would be scheduled every other year in countries throughout the world, wherever there was a need to draw attention to the plight of endemic crocodilians and encourage the development of conservation and sustainable use programs.

Pioneers in crocodilian conservation

There were many biologists and private individuals throughout the world who had already been engaged in one form or another in crocodilian conservation and science at the time of the 1st CSG meeting (Brazaitis and Colwell, 2011). Observations on the life history of the American alligator, *Alligator mississippiensis*, had first been published in 1935 (McIlhenny, 1935). However, science-based (Fig. 6 a, b, c) biological and ecological field studies and captive husbandry research on alligators began in earnest at the Rockefeller Wildlife Refuge, Grand Chenier, LA, in 1969, under the management leadership of Ted Joanen (Joanen, 1970). The program developed in Louisiana for the sustainable use of alligators and the continued preservation of the wild resource and its habitat, continues today as a model for the crocodilian management of all species throughout the world. Dr. Ruth Elsey carries on that tradition to date.

In Australia (Fig. 7), intensive studies, already underway in 1971 on the saltwater crocodile, *Crocodylus* porosus, by Messel et al. (1981), Webb and Messel (1978), and Webb et al. (1977), had resulted in volumes of ecological and population monographs, and other publications, undoubtedly making the species the most valuable, animal per animal, in terms of research dollars spent, followed only by the American alligator, *Alligator mississippiensis,* and Nile crocodile, *Crocodylus niloticus*.

Fig. 6. (a) Aerial view of Rockefeller Wildlife Refuge research center 1977; (b) temperature-controlled alligator incubators for eggs and hatchlings. (c) Generations of alligators reared in large natural habitat type pens at Rockefeller Wildlife Refuge reproduced and provided data on optimum conditions for sustainable use management and husbandry.

Fig 7. Prof. Harry Messel (left) and Dr. Grahame Webb (right) conducted extensive field surveys of *Crocodylus porosus* in Northern Australia.

Tomas Blohm was a Venezuelan businessman, rancher and conservationist. He and his wife, Cecilia de Blohm, had worked for years to preserve Venezuela's rich wildlife resources. Tomas pioneered the concept of cattle ranching while maintaining natural habitats—and habitats for crocodilians. He had opened his ranches in the *llanos*, rich in wildlife, to visiting scientists and researchers from around the world (Fig.8). Concerned for the near extinction of the Orinoco crocodile, *Crocodylus intermedius*, he had secluded a breeding pair in a remote region of one ranch. The crocodiles were captured in 1984 (Fig. 9) to serve as founders in establishing a captive breeding and reintroduction center at his ranch, *Hato Masaguaral*

Tony Pooley conducted observational studies on Nile crocodiles in St. Lucia, South Africa. A farming industry was already producing skins in South Africa and Zimbabwe.

A strategy for saving crocodilians

The 1st CSG meeting ignited an interest in crocodilian science among scientists around the world. It soon became clear that if the CSG were to achieve its goals and responsibilities, it had to adopt and integrate a strategy of encouraging crocodilian biological sciences, develop an appreciation for the inherent value in maintaining crocodilian wild populations and their habitats in endemic countries, encourage the industry to invest financially in maintaining crocodilian product values, and develop management and enforcement strategies that would ensure the sustainable use of the crocodilian resource into the future (Jelden et al., 2004).

Fig. 8. A young field biologist, John Thorbjarnarson, conducts field studies on caiman at the Tomas Blohm research center, *Hato Masaguaral*, Venezuela, in 1983.

Fig. 9. A female Orinoco crocodile, *C. intermedius*, is captured for transport to Blohm research center at *Hato Masaguaral*, Venezuela in 1983. Only a few animals remained in the wild and Blohm had sequestered a pair to keep them safe from poachers. Fourth from left: Thomas Blohm; 5th, Peter Brazaitis; 7th, John Thorbjarnarson; 9th, Mark Ludlow.

It was critical to the development of conservation and management strategies that the status of crocodilian species and populations were documented. Countries in which crocodilians could be an economic resource rushed to survey and document their populations and develop management plans so as to comply with CITES mandates and establish harvest quotas. Population biologists took to the field throughout South America, Australia and the United States.

New science

A cadre of biologists also emerged to apply behavioral sciences to study crocodilians. Dr. Myrna Watanabe, one of the first women to conduct behavioral reproductive research in the field, documented maternal behavior and communication between female American alligators and their young. As the first Western researcher to study Chinese alligators in China after the Chinese revolution, she and her Chinese collaborator, Dr. Huang Chu-chien, first documented the dire plight of the species in the wild in 1981, estimating that fewer than 500 remained in wild populations and natural habitats had all but disappeared (Watanabe, 1983).

Dr. Kent Vliet, University of Florida, documented social behaviors and physiology in American alligators. The University of Florida soon became a center of crocodilian research and training for crocodilian scientists. Dr. Jeffrey Lang, then of the University of North Dakota, documented agonistic behaviors and ecology of American alligators, and, later, Indian crocodiles. Les Garrick, then of Rutgers University, studied social behavior of American crocodiles, *Crocodylus acutus*, in Jamaica and crocodilians at the Bronx Zoo, NY. There were many more crocodile biologists throughout the world that came together under the CSG in a common cause of saving crocodilians from extinction.

Perhaps the most versatile and talented young herpetologist to emerge, garnering a reputation as a world-renowned crocodilian scientist, was Dr. John Thorbjarnarson (Fig. 10). Initially graduating from the University of Florida, he conducted conservation research on a wide range of species in over 30 countries as the Senior Conservation Officer for the Wildlife Conservation Society. John died in India on February 14, 2010 at the age of 52, of malaria contracted in West Africa.

The CSG would provide an integrated and collaborative vehicle for crocodilian research and information under a common sustainable use strategy. The first comprehensive action plan for the conservation of crocodilians was published by the CSG in 1992 (Thorbjarnarson, 1992).

A very few of the many dedicated crocodilian field biologists	
Alvarez del Toro, Miguel (Mexico)	Manolis,Charlie (Australia)
Archaval, Federico (Uruaguay)	Maskey, Tirtha (Nepal)
Blomberg, Goran (Botswana)	Mazotti, Frank (USA)
Brisbin, I. Lehr (USA)	Mcilhenny, E.A (USA)
Brazaitis, Peter (Brazil, Palau)	McNease, Larry (USA)
Britton, Adam (Australia)	Medem, Federico (South America, Colombia)
Bustard, Robert (India)	Moler, Paul (USA)
Campbell, George (USA)	Onions, J.T. Victor (Australia)
Campos, Zilca (Brazil)	Ottenwalde, Jose Alberto (Dominican Republic)
Chabreck, Robert (USA)	Ouboter, Paul E. (Surinam)
Choudhury, B.C. (India)	Plotkin, Mark (USA)
Cox, Jack (Borneo)	Pooley, Tony (Natal, South Africa)
Daniel,J.C.(India)	Powell, James H. (USA, Mexico)
David, Dennis (USA)	Rao, Abdul Latif (Pakistan)
De Carvalho, A. Leitao	Rao, R. J. (India)
Elsey, Ruth (USA)	Rebello, George (Brazil)
Godchalk, Robert (USA, Venezuela)	Rivero-Blanco, Carlos (Venezuela)
Gorzula, Stephan (Venezuela)	Ross, Andy (USA: Phillippines)
Graham, Allister (Uganda)	Scott, Norman (Paraguay, USFWS)
Grigg, Gordon (Australia)	Seijas, Andres Eloy (Venezuela)
Hall, Phillip (USA, PNG, S. Am.)	Singh,Lala A. K. (india)
Herrera, Carlos G. (Colombia)	Stockwell, Jane Harvey (Austraalia)
Hines,Tommy (USA)	Subba, M.V. (India)
Hollands, Martin (PNG)	Thorbjarnarson, John (USA, global)
Huag, Chu-chien, (China)	Trelancia,Ana Maria (Peru, Brazill)
Hutton, Johnathan (Zimbabwe)	Varona, Louis (Cuba)
Joanen, Ted (USA)	Vliet, Kent (USA)
Kar, Sudhakar (India)	Waitkuwait, Wolf-Ekkehard (W. Africa)
King, F. Wayne (USA)	Watanabe, Myrna E. (USA, China)
Kushlan, James A. (USA)	Werner, Yahuda L. (Israel)
Lamar, William (USA, Colombia)	Whitaker, Romulous (India)
Lazcano-Barrero, Marcos (Mexico)	Woodward, Allen (USA)
Magnusson, William (Brazil)	Yahoda, John C. (Ecuador)
	Yamashita, Carlos (Brazil)

Fig. 10. A cadre of biologists soon made their mark in an array of crocodilian sciences conducted around the world. The most versatile and talented young herpetologist to emerge, was Dr. John Thorbjarnarson. John's research on crocodilians spanned 30 countries and produced a host of scientific publications.

Partnering with industry

The CSG would also find itself saving the crocodilian leather industry from destroying itself, as saving many species of crocodilians depended on their fiscal value as a natural resource. The sustainable use strategy would make the CSG an awkward partner in the crocodilian leather industry. Of necessity, it was an incestuous relationship that tended to encourage collaboration with the industry in exchange for their needed cooperation and financial support. However, the industry saw itself threatened, and termed itself as an "endangered species," although the industry had brought about the possibility of its own demise by killing to extermination the very animals it depended on for survival.

Ms. Clare Hagan, the representative of the leather industry at the 1st CSG meeting, had attended with an industry attorney at her side. He had remarked to her that "the scientists" would spell the end of the industry. She had replied that it might be so, but that "the scientists" were right." She went on to insure, through her fashion designs, that reptile leather manufacturers would no longer utilize endangered sea turtle leather in the United States. She made conservation come to the leather industry.

Under a deluge of new trade controls, the industry first resisted and considered the controls onerous and unworkable. Perhaps most onerous to the industry were the CITES resolutions (CITES Conf. 11.12; Ottawa, 1987; Ft. Lauderdale, 1994) calling for the universal tagging of all crocodilian skins in trade for purposes of tracking and determining skin origins and species identification.

The industry soon learned that collaborative efforts on its part could bring with it a more-favorable regulatory environment and the ability to enjoy a more-positive public opinion. However, industry interests tended to invest in and favor programs and research in those species of crocodilians with the greatest commercial potential. Seemingly excluded were sometimes those species that were not of commercial use, species that were too few in remaining numbers to be economically significant, or in investing in preserving wild crocodilian habitats. Commercial farming and ranching also tended to produce more reliable numbers of skins and better financial returns on investments. However, ranching did rely on preserving habitats and wild populations as necessary for the continued production of eggs and young. By 1985, 61 countries had developed crocodile farming capabilities (Luxmoore et al. 1985).

Not all commercial investments would go to the neediest species. The greatest investment in crocodilian conservation came in Colombia, where upwards of 700,000 caiman skins a year, more than those of all other crocodilian species combined, are produced from farms and ranches each year (Caldwell, 2012). Other than the endangered and possibly extinct Rio Apaporis caiman, *Caiman c. apaporiensis*, no caiman species are now considered endangered or threatened. However, caiman are possibly one of the most commercially invested of crocodilian species. As an aside, given the lack of disclosure requirements, products made from less expensive caiman skin may be sold to consumers who may erroneously believe they originate from more costly genuine alligator or crocodile, adding to caiman profitability.

An exception is the Chinese alligator, *Alligator sinensis*, a critically endangered species now produced extensively on farms but are not known to be commercially traded. The species suffers from lack of suitable habitat and is virtually extirpated from the wild.

Enforcement and the CSG

The CSG sometimes found itself lodged between the interests of industry supporters and regulatory enforcement efforts. One early order of business was to assess the stocks of crocodilian skins on hand in Bolivian tanneries, a primary source of contraband black caiman, *Melanosuchus niger*; broad-snouted caiman, *Caiman latirostris*; and Yacaré caiman, *Caiman yacare*, skins at that time. CSG members inspected Bolivian tanneries on behalf of the CITES Secretariat in June 1987.

In the US, the US Department of Interior, US Fish and Wildlife Service (USF&WS), had implemented the Endangered Species Act of 1973 (ESA), and had already listed the Yacaré caiman of central South America, the mainstay skin of the crocodilian leather industry, as an endangered species. Although prohibited from US trade, Yacaré caiman remained legal in trade throughout the rest of the world. The industry, already struggling to comply with scientific terminology and speciation, found that a plethora of new and undocumented taxonomic names to distinguish caiman species had also been added to the scientific literature (Wermuth and Mertens, 1977), further adding confusion and complicating the enforcement of CITES and the ESA. As a solution, CITES and the USF&WS, in collaboration with the CSG, launched a second comprehensive Central South American study in 1983 to define the distribution of caiman species throughout Brazil, Bolivia and Paraguay, augmenting the study conducted by Federico Medem 10 years earlier (Brazaitis et al., 1988; King and Roca, 1989; Scott et al., 1988).

The early history of the CSG is a story of ordinary people, scientists and business people, from the most affluent centers of fashion and industry to the remote heart of tropical regions, where crocodilians live, coming together in a common interest: to insure the future existence of crocodilians. Certainly, this brief, truncated summary of the early history of the CSG cannot do justice to the work that has been done or give sufficient attribution to the many scientists and collaborators who did it. In 1971, at the time of the 1st Working Meeting of the IUCN CSG, 14 of the 21 then-known species of crocodilians were considered to be threatened and in danger of extinction by IUCN. In 2014, of 23 recognized species, three species remain vulnerable and eight species remain endangered, including six that are critically endangered. Twelve species are currently listed as of low risk. Of those, nine species are commercially utilized, farmed and ranched species. These include seven species that were originally threatened and are no longer threatened (http://www.iucncsg.org/pages/Conservation-Status.html).

Perhaps the history of crocodilian conservation and management efforts was best put forth by the most eminent crocodilian biologist of our time, the late John Thorbjarnarson (Thorbjarnarson, 1999). There is much work yet to do.

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This paper is dedicated to the memory of conservation biologist, John Thorbjarnarson and to New York State Conservation Officer, John Fitzpatrick.

The Development of the Louisiana Alligator Program: A Historical Perspective

Ted Joanen

M. LePage du Pratz (1758) reported many alligators (*Alligator mississippiensis*) in the St. Louis River (now known as the Mississippi) at New Orleans, Louisiana. However, no mention was made of any commercial trade existing at that time. According to Stevenson (1904), the alligator has been used in commercial trade since 1800 (Table 1). Audubon (1827) reported alligators to be very abundant in the Mississippi and Red Rivers of Louisiana. He stated "that many thousands were being killed for articles of trade and many of the squatters and Indians, for a time, followed no other business. The discovery that the skins were not sufficiently firm and close-grained to prevent water passage or dampness put a stop to the general destruction of alligators, the effects of which had already become very apparent. The alligators are caught frequently in nets by fishermen; also Negroes kill them during the autumn period as the alligator leaves the lakes to seek winter quarters by burrowing under the roots of trees, or covering themselves largely with earth along their edge." According to Stevenson (1909), alligator skins became somewhat fashionable in about 1855, but for only a short period. The demand ended after a few thousand skins had been shipped from the Gulf States. Alligator skins were used extensively during the Civil War (1860-1865), with many thousands of alligators being killed to supply shoe and saddle leather. Shortly after the war when free commerce in shoe material was restored, the alligator was again left alone for a brief period.

Stevenson (1904) related that in 1870 "a large demand was soon created resulting in the slaughter of many thousands of animals each year, giving employment to hundreds of men. The demand soon exceeded the production capacity of the US, and a large number of skins were imported from Mexico and Central America." As a result of the large demand for alligator skins, imitation alligator leather was first prepared in large quantities, principally from sheep skin or from buffed cowhides and embossed with the characteristic alligator markings by passing the skins between two rollers. During 1869-1870, the alligator rose to the top of the fashion scale of all leathers (Joanen and McNease 1991).

A quote on the quality of the skins from Louisiana, Mexico, and Florida was given by Stevenson (1904), "The Louisiana skins differ from those of Florida and Mexican skins in being more pliable and in having the scales more artistically colored and shaped. Consequently they are preferred for such small articles as pocketbooks, and usually sell at the highest price. Skins obtained from Mississippi and Texas are similar to those secured in Louisiana, while those from Georgia and South Carolina are similar to the Florida skins, except that the 'corn markings' are not so numerous."

Smith (1893) estimated that no less than 2 ½ million alligators were killed in Florida during 1800-1893. A good market was developed for alligator skins in about 1870, and as late as 1902, the output of US tanneries was approximately 280,000 skins annually with about half of these being furnished from Mexico and Central America (Stevenson 1904). At that time it was estimated that Florida supplied 22% and Louisiana 20% of the total number of skins used in the USA each year. McIlhenny (1935) estimated that 3 to 3 ½ million alligators were harvested in Louisiana between 1880 and 1933. Kellogg (1929) reported approximately 10,000 skins per year were taken in

Georgia during 1922-1926. He further stated that as a result of the drought conditions that existed in Louisiana in 1924 and 1925, unusually large numbers of skins were taken. In 1925 and 1926, 21,885 and 36,041 skins were taken, respectively, in Louisiana. According to Kellogg (1929) the total number of alligator skins taken in the USA during 1920-1929 could hardly have exceeded 50,000 per year. This estimate was probably low because in 1926, over 36,000 skins were taken in Louisiana alone. Louisiana severance tax records show 414,126 skins sold during 1939-1960, with the majority (57%) believed to be taken during 1945-1953. The alligators taken in Louisiana dropped from 35,796 in 1948-49 to 1,091 in 1960-61. The only sizeable population remained on state- and federally-owned refuges.

Prior to the 1960s, size limits were not imposed on Louisiana's alligator harvest, and all size classes 2'(0.61 m) and greater were included. No matter how large a skin was, the hunter was paid for a maximum skin length of 8' (2.44 meters). For a 10', 11', 12', or 14' (3.05-3.60-4.27m) skin, he received the same amount of money as he did for an 8' (2.44m) skin (Arthur 1928). Louisiana Department of Conservation records indicate that the 1943 season was the first time alligator skins 10' (3.05m) and above were recorded. It is believed that during the 1943 season, skins were first bought on a length per foot basis, and a grading system similar to that used today was introduced.

Stevenson (1904) reported that the principal tanneries in the USA were located in Newark, New Jersey and New York City, New York. Some skins were prepared in New Orleans, Louisiana; Jacksonville, Florida; and in Massachusetts. Raw skins were also exported to Germany and England for tanning. Large skins (>10' (3.05m)) in length had little value due both to their scarcity and to bones in the cuticular plates, which made them extremely difficult to tan. Hornback skins, usually from smaller crocodilians prepared with the dorsal portion intact were supplied principally from Mexico and Central America. The Louisiana and Florida skins were not as flexible along the back and were sold as belly skins with only the ventral and lateral surfaces of the animal included.

Raw green alligator skins were sold according to length, whereas tanned skins were sold by the width of the belly leather at the widest point. As a rule, Louisiana skins brought the highest prices and those from Florida the lowest. The skins of caimans from Brazil, Venezuela, and other South American countries had little value and did not enter markets in the USA (Stevenson 1904). According to Pierre Granitz, prior to 1940 (pers. comm.) skins from Florida and Georgia were shipped to France while the Louisiana skins were under contract to the prestigious New York market. French tanneries underwent a period of reconstruction during 1945 to 1949, thus the period of most activity was between 1949 and 1960 (Joanen and McNease 1987).

As the alligator population declined in the early 1950s, tanners developed new markets for small-sized skins. A tremendous interest was generated by Japanese markets for hornback alligator skins (2'-3' (0.61-0.91m) size class). Buyers encouraged hunters to take small skins in order to fill the demands which could no longer be met by the declining population of larger-sized animals. The market was short-lived, and in 1962, Louisiana closed its season to the taking of alligators and began a concentrated effort to manage this valuable resource. Because of the decline of alligator populations in the 1950s coupled with the closure of the alligator season in the Southeast US, many of the prestigious US tanners and manufacturers that were family-owned businesses for generations went out of business.

No season was allowed in 1974 because the Federal Endangered Species Act was passed. After an eighteen-month delay caused by delisting requirements of the US Department of the Interior Fish and Wildlife Service, Louisiana again initiated its harvest program expanding it to three parishes (1975-1977). Due to limited markets for skins within the USA and the ban on shipping skins overseas (a result of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)), no season was allowed in 1978. CITES in March 1979 allowed skins to be exported and enter international commerce. Along with CITES action, the US Fish and Wildlife Service delisted an additional nine coastal Louisiana parishes in 1979 and 1980. In 1981 the alligator was reclassified in the remaining fifty-two parishes as threated by similarity of appearance, and a statewide harvest was authorized (Joanen and McNease 1987).

Legislation

The Louisiana Department of Wildlife and Fisheries (LDWF) manages two alligator programs. One is based on a wild harvest strategy, and the other deals with farming (limited production from captive adults) and ranching of wild collected alligator eggs. Louisiana's first program aimed at managing the wild alligator population based on a sustained-yield harvest was initiated in 1972. The management program resulted from 15 years of research, enforcement, and the enactment of effective state and federal laws governing the taking, possession, and transportation of alligators and their products. By 1970, such legislation was in effect in Louisiana (Joanen, et al 1983).

Present day alligator populations appear to be only slightly below those which existed in Louisiana at the turn of the century. Data on both skin size classes from the early 1900s and the number of skins harvested have been used to reconstruct the Louisiana population as it existed at the turn of the century. A comparison of these early alligator harvest data (Taylor, pers. comm.) to recent data (Taylor and Neal, 1984) indicates that the alligator populations which existed some 90 years ago were only slightly greater than those existing today.

Public Law 91-135, known as the "Amended Lacy Act," was passed in December 1969. Lacy Act provisions made it a federal crime to sell or transport in interstate or foreign commerce any form of wildlife or products made from wildlife taken in violation of the laws of any state or foreign country. In 1970, the Louisiana legislation enacted Act 550 giving the LDWF full authority to regulate the alligators in the state. Louisiana law classifies the alligator as a non-game quadruped along with wild fur-bearing animals valuable for their skins or hides. The alligator is, therefore, considered a commercial wildlife species. Act 550 formed the framework which permitted the implementation of a closely-regulated commercial harvest (Palmisano et al 1973).

Due to the species' value and vulnerability to hunting, the LDWF passed special regulations aimed at regulating the harvest of surplus animals and to equally distribute the kill in relation to population levels. These regulations further complemented Act 550 and mandated a system of hunter application, licenses, tags, and report forms necessary to implement the management program. Under the Endangered Species Act of 1973, the US Fish and Wildlife Service designated the American alligator to be placed in these basic classifications: endangered, threatened, or threatened due to similarity of appearance (TSA) throughout its range. With the passage of the act, the alligator was classified as an endangered species. The state of Louisiana objected to the endangered status classification and began the delisting process for alligators within the state. In 1981 the alligator was unclassified in Louisiana by the US Fish and Wildlife Service as TSA, and a statewide harvest was authorized. As far as the state of Louisiana was concerned, the Endangered Species Act of 1973 did very little to help restore the alligator. The LDWF did not agree with the classification of "Endangered" status for the alligator population.

The Louisiana alligator program begun in 1959 had achieved considerable success in rebuilding the alligator population by 1973. By the late 1960s, populations expanded to the land where they were becoming a nuisance. In 1970, the first steps were taken towards harvesting the alligator surplus with the enactment of state legislation setting up the basic frameworks of the season. By 1972, a harvest plan had then developed which would control the taking of alligators, and through a system of tags and report forms, effectively prevent illegally-taken skins from entering the legal traffic. Enforcement efforts had already reduced poaching in southwestern Louisiana to a negligible level.

The US delegation signed as party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1974. As an Appendix I species, this barred all international shipment of alligator skins overseas. At the 1976 third working meeting of the International Union Conservation of Nature/Crocodile Specialist Group (IUCN/CSG) held in Maningrida, Australia, a unanimous vote was cast to reclassify the alligator from Appendix I to Appendix II of CITES. This proposal was submitted to CITES at the Costa Rican meeting of the parties in 1979, and the alligator was reclassified to Appendix II which allowed skins to be exported and enter international commerce. Along with the CITES action, the US Fish and Wildlife Service delisted an additional 9 coastal Louisiana parishes. As a result, the LDWF authorized a regulated harvest in 12 coastal parishes, including the three parishes previously delisted by the US Fish and Wildlife Service in southwest Louisiana in 1974. In 1981, the alligator was reclassified in the remaining 52 parishes as TSA, and a statewide harvest was authorized.

Alligator meat entered commercial sales in Louisiana in 1979 according to LDWF regulations and Office of Health Services and Environmental Quality – Department of Health and Human Resources. In August of 1980, the US Fish and Wildlife issued a final rulemaking, allowing the nationwide sale of alligator meat and parts. Rules and regulations concerning the sale of alligator meat and parts were promulgated by Louisiana's Food and Drug Control Unit, Office of Health Services and Environmental Quality, and by the LDWF. These were adopted by the US Fish and Wildlife Service in their 1980 rulemaking (Joanen and McNease 1982). In 1985 the US Fish and Wildlife Service changed its special rule regulating commercial activities with alligators to allow the export of meat and other parts, such as skulls and teeth under criteria set forth by CITES (Joanen et al 1997).

Establishing Louisiana's Alligator Research Program

Considerable resources have been invested by the LDWF in an extensive alligator research program initiated in 1959 to study the natural history, management, and captive propagation of the species (Chabreck 1966, Joanen 1969, Chabreck and Joanen 1979, Joanen and McNease 1970, 1972, 1974, 1981, 1987a and b, 1989, 1991, Joanen et al 1983, McNease and Joanen 1974, 1976, 1977). The state's alligator program was housed at the state-owned Rockefeller Refuge, an 85,000 acre coastal marsh refuge located in Grand Chenier, Louisiana (Joanen 1982). The refuge has always maintained good enforcement and as a result has always housed a sizable population of alligators.

A policy of managing alligator populations as a renewable natural resource on a sustained-yield basis was adopted to provide an incentive to landowners to manage wetlands as wetlands rather than for other commercial purposes (Joanen and McNease 1973). In 1962 the LDWF turned its attention to professional management of this valuable wetland resource. During the period of total protection (1962-1972), the institutional and political framework for the implementation of a sustainable use program based on sound scientific information was developed. The goals of the program were to manage and conserve Louisiana alligators as one of many components in the state's wetland ecosystem to the benefit of the species, its habitat, and associated wildlife. Inherent in this philosophy of managing the species was to allow and encourage the sustainable harvest of surplus alligators to benefit economically the citizens of Louisiana. Since most (approximately 80%) of the state's wetlands are privately owned, this would provide an incentive to landowners to maintain and enhance the alligators' wetland habitats.

Complementing research was a concentrated effort to reduce the illegal killing by the enactment of effective state and federal laws governing the taking, possession, and transportation of alligators and their products. Without the complete cooperation and dedication of the refuge, state, and federal agents, the Louisiana alligator program would have never reached the success it knows today. Enforcement efforts are the very foundation of any successful wildlife management program. Along with a strong enforcement effort, concerned individuals and land managers in Louisiana took the initiative to reverse the downward trend of the alligator population. Through the cooperation of the state and federal agents, the local courts, news media, and a concerned citizenry, alligator poaching was essentially eliminated.

The first study began on Rockefeller Refuge was a mark and recapture study used to determine the growth ratio of alligators in coastal Louisiana. During that earlier study more than 2500 animals were captured, marked, and released. Recovery of marked alligators over a period of 17 years provided information on growth rates of alligators under natural conditions. Comparisons between small alligators showed that growth rates of males and females were not different until animals attain a total length of 1 meter, after which growth of females declines sharply. Growth rates during different periods of the year are greatest during mid-summer and less during the spring and fall; no growth occurs during winter (October-March). A mathematical model indicates that males grow fairly rapidly for 20 years (until they are about 3.5 meters long) and that they reach a projected total length of 4.2 meters at age 80. Growth of females declines considerably after age 10, and individuals are only about 2.55 meters long at age 20. The maximum projected length of females is 2.73 meters at age 45.

During the summer of 1964, a study was initiated on the nesting ecology of alligators on Rockefeller Refuge. The objectives of the study were to determine the activities of the female associated with nesting, nesting temperatures, preferred nesting habitat, nest dimensions, number of eggs present, and reproductive success. The study also sought to determine the kind of nest losses due to predation and other causes.

Nests were equipped with the Stevens Model F Recorder, which was used to record the movement of the female over the nest. Taylor Model 76 J temperature recorders and Short and Mason hair hydrographs were used to record relative humidity inside the egg cavity. Although alligators crossed the nest at all hours of the day, the study clearly shows that activity is far greater at night. Daytime visits recorded only one-fourth the number of crossings recorded as compared to night time hours. The majority of the crossings occurred during the first, second, third, and ninth weeks of incubation. Temperatures within the egg cavity averaged 82.8°F with 73.9°F being the lowest temperature recorded and 91.0°F the highest. Relative humidity in the nest ran extremely high and relatively constant throughout the incubation period averaging 94.0-98.4% while the control unit averaged 78.2%. The average clutch size was found to be 38-9 eggs per nest. Predation was found to occur just after the eggs began to crack along the longitudinal axis, usually at the end of the seventh week of incubation. Nesting was found to occur from the first week of June and extend to the first week of July. However, the bulk of the nesting took place within a two-week period each year, with very few nests being located prior to or after this period. Nesting success showed 68.3% hatched successfully, 7.3% were partially infertile, 5.8% were infertile, and 18.6% were either destroyed by raccoons or lost to high water. Also 33.3% of the nests examined were classified as incomplete nesting attempts and contained no eggs. Hatching success was determined to average 58.2%. The size of the nesting females was found to be between 6 feet and 8 ½ feet (hind foot measurement taken from tracts of females and related to total length). Approximately 300 nests were located and followed during the study (Joanen 1969).

The Louisiana coastal marsh alligator population has been quantified annually by aerial nesting surveys (Chabreck 1966) along transects in representative habitat since 1970. LDWF annual survey data (Figure 2) validated these aerial surveys with actual counts along selected transects. Consistent annual growth has led to the conservative estimate of approximately 700,000 alligators in Louisiana wetlands. The entire Louisiana coastal marshes include 4,000,000 acres (Chabreck 1970) Classification of Louisiana coastal wetlands is based on salinity and resultant vegetative types (Chabreck et al 1968; Joanen and McNease 1972). The intrusion of saline water, both natural and as a result of human activities, is the greatest factor affecting alligator populations. Salinity of the environment is known to affect feeding habits (Chabreck 1972; McNease and Joanen 1977; Lauren 1985), reproduction (Joanen 1969, Joanen and McNease 1972; Ruckel and Steele 1985), physiology (Lauren 1985; Dunson and Mazzotti 1988), and growth rates (Mazzotti 1982; Lauren 1985). Prolonged exposure of young alligators to salinities of 3.5 ppt results in cessation of feeding and to salinities greater than 5. 3 ppt can result in death (Joanen and McNease 1972; Lauren 1985). Alligator population densities are related to salinity conditions (Joanen and McNease 1970, 1972a and b, 1978) being greatest in intermediate marsh (0.5-8.3 ppt salinity) and slightly less in fresh marsh (0.1-3.4 ppt salinity) and brackish marsh (1.0-18.4 ppt salinity). Nesting does not occur on the gulf side of the 10 ppt isohaline line (Joanen and McNease 1972a). Marsh type maps (isohaline lines) and associated vegetation of Louisiana are prepared about every 10 years by the Louisiana Department of Wildlife and Fisheries (Chabreck et al 1968; Chabreck and Linscombe 1978). These maps are used in assessment of populations within each parish by wetland habitat type, including subdivisions by salinity.

Air temperatures affect the timing of nesting and egg laying activity (Joanen and McNease 1978). Nesting occurred in June for the years with highest March-May temperatures and occurred as late as the first week in July when springtime temperatures were the lowest. This factor must be taken into account when setting up the time table for recording nest censuses. Extremes in water levels - droughts and flood conditions – adversely affect nesting of the aquatic-based alligators (Joanen and McNease 1972). This factor probably affects the degree of nesting more than any other environmental factor. Nesting was not observed in areas characterized by moderate-high salinities. Prolonged exposure of waters of 10ppt salinity and greater was linked to newly hatched alligators. Salinity tolerance appears to increase with age (McNease and Joanen 1977).

Alligators are commonly associated with fresh to slightly brackish aquatic marsh habitat, river systems, swamps, ponds, and lakes. Occasionally an animal may venture into saline waters for a short period of time. Joanen (1969) reported females nested in marshes with salinities up to 9%. Courtship occurs in deep open water during springtime (Joanen and McNease 1970). Adult females selectively seek out dense vegetation adjacent to isolated ponds for nesting during the summer. Adult and subadult males tend to prefer open water all year round and only occasionally venture into the more secluded and heavily vegetated areas used by the females (Joanen and McNease 1972). Alligators of both sexes, from hatchling to two years of age, frequent areas adjacent to the nest site using shallow ponds and potholes for feeding, basking, and overwintering (Chabreck 1965).

Radio telemetry-collared immature females showed a definite preference for deep water areas during the summer, autumn, and winter, and an avoidance of this type in the spring. Minimum home range size averaged 438.6 acres for 15 radio telemetered immature females. Immature female habitat preference of natural marsh in autumn followed much the same habitat as adult females. Thirteen immature male alligators followed with radio telemetry showed a marked preference for deep water areas during the summer and autumn and a slight avoidance for spring. Usage by males of natural marsh areas was substandard for all seasons when compared to availability. Immature males' home range averaged 564.9 acres (McNease and Joanen 1974).

Fourteen male alligators were equipped with radio collar-type transmitters and monitored during a 339 day period. Minimum home range size varied from 452 acres to 12,500 acres. Daily movement was quite extensive for all of the alligators followed; the longest minimum daily distance travelled being 27,750 feet. Minimum daily movement for individuals tracked during spring, summer, and fall averaged 2,411feet. The longest seasonal range size was recorded during the summer period, followed in descending order of age by the autumn and the spring. Winter movement was confided to the general area around the den site. Over the duration of this study, 73% of the fixes plotted were in canals, and 27% were in ponds, potholes, or dens in the marsh. Movement and activity data indicated that canals and deep water bayous are extremely important in all phases of the life history of the adult male alligator.

Adult female alligators were fitted with radio telemeter gear and followed during the spring, summer, and fall on Rockefeller Refuge. Minimum home range size for the alligators equipped with radio collars measured 6.4 to 41.0 acres. Courtship and breeding took place in open water, canals, bayous, or lakes, while nest construction, egg laying, incubation, and post hatching took place in dens located in natural marsh. Average daily movement for individual animals ranged from a low of 45 feet per day to a high of 111 feet per day and averaged 79 feet.

Nesting chronology and factors affecting nesting was investigated at Rockefeller Refuge from 1964 through 1987. Courtship activities generally began in early April and progressively intensified until early June. From late May through the first week of June, courtship and copulation were intense, females ovulated, and the high point of spermatogenesis occurred. The reproductive cycle for male alligators was characterized by a buildup of spermatogenesis which peaks during a relatively brief 2-week period of sexual activity. After breeding spermatogenesis ceases and testes regress in size. Female alligators exhibited various stages of oogenesis occurring throughout the year, but mature ova were present for only a short period of time during late May and early June. Time intervals between ovulation and egg-laying were 3-3 ½ weeks as determined by necropsy findings and field observations (Joanen and McNease 1980 and 1989).

According to McIlhenny (1935) alligators at some time in their life will eat every living thing coming in range of their jaws. In food habit studies conducted in the marshes of Southwest Louisiana (Chabreck 1971), immature alligators were found eating mainly invertebrates, predominantly blue crabs (*Callinectes sapidus*) in the brackish marshes and crawfish (*Procambarus clarkia*) in the fresh water marshes. About the time alligators mature, McNease and Joanen (1977) found that the diet shifted from invertebrates to vertebrates, primarily mammals. Nutria (*Myocaster coypus*) were the most important species represented in the diet of alligators in freshwater marshes. Fish and arthropods were important foods in the more saline areas. Studies by McIlhenny (1935) and O'Neil (1949) prior to the introduction of the nutria reported muskrat (*Ondatra zibethicus*) to be an important food item in the diet of alligators. Valentine, et al (1972) reported the fluctuations in mammal populations were reflected in alligator diets because muskrat rated high in 1946 when they were plentiful, and nutria rated high in 1961 when their populations peaked. They also reported that crustaceans and fish were important foods for alligators of all ages, while reptiles and birds marked fairly high in the diets of longer alligators.

Coastal areas are subjected to hurricanes from June through September in Louisiana. Heavy rains may also flood coastal marshes. Thus alligator nests are subjected to flooding at any time during incubation. Several authors have documented alligator nest losses due to flooding (Hines et al 1968, Joanen 1969, Fleming et al 1976). Floods damage nests more frequently than any other climatic factor. Losses are generally catastrophic and may exceed the subtle reduction in nesting effort caused by droughts. A study was designed to determine the effects of flood duration on hatchability of alligator eggs on Rockefeller Refuge. At various stages of incubation, alligator eggs were subjected to a simulated flood of variable duration. Hatchability of eggs flooded for 6-12 hours during the first 30 days of incubation produced live young slightly below the hatchability of the control group. Twelve hours of flooding in the remainder of incubation killed all embryos. The study demonstrated that minor flooding can be tolerated, however extended submergence for 12 hours or longer after the first 30 days of incubation produced total mortality (Joanen et al 1976).

The Louisiana coastal marsh alligator population has been quantified annually by aerial nesting surveys (Chabreck 1966) along transects in representative habitat since 1970 (LDWF annual survey data validated by actual counts along selected transects). Consistent annual growth has led to the conservative estimate of approximately 680,000 alligators in Louisiana's coastal wetlands. The coastal alligator population quadrupled over a 20-year period (Joanen, et al 1997). Data analysis was based primarily on Chabreck's (1966) figure of 5% for the percentage of nesting females in a population. The numbers of nests transected by marsh type and zone were converted to acres per nest. The acres/nest figure was then divided into total size of each individual sample area to arrive at total nesting females. A simple 20X conversion connected to total population.

By the late 1960s alligator populations expanded to the land where they were becoming a nuisance. They appeared in stock ponds, swimming pools, flower gardens, and garages. Many were killed on highways posing hazardous obstacles to nighttime motorists. Large alligators in canals and bayous were often killed when hit by boat propellers. The problem was greatest in areas of high alligator populations during periods of drought.

By 1972, a harvest plan had been developed which would control the taking of alligators, and through a system of tags and report forms effectively prevent illegally taking skins illegally taken skins from entering the legal traffic. Enforcement efforts had already reduced poaching in Louisiana to a negligible level. The Louisiana Wildlife and Fisheries Commission, acting on the advice of researchers and professional administrators, decided to test the system by implementing an experimental harvest program in September 1972. A 13-day experimental alligator season was conducted in lower Cameron Parish that year. Alligators four feet and over were taken only between the hours of sunrise and sunset.

Reasons for recommending the season included: 1 – alligators are a renewable resource and should be managed on a sustained yield basis thereby providing economic incentives for preserving marshland, as well as preventing undesirable over-population of the reptiles; and 2 – as a result of strict law enforcement, excellent cooperation on the part of the courts, closed hunting seasons, for as long as 10 years, restocking of depleted areas, and extensive research by commission biologists, the population have increased significantly in certain regions of Louisiana to warrant a closely controlled harvest; and 3 – the season was carried out in the parish of Louisiana that had the highest population of alligators in the state strictly on an experimental basis to develop the proper procedures to conduct future seasons.

The experimental season was designed to evaluate harvest quotas, methods of hunting, tagging procedures, hunter interest, public acceptance of season, and shipment of raw hides. Information obtained from night counts on Rockefeller Refuge in 1966 and data gathered from managed hunts on Sabine National Wildlife Refuge in 1947 and 1948 were used to determine the size composition of the alligator population in Cameron Parish. These data indicate that alligators four feet in length and longer constituted 39.4% of the population (Giles and Childs 1949).

In practice the maximum harvest rate of 3-5% for a population would allow for a harvest of surplus alligators while providing an economic incentive for the hunter and landowner. This conservative harvest level provides a hedge against unknowns and unpredictable factors, ensuring that the population would not be overharvested. The success of this strategy was validated by the continued growth of the population, by the consistent size of alligators taken in the statewide harvests and by comparisons of sex and size-class structure from hunted and non-hunted populations. The alligators of Marsh Island were totally protected and unhunted, that is “preserved” for a period of 24 years between 1962 and 1986. The size-class structure of this population (as reflected in proportion of adults in the first hunt in 1986) and that of statewide population are very similar. Over the period 1972-90, approximately 80% (Joanen and McNease 1991) of the alligators hunted in Louisiana were adults (6 feet and above) virtually identical to the percentage of adults (83%) taken at Marsh Island in 1986 (Joanen et al 1997).

Not only is the harvest rate low compared to much higher (20-30%) harvest rates prescribed for species such as rabbit, quail, squirrel, and deer, but the offtake of alligators is also regulated to a degree rarely seen in wildlife management – to the land of the individual alligator. This is achieved as a result of the tagging requirement developed by the LDWF to regulate effectively the alligator harvest. A locking tag (specific to Louisiana alligators) with unique serial numbers must be affixed to any alligator skin before it leaves the site on which the animal was killed, whether as a result of the wild harvest or farming. This tagging system is a part of the licensing and hunting regulations developed by the LDWF. Any skin not bearing the Louisiana CITES tag will be confiscated; fines can be imposed and licenses revoked. To conform with and assist CITES, this tag must remain on the skin whether salted or processed as leather or traded internationally.

There can be no doubt that the alligator in Louisiana can be managed sustainably without damaging the viability of the resident population. The continual monitoring of the population, the dedication of the LDWF to professionally managing the Louisiana population, and the natural resiliency of the species ensure that any indication of over harvest to the population from other factors, even those unknown and unpredictable, will be responded to in such a way as to protect the Louisiana alligator population and ensure its long-term viability.

Establishing Louisiana’s Alligator Farm/Ranch Program

Considerable resources have been invested by the Louisiana Department of Wildlife and Fisheries in an extensive research program aimed broadly at establishing the feasibility of raising alligators in captivity for commercial and conservation purposes. In the late 1960s and early 1970s, interest had been stimulated in rearing crocodilians in captivity, mainly brought about by a generally declining worldwide population of crocodilians and restrictions placed on the harvest of the wild crop. (Blake 1970; Yangprapakorn et al 1971; Pooley 1971, 1973; Joanen and McNease 1971, 1975, 1984; Downes 1973; Blake and Loveridge 1975; Webb et al 1983; Singh 1984)

However, the lack of sources for suitable farm stock had severely limited the expansion of alligator farming operations in the United States. The LDWF realized this need and has provided stock off state-owned lands since 1977. At that time, private alligator farms in Louisiana were restricted to a closed farming system. Since 1977, 67,139 hatchling alligators were supplied to private farms in Louisiana. These farmers were the real pioneers of the industry, along with a few independent Florida alligator farmers, and deserve the credit of developing the program as we know it today.

A contract was signed by the LDWF and the farmer that he would follow the housing requirements (controlled environmental chambers, feeds and feeding, husbandry procedures as recommended by the LDWF). Also, the farmer was to allow periodic inspections by LSF personnel (Joanen and McNeese 1987b). Farmers were given hatching annually until their breeding stock became sexually mature and capable of producing the number of young required to become self-sustaining. Eggs were produced from captive adults and these were subsequently incubated artificially and their young were raised in captivity, primarily for the production of skins. Louisiana’s relatively young breeding herd numbers produced 7,607 hatchlings in 1990, which amounted to 3.1% of

Louisiana's annual production. However, the state-sponsored hatchling supplement program did not satisfy the demand for new farm expansion in Louisiana.

Taylor and Neal (1984) reported that wild alligators experience a high natural mortality within the first 4 years of life. This study revealed that natural mortality losses were high; 83% of the eggs and young alligators in the wild are lost to natural causes, and only 17% reach the 4' size class. Because of extremely high mortality in wild alligators and the lack of a source for farm alligators, the LDWF in 1986 allowed the collection of wild alligator eggs from private lands (ranching) for the first time. Staff biologists of the LDWF evaluate alligator productivity on each property allowed into the ranching program based upon the latest nesting survey. The department then sets quotas and issues permits relative to the number of eggs that are available for removal.

The farmer is obliged to return to the wild (area where eggs were collected) live alligators within a size range of 36" to 60" representing a calculated percentage of the number of fertile eggs hatched. The actual percentage varies depending upon the size released. The return rate back to the wild simply represents the best estimate of survivability in Louisiana wild alligators. The Department's technical staff supervises the releases and assists in the actual return back to the wild. All alligators released are tagged using a serially numbered second monel web tag, tail notched, and total length measured to the nearest ½ inch (Joanen and McNease 1987b).

Results from Elsey et al (1992a and b) showed that these released alligators eat and grow as well as their wild counterparts. The ranching program therefore does nothing to restrict the inherent diversity of the wild population. Taking a portion of the most fragile part of the population into captivity serves to buffer the Louisiana alligator population during periods of unmanageable habitat stress such as hard freezes or hurricanes.

Experimental Designs

Temperature is an important factor governing growth and it varies considerably throughout the range of the alligator. In southern Louisiana, Chabreck and Joanen (1979) reported approximately 7 growing months per year for immature wild alligators, and Joanen and McNease (1971) reported similar growth periods for adults. Coulson et al (1973) demonstrated that under laboratory conditions, alligators did not initiate feeding activities at temperatures below 72°F (22°C). It was not until the advancement of controlled environmental chamber culture (Coulson et al 1973) that alligator farming began to demonstrate itself as an economically sound business venture. Coulson's studies (1973) demonstrated captive reared alligators from heated environments had a superior body condition as compared to wild alligators (they were 10% heavier for given length) and were twice the length of wild alligators of the same age. Joanen and McNease (1976) reported alligators fed a ground fish diet which in controlled environmental chambers maintained at 86°F converted 49.5% of the food consumed (day weight) into body mass over a 9-month period. After 26 months of intensive feeding, females averaged 42.7lbs and were 5'3", while males were 56.5lbs and 5'6". In Louisiana, growth rates under natural conditions would require at least 4-5 years for an alligator to reach 5' in length (Chabreck and Joanen 1979). Mortality under environmental chamber culture was found to be quite low. Survival rates from hatchling to the end of the third year averaged 95% (Joanen and McNease 1976).

Early feeding trials included ground nutria carcasses (*Myocastor coypus*) and ground Atlantic croaker (*Micropogonias undulates*) along with a commercially prepared diet of catfish and turtle rations. The alligators did well on the ground nutria and ground Atlantic croaker, however the two commercial feeds (catfish and turtle rations) proved totally ineffective and feeding trials were discontinued after only 4 months. Apparently the alligator, a carnivore, was unable to synthesize vegetable-based proteins incorporated into these feeds (R.A Coulson, pers comm., 1974). Today, diets for captive alligators in Louisiana are largely centered around feeding dry pelletized food rather than the fresh or fresh frozen foods fed in the early developmental years of the program (Staton M.A, 1988; Staton et al 1990a, 1990b, 1990c, 1992).

The advantages of using the heated grow-out system as compared to natural ponds were documented as increased food conversion rates, growth, and survivability. This allowed the farmer to produce a marketable size animal, 4’-5’ long in less than two years. As a result of these findings, the LDWF mandates the use of controlled environmental chambers on all farms for housing alligators up to 4’ in length and must be capable of maintaining a constant minimum temperature of 85°F.

Stocking densities of alligators held in controlled environmental chambers were evaluated by Elsey et al (1990). Alligators maintained at the lowest stocking density were significantly heavier and grew significantly faster and had significantly lower plasma corticosterone than alligators maintained at the highest stocking density. Plasma corticosterone showed a strong negative correlation with change in body weight; the faster the rate of growth, the lower the hormone levels. These results are similar to those of Joanen and McNease (1976) who recommended a density of 1 square foot per animal for optimum growth of juvenile alligators grown in total darkness in controlled environmental chambers. Blake (1974) also suggested a stocking density ($0.18m^2$/animal) for rearing young Nile crocodiles to prevent fighting and injury. A similar stocking density was recommended by Webb et al (1983) for *C. johnstons*.

Structure and Composition of Alligator Eggs

The alligator egg shell consists of dense calcite crystals regularly arranged on a fibrous egg shell membrane. The calcified portion of the shell contains pores and erosion craters which change in size and morphology throughout incubation. Details of the structure and composition of alligator egg shells can be found in Ferguson (1982-1985). Inside the egg is a spherical yellow yolk bonded by a thin membrane which is surrounded on all surfaces, but largely at the ends of the egg by opaquely translucent albumen (egg white). The yolk provides most of the nutrition for the developing embryo, while the albumen is an important source of water. The egg shell provides calcium and magnesium for bone development in the last half of incubation as well as protects the albumen, yolk, and embryo from dehydration and mechanical damage. The porosity of the egg shell is important: early in incubation, it must be compact enough to prevent dehydration of the content and provide mechanical strength to resist the forces of the mother crawling on top of the nest; while later in incubation, it needs to be porous enough to facilitate gas exchange between the ever enlarging embryo and the outside environment and brittle enough to flake away to facilitate hatching.

At the time of egg laying, the alligator embryo is well-developed and is floating free on top of the yolk. The attachment of the embryo to the egg shell membrane takes place within 24 hours of egg laying. A small opaque band begins to develop on the external surface of the egg. The opaque spot then increases in size and is almost completely banded around its midpoint axis within 7 days of egg laying. The complete band then moves progressively toward both ends of the egg. This usually takes place in a uniform fashion. The egg is about three-quarters banded about half way through incubation, and the egg shell is completely opaque from about two-thirds of the way through incubation to the end of incubation.

Time of Egg Collection

The optimum time for egg collection is within 24 hours after egg laying. However, occasionally geographical and logistical circumstances force later egg collections. Eggs can be successfully collected and transported at any state of development. However, embryos are particularly sensitive to movement around 8-12 days after egg laying. Eggs can also be collected after the fourth week of incubation. The reason eggs can be safely moved after 4 weeks of incubation, if handled gently and correctly, is that the embryos along with the embryonic membranes have developed sufficiently and become strong enough to resist damage from being moved about and stressed inside the eggshell (Ferguson 1981).

Methods of Collecting and Transporting Eggs

Two very important steps in collecting eggs for artificial incubation are to handle the eggs very gently and to permanently mark the top surfaces of the eggs so as to preserve their original nest orientation. After the egg is marked, it is packed in single layers completely enclosed with natural nest material. The nest material serves many important functions; it protects the egg from rolling around in the containers; cushions the egg from shock and stress; insulates so that the temperature does not change dramatically; maintains egg moisture levels; and produces bacteria needed for exterior shell degradation (Ferguson 1981).

Incubation Techniques

Information on incubation techniques for crocodilian eggs has been reported by Pooley (1971), Yangprapakorn et al (1971), Blake and Loveridge (1975) Joanen and McNease (1973, 1977, 1981, 1985), Chabreck (1978), Whitaker (1981), Ferguson (1981), and DeVos (1982). Hatchlings produced by these techniques have varied considerably in growth and survivorship, and most researchers report a percentage of animals which are noticeably inferior to others. Growth rates have also been reported to vary with stocking rates, grow-out temperatures, hygiene, and diet.

Studies have demonstrated that embryonic growth and sex determination of alligators are affected by incubation temperatures (Ferguson and Joanen 1982, 1983). Exclusively females hatch from eggs incubated at 86°F (30°C), and they weigh significantly than the exclusively males that hatch from eggs incubated at 93°F (33.9°C). This weight difference is a consequence of the females having more abdominal yolk than the males (Ferguson and Joanen 1982, 1983).

Studies by Joanen et al (1984) demonstrated that 89°F (31.7°C) and 87°F (30.6°C) incubation produces hatchlings that are marginally lighter than those produced at 91°F (32.7°C) and 85°F (29.4°C) but which nevertheless survive better as both embryos and hatchlings, grow faster, attain longer mean sizes, and have a smaller proportion of runts. Incubation at 89°F (31.7°C) results in a high male/female sex ration and the least number of runts of any temperature treatment tested. The males produced at this temperature grew faster and attained larger sizes than any other sex-temperature combination. Incubation at 87°F (30.6°C) produced high female-male sex ration and the longest females of any treatment, although they were not as large as the 89°F (31.7°C) males; furthermore, incubation at 87°F (30.6°C) resulted in twice the number of runts as did incubation at 89°F (31.7°C). Incubation at 85°F (29.4°C) produced heavy hatchlings which were all females, but they had slow growth rates and about five times the number of runts as did incubation at 89°F (31.7°C). Similarly, incubation at 91°F (32.7°C) produced the heaviest hatchlings, which were all males, and which grew slowly and had around four times the number of runts as animals incubated at 89°F (31.7°C).

As a result of the management, research, and enforcement efforts, there can be no doubt that the alligator in Louisiana can be managed sustainably without damaging the viability of the resident population. The continued restoring of the population, the dedication of the LDWF to professionally manage the Louisiana population, and the natural resiliency of the species ensure that any indication of overharvest or damage to the population from other factors, even those unknown and unpredictable, will be responded to in such a way as to protect the Louisiana alligator population and ensure long-term viability.

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Louisiana's Alligator Management Program

Buddy Baker

Department of Wildlife and Fisheries

On behalf of the Louisiana Department of Wildlife and Fisheries I also want to welcome you here to what we in Louisiana refer to as "the Sportsman's Paradise". I know many of you have travelled long distances from overseas to participate in this important meeting. We're glad that you made it.

I can't tell you how excited we are that the CSG has decided to bring this years working group meeting to Louisiana. I want you to know that we consider this a great honor. In my day job I serve as Director of numerous coastal related projects including the Alligator Management Program. Additionally, I am on loan to represent the 50 state fish and wildlife agencies on matters related to CITES. It's through participation in these CITES conferences and working group meetings that I've come to realize how extremely effective and highly respected the CSG is. It's been my observation that the CSG, more than any other IUCN specialist groups has been effective in keeping management centered on science as opposed to politics. The CSG obviously benefits from having a committed membership with strong leadership. I want to assure each of you that we the staff at the DWF appreciate all that you do in your commitment to protecting and managing crocodilians around the world.

Over the next few days you'll hear a number of presentations from our staff on alligator management in Louisiana. We consider the restoration and management of the American Alligator to be one of our agencies greatest successes. This success hasn't come without a great deal commitment of energy and financial resources. You've just heard about the commitment of resources from our federal governing body of Congress and from the state Governor's office. What I hope you will take away from this week is that successful wildlife restoration and management must have the support of all levels of government. And of course it must be supplemented with hard work and with funding.

Our agency, the LDWF, is the state agency charged with the direct management and regulation of alligators. Our agency charge, however, goes way beyond alligators and includes the authority for all species of wildlife found in Louisiana, from whooping cranes to white-tailed deer and from yellow fin tuna to paddlefish. Our agency includes approximately 800 employees in numerous Divisions (Wildlife, Fisheries, Enforcement & Administration). The Wildlife Management Division has approximately 220 biologists, technicians, researchers and habitat managers. The Enforcement Division has around 260 officers. These officer are scattered throughout the state to enforce the states regulations on alligators and other wild species.

The successful management of our alligator population in Louisiana is not simply a government endeavor. It is successful because it's a true cooperative endeavor between government and the public sector. Landowners, alligator trappers and alligator farms all are involved in the management process. It's the alligator industry that supplies the funding for the management and regulatory program. Industry participants contribute approximately $2 million per year in the form of licenses and shipping fees. No additional public tax based funds are required to run the program. These industry participants are involved in the process beyond simply funding the program. Alligator hunters, farmers and landowners are also directly engaged in the management and regulation setting for alligators through a government mandated public advisory committee.

Our state has had a long history of alligator utilization and a long history of management. Early natural history studies were undertaken here in Louisiana by Mr. E. A. McIlhenny of Avery Island; famous for Tabasco sauce, with which you may be familiar. Our agency biologists pioneered alligator farming research studies at our own Rockefeller Wildlife Refuge right down the road at Grand Chenier. Hopefully you'll be staying through Saturday so that you can participate in the field trip to Rockefeller Refuge.

Those early studies at Rockefeller Refuge led to our successful egg "ranching" program which began in 1986. Under this program, our landowners and farmers are permitted to collect eggs from the wild. As most of you know this permitted process has a put back requirement where a portion of the juvenile alligators are returned back to the wild for future generations, and the remainder is used for commerce. I won't attempt to go into detail about our management and research programs. Our Alligator Program staff will have lots of opportunity to share these details with you throughout the week.

Even with good science, our alligator program experiences challenges. Many of you will recall that our beautiful state was devastated by the effects of Hurricanes Katrina and Rita in 2005, and again just three years later by Hurricanes Gustav and Ike in 2008. The images of historic New Orleans with devastating flooding are hard to forget. Well, our coastal marshes with so much critical alligator nesting habitat were also adversely impacted. We continue to work towards coastal restoration and protection to ensure the future of our valuable and irreplaceable wetlands. Here in Louisiana we understand that ultimately protection of our alligators is inextricably linked with protection of the habitat.

We're very proud of the success of Louisiana's alligator management program. This "Marsh to Market" program is currently recognized throughout our country as a model of for the wise use of a natural resource. It's worth noting that the sustainable harvest of alligators in Louisiana generates about $80 million dollars per year for alligator trappers, farmers and landowners in Louisiana. This $80 million provides incentive to properly manage the land, it provides income for many south Louisiana families, and it helps to preserve a Cajun culture. While we're very proud of what we've accomplished in managing the American alligator here in Louisiana, the story doesn't stop at this point. Through our dedicated funding source and the through the efforts by our staff to secure additional grant monies to support further research, we will continue to investigate best management practices for alligators in Louisiana. We look forward to sharing details of our program with you this week. And we hope you can provide input and exchange ideas with us this week so that together we can solidify a long term future for crocodilians around the world.

Thank you and have a wonderfully productive and fun time here this week.

Florida's Alligator Management Program: An Update

2002 To 2014

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Abstract

Florida's Alligator Management Program has developed around the premise that the economic value derived from consumptive use of Florida's alligator (*Alligator mississippiensis)* resource can provide economic incentives to conserve alligators and preserve their wetland habitat. The expansion of management programs and growth of an industry dependent on the alligator resource has provided a constituency group to serve as advocates for wetland conservation. The major objectives of the program are to implement sustained alligator harvest programs while optimizing the economic, aesthetic, and ecological values of alligators as a renewable natural resource. By emphasizing these values, not only are there incentives for conservation of the alligator, but also the wetland ecosystems they inhabit. The intent of this paper is to provide the current status of this unique and comprehensive management program relative to the last update provided to Crocodile Specialist Group members in 2002 (Dutton et al. 2002).

Introduction

Alligators have been an important component of Florida's wetland systems for thousands of years, and have also been commercially used in Florida as early as the late 1800's. Because harvesting of alligators went unregulated through the early 1900's, concerns about population declines in easily accessible areas stimulated establishment of a four-foot minimum size limit (the first statewide alligator regulation) by the former Florida Game and Fresh Water Fish Commission in 1943 (now part of the Florida Fish and Wildlife Conservation Commission, and hereinafter referred to as the "FWC"). Alligator populations continued to decline despite regulatory efforts through the late 1950's and early 1960's. As a consequence, the alligator harvest season in Florida was closed in 1962. Wide spread illegal exploitation continued, however, due to an inability to affectively enforce state laws, culminating in American alligators being included on the first federal endangered species list in 1967. In 1970, strict federal regulations were imposed through an amendment to the Lacey Act that made it illegal to transport illegally taken alligators between states. Under this highly effective regulation, illegal trade came to an end, and alligator populations in areas where declines had been observed made impressive comebacks (Hines 1979).

Alligator population surveys conducted by FWC biologists in the mid-1970's indicated that most populations were increasing rapidly (Hines 1979; Wood et al. 1985). During this time, the FWC was receiving 4,000 to 5,000 nuisance-alligator complaints annually. In 1977, the status of Florida's alligator population was reclassified from endangered to threatened by the U. S. Fish and Wildlife Service, following the population status evaluation conducted by the FWC's alligator research staff. This change in status allowed the FWC to initiate management of the nuisance-alligator problem through harvest, resulting in our current Statewide Nuisance Alligator Program (SNAP) (Hines and Woodward 1980, and Woodward and Cook 2000). The American alligator is currently listed under the Endangered Species Act as threatened due to similarity of appearance (Neal 1985).

In 1980, the FWC's alligator research staff began focusing its efforts on the effects of alligator harvests on wild populations. As a result of these investigations and subsequent experimental alligator harvests on selected wetlands, the FWC created an Alligator Management Program (AMP), later to be part of the FWC Division of Hunting and Game Management (HGM).

The AMP originally developed around the premise that the economic value derived from consumptive use of Florida's alligator resource can provide economic incentives to conserve alligators and preserve their wetland habitat. The expansion of management programs and growth of an industry dependent on the alligator resource can provide a new constituency group to serve as advocates for wetland conservation. In recent years, recreational hunting of alligators has emerged as the component of the alligator management program with the largest user group. The major objectives of the AMP are to implement sustained alligator harvest programs while optimizing the economic, aesthetic, recreational, and ecological values of alligators as a renewable natural resource. By emphasizing these values, the FWC hopes to provide incentives for conservation of not only the alligator, but also the wetland ecosystems they inhabit.

The following is a summary of the major program components of Florida's alligator management program. A suite of rules adopted, and frequently amended, by the FWC collectively governs each of the program's elements. Although complex, these rules ensure sustainable harvests of the resource and credibility and integrity of the alligator management program. This is important for meeting the conservation and management goal for alligators in Florida but is required by the U.S.F.W.S. special rule under which harvests are permitted in the USA. It is also essential for meeting the requirements of the Convention on International Trade in Endangered Species (CITES) to conduct international trade in alligators. Current versions of Florida's alligator management rules can be viewed on the Internet at: http://myfwc.com/media/1531908/alligator_rules_booklet.pdf.

Public Waters Alligator Harvest Program

Under this program, alligator populations are managed on designated public waterbodies (ranging in size from 500>100,000 ha), as well as legally accessible public and privately owned wetlands occurring within counties that have an established county-wide harvest quota. These Alligator Harvest Management Units (AMUs) are established by executive order (a document signed by our FWC's Executive Director), and the FWC's Executive Director, or his designee, establishes annual harvest quotas via a signed memorandum. Figure 1 depicts the total annual harvest quotas established for all AMUs each year since 2002.

Research biologists assigned to the Alligator Management Standing Team (AMST) review and recommend AMUs for establishment annually. Procedures for two types of AMUs are used in this evaluation: (1) those for which a harvest quota is established by annual, intensive population monitoring (used on areas referred to as "variable-quota AMUs") and (2) those for which a harvest quota is established by either a one-time alligator habitat inventory or population survey (used on areas referred to as "static-quota AMUs"). Brunell et al. (2002) provides a complete and detailed account of the current protocol used to recommend new AMUs, calculate recommended harvest quotas for AMUs, identify AMUs to be closed to harvest, and determine when closed AMUs should be reopened. Figure 2 depicts the total number of AMUs with harvest quotas that have been established annually since 2002.

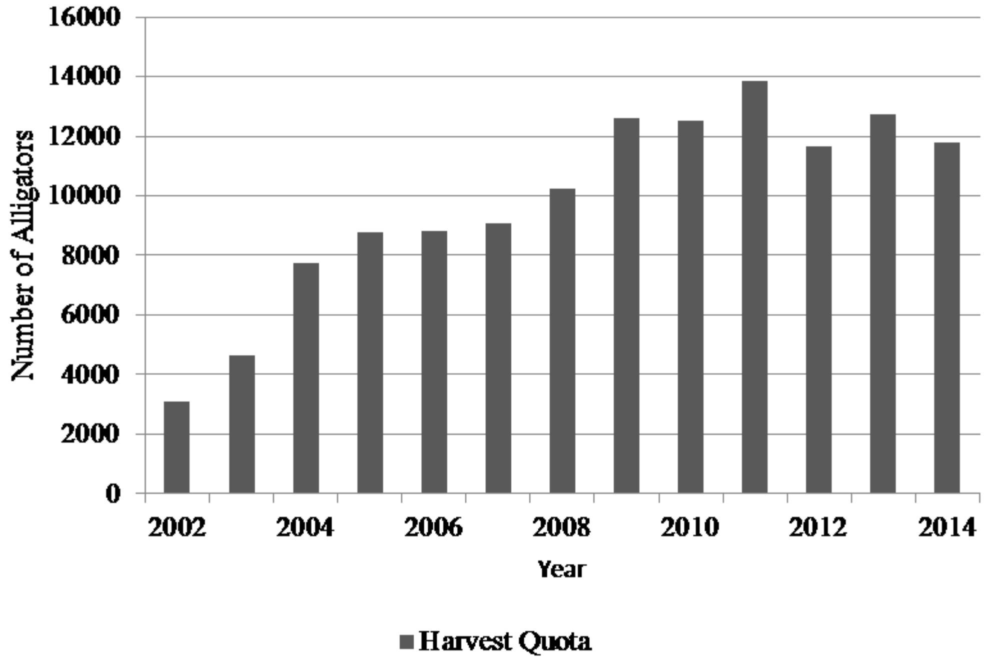

Fig. 1, total annual alligator harvest quotas established on alligator management units in Florida from 2002 – 2014.

The Commission's public waters alligator harvest program continues to be an important component of the overall management strategy. It captures statewide, national, and international

Interest and provides an excellent opportunity to inform the public about the value of alligators and wetlands, while allowing participants to enjoy harvest benefits from this renewable natural resource. Table 1 summarizes the various participation and harvest trends in this program from 2002 - 2013. Of particular note is the continued increase in the number of permitted applicants during this period. This has increased participation in the hunts, which has generated additional revenues to support other changes in the other alligator management program elements. The gross value of the hides and meat produced under this and the various other harvest program elements from 2002 through 2010 are summarized in Table 2.

Private Lands Alligator Management Program

Since a large percentage of Florida's wetlands are privately owned, conservation of alligator habitats on private lands is critical to the continued well-being of alligator populations in the state. The FWC has given landowners an incentive for maintaining these habitats by providing them an opportunity to manage and harvest alligators on their lands. To participate in the program, applicants must own or lease a parcel of suitable wetland alligator habitat. A group of landowners or authorized lessees with adjoining properties may apply jointly.

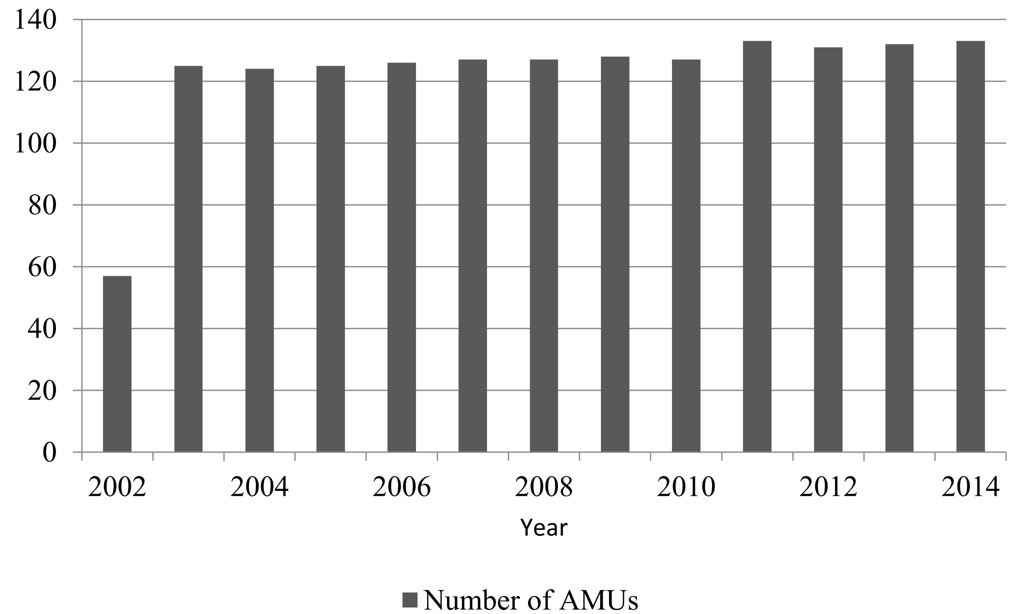

Figure 1. Total number of established alligator management units in Florida from 2002 – 2014.

Table 1. Public waters alligator harvest program summary for Florida, 2002-2013.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Number of Applicants	2,705	N/A	N/A	N/A	N/A	N/A	N/A	13,422	13,105	14,829	16,537	17,789
Permits Available	1,548	2,317	3,874	4,391	4,406	4,527	5,126	6,309	6,264	6,919	5,732	6,371
Permitted Applicants	1,519	2,040	2,681	2,787	4,388	4,493	5,117	5,006	4,564	5,819	5,475	5,996
Tags Issued	3,038	4,080	5,363	5,574	8,775	8,977	10,234	12,593	12,108	13,806	11,538	N/A
Alligators Harvested	2,161	2,829	3,237	3,460	6,430	5,963	6,377	7,839	7,736	8,103	6,709	7,995
Percent Harvested	71	69	60	62	73	66	62	62	64	59	58	N/A
Avg. Carcass (ft.)	8.3	8.3	8.4	8.4	8.4	8.5	8.4	8.0	7.9	8.1	8.3	8.3

Table 2. Production levels and estimated wholesale producer values of alligators harvested in Florida during 2002-2010.

	Hides Produced (No.)			**Feet of Hides**			**Meat Produced (lbs)**		
Year	**Wild**	**Farm**	**Total**	**Wild**	**Farm**	**Total**	**Wild**	**Farm**	**Total**
2002	11,070	27,473	38,543	81,222	140,662	221,884	230,787	207,727	438,514
2003	11,719	22,627	34,346	86,321	112,230	198,550	247,651	153,020	400,671
2004	13,161	21,461	34,622	98,380	103,013	201,393	292,701	129,335	422,036
2005	15,909	28,141	44,050	118,458	126,072	244,530	349,056	133,071	482,127
2006	23,653	23,283	46,936	175,630	104,308	279,938	513,974	110,099	624,073
2007	22,502	28,153	50,655	169,138	130,630	299,768	510,139	150,605	660,744
2008	22,448	27,444	49,892	168,893	140,513	309,407	510,600	207,508	718,108
2009	17,110	16,621	33,731	128,062	93,078	221,139	382,201	172,203	544,404
2010	15,261	18,239	33,500	113,368	102,138	215,506	332,131	188,966	521,097

Private lands participants may choose from several available harvest options, depending on the acreage of alligator habitat on their properties and/or alligator population information provided to the FWC. Private landowners may elect to harvest non-hatchling alligators, hatchlings, and eggs from their properties.

Participation in the private lands program has continued to expand since 2002. Being a truly commercially oriented harvest program, the level of property enrollment has generally been dependent on the status of the alligator hide and meat markets. However, even during depressed alligator hide market conditions, this program has continued to expand. Table 3 summarizes the participation and harvest trends of this program since 2003. The gross value of the hides and meat produced under this and the various other program elements from 2002 through 2010 are summarized in Table 2.

Table 3. Private lands alligator management harvest program summary for Florida during 2003-2013.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total Properties	132	110	112	148	168	187	153	82	155	153	233
Acres (Millions)	2.195	1.977	1.905	2.173	2.106	2.137	2.143	2.132	2.23	2.35	2.53
Tags Issued	6,542	4,959	5,525	8,924	10,708	10,220	7,948	6,338	8,326	8,887	N/A
Adults	3,049	2,634	3,355	5,559	6,191	6,338	2,097	1,669	2,855	3,708	N/A
Adult Harvest Rate (%)	47	53	61	62	58	62	26	26	34	42	N/A
Avg. Carcass Length (ft.)	7.2	7.1	7.4	7.4	7.6	7.6	7.9	7.8	7.7	7.9	N/A
Eggs	23,136	17,570	34,110	34,064	48,057	54,790	22,772	35,287	38,698	54,095	79,448
Hatchlings	0	0	0	0	0	0	0	0	0	0	0

Statewide Nuisance Alligator Program (SNAP)

This program is administered by the AMP through contracts between the FWC and professional alligator trappers, and is designed to permit the harvest of alligators that are determined to be a threat to the welfare of the public, or their pets or property. Currently, approximately 120 professional trappers are contracted to remove specific nuisance alligators. Members of the public call the SNAP hotline to file complaints regarding nuisance alligators, which are evaluated by AMP staff to determine if the alligator should be removed by a contracted nuisance-alligator trapper (Hines and Woodward 1980; Jennings et al. 1989; Woodward and Cook 2000). The program has helped to hold alligator attacks at a low level and has proved to be a quick and cost effective response to nuisance-alligator complaints (Woodward and Cook 2000). Because this program has been viewed as a success, the only real change since its inception in 1978 is that the number of contracted trappers has had to increase to meet the demands of Florida's growing human population. Table 4 provides a summary of program trends since 2002. The gross value of the hides and meat produced under this and the various other harvest program elements from 2002 through 2010 are summarized in Table 2.

Table 4. Summary of Florida's nuisance alligator harvest program during 2002 to 2013.

Year	Complaints Received	Permits Issued	Alligators Harvested	Alligators Harvested/ Complaint	Meat Yield (lbs.)
2002	14,738	11,961	5,833	0.39	136,018
2003	17,161	13,873	5,841	0.34	124,302
2004	18,072	15,485	7,290	0.40	141,583
2005	13,781	12,897	9,094	0.66	137,701
2006	17,601	15,339	11,664	0.66	200,007
2007	12,198	10,698	10,348	0.85	178,096
2008	12,878	10,330	9,733	0.76	125,638
2009	13,049	10,118	7,174	0.55	79,344
2010	13,047	10,162	5,856	0.45	58,844
2011	15,754	11,846	6,995	0.44	58,967
2012	17,043	12,727	7,975	0.47	41,763
2013	15,219	11,520	7,636	0.50	N/A

Public Waters Alligator Egg And Hatchling Collection Program

This program permits the collection of alligator eggs and hatchlings from public waters by licensed farmers who have met specific requirements established by FWC rule. However, the number of farms allowed to participate is restricted due to the limited availability of eggs and hatchlings in the wild. Restricted access effectively guarantees continued access to a finite source of eggs and hatchlings and avoids diluting the availability of "raw materials" to farmers who have made significant capital investment in rearing facilities.

AMST staff review and recommend alligator egg collection areas for establishment annually. Candidate areas are identified based on staff familiarity with their region and suggestions provided by other personnel and the public. Since 2006, quotas on egg collection areas (ECAs) have been established using a combination of historical nesting data and current nightlight population survey data for hatchling and juvenile size classes (Dutton 2006). Egg collections are conducted under direct supervision of FWC biologists. Table 5 summarizes trends in egg collections under this program element since 2003.

Table 5. Public waters egg collection program summary, 2003-2013.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
ECAs	24	16	25	22	24	33	33	30	20	18	19
Nest Quota	1,062	1,561	1,667	2,108	1,538	1,742	2,180	1,999	1,900	1,851	2,096
Eggs	25,905	40,460	35,638	45,730	26,588	39,377	32,451	40,657	35,126	37,517	36,837

Hatchling collection quotas were established in 1987 based on the quantity and quality of alligator habitat in 65 of the state's 67 counties, and remained unchanged until 2009. At that time updated GIS technology and years of alligator growth and mortality data were utilized to reevaluate the quota for each of the eligible 65 counties in Florida. The result was a slightly reduced total quota, but a quota that both the FWC and the stakeholders felt was more sustainable. Quotas range from 50 to 500 hatchlings per county. Eligible farmers elect one of their peers to coordinate the collection of each county's quota and delivery their portion of the collected quota to them for an agreed upon fee. Hatchlings collections are permitted from September 1 through November 15. The coordinator elected by the permitted farmers and he or she's designated agents are allowed to collect hatchlings independently of FWC oversight, but are required to tag hatchlings immediately upon capture. Table 6 summarizes participation and collection trends under this program element since 2002.

Table 6. Public waters hatchling collection program summary, 2002-2013.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
# of Counties Permitted	55	48	17	52	64	61	40	18	48	56	56	53
Total Collection Quota	10,200	10,200	10,200	10,200	10,200	10,200	10,200	8,700	8,700	8,700	8,700	8,400
Hatchlings Collected	3,491	4,107	337	4,399	4,346	6,492	4,075	1,923	7,133	4,692	5,542	4,664
% of Quota Collected	34	40	3	43	43	64	40	22	82	54	64	56

Alligator Farming

Alligator farming in Florida has relied on wild egg and wild hatchling stock to support the continued growth of the industry since 1988. Despite periodically depressed alligator hide market conditions during the last decade, the number of licensed farms and the number of active farms producing hides since 2002 has since remained relatively stable. Inventories have continued to be sustained at above 80,000 animals. Participation and production trends under this program element from 2002 through 2010 are summarized in Table 7.Table 7. Estimated producer value and levels of alligator harvest on Florida farms during 2002-2010.

Year	Licensed Farms	Active Farms	Hides Produced	Est. Total Ft. Hides	Ave. Hide Size Length (ft)	Width (cm)	Est. Meat Prod. (lbs)	Total Value
2002	65	18	27,473	140,662	5.10	32.0	207,727	$3,941,416
2003	63	15	22,627	112,230	5.00	31.0	153,020	$3,143,619
2004	61	14	21,461	103,013	4.80	30.0	129,335	$3,543,909
2005	59	13	28,141	126,072	4.50	28.0	133,071	$4,065,792
2006	58	13	23,283	104,308	4.50	28.0	110,099	$5,710,838
2007	59	14	28,153	130,630	4.60	29.0	150,605	$6,800,998
2008	58	13	27,444	140,513	5.10	32.0	207,507	$6,977,487
2009	60	15	16,621	93,078	5.60	35.0	172,203	$2,343,281
2010	59	15	18,239	102,138	5.60	35.0	188,966	$2,571,391

Active Farms: Farms that produced hides that were subsequently tagged with CITES tags.
Hides Produced: Number of hides that were tagged with CITES tags.
Total Ft. Hides: Calculated from (Hides Produced * Ave. Size (ft.)).
Ave. Size - Length: Average total length from interviews with farmers and dealers. Based on average belly width after 1995.
Ave. Size - Width: Converted from ave. length based on a conversion factor of 6.25 cm belly width per linear ft.
After 1995, prices were based on reports from dealers.
Hide and Meat Prices: Ave. wholesale value based on interviews with farmers, dealers, and tanners.
Meat Produced: Derived from farm reports during 1985-92.
Before 1985 and after 1992, derived from estimated weight of alligators (Woodward et al. 1992) and an assumed 30% meat yield.

Summary

All of these programs allow the FWC to manage alligators on a sustained yield basis and recognize them as an ecologically, aesthetically, recreationally, and economically valuable renewable natural resource. Revenues generated through user-fees provide funding for alligator management and research. Most importantly, the economic value of the species gives user groups a vested interest in the welfare of wild alligator populations. Therefore, there is an incentive for beneficiaries to become political advocates for wetland preservation, which ultimately conserves habitat not only for alligators, but for a wide variety of Florida's wildlife. The recovery of the American alligator is touted as a success story in U.S. wildlife conservation efforts, and now it is generally recognized by resource professionals that sustained use of alligators can have conservation benefits.

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Effects of Feral Swine (*Sus scrofa*) on Alligator (*Alligator mississippiensis*) Nests in Louisiana: A Three Year Summary

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Abstract

Rapid spread of the introduced *Sus scrofa* (feral hog) is a concern for landowners due to destructive rooting behavior damaging natural habitats. In response to reports by landowners of alligator nest losses due to feral swine, in 2011 we sent a questionnaire addressing this to Louisiana alligator farmers licensed to collect eggs from wild nests. Over half (51.4%) reported loss of alligator nests; an estimated 598 nests were damaged/destroyed on 37 properties. Four farmers reported this was the first year they have lost nests to feral swine despite years collecting alligator eggs. Others reported seeing wild hogs while in the field or seeing sign of hogs; suggesting future losses may occur as the range and population of this non-native species is expanding in alligator nesting habitat. Nearly all farmers who lost nests to feral swine (94.7%) reported hog damage was increasing on their properties. Additional surveys sent in 2012 and 2013. In 2012 some 252 nests were estimated lost on twenty properties; five of which were new properties not previously affected. In 2013, an estimated 393 alligator nests were lost to feral pigs, and sixteen new properties not previously damaged were impacted. In addition to deleterious effects on wetland habitats caused by feral swine, the financial impact of loss of the alligator egg revenue is significant. Some farmers reported that hog removal efforts limited their feral swine damage relative to past years. Factors affecting yearly variation in feral swine damage will be discussed.

Introduction

Many landowners across the United States are experiencing problems with property damage from feral swine (*Sus scrofa*) which are expanding their range (Ditchkoff and Mayer 2009, Mayer and Brisbin 2009). In addition to agricultural and residential damage, feral hogs can destroy crops, damage wildlife habitat, compete with other species for food, prey on wildlife, and transmit diseases to wildlife, livestock, and humans (Kimmel 2011, Perot 2011). They have established populations in at least 38 states and are spreading rapidly, with estimated economic losses to agriculture and the environment at $800 million annually (Mouton 2009). Additionally, their extensive rooting of soils can disrupt wetlands and lead to wetlands losses in already fragile ecosystems (Mouton 2009). Methods are being developed to accurately survey wild pigs (Williams et al. 2011) and recent legislation has been enacted in Louisiana to provide more options for property owners to take “outlaw quadrupeds”, including feral hogs (Louisiana Department of Wildlife and Fisheries [hereafter LDWF] press release, July 14, 2011; Perot 2011). Studies are underway in Louisiana to evaluate the possible effect of soil quality on reproductive efficiency in this prolific species (O’Boyle and Tolson 2011) which may help elucidate why their range is expanding in certain regions, and impacts on forestry and agronomic activities in Louisiana have been detailed (Tolson and LaCour 2013). Feral hogs now occur in every parish (county) in Louisiana (D. LeBlanc, pers. comm.) and there are established breeding populations in at least 36 states (National Feral Swine Mapping System NFSMS as cited in Tolson and LaCour, 2013). A recent report (Mayer and Brisbin 2009) reviews management and control techniques for this damaging species. In recent years the LDWF (2013) relaxed regulations to allow for additional harvest opportunities of feral pigs (Tolson and LaCour 2013). Although feral hogs have only rarely been noted as a predator of *Alligator mississippiensis* (American Alligator) eggs in Louisiana (McIlhenny 1935) their recent population growth and range expansion could make this mortality factor of greater import adversely affecting Louisiana's valuable alligator population.

As we previously reviewed (Elsey et al. 2012) numerous studies have been conducted on the nesting ecology of alligators in southeastern states, and wildlife managers in Louisiana, Florida, South Carolina, Texas, and Georgia have documented nest losses due to predation and flooding (Cooper and Slaughter 2008, Deitz and Hines 1980, Fleming et al. 1976, Goodwin and Marion 1978, Hunt and Ogden 1991, Joanen 1969, Metzen 1977, Platt et al. 1995, Ruckel and Steele 1984, Wilkinson 1983). Raccoons (*Procyon lotor*)are the most often cited mammalian predator in these studies, but in some cases river otters *(Lontra canadensis*) have been suspected as predators on alligators (Deitz and Hines 1980), and American black bears *(Ursus americanus*) have also been documented as causing nest/egg loss (Hunt and Ogden 1991, Metzen 1977).

In our earlier publication (Elsey et al. 2012) we reported that in McIlhenny's classic study on alligators (1935) he noted alligator eggs to be eaten by a number of animals, including "'coons, opossums, skunks, hogs, and bears". Additionally, Fogarty (1974) noted a hog was seen rooting through one nest of 64 (1.6%) studied in the Florida Everglades. More recently, Ruckel and Steele (1984) noted that four of 31 nests at their Rhetts Island study site in Georgia were destroyed by feral hogs, and one other nest was destroyed by a combination of raccoons and feral hogs; thus 5 of 31 nests (16.1%) were lost all or in part to hogs. In a long term multi-year study in Florida, Woodward et al. (1992) noted one nest was depredated by wild hogs; as evidenced by extensive rooting and hoof-prints around the nest. Biological staff from our agency (Campbell 1997) noted signs of hog presence in nesting areas and nests destroyed by hogs during a pilot study evaluating alligator nests in swamp habitat with a cooperating alligator farmer licensed to collect wild alligator eggs.

Commercial alligator farming programs exist in many southeastern states. A major component of the program in Louisiana involves egg "ranching", wherein alligator farmers may collect eggs from nests in the wild to stock alligator farms under permits and quotas established by the LDWF. This program has been described in detail (Elsey et al. 2001), and can have an economic value of nearly $60 million in strong market years for the valuable leather industry (LDWF 2009).

To better evaluate alligator nest losses and quantify potential impact to alligator nesting habitat in Louisiana due to feral hogs, we developed a questionnaire in 2011 to request information on nest destruction due to feral pigs. Information obtained might be of use in assisting wildlife managers in controlling feral hogs on their properties which may damage valuable wetland resources, including alligator eggs. Based on the results obtained in 2011, additional follow up surveys were conducted in 2012 and 2013.

Methods

A brief (one page consisting of seven questions) survey was developed in 2011 and sent to the 37 Louisiana alligator farmers who had permits to collect alligator eggs from the wild that year. Self-addressed stamped return envelopes were provided to facilitate replies to the brief survey, and a cover letter assured respondents their replies would in no way affect future egg quotas which are determined by our agency (additional details in Elsey et al. 2012). The form also indicated farmers could telephone the LDWF office and discuss their answers and observations over the telephone, rather than having to complete the written questionnaire, if this was easier. The brief questions (Elsey et al. 2012) included:

1. Did you see any evidence of hog (feral pig) damage to alligator nests during your collections this year?

2. If so, on which land companies did you see hog damage to alligator nests? (please list how many nests damaged on each property; and whether they were slightly damaged or completely destroyed). Please provide as much detail as is possible. Any photos are appreciated as well.

3. Have you ever seen hog damage to alligator nests in past years? List years if possible.

4. Does hog damage seem to be increasing on your properties, decreasing, or staying about the same?

5. Have you observed live hogs in the marsh when collecting eggs or flying to mark nests? If so, which properties?

6. Have you seen hog sign (footprints/tracks, scats/droppings, etc) near nests while collecting nests?

7. How many years have you been collecting eggs from the wild?

The questionnaire was mailed in mid-July (19 July 2011), by which time a few farmers may have already recently completed the summer's egg collections, but many would still be actively collecting eggs. Thus we hoped most farmers would remember if they had seen any evidence of feral swine damage, but we did not want to seem to be "encouraging" reporting of questionable findings or cause over interpretation of damage to alligator nests caused by other means. The number of licensed egg permittees is low (n = 37) and we had a 100% response rate in 2011. In some cases this was done via telephone and we recorded the information supplied.

As we noted (Elsey et al. 2012) we were confident alligator farmers could distinguish nest depredation by feral swine from other predators (mainly raccoons) as nests depredated by raccoons typically have numerous small penetration holes, apparently made as raccoons probed for eggs (Woodward et al. 1992). Wild hogs would generally create more nest damage and disrupt the integrity of the nest mound with rooting activities; and hoof prints and tracks of pigs might be seen at the nest site (see Elsey et al. 2012). Additionally, nearly 68% of licensed Louisiana alligator farmers had over twenty years of experience collecting alligator eggs and thus were felt to be reliable observers in submitting the requested data in 2011.

The survey was not developed until after the egg collection season started, thus the results in the pilot study were in many cases estimates the farmers made after completing egg collections. If a farmer reported a range of nests damaged (for example, "3-4 nests lost on Property A") we assumed the lesser quantity and considered three nests lost. If they reported a range such as "8-10 nests lost on Property B" we considered this as nine nests lost. The farmer with the most nests damaged in 2011 reported an estimate based on a percentage of nests damaged in each section that the ultra-light aircraft pilot surveyed, and the number of nests ultimately marked (the pilot did not throw a nest marker at nests already destroyed by feral swine at the time of survey, as ground crews would not need to visit that individual nest site).

Some farmers specifically reported they did not have hog damage but did lose a few nests to raccoons in 2011; others reported some feral swine damage but more raccoon damage, which lent support to our supposition that alligator farmers could distinguish the two factors. One farmer reported rare alligator nest losses due to bears; the property manager has frequently observed bears on the area but has not observed hogs.

Hundreds of alligator egg permits are issued to licensed Louisiana alligator farmers annually; in 2011 we issued 531 permits on individual properties with a total egg quota total of over 785,000 eggs. The number of egg permits individual farmers have varies widely (range 1 – 75 in the year 2011); the number of eggs in each farmer's quota total ranged from 700 eggs to 95,915 eggs in 2011. The single smallest permit had an egg quota of 35 eggs, and the largest single 2011 year permit had a quota of 55,535 eggs. Alligators occur statewide in Louisiana, but the majority of the alligator habitat (and thus alligator nests, population, and egg quotas) occur in the coastal parishes. A variety of habitats exist, including large lakes, upland areas, cypress tupelo swamps, and coastal marshes (Elsey and Kinler 2004).

In 2012 and 2013 we made the survey form even shorter, and simply asked alligator farmers if they saw any alligator nest damage attributed to feral pigs, and if so, on which property/properties and asked them to identify the parish (county) where the damage occurred. A column was also included for any remarks they might choose to included, and we requested any photos of hog damage, if available. We sent the questionnaire prior to the beginning of egg collections to encourage farmers to be aware of possible damage they might encounter and accurately report numbers of nests lost and locations soon after the observation, rather than relying on memory of what they'd observed weeks earlier.

Results

Alligator nest damage in 2011, extent of nest damage, and properties affected

Numerous farmers (51.4%) reported feral swine damage to alligator nests in 2011. Nineteen farmers reported losing approximately 598 alligator nests to feral swine in 2011. Properties affected were broadly distributed across the state (Figure 1; also see Elsey et al. 2012), although more occurred in the coastal zone where alligator populations are greatest. Two farmers who collect eggs on one large property lost some 315 nests as a conservative estimate for their combined collections. They successfully collected 40,500 eggs combined; but lost approximately 25% of the nests produced to wild pigs. One farmer with 75 egg permits lost 132 nests on nine properties; fifty nests were lost on his largest property which had about one third of his entire egg quota. One farmer lost 27 nests on a single large wetland property; another farmer with a single egg permit lost 10 of 39 (25.6%) alligator nests he located to hog damage. In 2011, Louisiana alligator farmers collected over 352,000 eggs, or some 13,000 nests. Thus, the estimated 600 nests damaged by hogs represent approximately 4-5% of the nests collected.

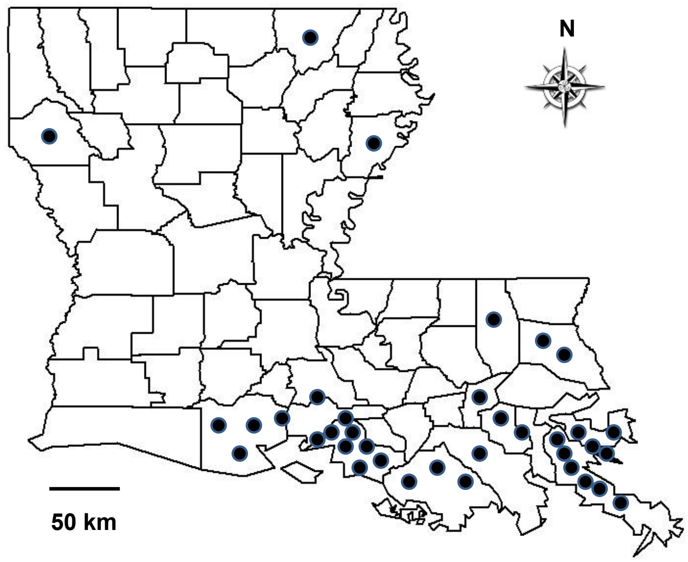

Figure 1. Map showing parish locations with hog damage in Louisiana in 2011. Each point represents a property with at least one nest damaged by feral swine and indicates the parish wherein that property is located. Points located on the border of two parishes represent land properties with hog damage with sufficient acreage that the properties are located within two adjoining parishes.

Some farmers reported damage on only one property in 2011; others noted hog damage to multiple properties. Nest quantities reported damaged ranged from one to approximately 300. Most farmers reported damaged nests were totally destroyed; one farmer verbally reported the nests were "flattened". Only one farmer noted that in some cases they were able to collect some eggs from nests partially damaged by feral swine. Another farmer reported the top of the nest was torn away and a few eggs consumed; the other eggs were scattered and lost due to heat exposure. The damaged or destroyed nests were located on 37 separate properties across the state.

One farmer noted hog damage to nests on seven different properties in 2011 (approximately 15 nests lost). His most severely affected property might have been damaged even more extensively except for trapping and removal of 69 feral swine that year. Another farmer removed over 50 pigs by trapping; he has seen hogs and hog sign near nests for many years but 2011 was the first year he actually lost two nests to rooting by hogs.

Prior alligator nest damage and trends in alligator nest damage

Most farmers who saw damage in 2011 had seen damage previously over the last few years. One farmer in southwest Louisiana had a decreased nesting effort in 2001 due to severe drought; thus he did not attempt egg collections and thus could not asses hog damage, but he had previously seen hog damage to alligator nests on several properties. Another farmer similarly affected by drought saw so few nests he did not collect eggs in 2011 in southwest Louisiana but he previously had seen feral swine damage in southeast Louisiana. Four farmers noted nest damage attributed to feral swine in 2011, but had not seen this previously, despite a range of 15 to 22 years experience collecting alligator eggs; indicating feral hogs may be now extending their ranges in coastal Louisiana and/or increasing the overall population level.

Nearly all farmers (94.7%) who reported feral swine damage in 2011 noted that hog damage was increasing based on their observations. Several farmers noted they would previously observe rare hog damage in isolated locations affecting one or two nests, but now see areas with larger regional damage of several nests. Another farmer similarly described “hot spots” of extensive hog damage, and said feral swine damage seems to be worse in each successive year over the last three or four years.

One farmer noted that they were seeing less hog damage due to their eradication program, but the overall range of hogs on their property had increased. This farmer/land manager had extensive records, and noted a yearly increase in hog damage, beginning with approximately ten nests lost to feral swine in 1998 to approximately 100 nests lost in 2008. Due to their hog eradication program, they lost fewer nests (n = 27) in 2011 to hog damage. Thus, three farmers (two others as noted above in “extent of nest damage”) described beneficial effects of hog eradication programs in limiting swine damage to alligator eggs/nests.

Three farmers who did not actually lose alligator nests to feral swine in 2011 did report that they saw an increase in hog damage to their properties. One farmer verbally reported a “population explosion” of feral swine causing problems to him as well as local corn farmers. One farmer said hog damage was decreasing, but this is based on his having had one nest destroyed three years ago, and none since.

Observations of live feral swine and hog sign

Most farmers who saw egg damage to nests reported having seen live hogs both while collecting eggs or when flying to mark nests for later collection by airboat. One farmer spontaneously remarked he saw feral swine “by the dozens” while conducting egg-collecting activities. Several farmers noted their pilots (helicopter or ultra-light aircraft) observed live hogs or nest damage while surveying to locate nest sites; some saw nests already destroyed and thus did not mark those nests for later collection. Five farmers who had not yet experienced nest loss/damage to hogs (or had no damage in 2011, but did in the past) saw live hogs on their properties while collecting eggs or marking nests, however.

As expected, farmers who incurred nest losses to feral swine reported seeing hog sign at nests in 2011. Of concern is that four farmers reported seeing hog sign (tracks, rooting) on their properties (but no damage to nests as of 2011) indicating they may have the potential to suffer nest losses as well as continued wetlands disruption or erosion in future years.

Experience level of respondents

Most farmers who are currently active have been licensed alligator farmers for many years; many since the inception of the alligator egg “ranching” program in 1986. Thus, the farmers surveyed had an extensive experience level and observed a prior lack of feral swine and/or noted the influx of this species over the years. The least experienced farmer surveyed in 2011 had four years of egg collecting experience; most others (23 of 34 [67.65%] farmers who responded to this question) had over twenty years of experience and observations, only four respondents had less than ten years experience collecting eggs.

Results in 2012 and 2013

In 2012 alligator farmers reported some 252 alligator nests damaged/lost on 20 properties, five of which had not previously had nest losses due to feral pigs. Some wetlands experienced flooding of nests due to storm tides in 2012; it may be that nests were lost to high water before they could be lost to feral pigs. In 2013 an estimated 393 nests were lost on 38 properties, sixteen of which were properties not previously affected (Fig. 2).

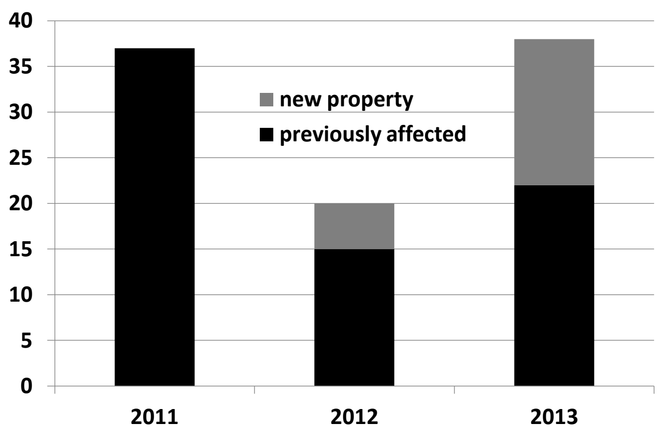

Figure 2. Number of properties affected by feral hog damage in Louisiana 2011 – 2013. New properties affected in 2012 or 2013 that were not affected in 2011 in gray upper panels.

The total number of eggs collected in Louisiana rose to 413,648 in 2012 and again to 498,285 in 2013 due to excellent water levels and high nest counts, as well as strong market demand for eggs and alligator hides. In 2013 some alligator farmers kept more detailed records of nest lost, Table 1 shows the results from one farmer's estimated of nests lost to feral pigs. Of interest some smaller properties could be severely impacted with 36.4 – 50.0% of 20 – 22 nests marked being lost to pigs, while other properties were less affected (property "C" at 3.8% of 130 nests) and the rancher's ten other properties (175 nests marked combined) had no losses to pigs.

Property	Nests Lost to Feral Pigs	Nests Marked	Percent Lost
A	10	20	50.0 %
B	8	22	36.4 %
C	5	130	3.8 %
ten other properties combined	0	175	0%

Table 1. Results from one farmer in 2013 showing varying levels of hog damage to alligator nests between wetland properties.

Additional nests lost but unreported

There are also alligator nests lost to feral pigs that go unreported, as some wetlands in Louisiana are not enrolled in the egg ranching program (some privately owned properties, federal refuges, etc). During a helicopter flight for aerial gunning as a control measure for feral pigs, a crew harvested a large pig seen destroying an alligator nest in late June 2013 on Sabine National Wildlife Refuge in southwest Louisiana (D. LeBlanc, pers. comm.). One alligator farmer who ranches eggs in north Louisiana has also seen alligator nests lost to feral pigs on private properties for which he serves as a nuisance control officer to remove feral pigs; however these properties are not enrolled in the egg ranching program and thus are not reported in our survey results. On a few properties the landowner (rather than the alligator farmer) collects the eggs; and feral pig losses in those cases would likely be unknown to the alligator farmer and thus perhaps not reported.

Discussion

As we previously reported (Elsey et al. 2012) the very high numbers of total nests now being lost and large proportion of alligator farmers losing valuable alligator nests and eggs to feral hogs was an unanticipated result and cause for some concern. A disturbing trend was also noted of most farmers reporting increasing evidence of hog presence and damage to their wetlands, alligator habitat, and egg resources. Several experienced alligator farmers saw hog damage for the first time in 2011, suggesting populations of this non-native species are rising and/or expanding their range in Louisiana. It is possible that storm surge from recent severe hurricanes (Hurricanes Katrina and Rita in 2005 and Hurricanes Gustav and Ike in 2008) may have led to dispersal of feral pigs (D. LeBlanc, pers. comm., Ribbeck 2014).The results presented here are minimums; some helicopter pilots did not mark nests that they saw from the air were already destroyed, thus ground crews would not have visited these nests and they would have been unreported as having been damaged by hogs. Also, some remaining uncollected nests (if any were left after a farmer collected his full egg quota on a property) may have been later depredated by feral swine.

Early egg collection of alligator nests can prevent flooding, predation, and lightning fire losses; avoiding high natural mortality was a factor considered in implementing egg ranching programs in Louisiana (Elsey and Trosclair 2008). Avoidance of feral pig damage could be another reason to encourage participation in egg collecting programs in some regions. One farmer suggested his early egg collections (late June 2011) averted hog losses seen the prior year when he had collected later than usual (mid- July). Farmers who have “hot spots” with extensive hog presence should perhaps be encouraged to collect these areas first to avoid nest losses. It may well be that feral swine damage to wild alligator nests may have been far greater if the egg collecting program were not in place, which limits some of the natural mortality factors.

It may also be that unusually high water levels in 2011 (Mississippi River levels were much higher than normal due to record snowfall in northern states) led to increased hog damage that year. Indeed, it has been suggested that feral hogs were dispersed to Sherburne Wildlife Management Area in southeast Louisiana that year as high water levels mandated opening of the Morganza spillway for flood relief (Ribbeck 2014); the spillway had not been opened since 1973. In contrast however, Fleming et al. (1976) reported an absence of predation by raccoons on alligator nests after prolonged high marsh water levels. Mazzotti (1989) attributed low levels of *Crocodylus acutus* Cuvier (American crocodile) nest predation to the low density of active nests in any given year. It may be that the higher than average alligator nesting in southeast Louisiana in 2011 led to the observed increase in feral swine damage seen that year; in addition to what clearly appears to be range and population expansion of feral swine statewide.

In the initial year of our survey, six farmers noted damage on other properties in past years that were not damaged in 2011; it would be of interest to determine why some properties are targeted or if feral swine move vast distances regularly and thus affect alligator nests randomly in various locations. In 2012 one farmer specifically noted both alligator nests he lost were constructed on levees; in 2013 a farmer reported all twelve nests he lost were near canals/levee systems. In 2013 another farmer speculated that alligator nests on levees would be more vulnerable to feral pigs.

Nest losses have also occurred in other crocodilian species due to pigs; Webb et al. (1983) noted wild pigs took five nests at one site (6% of the total) in a nesting study on the Australian freshwater crocodile *(Crocodylus johnstoni*). Similarly, Hall and Johnson (1987) documented losses of nests of the New Guinea crocodile (*Crocodylus novaeguineae*) due to predation by varanid lizards (*Varanus sp.*) and wild pigs. Platt et al. (2008) noted a Morelet's crocodile (*Crocodylus moreletii*) nest was destroyed by collared peccary (*Tayassu tajacu*) in northern Belize. Crawshaw and Schaller (1979) suggested possible local vertebrate predators in their study of *Caiman crocodilus yacare* in Brazil were domestic pigs (*Sus scrofa domesticus*) and peccaries (*Tayassu*), among others. Campos (1993) also documented tracks and feces of feral pigs near nests of yacare caiman that had been destroyed by predators in the Pantanal of Brazil. Larriera and Pina (2000) also found feral pig destruction of *Caiman latirostris* (broad-nosed caiman) nests in northern Argentina. A recent review (Somaweera et al. 2013) reviewed the effects of feral pigs and other predators in shaping crocodilian natural history.

Alligator nest losses due to feral swine and the apparent recent increase in this mortality factor is a disturbing trend and is of some concern and should be continued to be monitored closely, but we do not believe this is an imminent threat to alligator populations. Indeed, the estimated 252 nests lost to feral pigs in 2012 represent only 0.6% of the estimated 42,151 nests produced in the coastal zone (but approximately 1.52% of those nests collected by ranchers, assuming about 25 eggs are collected per nest). In 2013, the reported 393 nests lost to feral swine constitute only 0.9% of the estimated 45,069 nests seen on the coastal nesting survey but approximately 1.97% of those nests collected by ranchers. However, this additional mortality factor could become problematic if it continues to increase unchecked. Although we saw fewer nests damaged in 2012 than in 2011, five additional new properties were affected in 2012, and sixteen new properties incurred hog damage to alligator nests in 2013.

In recent years our aerial nesting surveys have estimated over 30,000 nests just in coastal Louisiana; thus the nearly 600 nests lost to feral swine in 2011 would represent some 2% of the statewide nest production. The possible financial losses due to alligator egg destruction by pigs to alligator industry personnel could be significant. If eggs are valued at perhaps $10 each and with conservative estimates of 25 eggs per nest, a loss of $147,500 would have be incurred for just the egg value in 2011; there would be an additional loss of revenue from the finished leather goods products. Although this study is limited in scope to alligator nest damage, of greater concern is the negative impact these invasive feral swine are having by damaging wetlands along the coast of Louisiana recently that are recovered from damage by nutria (*Myocastor coypus*) as reported by Mouton (2009). Indeed, researchers have determined that feral swine damage to coastal wetlands is more severe than nutria damage (Mouton 2009).

We previously reported (Elsey et al. 2012) that as far back as 1929 (Kellogg 1929), the range of swine and alligators have apparently overlapped in Louisiana, as a hog was reported found in an alligator stomach on Rainey Wildlife Refuge in Vermilion Parish. McIlhenny (1935) also describes witnessing alligators taking hogs and details one instance of a "duroc boar hog" weighing not less than 500 pounds being taken by a large alligator while the hog was swimming across a stream. O'Neil (1949) noted hogs as a predator of muskrats (*Ondatra zibethicus*) in Louisiana coastal marshes. This is relatively uncommon, however; Neill (1971) said "troops of feral hogs, so common in parts of the Southeast, are not often menaced by alligators". Taylor (1986) noted hogs in two of 111 alligator stomachs (1.8%) examined. In Georgia, Shoop and Ruckdeschel (1990) noted feral swine in five of 28 alligator fecal samples from scattered localities on Cumberland Island.

Of interest, a recent study done on alligator nesting at the northern fringe of its range in Oklahoma documented trail camera images feral pigs at an alligator nest the day after the nest hatched (Robison 2013). It is possible the calls of the new hatchlings attracted the feral pigs to the area.

Although the finding of alligator nest losses is not new, and the range of alligators and swine in Louisiana is known to overlap, the recent tremendous increase in extent of damage and apparent range expansion and potential for future continued losses are of concern. Land managers and industry participants may work together with regulatory agencies to consider eradication programs in the future. These farmers and land managers who saw signs of hog damage to wetlands or live hogs (despite them not yet having experienced actual alligator nest losses) might be encouraged to consider eradication in the future to avoid later costly loss of alligator nests and collect nests in those areas as early as possible to avoid feral swine damage. The role of the female alligator in nest defense as a deterrent to hog depredation could be an area for future investigation.

This may be another example where introduction of a non-native species had led to serious unanticipated consequences. It was encouraging to receive reports that several proactive farmers or land managers who trapped or removed hogs believed it did limit even further alligator nest damage than was reported. Future research might help elucidate if there is a habitat type preferred by hogs where the most nest damage occurs, or if they are generalists and adapt to many habitat types. There may be landscape characteristics that lead to more depredation upon alligator nests by hogs in some regions.

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Introduction to the Session and to Zoo Programs and Practices

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Abstract

"The Impact of Zoos on Crocodilian Conservation and Biology" highlights the diverse efforts made by zoos, aquariums and other living institutions for crocodilian conservation. The CSG Zoos Thematic Group was created to strengthen ties between zoos and the CSG. This article introduces zoological associations, programs, and practices that zoos utilize in animal management and cooperative breeding efforts, so any references to these in later chapters will be understandable for those not in the zoo profession. Professional associations, such as the Association of Zoos & Aquariums (AZA), the European Association of Zoos and Aquaria (EAZA), Zoo Aquarium Association (ZAA) and World Association of Zoos and Aquariums (WAZA), require rigorous standards of zoos for accreditation. Taxon Advisory Groups (TAGs) consist of zoo professionals specialized in husbandry, captive management, and conservation needs of specific taxa. The AZA's Crocodilian Advisory Group (CAG), the first TAG, formed in 1987. TAGs develop Regional Collection Plans (RCPs) and maintain studbooks to manage breeding and transfer plans, conservation initiatives, and scientific research. Zoos coordinate cooperative breeding and transfer activities, principally of endangered or critically endangered species, through programs like AZA's Species Survival Plans® (SSPs) and Red studbooks and EAZA's European Endangered Species Programs (EEPs) and European studbooks (ESBs). Animal record keeping systems allow access to animal identification, ownership, location, studbook information, demographics, transfers, and medical records. ISIS (International Species Information Systems) is the largest international network of animal records, using its Zoological Information Management System (ZIMS) to link data for more than 2.6 million animals of 10,000 species.

Introduction

Zoos, aquariums and other living institutions are deeply involved in the conservation of endangered crocodilians. In recognition of the important roles these institutions play in conservation, research and education, the CSG Chair, Dr. Grahame Webb, established the CSG's Zoos and Public Education Thematic Group in 2004 and asked me to serve as the CSG Vice Chair for this group. In 2012, the CSG Executive Committee split the thematic group into two groups and named Clara Lucia Sierra Diaz as the Vice Chair for the Public Education and Community Participation Thematic Group. The Zoos Thematic Group includes a few dozen members of the CSG experienced in captive management, zoo husbandry, captive breeding and reintroduction.

Although crocodilians have been held in captivity since at least ancient Roman times, historically, zoo collections were simply menageries of mixed species. It was really only in the 1960's and 1970's when zoos first began keeping crocs in breeding pairs and captive reproduction was first recorded. Since that time, all living species of crocodilians have been reproduced under captive circumstances. Zoological collections in the United States include virtually all of the living species, as do those in Europe.

Exhibition of captive crocodilians in zoos, aquaria and other living institutions bring these animals and their conservation dilemmas into the public conscience. Zoo specimens serve as ambassadors for their species in the wild. Through visitation to zoos and aquariums, zoo education and outreach programs have the ability to reach millions of people worldwide each year. While the majority of these visitors may live in urban areas and regions of the world outside the native range of crocodilians, zoo interpretation and education programs can raise the awareness of the importance of crocodilians in the natural world and encourage support and participation in programs necessary for the long-term survival, management, and conservation of crocodiles. People must be inspired and motivated to care about the threats that animals face in the wild. As such, zoos' actions can direct public participation and financial support to conservation projects of endangered and critically endangered crocodilians.

"The Impact of Zoos on Crocodilian Conservation and Biology"

"The Impact of Zoos on Crocodilian Conservation and Biology" symposium highlights the diverse efforts made by zoos and aquariums for crocodilian conservation. This session was coordinated by a number of members of the CSG Zoos Thematic Group, and from zoos all over the world. The intent has been to select topics that illustrate the impact these institutions can and do have on the conservation of endangered species of crocodilians. Basic zoo matters, such as improved husbandry, captive breeding, and enrichment, have been excluded, unless they can be directly linked to conservation or recovery programs that have focused field outcomes.

Early in the discussion of the topics we would like to cover in this forum, Chris Banks from Zoos Victoria succinctly summarized this focus with these thoughts (slightly paraphrased here):

Zoos can support the <u>conservation of crocodilians</u> in two overarching ways -

1. Increased alignment of zoo-based crocodilian management with *in situ* conservation outcomes:
    a. Increased collaboration/cooperation between zoos (individually and regionally) to generate conservation outcomes for crocodilians - joint campaigns, funding for *in situ* actions, etc.
    b. Increased collaboration and cooperation between zoos, regionally and globally, through partnerships, studbooks, etc., to improve management and, as a result, conservation outcomes. An example might be sister zoo relationships, between a developed zoo and developing zoo (to use WAZA's terminology).
    c. Increased collaboration/cooperation between zoos (individually and regionally) and range state agencies - through partnerships, agreements, etc. For movements of animal involving CITES 1 listed species, this is mandatory but could probably be improved - or at least streamlined.
2. Increasing community involvement in and engagement with crocodilian conservation.

I believe these thoughts are reflected in most, if not all, of the topics that are included in this Zoos symposium.

Professional Zoo Associations and Zoo Programs

For those less familiar with the general practices used by zoos, the following brief discussion will introduce some of the professional zoological associations, and their associated programs and practices used in captive animal management and in the cooperative population management of endangered species within zoos.

There are numerous regional and global professional associations of zoos, aquaria, associated institutions, and zoo professionals; too numerous to introduce or even mention all here. In most cases, these associations impose and require rigorous standards of animal husbandry and welfare for accreditation of a zoological institution with the association. Accreditation requires a commitment to an association's codes of practice, ethics, animal welfare, and animal transfer or transaction policies. Professional associations also help coordinate breeding efforts, conservation programs, and professional development of personnel, within and between these accredited institutions.

Association of Zoos & Aquariums (AZA) – www.aza.org/ - The AZA is a professional organization of 218 AZA-accredited zoos and more than 6,000 member institutions, individuals and vendors from all over the world first established in 1924. Demanding accreditation standards set by the AZA urge the professional conduct and standards of AZA institutions and partner organizations. AZA-accredited institutions provide support for research and conservation projects worldwide. In 2010 alone, AZA facilities provided U.S. $130 million in support to conservation projects in more than 100 countries.

The AZA has a variety of **Animal Programs** associated with cooperative management of selected species - coordinating captive breeding efforts, identifying research and conservation priorities, etc.

Taxon Advisory Groups (TAG) within the AZA are, as the name implies, groups of zoo professionals experienced in the husbandry, captive management, and reproduction of a specific taxon of animals, such as crocodilians. Each AZA institution may have a single Institutional Representative within each TAG. TAGs act as advisors to the zoos within the association on matters concerning that specific taxon. TAGs make recommendations on which species cooperative management programs should focus through the production of a Regional Collection Plan. TAGs also provide a forum in which members can discuss animal care, husbandry and management issues, reproductive and heath-related issues, and best practices. The AZA **Crocodilian Advisory Group (CAG) –** http://www.cag.crocodylia.com - was the first TAG within the AZA, established in 1987. I am currently the chair of the CAG. The AZA now recognizes 46 different TAGs.

Regional Collection Plans (RCP) are documents produced every three years by each TAG identifying the species and types of animal programs on which the TAG has chosen to concentrate space and other resources. The RCP also details the processes and criteria used by the TAG to make these species selections. Details regarding the captive populations of these species in AZA facilities are documented, including the number of founders and potential founders, and the target population size, are included. Program leaders and their contact information, dates when studbooks and population management plans (PMPs) were last updated, and a summary of space utilization and availability are often summarized in the RCP as well.

Species Survival Plans® (SSP) (http://www.aza.org/species-survival-plan-program/) provide coordinated captive breeding programs, *in situ* conservation programs, habitat preservation and restoration, public education and research, for many of the world's most threatened and endangered species. An SSP Coordinator organizes and coordinates holdings, transfers, pairings, and breeding efforts for that species among participating institutions. The AZA has established three levels of animal program management designations, including Green and Yellow SSP programs, as well as Red studbook programs. Green and Yellow SSPs require a population size of at least 50 individuals. Programs may be elevated to Green SSP status if the projected genetic diversity (%GD) of the population at 100 years or 10 generations is 90% or better. Programs in which %GD is <90% are classed as Yellow SSPs. Formal population management planning is required for SSP populations through the AZA's Population Management Center.

Red Studbook programs are maintained for managed populations consisting of fewer than 50 individuals. Studbooks are maintained by a studbook keeper. Red programs may involve formal population management.

The CAG maintains studbooks and SSP programs for the most endangered crocodilians species: Chinese alligator (*Alligator sinensis*), Cuban crocodile (*Crocodylus rhombifer*), Siamese crocodile (*C. siamensis*), Philippine crocodile (*C. mindorensis*), Orinoco crocodile (*C. intermedius*), Slender-snouted crocodile (*Mecistops cataphractus*), Indian gharial (*Gavialis gangeticus*), and Tomistoma (*Tomistoma schlegelii*).

European Association of Zoos and Aquaria (EAZA) - www.eaza.net - The EAZA is a professional association of zoos and aquariums in Europe formed in 1992, with more than 345 member institutions from 41 countries. The EAZA manages cooperative breeding programs:

European Endangered Species Programmes (EEPs), similar to the SSP programs of the AZA, are intensive, cooperative, population management plans for individual species. Each has a coordinator and a species committee that makes pairing, breeding and transfer recommendations designed to promote and maintain the genetic diversity of the captive population. Husbandry guidelines should be produced for each EEP. EEPs usually include only specimens kept in EAZA institutions - exceptions must be approved by the EEP committee. There is an EEP maintained for *Alligator sinensis*.

European studbook (ESB) programs are less intensive management plans than the EEPs. A studbook keeper maintains records of all specimens in the program and all life events, including data on births, deaths, transfers, etc. ESBs exist for *Crocodylus mindorensis*, *C. rhombifer, Tomistoma schlegelii*, and the African dwarf crocodile (*Osteolaemus tetraspis*). ESB keepers play an advisory role in issuing transfer recommendations. ESBs may include specimens from non-EAZA institutions and from some highly qualified private collections.

The EAZA has a single Taxon Advisory Group for all reptiles, which is chaired by Ivan Rehak (ophis@tiscali.cz). Fabian Schmidt (fschmidt@zoo-leipzig.de), Zoo Leipzig, oversees the crocodilian matters in this.

Zoo and Aquarium Association (ZAA) - http://www.zooaquarium.org.au - The ZAA is a primary association of zoos, aquariums, research institutions, and government departments within Australasia. Established in 1990, the ZAA has more than 90 accredited member organizations, including 86 zoos and aquariums. Many of these zoos have developed significant and effective **Community Campaigns** (http://www.zoo.org.au/fighting-extinction/conservation-campaigns) to involve and invest local communities in the conservation of their biological diversity. ZAA institutions provide more than AU $2 million annual to universities and other research institutions to promote conservation research, in addition to the resources they provide for research conducted at their facilities. There is a single TAG for Reptiles directed under the ZAA's Australasian Species Management Program (ASMP). Paul Andrew (pandrew@zoo.nsw.gov.au), Taronga Zoo, chairs that TAG. Chris Banks (cbanks@zoo.org.au), Zoos Victoria, has worked with conservation of the Philippine crocodile (*Crocodylus mindorensis*) for more than two decades and has overseen the development of the National Conservation Strategy for that species. Additionally, Zoos Victoria has donated a remarkable contribution of resources, financial support, expertise and training, books, equipment, and in-kind services, over the years to *in situ* conservation and community development associated with the conservation of the Philippine crocodile.

World Association of Zoos and Aquariums (WAZA) – www.waza.org - Consisting of more than 300 zoos and aquariums as institutional members, WAZA has advanced several conservation strategies (http://www.waza.org/en/site/conservation/conservation-strategies) to implement conceptual development of practices and strategies for zoos and aquaria to adopt. Conservation Strategies are published in multiple languages to communicate the message of the strategies and to facilitate promotion and adoption to a broader audience. Through a series of workshops organized by WAZA in the years 2000/2001, a strategy was developed to increase WAZA support and member participation in *in situ* conservation. The strategy involves the branding of conservation projects or programs by WAZA (http://www.waza.org/en/site/conservation/waza-conservation-projects), after these projects have met sets of endorsement criteria. Since that time, WAZA branding of projects has taken on increasing clout within the conservation community. Branding of conservation priorities in the Mesangat wetlands of East Kalimantan was instrumental in the establishment of the EAZA/IUCN SSC Southeast Asia Campaign. The Mabuwaya Philippine Crocodile Conservation Program (www.mabuwaya.org) also has been WAZA-branded. In partnership with the EAZA and the European section of the IUCN/SSC Conservation Breeding Specialist Group (CBSG Europe), WAZA is establishing a World Zoo and Aquarium Conservation Database (http://conservationdatabase.org/). This database currently catalogues more than 900 in situ conservation projects supported by the international zoo community.

The International Species Information System (ISIS) (http://www.isis.org) - ISIS maintains an extensive database of animal specimens held in zoos and aquariums, and details of their zoo environments. This system, the **Zoological Information Management Systems (ZIMS)**, links records from more than 800 member zoos and aquaria in at least 80 countries, and includes comprehensive data on more than 2.6 million captive animals of 10,000 species.

Closing

Globally, zoos, aquariums, and other living institutions have a tremendous potential for outreach and public education. There are estimated to be more than 1,500 zoos worldwide. The AZA's approximately 220 institutions receive more than 175 million visitors per year. The 345 member institutions of the EAZA host more than 140 million visitors each year. ZAA institutions have over 17 million visitors annually. The 300 or so members of WAZA, including the leading zoos, aquariums, professional zoo associations, affiliated organizations and corporations, all over the world, represent a network of close to 1,400 zoos and aquariums, with more than 700 million visitors annually. The AZA CAG and the affiliated Reptile TAGs in the EAZA and other zoo associations are continually working to encourage zoos to exhibit crocodilians or to increase the number of croc exhibits in their collections. The public display of crocodilians not only presents opportunities to educate the public on matters of crocodilian conservation, sustainable utilization as an effective conservation strategy, and human-crocodile conflict, but also to solicit their support of *in situ* conservation efforts. Additionally, and possibly most importantly, the zoos that hold and exhibit crocodilians are the zoos that provide institutional support to these *in situ* efforts.

Evaluating Potential Reintroduction Sites for the Critically Endangered Chinese Alligator in the Yangtze River Valley

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Abstract
The Chinese alligator (*Alligator sinensis*) is the most critically endangered crocodilian in the world. The few remaining wild alligators (<150) occupy small patches of marginal habitat and any increase in the size of these populations is precluded by the limited availability of suitable habitat. In contrast to the situation in the wild, ca. 13,000 Chinese alligators are maintained at government breeding centers. An action plan prepared in 2001 recommended that new wild populations be established by reintroducing captive-bred alligators into suitable, but unoccupied habitat. To this end, we evaluated eight potential reintroduction sites in the Yangtze River Basin and consider four as high priority conservation sites: 1) Xiazhu Lake, 2) Wuchang Lake, 3) West Dongting Lake Nature Reserve, and 4) South Donting Lake Nature Reserve. Of these, Wuchang Lake offers the best prospects for reintroducing alligators, but will first require various habitat modifications that could prove costly. From a biological standpoint, Xiazhu Lake is the most desirable reintroduction site; however, jurisdictional and land use issues must be resolved before alligators can be released here. Reintroducing alligators at West and South Dongting Lake nature reserves is problematic owing to conflicting jurisdictional responsibilities of various agencies charged with managing these areas. Both West and South Donting Lake nature reserves are excellent habitat, although fence construction will be necessary to prevent alligators from entering aquaculture areas. We recommend that future reintroductions be preceded by community education campaigns to address potential human-alligator conflict and allay the concerns of rural villagers. Furthermore, we recommend that future reintroductions consist of larger numbers of alligators.

Introduction
The Chinese alligator (*Alligator sinensis*) is regarded as the most critically endangered crocodilian in the world (Xing 2010). Fewer than 150 Chinese alligators survive in the wild, and these occur in small populations at widely scattered locations; the largest population at any particular site numbers no more than 20 individuals and contains <10 adults (Thorbjarnarson and Wang 1999; Thorbjarnarson et al. 2002; Thorbjarnarson and Wang 2010). Sites occupied by wild Chinese alligators are typically small patches of marginal habitat embedded within an agricultural landscape. The agricultural lands surrounding occupied habitats effectively isolate these sites, blocking the dispersal of alligators, and thereby precluding genetic exchange between wild populations (Thorbjarnarson and Wang 2010). Furthermore, the limited areal extent of occupied habitats prevents any significant increase in the size of wild populations (Thorbjarnarson and Wang 2010).
In contrast to the tenuous conservation status of wild populations, *ex-situ* propagation has been remarkably successful and thousands of Chinese alligators (ca. 13,000 in 2014; Lu Shunqing,

unpubl. data) are maintained at two government-operated conservation-breeding centers in China (Thorbjarnarson and Wang 2010; Platt 2012). An action plan prepared in 2001 by Chinese and international scientists recommended that new wild populations be established by releasing captive-bred alligators into suitable, but unoccupied habitat (Jiang et al. 2006; Thorbjarnarson and Wang 2010). The Chinese alligator is an excellent candidate for reintroduction because wild populations are nearing extinction, alligators reproduce readily in captivity and a burgeoning captive pool of animals is now available, captive-reared crocodilians adapt quickly to life in the wild after being released (Elsey et al. 1992, 1998, 2000; Thorbjarnarson and Xing, 2010), and in general, reintroductions of reptiles generally have higher likelihood of success than those of birds and mammals (Beck et al. 1994). Reintroduction of the Chinese alligator was accorded high priority by the IUCN Crocodile Specialist Group (Xing 2010) and forms the cornerstone of the conservation vision outlined by Thorbjarnarson and Wang (2010), which calls for establishing a network of relatively small wild populations managed together with the much larger captive population as a single "conservation metapopulation". To date, several small-scale reintroductions of captive-bred Chinese alligators have been conducted at Gaojinmiao Forest Reserve (Anhui Province), Hongxing Conservation Site (Anhui Province), and Dongtan Wetland Park (Shanghai Province) (Thorbjarnarson and Wang 2010; Wang et al. 2011). These projects have demonstrated the potential for reintroduction as a conservation strategy for landscape-scale restoration of wild populations of Chinese alligators.

However, several hurdles must be overcome before large-scale reintroductions of Chinese alligators can be undertaken (Platt 2012). Most importantly, potential release sites must first be identified and assessed as alligator habitat, which from a social as well as biological standpoint is an extremely challenging proposition. First, the Yangtze River basin supports 12% of the world's human population and almost every available wetland has been converted to agricultural production (Thorbjarnarson and Wang 1010). Therefore, issues that go well beyond the narrow purview of alligator conservation must be addressed before adequate habitat can be secured (Thorbjarnarson and Wang 2010). Secondly, because studies of wild Chinese alligators were not undertaken until the species had reached critically endangered status, and the few remaining wild populations are confined to suboptimal habitats (irrigation reservoirs surrounded by rice fields or upland forest), what actually constitutes suitable alligator habitat remains somewhat conjectural. Historic accounts (e.g., Pope 1940) provide some guidance in this regard as can reference to what is known about habitat use by the American alligator (*Alligator mississippiensis*), a closely related congener (Thorbjarnarson and Wang 2010). Given that a population of at least 2,500 free-living adults must be achieved before the future of the Chinese alligator can be considered secure in the wild (Thorbjarnarson and Wang 2010), an obvious need exists to evaluate areas where populations can potentially be re-established.

As a prelude to expanding the previous, albeit piecemeal reintroduction efforts, we first identified and then evaluated a number of potential release sites for captive-bred Chinese alligators in the Yangtze River Basin. Our short-term objective is to reestablish additional wild populations of Chinese alligators, with the ultimate goal of eventually restoring this iconic species as a functional component of wetland ecosystems within its historic distribution. We here report our results and provide recommendations for future conservation action.

Methods

To identify potential reintroduction sites, we first developed a set of criteria which consisted of six categories and a total of 17 indicators. The latter included seven ecological indicators, three indicators of environmental disturbance, three management indicators, one funding needs indicator, one indicator of capacity building, an indicator of alligator habitat suitability, and two indicators of potential threats to reintroduced alligators. To estimate the number of alligators that a particular site could potentially support (i.e., carrying capacity), we used a value of one adult alligator per 2.5 ha (Thorbjarnarson and Wang 2010) and multiplied this number by the hectares of habitat deemed suitable for alligators. It should be noted that "suitable habitat" was usually less than total wetland area as many wetlands contain areas where alligators would be incompatible with the existing land-use (e.g., duck and fish farms). We then incorporated these indicators into a detailed questionnaire that included 32 questions. In September 2010, under the auspices of the National Wildlife Research and Development Center of the State Forestry Agency (SFA) and Wildlife Conservation Society-China Program, we distributed this questionnaire to management authorities responsible for 50 potential sites within the historical range of Chinese alligators, and ultimately received a response from 22 sites (44%). Based on these responses, we selected a core group of the most promising reintroduction sites and conducted a detailed field evaluation of each during October-November 2010.

Results and Discussion

Based on a qualitative field assessment, we selected eight sites (Figure 1; Table 1) as the most promising locations for future Chinese alligator reintroductions: 1) Xiazhu Lake (Deqing County, Zhejiang Province); 2) Wuchang Lake (Wangjiang County, Anhui Province); 3) Longgan Lake (Susong County, Anhui Province); 4) Liangzi Lake (Wuhan County, Hubei Province); 5) Yangtze River Xinluoduan Baijitun Nature Reserve (Honghu County, Hubei Province); 6) Yangtze River Tianerzhou Baijitun Nature Reserve (Huangmei County, Hubei Province); 7) West Dongting Lake Nature Reserve (Hanshou County, Hunan Province); 8) South Dongting Lake Nature Reserve (Shishou County, Hunan Province). Of these eight sites, four of these were considered to be high priority conservation sites. Below we describe each site and discuss issues related to alligator reintroductions.

1. Xiazhu Lake (Zhejiang Province)

Xiazhu Lake offers excellent prospects for establishing a large population of Chinese alligators in a comparatively natural wetland. Xiazhu Lake is a complex of shallow-water lakes (1.5-2.8 m deep), canals and over 600 small islands within the drainage of the Tai Hu lacustrine system. The many small islands in the lake make this an especially attractive site because these would no doubt provide excellent nesting habitat (Thorbjarnarson et al. 2001) for reintroduced alligators. The lake is used extensively for the cultivation of hydrophytes (primarily *Trapa natans*) and fishing, but is in the process of being designated as a provincial wetland park under the Zhejiang Tourist Bureau. Although the wetland reserve is quite large (3,600 ha), only the core area of 1,150 ha is suitable for the protection of wildlife. Nevertheless, this is by far the most biologically suitable of the potential reintroduction sites that we identified. Additionally, Xiazhu Lake is a popular destination for domestic tourism, raising the possibility that Chinese alligators could become an important attraction if reintroduction proves successful.

According to Thorbjarnarson and Wang (2010), reintroducing alligators to Xiazhu Lake would be the "single most important step" yet undertaken in Chinese alligator conservation. However, several major hurdles must be overcome before alligators can be released at this site. First, conflicting jurisdictional boundaries exist, with management of the lake under the authority of the Tourism Bureau while alligator conservation is within the purview of the Forestry Department. Second, the proposed wetland park actually belongs to a myriad of local farmers and cooperative agreements must be reached with each of these stakeholders before any reintroduction of alligators can take place. Although tourist entrepreneurs around the lake as well as the Tourism Bureau are strongly in favor of reintroducing alligators, it is less clear if local farmers would support this action. At the very least, farmers would have to be compensated for loss of income from lands set aside for alligator conservation.

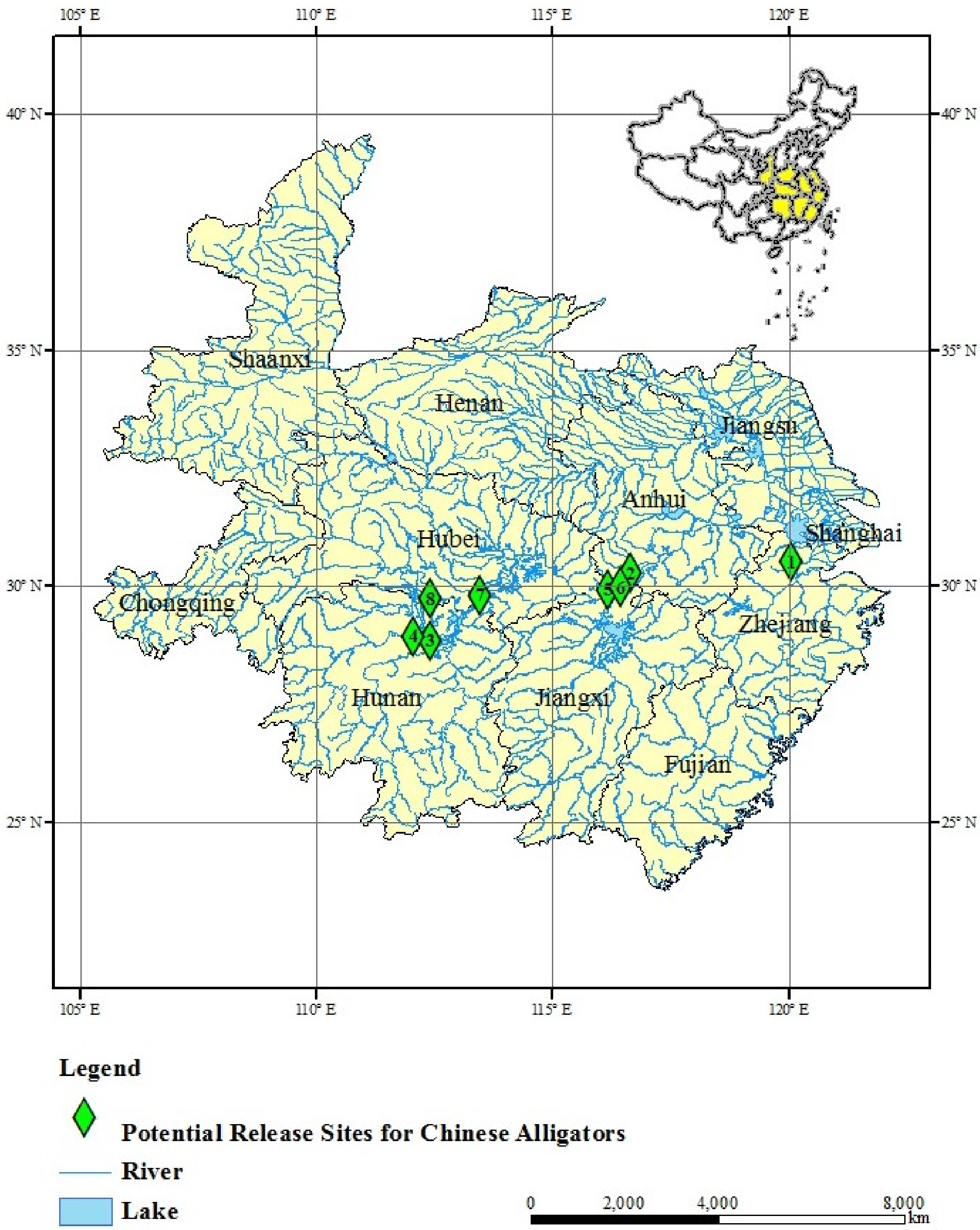

Figure 1: The location of eight high priority reintroduction sites for Chinese alligators identified during a survey of the Lower Yangtze River Basin. Sites 1-4 are considered the highest priority sites. Numbered sites: (1) Xiazhu Lake; (2) Wuchang Lake; (3) South Dongting Lake Nature Reserve; (4) West Dongting Lake Nature Reserve; (5) Anhui Longgan Lake; (6) Huang Lake; (7) Yangtze River Xinluoduan Baijitun Nature Reserve; (8) Yangtze River Tianerzhou Baijitun Nature Reserve.

Table 1. Prioritized evaluation of potential reintroduction sites for Chinese alligators in the lower Yangtze River Basin.

Site name	County, Province	Area available for alligators (ha)	Priority	Potential carrying capacity
Xiazhu Lake	Deqing, Zhejiang	214	Highest	100
Wuchang Lake	Wangjiang, Anhui	1,000	Highest	100
South Dongting Lake	Yuanjiang, Hunan	24,000	High	>5,000
West Dongting Lake	Hanshou, Hunan	8,000	High	>5,000
Longgan Lake	Susong, Anhui	1,500	Middle	700
Huang Lake	Susong, Anhui	800	Middle	400
Yangtze River Xinluoduan	Honghu, Hubei	5,000	Low	2,500
Yangtze River Tianerzhou	Shishou, Hubei	2,000	Low	1,000

2. Wuchang Lake (Anhui Province)

Wuchang Lake offers another potential opportunity to establish a sizeable breeding population of Chinese alligators in the wild. The lake encompasses almost 1,000 ha and at present, fishing, aquaculture, and cultivation of hydrophytes are the principal economic uses of the site. Wuchang Lake is characterized by a large amount of open water with a minimal amount of shallow water and shoreline habitat favored by alligators. As at other potential sites, a number of issues must be resolved before alligators can be reintroduced. First, it appears that considerable habitat modifications must carried out prior to any release. These modifications include construction of a lengthy fence to prevent reintroduced alligators from wandering into the commercial eel farms fringing the lake. Extensive excavation and restructuring of the lake bed with heavy equipment will be required to create shallow water habitat suitable for alligators. Small islands should also be constructed from excavated fill to serve as future nesting and burrow sites. Wuchang Lake is included within the Anhui Yanjiang Wetland Nature Reserve and management jurisdiction lies with the SFA. Additionally, local authorities and the SFA are supportive and anxious to reintroduce alligators to Wuchang Lake. Because Wuchang Lake is readily accessible from nearby Anqing City, any alligator reintroduction is likely to enhance local tourism.

3. West Dongting Lake Nature Reserve (Hunan Province)

West Dongting Lake, located at the western end of Dongting Lake, which comprises an area of 356 km^2 and is one of the largest freshwater lakes in China. During years when insufficient rainfall occurs, parts of Dongting Lake become completely dry. The lake consists of a mosaic of rivers, stream channels, reed beds, beach, protected forests, fish ponds and ricefields and appears to be excellent habitat for reintroduced alligators. Furthermore, over 100 islands are found in the lake, most of which are heavily vegetated and could serve as nesting sites for reintroduced alligators. West Dongting Lake is a National Nature Reserve under jurisdiction of the Agriculture Department, which has no mandate for alligator conservation. However, local officials are extremely supportive of alligator reintroductions. Extensive fencing of areas designated for reintroduction must occur before any alligators are released. Local farmers expressed concerns that burrowing alligators could compromise the structural integrity of Dongting Lake Dam.

4. South Dongting Lake Nature Reserve (Hubei Province)

South Dongting Lake Nature Reserve encompasses 1680 km^2 at the southern end of Dongting Lake. The reserve includes 118 densely vegetated islands and a reed bed (*Phragmites australis*) encompassing 24,000 ha, the largest such stand in the world. The islands are embedded in the reed beds and consequently are difficult for people to access, making these highly desirable as nesting and burrowing sites for reintroduced alligators. The lake also supports a diversity of potential prey, including mollusks, crustaceans, and fish. Like West Dongting Lake, extensive fence construction must be undertaken before alligators could be reintroduced at this site. Furthermore, conflicting jurisdictional responsibilities of various agencies charged with managing the lake must be resolved before reintroduction can be attempted. As at West Dongting Lake, farmers at South Dongting Lake are concerned about potential problems that might arise from the burrowing habits of Chinese alligators.

Conclusions and recommendations

In summary, much remains to be accomplished before captive-bred Chinese alligators can be reintroduced at any of the four high priority conservation sites we identified in the lower Yangtze River Basin. From a biological standpoint, Xiazhu Lake is by far the most desirable reintroduction site, but resolving jurisdictional and land use issues will no doubt prove challenging. However, if these issues can be resolved, Xiazhu Lake has the potential to support a globally significant, and perhaps the world's largest wild population of Chinese alligators. Resolving these issues will require support at the county, provincial, and national levels. Nonetheless, securing Xiazhu Lake as a conservation site is a worthwhile objective that is attainable given sufficient effort. We therefore recommend that additional attention be focused on Xiazhu Lake and efforts made to involve all stakeholders (perhaps through a workshop) in developing a comprehensive conservation plan for the area that will include alligator reintroductions.

Of the four potential high-priority sites yet identified, Wuchang Lake currently appears to offer the best prospects for reintroducing Chinese alligators, although the necessary habitat modifications could prove costly. These habitat modifications are relatively simple from a technical standpoint, and include such actions as constructing a barrier fence to prevent movement of alligators into adjacent agricultural lands, creation of suitable shallow-water foraging habitat, and construction of islands that alligators require for nesting and burrowing. Once these modifications are completed, alligator reintroduction could begin as soon as islands become sufficiently vegetated (approximately 1-2 years). Therefore, undertaking habitat modifications at Wuchang Lake should be accorded the highest priority in conservation planning.

Reintroducing alligators at West and South Dongting Lake appears more problematic, but should nonetheless be part of any long-term conservation strategy. Both sites offer excellent habitat for reintroduced alligators, but fences must first be constructed to prevent alligators from entering areas designated for aquaculture. Furthermore, there is a danger that released alligators could damage levees and dams through the construction of burrow and tunnel networks.

In conclusion, we recommend that future reintroductions of Chinese alligators be preceded by intensive community education programs in villages adjacent to any proposed release site. These programs should address the concerns of rural villagers regarding potential human-alligator conflict, which for the most part seems focused on the potential damage to dams and levees that could result from the burrowing habits of alligators. Safety is less of a concern, but nonetheless it must be stressed that the small body size and cryptic behavior of Chinese alligators makes it unlikely these animals will ever attack humans. Additionally, mechanisms should be in place to address local human-alligator conflicts before any reintroductions take place. Finally, because previous small-scale efforts have demonstrated that reintroduction is an effective strategy for restoring viable populations of Chinese alligators in the wild (Thorbjarnarson and Wang 2010; Wang et al. 2011; Lu et al. 2014), we recommend that future reintroductions be up-scaled to include larger groups of individuals. Larger reintroductions are more likely to succeed and will increase the trajectory of population recovery (Germano and Bishop 2008).

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Assessing Methodologies for Monitoring Siamese Crocodiles in Lao, PDR

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Abstract

In 2008 the Wildlife Conservation Society-Lao Program working closely with the Government of Lao, PDR designed and implemented a long-term recovery plan for the Siamese crocodile (*Crocodylus siamensis*) in Laos. Population monitoring was recognized as crucial component of the recovery strategy as it provides a scientific basis for assessing conservation actions and making changes if necessary. We evaluated four methodologies previously recommended for monitoring Siamese crocodile populations: nocturnal spotlight counts, camera trapping, track and sign surveys, and nest counts. Spotlight counts failed to detect crocodiles even at sites where their presence was confirmed by other means. With the exception of images taken at an active nest, no photorecords of Siamese crocodiles were obtained through camera trapping. Measureable quality rear-foot tracks and numerous scats were found at several conservation sites. However, because the results of track and sign surveys are highly variable and difficult to interpret, and probably depend on poorly understood intrinsic and extrinsic factors, this methodology appears poorly suited for rigorous population monitoring. Seven crocodile nests were found during 2011-13, but only three contained viable eggs, suggesting a paucity of males in the larger metapopulation. Annual nest counts appear to be the most appropriate method for long-term monitoring Siamese crocodiles in Laos, although at least five years of data must be accrued before population trends can be statistically detected.

Introduction

Monitoring of animal populations is defined as the estimation of absolute or relative abundance for the purpose of drawing inferences about variation in abundance over time and/or space (Nichols and Karanth 2012). Unlike a survey which determines conditions at a single point in time, monitoring tracks changes over time, and if properly conducted, can determine if wildlife populations are increasing, decreasing or stable (Kremen et al. 1994). Such data are essential for establishing appropriate conservation objectives, evaluating the effectiveness of management interventions and policy decisions, assessing the impact of threats, and informing stakeholders (Hedges 2012). Most importantly, long-term monitoring can ultimately develop a body of empirical knowledge with the potential to improve the predictive capacity of managers to deal with novel situations, thereby increasing the effectiveness of conservation strategies (Hedges 2012). As such, population monitoring should be a key component of any long-term conservation plan (Kremen et al. 1994).

In 2008 the Wildlife Conservation Society-Lao Program (WCS) working in close collaboration with the Government of Lao, PDR (hereafter Laos) designed and implemented a long-term recovery plan for the Siamese crocodile (*Crocodylus siamensis*) in Laos (Hedemark et al. 2009). The Siamese crocodile is regarded as one of the most critically endangered crocodilians in the world with wild populations extirpated or nearly so in every known range country (Simpson and Bezuijen 2010). In Laos, small but potentially viable populations are confined to scattered wetlands in Attapu, Salavan, and Savannakhet provinces, and remain threatened by incidental take in fishing gear, deliberate killing for meat and skins, collection of eggs for use in traditional medicine or domestic consumption, and habitat loss (Stuart and Platt 2000; Thorbjarnarson et al. 2004; Platt 2012; Bezuijen et al. 2013).

Surveys conducted from 2003-2008 identified a number of crocodile populations in Savannakhet Province that would likely respond to protection (Thorbjarnarson et al. 2004; Bezuijen et al. 2006, 2013), and a community-based conservation project was initiated shortly thereafter (Hedemark et al. 2009; Platt 2012). Most of these populations already received some degree of *de facto* protection from local animist beliefs that hold crocodiles sacred (Platt 2012; Bezuijen et al. 2013). As part of this project, six community-controlled wetlands known to harbor crocodiles were selected, community buy-in was secured, and during subsequent participatory village meetings community members developed site-specific conservation regulations designed to insure crocodile recovery and protect critical habitat (Hedemark et al. 2009; Platt 2012). Additionally, Village Crocodile Conservation Committees (VCCC) were established in each community and after appropriate training, cadre were tasked with assisting in the collection of crocodile eggs for a head-starting program, enforcing conservation regulations, and monitoring crocodile populations (Platt 2012).

Developing effective methodologies for monitoring Siamese crocodile populations was accorded high priority in the draft recovery plan prepared by WCS and the Government of Laos in order that proposed conservation actions could be assessed in an adaptive management context (Walters 1986; Salafsky et al. 2001). Ideally the methodology ultimately adopted by VCCC teams should be relatively simple and inexpensive to implement and have a high probability of detecting crocodiles. Most importantly, this methodology must yield an index of relative abundance that accurately reflects changes in crocodile populations over time. To this end we evaluated four methodologies (nocturnal spotlight counts, camera trapping, track and sign surveys, and nest counts) proposed by Simpson (2006) for monitoring Siamese crocodile populations and here report our results.

Study area

Crocodile conservation sites are located within the Mekong Plain in Champhone and Xanbouly districts of Savannakhet Province in central Lao PDR. This region supports the highest rural population density within Laos, and contains most of the nation's productive agricultural lands (Bezuijen et al. 2006). Rice is the principal crop (Kosaka et al. 2006) and the conversion of natural wetlands to rice agroecosystems constitutes a major threat to the continued survival of *C. siamensis* in Laos (Simpson and Bezuijen 2010). The five wetlands selected for inclusion in the crocodile conservation project are located along the Champhone (Kout Kaen, Xelat Kadan, Nong Maehang, and the Kout Mark Peo–Phai Cheo Reservoir Complex) and Xangxoy (Kout Kouang and Kout Koke) river systems. These wetlands appear to contain elements of a single interacting crocodile metapopulation linked by riverine corridors (Platt 2012) that is thought to number between 50-70 crocodiles (Table 1).

Wetlands included in this conservation project range from slightly disturbed to heavily impacted, fragmented habitats; most are oxbow lakes subject to overbank flooding during the wet season (June-September). A brief physical description of each wetland is provided below. Place names follow Hedemark et al. (2009) and are largely in accordance with topographical maps issued by Service Geographique d'Etat.

1. **Kout Kouang and Kout Koke**.—These two wetlands, connected by a narrow channel, are the least disturbed of all crocodile conservation sites. Both are oxbow lakes in the floodplain of the Xangxoy River, and characterized by extensive mats of floating peat supporting grasses, ferns, shrubs, and small trees. Water is extracted from Kout Kouang by local farmers to irrigate nearby rice-fields during the dry season, and fishing occurs in both lakes. The vegetation surrounding these lakes is primarily floodplain bamboo forest and scrub with scattered areas of rice cultivation.

2. **Kout Kaen and associated wetlands**.—This site was formerly a meandering, isolated oxbow channel the Champhone River floodplain. The main channel reportedly contained water (1.5-2.0 m deep) throughout the year, although most of the adjacent wetlands were dry by late May or early June (Hedemark et al. 2009). During the wet season this area is deeply inundated (>3 m) by overflow from the Champhone River. An earthen dam approximately 1.6 km long was constructed in 2011 to create crocodile habitat and supply irrigation water for area farmers during the dry season. The dam has greatly altered the hydrology of Kout Kaen and adjacent wetlands; the main channel is now considerably deeper, the adjacent wetlands contain water throughout the year, and open water now extends 2.4 km upstream from the earthen dam. Adjacent wetlands consist of water hyacinth (*Eichhornia crassipes*) beds, dense stands of cat-claw mimosa (*Mimosa pigra*), and grass-covered floating peat mats. Shoreline vegetation is dominated by floodplain bamboo forest and scrub interspersed with numerous small rice-fields.

3. **Kout Xelat Kadan**.—This site consists of a small oxbow lake in the Champhone River floodplain covered by extensive mats of water hyacinth. Although much of this vegetation was manually removed in 2010, it has since returned. The site is completely inundated by the normal wet season rise of the Champhone River. One shore of the lake has been largely denuded of native vegetation and converted into rice-fields. However, the opposite bank remains densely forested, and reportedly protected against further encroachment by village-level restrictions. Local farmers pump water from this oxbow during the dry season to irrigate adjacent rice-fields; in the past this offtake severely threatened the biological integrity of the site (Hedemark et al. 2009), but village-level regulations have recently been enacted to prevent a complete dry season drawdown. Little fishing is conducted here because the dense aquatic vegetation precludes the use of monofilament nets.

4. **Kout Mark Peo**.—This wetland complex in the Champhone River floodplain consists of Kout Mark Peo, Kout Pinoy, and Phai Cheo Reservoir. Kout Mark Peo and Kout Pinoy are oxbow lakes adjacent to the main river channel, subject to overbank flooding during the wet season, and contain water throughout the year. Extensive mats of floating vegetation cover the surface of both oxbow lakes and dense woodland and floodplain bamboo forest occur along the shoreline. Phai Cheo Reservoir was constructed during the mid-1980s to provide irrigation water for rice-fields near Tan Soun Village. The reservoir is approximately 3,200 ha, although the surface area fluctuates depending on season; heavy rains can substantially increase the surface area and flooding of peripheral wetlands and rice-fields is common. The deeper parts of reservoir are characterized by open water, with dense stands of emergent aquatic vegetation in shallows. Woody snags and floating mats of vegetation occur throughout the reservoir. The shoreline is dominated by floodplain bamboo, scrub forest, and thickets of *Mimosa pigra*. Some peripheral wetlands around the reservoir have been converted to seasonal rice-fields. Fishing with monofilament nets and traps occurs throughout the reservoir, which also serves as a major source of irrigation water during the dry season.

5. **Nong Maehang**.—This site is a complex of oxbow lakes in the Champhone River floodplain adjacent to Kengkok Village that contain permanent water throughout the year. Much of Nong Maehang is covered by floating grass- and sedge-covered mats used by villagers as goat pasture. The west bank has been largely stripped of natural vegetation and rice fields extend almost to the water’s edge, while some forest cover remains on the east bank, although most large trees have been removed. Water is extracted from Nong Maehang to irrigate rice-fields during the dry season. Fishing, snail collecting, and frog hunting are important subsistence activities at Nong Maehang.

Table 1: Estimated size of Siamese crocodile populations at conservation sites in Savannakhet Province, Laos. Data from Hedemark et al. (2009). Population estimates are primarily based on sightings reported by villagers.

Location	Population size	Comments
Kout Kouang	2 adults	Nest containing non-viable eggs found in 2008.
Kout Koke	1 adult	Hatchings observed in 2008.
Kout Kaen	1 adult	Juvenile (TL = 47 cm) captured by fishing net in 2008 and released; one adult and a juvenile observed in 2006.
Kout Xalat Kadan	10-12	Size classes not stated; remains of an apparently successful nest found in 2008.
Kout Mark Peo and Phai Cheo	50	Population contains at least one pair of adults; six juveniles and an adult observed in spotlight survey in 2005. Site could harbor largest remaining population in Champhone and Xangxoy river systems.

Methods

Nocturnal spotlight counts

Nocturnal spotlight counts are used to census crocodilian populations worldwide and a variety of other population estimation techniques (e.g., mark-recapture) have confirmed the accuracy of this methodology (Bayliss 1987; Hutton and Woolhouse 1989; King et al. 1990). Spotlight surveys are generally conducted from a boat (Bayliss 1987; Fukuda et al. 2013), but can also be done from land (Subalusky et al. 2009); headlamps are used to search for the reflective eyeshines of crocodilians along transects, often defined by the shoreline of rivers or lakes (Chabreck 1966; Bayliss 1987). Spotlight counts are used to calculate an encounter rate (crocodiles observed/km of survey route), which serves as index of relative abundance because not all crocodiles present are observed during a survey (Bayliss 1987). The relationship between the spotlight count and actual population size is assumed to remain constant over time, such that any change in the encounter rate should reflect a proportional change in the total population (Bayliss 1987; Nichols 1987). An important, although often unstated assumption of relative indices is that detectability remains constant across space and time (Nichols 1987; Subalusky et al. 2009). Relative indices are powerful tools for monitoring population trends when survey techniques are standardized (Bayliss 1987). Sighting probabilities can also be calculated from repeated spotlight counts, which allow calculation of a "sighting fraction", i.e., the proportion of the population observed during a single survey. The absolute population size can be estimated if the sighting fraction is known (King et al. 1990).

We conducted spotlight counts from December 2011 to March 2012, a period coinciding with the cooler months of the annual dry season when water levels were slowly receding, but had yet to reach the seasonal minima. We conducted spotlight counts from small manually propelled wooden boats using Maglite flashlights and 12-volt headlamps to search for crocodile eyeshines. At sites where dense aquatic vegetation precluded boat access, pedestrian surveys were conducted by walking slowly along the shoreline and searching for eyeshines. Spotlight surveys usually began shortly after sundown and continued until a complete circuit had been made around the wetland. However, at some sites, dense shoreline vegetation precluded a complete circuit of the wetland. The coordinates of the beginning and endpoint of each survey, and distance traversed during the survey were determined with a handheld GPS unit. Survey routes were calculated as kilometers of shoreline distance (King et al. 1990).

Camera trapping

Camera trapping is a particularly effective tool for monitoring large mammals (Swann et al. 2004), but has also been used successfully with smaller mammals, birds, and on occasion reptiles, including crocodilians (Thorbjarnarson et al. 2000; Platt et al. 2002; Charruau and Hénaut 2012; McGrath et al. 2012; Chowfin 2013). We conducted camera trapping at conservation sites during February-May 2012. Each Reconyx® camera trap was used in conjunction with a bait station consisting of a domestic chicken carcass suspended above the water at locations where tracks, scats, and local reports indicated crocodiles were likely to be found. Camera traps were positioned to cover the bait as well as the probable avenue of approach. When triggered, cameras took three photographs with a two second interval between exposures. Camera traps were deployed in late February and recovered in early May. Trapping effort (trap nights) was calculated for each site as the number of nights each camera was deployed multiplied by the total number of cameras deployed at a site. We also placed camera traps near active nests during May-June 2012 and 2013 in an attempt to photograph attending female crocodiles. Cameras were mounted on trees near the nest, or if suitable trees were unavailable, a small wooden frame was constructed approximately 3-4 m from the nest mound.

Track and sign surveys

Village Crocodile Conservation Teams conducted regular monthly pedestrian patrols at conservation sites to search for crocodile tracks, scats (feces), and other signs such as dragmarks, trails, and basking sites. Rear-foot tracks are characterized by the imprint of four toes and webbing (Simpson 2006), and because track length is related to body size, measurements are a reliable estimator of total length (Platt et al. 2009). Rear-foot tracks are used in preference to forefoot tracks because when crocodiles walk, the rear feet carry a larger proportion of the body weight and leave deeper and more distinct imprints than the much smaller forefeet (Hutton 1987). Importantly, measurement error is minimal because track length differs little (±0.1 cm) from actual rear-foot length (Platt et al. 1990; Wilkinson and Rice 2000). Rear-foot tracks (RFT) were measured from the posterior-most margin of the heel to the tip of the longest claw (third digit) and total length (TL) estimated from the formula $TL = 11.74RFT - 7.40$ (Platt et al. 2009).

Crocodile scats are pale gray or white, consist largely of uric acid, emit a strong odor when freshly deposited, have a brittle, chalky texture when dry, and often, but not always contain undigested remains of prey (Fisher 1981; Simpson 2006). Village teams photographed, collected, and air-dried any crocodile scats found during surveys. We calculated the mean diameter of each scat based on measurements taken at the three widest points of the scat using dial calipers. We are currently collecting scats from a group of captive crocodiles of known body sizes, which will be used to determine the relationship between scat diameter and TL. Village teams also noted the presence of other crocodile signs such as drag marks, scrapes, and basking sites. Finally, teams recorded observations of any crocodiles opportunistically encountered during the pedestrian surveys and estimated their TL.

Nest counts

Nest counts are a valuable tool in crocodilian managements programs and have been successfully employed to monitor populations of both hole- and mound-nesting species (McNease et al. 1994; Rainwater and Platt, 2009). Trends in nest count data provide a statistically rigorous means to assess the numerical response of the population over time (Nichols 1987; McNease et al. 1994). Furthermore, if the proportional representation of sexually mature females in the population can be determined, nest counts also be used to estimate population size (Chabreck 1966; Nichols 1987; Webb et al. 1989). This method is most applicable to crocodilians that construct conspicuous nests in open habitats (e.g., *Alligator mississippiensis*) or in the case of hole-nesting species, concentrate at specific sites each year to deposit eggs (e.g., *Crocodylus acutus*). A number of crocodilian management programs employ aerial surveys to quantify annual nesting effort as even in densely vegetated habitats inaccessible to boats, nests can be detected from helicopters or low-flying fixed wing aircraft (McNease et al. 1994). Moreover, because many species exhibit strong interannual nest site fidelity (Elsey et al. 2008; Platt et al. 2008), once these sites have been identified, searching tends to become increasingly efficient over time. Long-term population trends can be determined by regressing annual nesting effort (y) against year (x) (McNease et al. 1994).

We monitored crocodile nesting activity each year with the dual objectives of quantifying annual nesting effort and obtaining eggs for artificial incubation and head-starting. Village teams searched likely nesting habitat beginning in mid-May and continuing through mid-July when rising water levels rendered many areas inaccessible. Village teams notified WCS personnel when nests were found and arrangements were immediately made to visit the site, inspect the nest, and collect eggs. Before opening, the nest the mound was measured, overhead canopy cover was estimated, and distance to the nearest water determined. GPS coordinates of the nest were recorded and photographs taken of the mound and surrounding habitat. The top of the mound was then carefully opened to expose the clutch. Egg length and width were recorded with dial calipers, egg mass determined with a Pesola scale, and the presence (or absence) of an opaque band on the eggshell was noted. The date of clutch deposition was estimated by the extent of opaque banding on the eggshell and reports of the village crocodile team. Eggs were then securely packed into a Styrofoam box containing natural nesting material and transported to either the Lao Zoo or a facility in Tan Soun Village for artificial incubation.

Results and Discussion

Nocturnal spotlight counts

We conducted nocturnal spotlight counts at Kout Mark Peo and Phai Cheo Reservoir (28.8 km), Nong Maehang (13.3 km), and Kout Kouang – Kout Koke (4.6 km) (Table 2). Dense aquatic and shoreline vegetation prevented spotlight counts at Kout Kaen and Kout Xalat Kadan. At Kout Mark Peo and Phai Cheo Reservoir, dense mats of floating vegetation and impenetrable stands of *Mimosa pigra* prevented access to large areas likely to harbor crocodiles. No crocodiles were encountered during any spotlight count, although tracks, scats, nesting activity, diurnal sightings, and reports from villagers indicate crocodiles were present at these sites during the survey period.

These results were not unexpected given the habitat conditions at conservation sites. Spotlight counts are most effective in open lacustrine and riverine habitats where the likelihood of detecting crocodilians is generally high. In marshes and swamps, detectability can be severely curtailed by aquatic vegetation that obstructs viewing and provides concealment for crocodiles (Webb 2000; Platt et al. 2004; Subalusky et al. 2009). Similar to our results, Bezuijen et al. (2013) observed few crocodiles during spotlight counts of comparable habitat in Laos, and concluded this methodology was ill-suited for use in densely vegetated wetlands, particularly at sites harboring few crocodiles. Furthermore, because individual sighting probabilities are usually low even where crocodiles are common (9-25%; Taylor and Neal 1984; Woodward et al.

Table 2: Summary of nocturnal spotlight counts conducted at conservation sites in Savannakhet Province, Laos (December 2011-March 2012). No crocodiles were observed during these spotlight counts.

Location	Date	Km surveyed
Kout Mark Peo and Phai Cheo Reservoir	6 December 2011	8.0
	7 December 2011	9.0
	22 February 2012	1.7
	23 February 2012	1.7
	8 March 2012	8.0
	23 March 2012	1.0
	24 March 2012	1.7
Nong Maehang	25 February 2012	0.6
	26 February 2012	0.6
	11 March 2011	2.0
	12 March 2011	8.0
	26 March 2011	2.1
Kout Kouang – Kout Koke	16 March 2012	4.6
Total km surveyed		**46.7**

1996), spotlight counts have limited utility for monitoring low density populations. When individual sighting probabilities are depressed, the effort required to detect crocodiles becomes prohibitively high (Bezuijen et al., 2013). For these reasons, we do not regard spotlight counts as an appropriate methodology for long-term monitoring of crocodile populations at conservation sites in Laos.

Camera trapping

We deployed 19 cameras at five wetlands for a total of 1294 trap nights (Table 3). Our efforts yielded no photorecords of crocodiles, although various birds and small mammals were detected. Crocodiles apparently failed to respond to our bait stations, which was somewhat surprising given that carrion is readily consumed when available (Pittman 1941; Atwell 1959), and in the past, baited hooks were a favored tactic for harvesting *C. siamensis* in Laos (Bezuijen et al. 2013). That said, we cannot rule out the possibility that crocodiles approached our bait stations, but failed to trigger cameras. Merchant et al. (2012) found that motion-sensitive infrared cameras

Table 3: Camera trapping effort at conservation sites in Savannakhet Province, Laos during February-May 2012. Effort (trap nights) calculated as: TN × N where TN = trap nights and N = number of cameras deployed at a particular site.

Location	deployed	retrieved	Days elapsed	cameras deployed	trap nights
Kout Mark Peo	22 February	2 May	70	5	350
Xalat Kadan	24 February	3 May	69	2	138
Nong Meahang	25 February	3 May	68	2	136
Kout Kaen	27 February	4 May	67	3	201
Kout Kouang/Koke	28 February	5 May	67	7	469
Total				**19**	**1294**

were unable to consistently make photo-captures of American alligators (*Alligator mississippiensis*) under captive conditions, and suggested a number of technical modifications to improve the likelihood of successfully photographing crocodilians. Based on our results, camera trapping was deemed an unsuitable tool for monitoring crocodiles at project wetlands in Laos.

Our efforts to photograph crocodiles at active nests proved somewhat more successful, although we experienced technical problems with the equipment, visitation by females was infrequent, and properly positioning cameras was difficult owing to multiple avenues of approach. Nonetheless, camera traps placed on two nests in 2012 and again in 2013, yielded a series of poor-quality images of an adult crocodile (presumably the attending female) taken at Kout Mark Peo in June 2013. Based on head length, we estimated the total length of this crocodile to be 2.5-3.0 m. Small rodents were also occasionally photographed at crocodile nests. Although the egg-eating proclivities of small rodents are well documented (e.g., Platt et al. 2008), egg losses attributable to rodents did not occur during the project.

Track and sign surveys

Measureable quality rear-foot crocodile tracks were found only at Xalat Kadan (n = 4) and Kout Kouang (n = 1) during December 2011 (n = 2), January 2013 (n = 1), and February 2013 (n = 2). The estimated TL of these crocodiles ranged from 110 to 297 cm. The single track found at Kout Kouang indicates at least one subadult crocodile (TL = 110 cm) was present in the wetland. Two of four tracks found at Xalat Kadan were similar in length and probably left by the same crocodile, which was estimated to be about 280 cm long. Two other tracks found at Xalat Kadan were produced by crocodiles with estimated TL of 110 and 218 cm.

We collected 41 crocodile scats at Xalat Kadan (n = 7), Kout Kouang (n = 21), and Kout Mark Peo (n = 13) from December 2011 through March 2013. No scats were recovered from Kout Kaen or Nong Maehang. Scats were found primarily during January (n = 8), February (n = 8), March (n = 19), April (n = 1), June (n = 1), November (n = 2), and December (n = 4). Mean (±1SD) scat diameter was 32.4 ± 10.5 mm; range = 11 to 47 mm; Fig. 1), but because the relationship between scat diameter and body size in *C. siamensis* has yet to be determined, the TL of these crocodiles cannot be reliably estimated. It is probable that most of the scats were produced by sub-adult crocodiles.

Track and sign surveys require minimal training, are relatively inexpensive to implement, and except for the wettest months, can be conducted at frequent intervals throughout most of the year. However, based our experience track and sign surveys appear unsuitable for long-term population monitoring because survey results are highly variable and difficult to interpret, and probably depend on poorly understood intrinsic and extrinsic factors such as substrate condition, water levels, and social interactions between crocodiles (e.g., large crocodiles could control access to basking sites). Nonetheless, track and sign surveys are useful for determining the presence/absence of crocodiles at a site, provide crude estimates of the minimum number of crocodiles inhabiting a wetland, and might be useful in determining size-class distributions. Despite the limited utility of the data collected, track and sign surveys also serve to actively engage villagers in crocodile conservation efforts, maintain a team presence in the field that can discourage poaching and other illegal activities, and instill a sense of community involvement and pride in the conservation project.

Nest counts

We found seven *C. siamensis* nests during 2011-13 at Kout Mark Peo (n = 3), Phai Cheo Reservoir (n = 1), Xalat Kadan (n = 1), and Kout Kouang (n = 2) (Table 4). Despite seemingly suitable habitat and intensive frequent searching, nesting was not documented at Nong Meahang or Kout Kaen. Nests were found during multiple years at Kout Mark Peo - Phai Cheo Reservoir

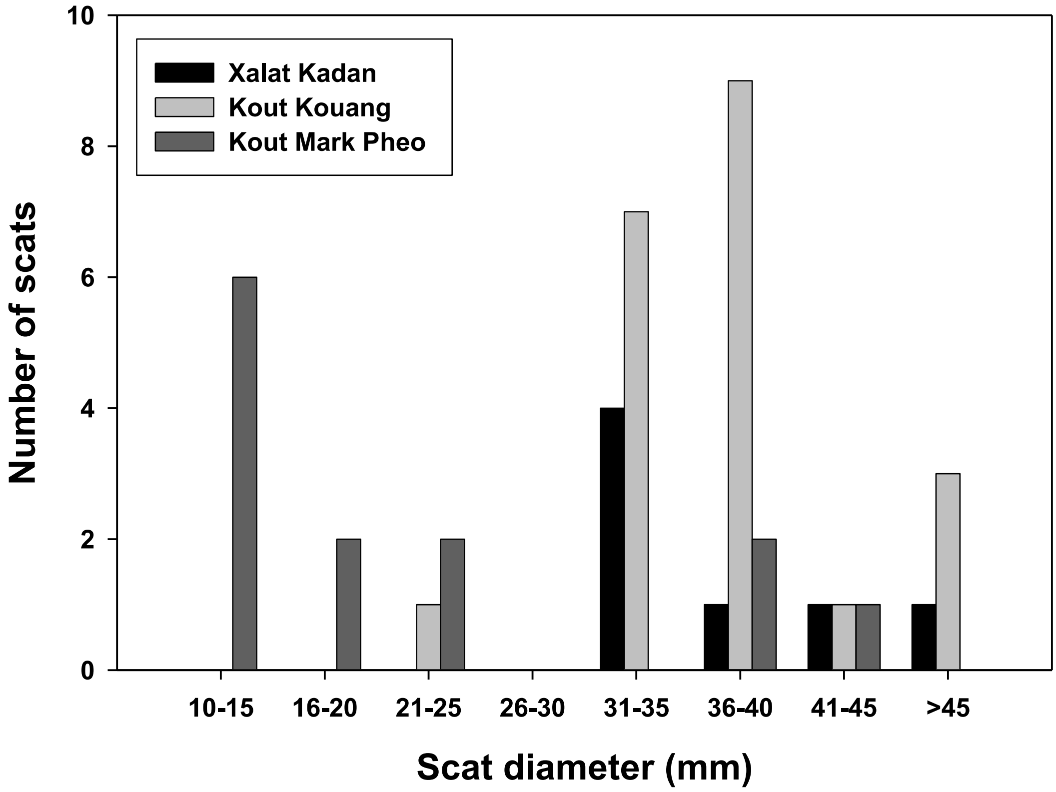

Fig. 1: Size distribution of Siamese crocodile scats (N = 41) recovered from Xalat Kadan, Kout Kouang, and Kout Mark Pheo in Savannakhet Province, Laos from December 2011 through March 2013.

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and Kout Kouang. Nesting occurred at Kout Mark Peo - Phai Cheo Reservoir during 2011, 2012, and 2013, while nests were found in 2011 and 2013 at Kout Kouang. An old nest mound with eggshells found at Kout Kouang in 2011 was probably constructed during the 2010 nesting season. Nesting was reported at Kout Mark Peo (2004 and 2008), Kout Kouang (2008), and Xalat Kadan (2007) by Bezuijen et al. (2013).

The crocodile nests we found were constructed at slightly elevated microsites on floating mats or in dense vegetation along the shore, and consisted of vegetation, detritus, woody debris, and soil scraped into a low mound (ca. 30-45 cm high) by the female. Of the seven nests, all contained eggs, although only four eggs remained in one nest at Phai Cheo Reservoir that had been opened by predators. The identity of the predator responsible for opening the nest was unclear; monitors (*Varanus* sp.) are important nest predators in Africa and Australia (Webb and Manolis 1989), but have not been observed in our study area. Villagers maintained that "birds" opened the nest, possibly Large-billed Crows (*Corvus macrorhynchos*). Corvids are known to prey on eggs and hatchlings of *Alligator mississippiensis* (Ouchley 2013).

Excluding the nest at Phai Cheo Reservoir, viable eggs occurred in only three of six nests (50.0%). Viable eggs were found only in nests at Kout Mark Peo with viability rates ranging from 94.5-100%. Three clutches collected from Xalat Kadan and Kout Kouang consisted of non-viable eggs. Opaque banding was not evident in the four eggs found in the depredated nest, suggesting these were also non-viable. However, if the nest had been opened by predators within

Table 4: Summary of Siamese crocodile nesting activity at conservation sites in Savannakhet Province, Laos monitored from 2011 through 2013

Location	Estimated date of laying	Clutch size	Number of viable eggs (%)	Nesting habitat/notes
Kout Mark Peo	29 May 2011	28	27 (96.4)	Floating peat mat among small trees; nest built on small log; no open water near nest.
	6 June 2012	33	33 (100%)	Shoreline in dense thicket ca. 15 m from water; sign of recent visitation by female crocodile.
	29 May 2013	37	35 (94.5%)	Floating mat; nest placed on slightly elevated microsite adjacent to log.
Phai Cheo Reservoir	Early June 2012	< 4	?	Floating mat among small trees; opened by (avian?) predators.
Xalat Kadan	7 June 2012	27	0	Shoreline in thick grass among scattered trees and shrubs; nest located about 30 m to water.
Kout Kouang	Mid-June 2011	20	0	Floating mat; clutch collected by villagers and later (August) measured by WCS personnel; no evidence of banding was noted. The remnants of an old nest mound (including eggshells) found in 2011 probably date from the 2010 nesting season. This nest mound was also constructed on a floating peat mat in dense vegetation immediately adjacent to open water.
	2 July 2013	16	0	Floating marsh; nest constructed at elevated base of trees about 0.5 m from water; female observed at nest by villagers; date of oviposition could not be determined owing to lack of banding; village team found nest on 30 June 2013.

24 hours of clutch deposition, embryonic development would have been arrested before bands could form. Similar to our results, Bezuijen et al. (2013) reported clutches of non-viable eggs in two nests found at Kout Kouang in 2008. Collectively, our data and those of Bezuijen et al. (2013) suggest a paucity of males in the larger metapopulation.

Although the reproductive phenology of *C. siamensis* in Laos requires additional study, our preliminary results suggest a close correlation with the annual monsoonal cycle. Courtship and mating probably occur during March and April, followed by nest construction and clutch deposition at the onset of the wet season in May and extending into early June. Eggs incubate through July and hatching occurs in August and September after a period of about 75 -80 days (Brazaitis and Watanabe 1983; Platt et al. 2011). Given this phenology, nest searches are best conducted in mid- to late June. Interestingly, the reproductive phenology of wild *C. siamensis* in Laos appears to differ greatly from those on farms in Cambodia (Platt et al. 2011). We suspect this is due to the large number of phenotypically indistinguishable hybrid crocodiles (*C. siamensis* × *C. porosus* and *C. siamensis* × *C. rhombifer*) present on commercial farms in Cambodia (Starr et al. 2009). Hybrid crocodiles often exhibit different reproductive phenologies and nesting behavior than either parent species (Platt and Rainwater, unpubl. data).

Conclusions

In summary, given the difficulty of detecting crocodiles during nocturnal spotlight counts in heavily vegetated habitats, and the limitations of camera trapping and track and sign surveys, annual nest counts appear to be the most appropriate method for monitoring long-term population trends and evaluating the success of our conservation actions in Laos. Because linear regressions require at least five data points for meaningful interpretation (Zar 1996), a minimum of five years of nest count data must be accrued before population trends can be statistically detected. However, our initial results are encouraging; three crocodile nests were found in 2012 and two in 2013, compared to a single nest in 2011. While this trend is probably attributable to the increased search effort and improvements in the skill of village teams rather than an actual increase in crocodile populations, our results demonstrate that a) crocodile nesting is occurring at conservation sites, and b) VCCC cadre are capable of finding nests.

Several other considerations are important if nest counts are used for monitoring recovery of Siamese crocodile populations. First, because the Champhone River corridor provides connectivity between conservation sites and crocodiles inhabiting these wetlands appear to interact as a single metapopulation, population trends should be analyzed by site and by pooling nest count data across all sites. Second, given the small number of crocodiles present at each conservation site, trends may be masked by annual variability in reproductive effort (Webb et al. 1989). Third, a considerable lag between population recovery and an increase in the number of nests can be expected owing to the time required for young crocodiles to attain sexual maturity and enter the pool of reproductive adults. Thus, several years may pass before an actual population increase is reflected in nest count data. The number of viable eggs must also be taken into account when evaluating population recovery. If significant numbers of non-viable eggs continue to be produced, other management options such as the release of adult males should be considered. Finally, it must be recognized that searching for nests at some sites (e.g., Kout Khean) may prove unfeasible given the habitat conditions. In that case, local reports of hatchlings encountered by villagers should serve as a proxy for an actual nest in the annual count, i.e., a group of neonate crocodiles should be scored as a single nest. Finally, although searching efficiency will no doubt improve as VCCC cadre accrue experience, nest counts will nevertheless remain a challenging and time consuming task.

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Crocodile Conservation Hub - Madras Crocodile Bank Trust

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Abstract

Surveys of the three species of crocodiles—mugger, saltwater crocodile and gharial—across India in the 1970s showed that the populations were not healthy. This resulted in the Indian Government declaring the highest level of protection for all the three species.

Responding to the need of that time, Rom and Zai Whitaker, with the support of like-minded conservation visionaries and organizations, established the Madras Crocodile Bank Trust (Croc Bank) in 1976 to create secure breeding populations of the three species. Starting with a handful of breeding individuals, by mid 1990s there were over 8,000 crocodiles in residence. Today Croc Bank is home to 18 species of crocodilians, including species that are listed by the IUCN as critically endangered and threatened.

The eight and a half acre specialized reptile zoo attracts close to half a million visitors per year. The Croc Bank in addition to being a zoo and a captive breeding center, is also involved in *in situ* research and conservation. The Croc Bank runs three permanent research stations and has several ongoing projects on diverse taxa and habitats. Today, after more than 30 years of experience in scientific research, conservation and education, Croc Bank is one of the leading centers of excellence in herpetology.

Croc Bank's vision of development will soon come into action. The upgrading of the zoo facilities with regards to number of species, exhibits and also education and outreach is planned to complement the recent expansion of our increasingly important in-situ conservation efforts.

Croc Bank

The Madras Crocodile Bank Trust and Centre for Herpetology (or Croc Bank) was the brainchild of Romulus Whitaker and Zahida Whitaker and a handful of like-minded conservation visionaries who began work on the facility in 1970s, in a desperate effort to save India's dwindling crocodilian populations. Today, after more than 30 formidable years of cutting edge science and grassroots education, the Croc Bank remains a world leader in the field of frontline conservation and the preservation of natural landscapes. The Croc Bank has been a pioneer in scientific research and conservation of reptiles for the past three decades. It provides support for surveys, standardization of data collection and maintenance techniques, developing field studies and developing and collation of educational materials.

The Croc Bank is a registered not-for profit trust and was formed on 26th August 1976. A board of trustees governs the trust and The Central Zoo Authority; New Delhi, India regulates the zoo. The mission of the trust is "To promote the conservation of reptiles and amphibians and their habitats through education, scientific research and captive breeding. Efforts are focused on, but are not limited to, Indian species and ecosystems and include both in-situ and ex-situ components."

The Croc Bank near Chennai, Southern India is one of the largest reptile zoos in the world and one of the oldest non-government environmental organizations in Asia. The Croc Bank was originally designed to be a living genetic repository of crocodiles for safekeeping, to protect and multiply until such time when they could be returned to restock their original wild habitats. This action was initially met with tremendous success, but today, release into the wild has stopped due to shrinking wilderness areas and the lack of suitable habitat.

What started with a handful of crocodiles and an experimental approach to captive breeding was so successful that by the 1990s there were over 8,000 crocodiles in residence. Today Croc Bank is home to 18 species of crocodilians, some of which are listed by the IUCN as critically endangered with a further few listed as threatened. As the need for the conservation of reptiles grew, the Croc Bank increased its repertoire to include turtles, lizards and snakes and it came to be known as the Madras Crocodile Bank Trust and Center for Herpetology in 2003. The need for turtle and tortoise conservation in particular has grown exponentially in recent years and the Croc Bank now successfully breeds several species of threatened chelonians, including two listed as critically endangered. 15 species of Turtles and 9 species of snakes are housed at the Croc Bank.

Over the years the Croc Bank has developed into a world- renowned public institution with strong community and government support at the local and national level. The Croc Bank is uniquely placed with almost complete staffing from the village across the road. The local tribe, the Irulas, bring in rats, crabs and snails. The village has a fishermen co-operative of 13 families that supplies fish for the animals. The Croc Bank purchases the entire catch brought in by the co-operative and this forms the sole source of income for the 13 families.

Education and Awareness at the Croc Bank

Apart from its commitment to the research and conservation of herpetofauna, it is a recognized centre for environmental education and public awareness with a wide audience across Asia.

At the Croc Bank, we believe that education is the ultimate key to long term sustainable conservation. We devote a large part of our time and resources towards educating people of all ages and backgrounds in the importance of conserving reptiles and natural ecosystems. Croc Bank has a visitation of about half a million visitors a year. Jointly with the curatorial and maintenance department, we have been promoting an enhanced visitor experience through interactive multi lingual talks, and species-specific signage around the park to provide information about the "ecosystem, biology and conservation status. *Young Reptiles*, our improvised interpretation centre, is used on a daily basis to conduct talks about reptiles and habitats and conservation issues for the public. Docents, volunteers and staff members interact with visitors in the park to ensure a positive visitor experience and to provide more information to our visitors by answering their questions and sharing knowledge. This level of interaction also helps change any misconceptions about reptiles. In-house education programs include nature camps and thematic workshops are conducted throughout the year. Through these camps and workshops, the participants get an opportunity to become familiar with wildlife conservation issues by learning about reptiles and amphibians and their biology using relevant media. For university, college and schools we are able to provide curriculum based programs.

Conservation and Research

The Croc Bank runs three permanent and fully staffed field bases and usually has several field projects on the go at any one time; The Chambal River Field Station housing the Gharial Conservation Alliance (GCA) and the India Turtle Conservation Program (TSA), The Andaman and Nicobar Island Environmental Team/ Centre for Island Ecology (ANET) and Agumbe Rainforest Research Station (ARRS).

The Gharial Conservation Alliance (GCA)

Based at the Madras Crocodile Bank Trust in Chennai, GCA is dedicated to saving the gharial from extinction and ensuring the establishment of sustainable wild populations. Conservation efforts of the GCA range from Gharial Ecology research, using radio-telemetry as a tool, scientific population surveys, education, awareness, and government lobbying.
Gharial Telemetry Project was initiated in June 2008 to investigate the circumstances of the 2007-08 mass die-off of gharial in the lower Chambal River. In the current effort 20 gharials and 2 mugger were tagged and are currently being tracked successfully. These tracking studies are providing new insights on the ecology of gharials and would be beneficial for gharial population management. Another effort is to produce a gharial spatial database as a comprehensive assessment of gharial and their habitat. GIS is used to layer threats, nesting sites, important locations for gharial, etc. It will provide a clear picture of which areas carry important gharial populations, which areas are having the worst impact, and this will help in prioritizing actions for conservation management.

Public awareness of the plight of gharials is necessary in order to galvanize public support for gharial and instigate government action to enforce protection of gharial and their habitat. Zoos are one of the best forms of public education. To see a gharial face –to- face is to appreciate the uniqueness of this animal. So far GCA partners in the zoo sector have played a vital role in fundraising and public education for gharial research and conservation efforts.

The Andaman and Nicobar Island Environmental Team/ Centre for Island Ecology (ANET)

The Andaman & Nicobar Islands attracted the attention of researchers and naturalists long before they appeared on the pages of guidebooks and travel magazines. By virtue of its isolation and distance from mainland India, the island chain’s healthy ecosystems display a robust biological diversity with a high level of endemism.

In the mid 1970s, Romulus Whitaker along with a few colleagues began crocodile and herpetofaunal surveys on the islands. A small fraternity of herpetologists realized the value of this natural heritage and the pressing need for its study and attempts towards conservation. In the late 1980s, Romulus Whitaker, Satish Bhaskar and Alok Mallick set up a research base in Wandoor, South Andaman for herpetological and other ecological studies on islands. Following this, The Andaman and Nicobar Islands Environmental Team (ANET), a division of the Madras Crocodile Bank Trust, was constituted in 1990. In 1993, with grants from Conservation International and the Royal Netherlands Embassy, five acres of land was purchased at Wandoor on the southern tip of the South Andaman Island.

Since then, ANET has undertaken extensive studies on the islands' flora, terrestrial and marine reptiles, marine turtles, herpetofaunal biogeography, bats, other small mammals, resource and land use, coral reefs and the various socio-economic factors impacting them. ANET also works extensively with the Forest Department and policy makers; helping devise ecologically sound management plans for Protected Areas, waste management, education and other important island specific issues. Additionally, it has an ongoing environment education program. ANET's collaboration with Kalpavriksh Pune and the Centre for Environmental Education produced a teacher-training manual ('Treasured Islands') in English and Hindi, for the schools in the region. Today, ANET remains the primary active environmental NGO and the only research base of its kind in the islands. By virtue of its twenty-year-old research and education base, experienced staff and its good relationship with local communities and various government bodies, ANET is uniquely positioned to undertake, encourage and facilitate further tangible contributions to conservation efforts within the archipelago.

Agumbe Rainforest Research Station (ARRS)

The idea to set up the Agumbe Rainforest Research Station had its origin four decades ago when Rom Whitaker visited the rainforests around Agumbe for the first time in 1971 and saw his first king cobra in the wild. His dream was to set up a research base to study this enigmatic serpent and other denizens of the rainforest about which very little was known. In 2005, he realized his dream when he located and bought a beautiful four-acre plot surrounded by forest with the money his mother, Doris Norden had willed him. In 2005 Rom received an award from The Whitley Fund for Nature, which was utilized to set up basic infrastructure and develop ARRS into a full-fledged forest research base. Since then ARRS has conducted novel research on the rainforest species like the first every King Cobra Radio Telemetry project. Currently small projects for long term monitoring and with conservation questions in mind are ongoing. Recently Whitley Fund for Nature granted the second/continuing award to ARRS for construction of the Agumbe Rainforest interpretation Centre and for support of small student projects in the Rainforest System of the Western Ghats.

Through education ARRS works towards sensitizing local people and the world at large about the need for rainforest conservation. Regular slide shows, presentations, nature camps and lecture/discussions are conducted on site, at schools and other venues to bring the magic of the forest to school children, college students, forest officials, special interest groups, the police and villagers.

India Turtle Conservation program (TSA- ITCP)

The TSA India program is managed by Indian biologists that seek local solutions to saving turtles including converting former poachers and providing alternative income sources. The focal point of this comprehensive program is the iconic and critically endangered red-crowned roof turtle. Multiple species initiatives are also underway for the Northern River Terrapin, narrow-headed softshell turtle, Leith's softshell turtle and the crowned river turtle.

Future

The Zoo is coming up to an exciting new phase of redevelopment of the collection plan and the enclosures and the interpretation centre. The upgrading of the zoo is also planned to complement the recent expansion of our increasingly important in-situ conservation efforts. The Croc Bank has been involved in nature conservation since the very beginning. It is far more than a typical zoo and in fact our core operation is as much a field based conservation outfit as it is a collection of captive animals for safekeeping.

Resources

MCBT- www.madrascrocodilebank.org
ANET- www.anetindia.org
ARRS- www.agumberainforest.com
GCA- www.gharialconservationalliance.org
ITCP- www.turtlesurvival.org

Cooperative Efforts to Conserve African Slender-snouted Crocodiles (*Mecistops cataphractus*)

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Abstract

The African slender-snouted crocodiles are the least known crocodilians in the world. Available data prior to the turn of the century was insufficient to evaluate its status, but already suggested that across its range, crocodiles of the genus *Mecistops* were deteriorating. Over the last decade, population and ecological studies, combined with genetic and morphological analysis, has lead to a better understanding of the conservation status and management needs for slender-snouted crocodiles. To respond to these species management needs, a collaborative partnership between the San Diego Zoo, the AZA Crocodile Advisory Group's Species Survival Plan, the Abidjan National Zoo, and Matt Shirley began in 2009 in simple support of fieldwork, but has now evolved to incorporate captive husbandry recommendations and training, facilitation of captive breeding and headstarting for wild reintroductions, and expansion of the partnership consortium to include other institutions like the Albuquerque BioPark and Busch Gardens – Tampa Bay. We present an overview of our cooperative efforts to illustrate how public – private – researcher partnerships can effect the real-time conservation of threatened crocodilians globally.

Résumé

Les faux-gavials d'Afrique sont les crocodiliens les moins connus dans le monde. Les données disponibles avant la fin du siècle étaient insuffisantes pour évaluer leurs statuts, mais elles ont déjà permis d'identifier que, sur toute leur aire de répartition, les populations de crocodiles du genre *Mecistops* diminuaient. Au cours de la dernière décennie, les inventaires et les études écologiques, combinés avec des analyses morphologiques et génétiques, ont permis une meilleure compréhension du statut des populations et des besoins de gestion et de conservation des faux-gavials. Pour mieux répondre à ces besoins en matière de gestion des espèces, un partenariat entre le Zoo de San Diego, le « Species Survival Plan » du Groupe Consultatif des Crocodiles de l'AZA, le Zoo National d'Abidjan, et Matt Shirley a commencé en 2009 afin d'appuyer les études sur le terrain. Ce partenariat a ensuite évolué pour intégrer les recommandations sur l'élevage en captivité ainsi que de la formation soigneurs. Maintenant, ce partenariat intègre la mise en place de l'élevage en captivité de cette espèce au Zoo National d'Abidjan ainsi qu'un projet de réintroduction dans le milieu naturel. Au fur et a mesure du temps et de l'expansion des activités, le partenariat a intégré des institutions telles que le Albuquerque BioPark et Busch Gardens – Tampa Bay. Nous présentons ici un aperçu de nos efforts de coopération dans le but d'illustrer comment des partenariats publique - privé peuvent jouer un rôle essentiel dans la conservation en temps réel pour des espèces globalement menacées telles que certains crocodiles.

The African slender-snouted crocodile was regarded by IUCN/SSC Crocodile Specialist Group as the least known crocodilian in the world (Shirley 2010). The available data, however, suggested that this enigmatic species was declining, prompting population and ecological studies to determine the conservation status and suggest necessary management actions. Further, genetic and morphological analysis, prompted by recent systematic re-evaluations of other African crocodiles (e.g., Eaton *et al.* 2009; Hekkala *et al.* 2011), revealed a deep phylogenetic divergence between West and Central African populations indicating that there may be more than a single *Mecistops* species (Shirley *et al.* 2014) and further emphasizing the conservation need of, particularly, the West African species.

In recognition of the conservation needs of *Mecistops*, a collaborative partnership was initiated between the San Diego Zoo and the AZA Crocodilian Advisory Group's Species Survival Plan that was launched with a $10,000 fund commitment toward the conservation and research efforts being conducted by then PhD student Matt Shirley from the University of Florida. Matt's work in Africa involved comprehensive surveys across West and Central Africa and radio telemetry studies to improve our understanding of *Mecistops* movements and habitat utilization needs. Both of these efforts provided a basis for significant natural history observations (e.g., breeding and foraging ecology) and sampling for phylogenetic and phylogeographic analyses to assess distribution-wide population connectivity and demographic history.

As a result of this commitment, combined with grants awarded from other zoological institutions, our understanding of *Mecistops* has increased significantly. Evolutionarily, we have shown that *Mecistops* is comprised of two cryptic species that diverged some 7 million years ago (Shirley *et al.* 2014), identified significant phylogeographic structure across both the Central and West African landscapes that are helping us objectively define crocodile conservation units for this species (and *Osteolaemus*), as well as detected significant, climate-driven population bottlenecks throughout the last 20,000 years that are likely the most significant contributors to the sparse genetic diversity seen today (Shirley 2013). Ecologically, we have shown that males have larger home ranges than females, adult males do not appear to exhibit territorial exclusion (unlike in other large-bodied crocodilians), home and core activity ranges appear to be larger for *M. cataphractus* of all size classes compared to other crocodile species, though linear home range metrics are smaller due to *Mecistops*' more extensive use of river-adjacent wetland habitats, both species exhibit a higher tolerance for savannah woodland habitats than previously suspected so long as critical, closed canopy breeding habitat is available, and both species may actually be significantly impacted by the presence and abundance of the competitively superior *Crocodylus niloticus* and *C. suchus* (Shirley, *unpub. data*). The latter, in particular, may be a long term conservation concern as forest habitat is being replaced more and more by the open habitats required by *Crocodylus sp.* in western Africa.

Among the more significant outcomes of this early support was a dramatically improved understanding of the status of this species through population surveys at sites in Gambia, Guinea, and Burkina Faso (Shirley, *unpub. data*), Cote d'Ivoire and Ghana (Shirley *et al.* 2009), Niger (Shirley and Eaton 2007), Gabon and Democratic Republic of Congo (DRC; Shirley, *unpub. data*), which were augmented by technical support given to largely African biologists conducting surveys in Liberia (Miller 2010), Nigeria, Benin, and far eastern DRC. A total ± 2,300 km of surveys were conducted (± 1,200 km in West Africa and ± 1,100 km in Central Africa) and resulted in about 1,700 *Mecistops* detections. These results are significant for two reasons. First, only 32 confirmed *Mecistops* sightings came from West Africa (1.8% of all sightings) and, even today, there is no single site where a *Mecistops* sighting is guaranteed in this region. This likely makes the West African slender-snouted crocodile one of the most endangered crocodilians globally. Second, the Central African slender-snouted crocodile appears to be doing all right, with robust and well-protected populations in Gabon and, likely, the remote corners of DRC and the Republic of Congo. Though populations in Cameroon, Central African Republic, and at its eastern and southern range limits in Tanzania and Zambia are quickly diminishing.

In 2012, in response to these survey results, we undertook a preliminary mission to Cote d'Ivoire to evaluate the potential for reviving the *Mecistops* captive-breeding colony at the Abidjan National Zoo established by Ekke Waitkuwait in the 1980's (Waitkuwait 1990, 2002). What we found was quite encouraging. First, the captive colony contained 9 male and 37 females, all adults and of which some are the biggest *Mecistops* in the world, also making this the largest captive colony of this endangered crocodilian in existence. Second, in 2012 the Ivoirian government began a significant zoo rehabilitation effort, which includes prioritization of re-establishing the crocodile captive breeding efforts. As part of this, we undertook to capture and evaluate the status of all individuals and separate *Crocodylus suchus* into a separate enclosure for easier captive management. The San Diego Zoo supported the purchase of P.I.T. tags and a microchip reader for ease of individual identification and captive management, including on-going medical and nutritional care. They additionally funded genetic analysis to determine the relatedness amongst the group and whether they contained any unique genetic diversity compared to animals sampled in the wild and in the AZA captive population.

In late 2013, Matt Shirley and team were awarded an IUCN Save Our Species (SOS) grant for the project "In-and Ex-Situ Conservation of *Mecistops* in the Upper Guinea Forest Region," which represents an exciting next step in the conservation for this unique species. In 2014, as part of this project and to ensure expansion of the zoo community commitment to *Mecistops* conservation, Kim Lovich (San Diego Zoo), Matt Eschenbrenner and Ralph Zimmerman (Albuquerque BioPark) visited Abidjan to better advise on captive care requirements, management training, plans for breeding, and, perhaps most importantly, keeper training. Veterinary evaluations revealed several dietary deficiencies in the colony that we are now working to overcome, and equipment donations enabled the zoo to construct a new incubator. Since that visit, we successfully produced three clutches totaling near 80 eggs which, as of mid-June 2014, are producing healthy, well-started hatchlings.

Capacity building for staff at the Abidjan National Zoo continues to be a key focal point for this collaboration. In 2014, Doué Barnabe Digbé, the assistant director, was awarded the Behler Scholarship to attend the AZA's Crocodilian Biology and Captive Management course at the St. Augustine Alligator Farm in St. Augustine, Florida. Digbé was the first African recipient of the Behler Scholarship, and was also the first awardee in need of English translation services to attend the course. The San Diego Zoo supported Digbé's participation by funding his travel expenses, as well as the cost of attendance of a San Diego Zoo reptile department keeper who is fluent in French to act as a translator for Digbé. Following the course, Digbé travelled to San Diego and spent time visiting the San Diego Zoo and observed vet procedures, reserve holding for a variety of bird, mammal, reptile and amphibian species, as well as our crocodile exhibits and holding areas. This opportunity afforded our Ivoirian zoo colleague is a shining example of multiple institutions combining resources to ensure linkages and capacity development in Africa for the conservation of endangered crocodile species.

The slender-snouted crocodile does not appear to have had an extensive history in North American collections. The first specimen to reach a North American zoo appears to be one received at the New York Zoological Park in 1910. The Philadelphia Zoological Garden received another early specimen of *C. cataphractus* on 29 May 1925. It lived for a period of almost four years and died on 31 January 1929 (B. Bahner, *per. comm.,* 1997). Since then, at least 23 slender-snouted crocodiles (2 not recorded in International Species Information System) were imported for North American collections between 1928 and 1985. Of these 23 specimens, 11 are still living, 4 were returned to Africa (St. Lucia Crocodile Center in Natal – outside the native range of this species), one was apparently transferred to the public, and 7 died from various causes. Presently there are a total of 40 (9.12.19) slender-snouted crocodiles managed at 13 North American facilities. A recent analysis demonstrated that all of these individuals are from the West African species (Shirley *et al.* 2014; Shirley *et al.* In Review).

The North American captive population data was analyzed by Randy Fulk (Small Populations Management Advisory Group), who recommended selected captive breeding and new additional bloodlines as founders in order to maintain the sustainability of the population within North American facilities. As part of the Cote d'Ivoire project, we are planning for the export of 2.4 captive bred *M. cataphractus* from the Abidjan National Zoo. Individual crocodiles were selected based on evaluation of their genetic relatedness, and our colleagues from the Albuquerque BioPark played a critical role in assisting with medical exams and health inspections for potential crocodile transport. New facilities committed to displaying and educating the public about *Mecistops* include Busch Gardens – Tampa, which, together with the San Diego Zoo and Albuquerque BioPark, receives more than 6 million guests annually, providing a great opportunity to educate the general public about conservation efforts for this unique crocodilian species. These Zoological institutions plan to continue to raise awareness and much needed funds to help support this collaborative conservation program for African slender-snouted crocodiles.

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Studbooks – Genetic and Demographic Analysis of Small Populations based on the Examples of the European Studbooks for the African Dwarf Crocodiles (*Osteolaemus tetraspis*) and the Philippine Crocodile (*Crocodylus mindorensis*)

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Abstract

Since many decades zoos play a vital role in conserving *ex situ*-assurance populations for many animal species. The ideal long-term goal is always to keep a genetically and demographically healthy assurance population in case one day even reintroduction of extinct species into suitable habitat should become necessary. Based on our experiences as European Studbook (ESB) keepers for the African dwarf crocodile (*Osteolaemus tetraspis*) and the Philippine crocodile (*Crocodylus mindorensis*) we provide several tools how to monitor and influence the development of such populations in human hands. Captive animals are registered in SPARKS (Single Population Animal Record Keeping System) and by the use of the software PM2000 or PMx (Population Management) an exact analysis of the demography (sex distribution, age pyramid, mortality and fertility) is possible as well as of the genetic relations (ancestry, mean kinship, inbreeding coefficient, genetic diversity). This enables the best planning to maintain a genetically and demographically healthy population as well as high genetic diversity among the zoo populations. Precondition is of course the resolved taxonomic status of the original population, i.e. the taxon (normally species) of concern. Based on the captive population management of the afore mentioned crocodile species we highlight the importance of thorough genetical screening to ensure the purebred status of the individuals held within the conservation breeding programs. Only after such research necessary transfer recommendations and breeding recommendations can be issued based on the obtained results to exclude hybrids or falsely identified species from the breeding program.

Why studbooks?

Studbooks are necessary in order to establish self-sustainable populations in zoos on a long-term view and make zoos independent from importing wild-caught animals. Originally when the EEPs were installed in Europe in 1985 there was no focus on especially endangered species. The abbreviation EEP originates from the German term “Europäisches Erhaltungszuchtprogramm”, which means “European Sustainable Breeding Programme”. Only later on the English term “European Endangered Species Programme” was established. As no natural selection is taking place in zoo breeding, it is important to retain the whole genetic diversity as high as possible in captive populations. It is the task of a studbook keeper to compile accurate and updated information on the population in the region for which he is responsible. These data may include birth and death rates, breeding success, changes in population size, transfers between zoological institutions and levels of inbreeding. The studbook ideally provides an overview of such data, based on which the studbook keeper can actually act as population manager and influence the further development of the captive population. However keeping a studbook accurate and managing a population are two different tasks that should be clearly distinguished.

Which aspects to consider?

Based on the studbook data, a population manager makes decisions about the placement of individual animals in relation to the rest of the population. When making these decisions, a studbook keeper has to consider mainly three aspects: a) pragmatical b) biological and c) genetical. Whereas the pragmatical aspects mainly include short distances for animal transports and permit issues when crossing borders, biological aspects are targeted on questions if animals can be paired together according to their size or age. Also social composition of groups needs to be considered to ensure animals are living in their natural social structure. The genetical aspects are more complex and should be addressed separately as own chapter in the following.

Genetical Management

Identifying the taxonomical unit

When keeping a studbook it is most important to know which animals should be included and which animals should no longer be considered. Generally most studbooks include one species only, although a few studbooks contain whole genera, whereas others include subspecies only. This seems easy at first sight, but the taxon must be clearly defined. This is becoming increasingly difficult, especially when we are faced with species complexes and cryptic species. In Europe, Zoo Leipzig is keeping the European Studbook for African Dwarf Crocodiles (*Osteolaemus tetraspis*) (SCHMIDT, 2013). Genetic research revealed within this species separate taxonomic units from different regions, which deserve to be treated as minimum evolutionary units independent from whether they are regarded as species or subspecies (EATON et al., 2009). Formerly regarded as monotypic species for the genus *Osteoalemus*, we know by now that this is a complex of at least three cryptic taxa, one from the Ogooué Basin, one from the Congo Basin and one from West Africa (EATON at al., 2009). This has implications for keeping a studbook, because the studbook keeper needs to know to which of these cryptic taxa the studbook animals belong to. Therefore the population within a studbook needs to be analysed and the results of such a study have consequences for managing the breeding programme. The European zoo population of *Osteoalaemus* was screened genetically, and it became obvious, that all three taxa are kept in Europe. Moreover it was detected that zoos have bred hybrids between these taxa in the past (FRANKE et al., 2013). The frequencies of the respective taxa and hybrids in the population have to be determined before management plans for the future development of the breeding programme can be established. Reasonably, further hybridization should be avoided and the animals should be managed according to the identified taxonomic units. However it must be ensured that founder animals of a breeding programme are definitely genetically pure members of the taxon, which should be kept in the studbook. Hybrids between different crocodiles have been described in many cases, also among one of the rarest crocodile species, the Philippine crocodile (*Crocodylus mindorensis*), where hybrids with the saltwater crocodile (*C. porosus*) recently were detected to occur under captive conditions in the Philippines (TABORA et al. 2012). Before starting a breeding programme for this endangered crocodile species coordinated by the Cologne Zoo in Germany (ZIEGLER et al., 2013), thus the first task was to genetically screen all potential founder animals to exclude possible hybrids (HAUSWALDT et al., 2013). The molecular analysis conducted by HAUSWALDT et al. (2013) also revealed the necessity of genetical comparisons to prove taxonomic status of individuals kept within a conservation breeding program,, to avoid misidentifications, in particular in the case of individuals with unidentified origin or which are difficult to determine solely by morphological characters.

Registration

The first step for a genetical management of a studbook population, is an accurate registration of the animals. The International Species Information System (ISIS) is a computer-based information system for wild animals species kept under human care. It is situated in Minnesota, USA, and includes informations of animal collections in 500 subscribing zoos worldwide. Single Population Analysis and Records Keeping System (SPARKS) is the studbook programme developed by ISIS. SPARKS allows to enter and edit data on a specific population, produces a variety of reports, undertakes several types of descriptive analyses and prepares the data for export into software for an exact genetical and demographical analysis. A studbook should at least provide the following information for each specimen ever included: Unique specimen identifiers such as local ID numbers, tags or transponders, the sex of the animal, the identities of the parents, birth and death dates, origin of the animals, age of the animals, transaction history and any data on the reproductive potential of the animal concerned. This information must be compiled for all animals and listed in the published studbooks.

Loss of genetic diversity

Zoo populations are vulnerable to the loss of genetic diversity. The reasons for this include the relatively small size of zoo populations, the fact that there is no genetic exchange unless animals are transferred between zoological institutions and the artificial environment, in which they live and which usually prevents a natural selection process. Such small populations can be expected to suffer different genetic problems. Breeding with related ancestors, also called inbreeding, results in an increased probability to get the same alleles from the ancestors. This can lead to inbreeding depressions, which is known from several captive populations. Inbred animals are not necessarily but may tend to be not as successful in surviving and reproducing as not inbred animals. Furthermore they tend to be more susceptible to diseases. Another problem in the small populations is the genetic drift. Founder animals of a studbook population represent only a random sample of the genetic variability in the wild population. Therefore the number of founder animals in a breeding population influences strongly the genetic diversity of the following generations. With only a few founder animals, also rare genotypes can be given on to further generations and the proportions can be shifted, so the genetic variability of a captive population bred in isolation for some years may differ significantly from the population in the wild. The more founder animals are available and the more randomly they are selected, the more exact the picture of the genetic variability of the wild populations is reflected. Other factors that influence the genetic diversity are the growth rate of the population and the final size of a stable population. The quicker a population grows and the larger it finally becomes, the better is the prerequisition to maintain a high genetic diversity. Also to avoid the genetic drift, the population size should be stable and not subject to major population fluctuations. With longer generation times, the genetic diversity can be kept high as well as by a fitting sex ratio. Breeding groups existing of several females and one dominant male lead to very well distributed genes of the male, whereas genetic diversity can be kept high when all founders are equally represented in a population.

Tools to manage the population

By providing the software Population Management 2000 (PM 2000) or since a few years its successor Population Management x (PMx) ISIS provides the studbook keepers, respectively in this case rather the population managers with a tool, with which the genetic management of a population can be improved significantly. This software calculates all important genetic values for the population as a whole but also for each individual in the studbook population. Graphs e.g. can be used to show the founder representation, retention or distribution in the existing population. Among else these programmes give the population manager the possibility to calculate inbreeding coefficients of all hypothetical pairings in the population and show its effects on the genetic diversity in the population. All possible candidates can be listed according to their age, their current location or their mean kinship, which is a value reflecting the genetical relatedness of this individual with all others in the population. Low mean kinship values indicate that there are only few relatives of this individual in the population making it more valuable for keeping a high genetic diversity in the population when breeding. The programmes also calculate genetic values such as gene diversity or founder genom equivalents for the whole population. The goal to keep the genetic diversity high in the population may sometimes conflict with the taxonomical selection of the breeding programmes. If there are for example many subunits (e.g. subspecies) with just a few founder animals, it may not be possible to retain a high genetic diversity over many years, whereas mixing these subunits may result in the possibility to keep a high genetic diversity for many decades. Therefore it has to be considered carefully which subunits may be included in a studbook in order to retain also a high genetic variability. There is no general rule, but decisions must be met and justified case by case.

It is also possible to use the programmes to calculate demographic reports for the studbook population. This may include age pyramids, which graphically show how demographically healthy a population develops. These tools can be also used to project the development of the population in the coming years taking growth rates into consideration. It may also be used to produce fecundity or mortality reports, reflecting the age of the animals, when reproduction is highest, or to show the probability of mortality at a certain age.

Genetic goals for keeping a breeding population in a studbook can be set in this tool. The population manager defines a genetic diversity he wants to keep over a certain time period. The software calculates if this is possible or if other variables in the population must be changed accordingly to reach these goals. Other variables that can be changed in order to retain a high genetic diversity including the generation length, the growth rate of the population, the current population size, the current gene diversity, the ratio of effective population size to the actual population size, the maximum allowable population size and the new founders that need to be added to the population in order to keep the goals. By changing these variables, genetic diversity may be retained longer. Consequently, the programme also calculates the number of pairs needed for breeding in order to reach these population goals taking into account clutch size and breeding probability as well as the sex ratio at hatching.

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Managing small captive populations of endangered crocodiles for conservation: Doing more with less.

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Abstract

In some cases, small captivity assurance populations may be the only short-term option for future preservation of wild populations of crocodilians. Well managed populations create options for future repatriation and reintroduction, buying time to secure appropriate habitat and to mitigate environmental quality issues that may be present. The resources for captive assurance programs are limited, both in the amount of genetic diversity secured for the founding of populations, and the captive resources to house, feed, breed, and rear subsequence generations. Thus, the efficient utilization of resources is essential to the success of these efforts.

If the husbandry is fully understood and repeatable, few groups of animals lend themselves better to small population management than crocodilians. The long reproductive lifespan, large total number of offspring that can be produced in a lifetime, low mortality rates, temperature sex determination, and the ability to identify individuals and manage pairs all can increase the genetic effective population size (N_e) of small captive assurance populations.

PopFrog.org , a recently developed internet-based tool for estimating target population size and founder numbers for initiating and maintaining captive populations for amphibians, is also useful to the crocodilian conservation community. This article will discuss the Popfrog tool in the context of crocodilian captive assurance population initiation and management.

Introduction

Despite great successes and efforts, some crocodilian taxa remain particularly vulnerable to extinction and are amongst the most endangered large vertebrates in the world. Several action plans have been developed for the most endangered taxa, some of which include the essential establishment of ex-situ assurance colonies for preservation and reintroduction (Ross, 1998). For the most endangered species, there are limited numbers of pure founders, and maximizing the gene diversity is an essential priority for safeguarding the future of these animals.

Several species of crocodilians have been successfully recovered with near-original genetic diversity, by farming activities, which have included diverting some of the production to wild population expansion and support. Starting with a founding base which may number in the hundreds or thousands secures almost all the expected gene diversity in a species. Then, with a substantial number of breeding animals per generation, it greatly diminishes the loss of genetic diversity associated with smaller populations. Rarely is a farming operation a solitary endeavors for a taxon. Most taxa are sustained at multiple farms in large numbers at multiple sites, preserving even higher levels of gene diversity in a meta-population model and providing some level of security from stochastic catastrophic events or infectious pathogens. These operations can be a resource for augmenting existing wild populations or reestablishing extirpated populations from specific areas. This, in addition to the harvesting of animals for commercial products, is another great demographic tool to maintain equality of family size and founder lineages to help maintain species genetic diversity. Commercial programs likewise can be self-funding, require little more than moderate regulatory oversight.

Unfortunately, the farming or ranching models are not appropriate for all crocodilian taxa. Some species' wild populations are so depleted, have little commercial potential, and need coordinated conservation efforts to assure their recovery and persistence, that a different, more intensive approach may be required with limited populations sizes. Moreover, conservation is an ongoing and long-term challenge. Today's successes do not assure long-term survival of any species, and assurance populations should be considered in the development of any recovery strategies (Ross, 1998; Banks, 2005; van Weerd, 2010), albeit with large commercial ventures or small carefully managed conservation populations.

Developing smaller conservation assurance populations can be effective if they are properly founded and managed. Success depends on identifying the target parameters of the number of founders (N_f), total number of animals that must be maintained each generation (commonly termed as the carrying capacity, K), the targeted GD retained, and the program duration. Physical facilities need to identified, designed and built, personnel resources need to be estimated, and above all, the amount of funding and other resources need to be carefully estimated (CBSG, 2011).

The amphibian community over the last few years has employed a useful tool that has potential utility for crocodilian biologists and conservation managers to estimate important population parameters for planning assurance populations. This tool, PopFrog (Popfrog.org), is a web-based program that estimates K and numbers of founders needed to meet specific program targets. It allows input parameters to be changed to see what the affect is on K and GD retained.

Results

PopFrog (Odum et al., 2011) is a web-based population management tool set for estimating target population size and GD retention of assurance populations. It was designed not only as a tool for conservation program managers, but also as a teaching tool for students of ex-situ conservation. It has been used in IUCN Amphibian Ark courses for this purpose. Although it was specifically developed based upon amphibian biology, many demographic similarities make PopFrog suitable for crocodilian program planning. In particular, both groups of animals can usually expand the captive population in the founding generation to carrying capacity (K). This is not the case for many mammal and bird species, and it is a factor that facilitates management of crocodilian assurance populations. (To better understand the terminology utilized in small population management, it is suggested that the reader review Lacy (1995)).

The program is designed on the thin-client model; Internet access and a simple web browser are all that is needed to access the set of population management tools. The tool options are as follows:

- New Management Population (How many founders are needed under a variety of scenarios)
- Existing Program Population (What can be accomplished with an existing captive population that is converted to an assurance population)
- Multiple Factors (Explore the impact of different multiple factors on the population performance under a variety of scenarios)
- Group vs. Pedigree (explore the impact on using either group management or pedigree management on a population's ability to maintain GD)
- Demographic Catastrophe (Explore options to overcome a demographic catastrophe (i.e., a poor-performing generation) for an existing program)

The program uses simple deterministic calculations (Hartl and Clark, 2007) to provide broad estimates of future population genetic performance. These general algorithms produce estimations that are appropriate for general planning; however, there are more accurate methodologies to

manage captive populations (Ballou and Lacy, 1995). The intention of the use of PopFrog is for planners to quickly estimate the resources necessary to meet program goals.
The impact of skewed sex ratio of the population founders is calculated as follows:

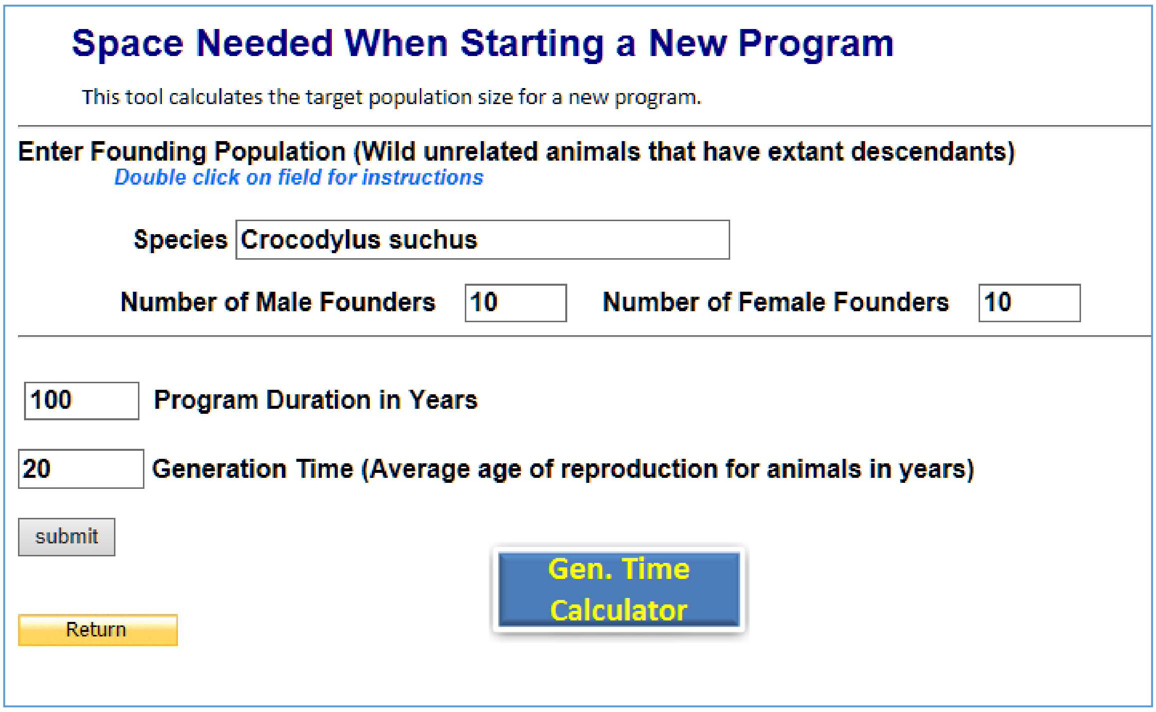
$$N_f = \frac{4N_m N_f}{N_m + N_f}$$

Where N_f is the effective number of founders, N_m is the number of male founders, and M_f is the number of female founders. Founders are defined as unrelated animals that have descendants in the captive population. The effective number of founders is then used to calculate the amount of GD represented in founders (GD_i)

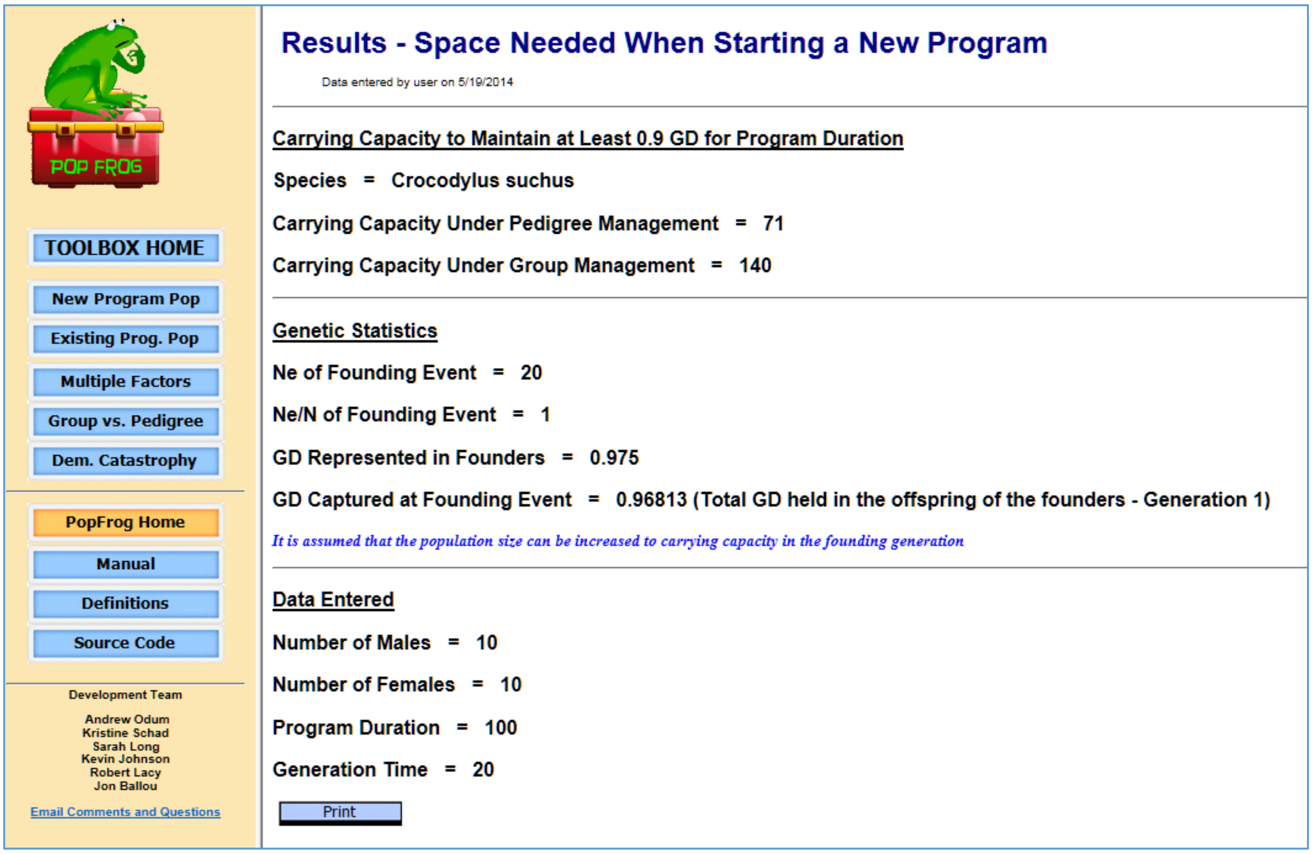
$$GD_i = 1 - \frac{1}{2\,N_f}$$

There is a full help function in the program.

Below is an example of an input screen for a hypothetical population of West African crocodiles:



The full results from this input are below:



This screen also shows the layout of the different tools available.

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Beyond the Park Gates: Zoos Step Up with Crocodile Conservation Program $upport

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Abstract

The mission of the 21st Century zoo is widely accepted to be conservation, education, recreation and research. In the past decade, concern over biodiversity loss has triggered a growing number of these institutions to contribute more funding to conservation and research that directly benefits species in the wild. Despite fierce competition from the "cute and cuddly, or, colorful" classes of creatures, financial and in-kind support by zoos for crocodilians is gaining momentum. Information was collected via questionnaires circulated on list serves and by direct communication in an attempt to quantify the monetary support for crocodilians by zoos over the previous 5 years. Here, we present the results of this analysis, showing that zoo support is behind most conservation programs for endangered crocodilians. We further share insights as to how zoo contributions might be increased in the future.

Introduction

The practice of keeping wild animals in captivity has been described in early records of human history. The first known "zoological garden" was created in ancient Egypt by Queen Hatasu after a voyage of discovery to the Somali coastline in Africa around 1700 BC. Explorers from that expedition brought back plants, rocks and animals, including a chimpanzee. From the big cats in the Coliseums of Rome (72 AD) to the royal menagerie held in the pits of the Tower of London from 1200 to 1830 AD, history is rife with wild animals being kept in captivity as displays of power by monarchs (Kisling 2001; Rees 2011). Indeed, the Coliseum had such demand for 'beasts' to use in its grand spectacles that local extinctions of lions, leopards and the loss of elephants from Northern Africa were the result (Hancock 2001; Rees 2011). Incidentally, the Coliseum was so technically advanced it could be flooded to allow 'games' with crocodiles and hippopotamuses. Little has been written about what must have been extensive holding facilities for these large numbers of wild animals (Hancock 2001).

In the 1700s, opposition to princely menageries surfaced in France in favor of a new type of establishment that could serve the masses as opposed to only the privileged. This concept took hold in Europe, with prominent menageries being competitively assembled in Versailles, Madrid, and throughout Germany, Italy and England. In 1828, the menagerie at Regent's Park in England became the first formal zoological garden; the animals living in the pits of the London Tower were moved to that location (Baratay and Hardouin-Fugier 2002).

Zoological parks began appearing in the United States after the Civil War. The first U.S. zoological park was the Philadelphia Zoo, which opened in 1874. By 1900, some twenty zoos opened their gates, with about two per year opening thereafter through 1940. With some notable exceptions, these establishments served mainly as an entertaining substitute for travel, satisfying human curiosity and craving for exoticism (Baratay and Hardouin-Fugier 2002).

Considering these origins, and given the complexities of running a modern zoological park, zoos have not generically touted themselves as leaders in conservation science. It was not until the 1960s that many zoos firmly embraced their potential roles in education, conservation and research. However, it took another twenty years before this "good idea" began to turn into action.

Today, conservation – along with education and research - is written into the mission of most zoos. The World Association of Zoos and Aquaria (WAZA) has as its own vision that "the full conservation potential of world zoos and aquariums is realized." (WAZA 2014). Each year, zoos around the world open their gates to over 700 million visitors – more than all popular sporting events combined (Hosey et al 2013). This is a huge audience that is available for zoos to target with the right conservation messages.

Within the past ten years, concern over the loss of biodiversity has translated into significant increases in funding from zoos for *in situ* conservation and research. The Association of Zoos and Aquariums (AZA) collects information annually from its member institutions in an attempt to quantify their monetary contributions. The 2012 AZA Annual Report on Conservation and Science lists contributions totaling over $160 million USD for projects in 115 countries (AZA 2012). This is a 633 percent increase over the previous decade, when contributions tallied for 2003 amounted to $21.8 million USD.

Sadly, crocodilians did not receive a large share of the $160 million in conservation support funding. According to Shelly Grow, Director of Conservation Programs at AZA, crocodilians were the beneficiary of only 1.8 percent of the species-specific projects reported by member institutions in 2012. Because the same conservation contribution data assimilated from AZA institutions is not similarly compiled from the other professional zoological associations - the European Association of Zoos and Aquaria (EAZA), Zoo Aquarium Association (ZAA) and World Association of Zoos and Aquariums (WAZA) – a survey was conducted in an effort to determine the nature and level of involvement of zoos worldwide in crocodile conservation program support.

Methods

A survey was circulated via various crocodile-related list serves, via personal emails, and by networking between zoo personnel and crocodile conservation program leaders. Respondents were asked to detail both monetary and in-kind contributions their institutions had provided for *in-situ* crocodile conservation initiatives each year. Funding amounts for education programs conducted *ex-situ* were not considered. The time span was 2009 to early 2014, covering just over five years. Respondents were also asked to provide information about the species and nature of the program supported. All responses were received electronically.

Results

Sixty-one institutions and support organizations from eleven countries responded to the survey. All of them had contributed to crocodile conservation initiatives within the past five years. Of note is the fact that contributions in 2013 were 236 percent higher than in 2009 ($323,492 versus $96,409).

Table 1. Zoo contributions in USD to crocodilian conservation initiatives 2009 – early 2014

2009	2010	2011	2012	2013	2014	Total $$	In-kind	Grand Total
$96,409	$161,765	$164,046	$181,881	$323,492	$113,126	$1,032,720	$150,650	$1,183,370

The totals listed above included the cost of a study to determine the amount of genetic variation within and between the two extant populations of Philippine crocodiles. Because of the implications for the conservation of this Critically Endangered species in the wild, the research results are extremely important. Therefore, this *in-situ* work was included in the totals.

Of the 61 respondents, only 8 included in-kind contributions in addition to their institution's financial support. In-kind contributions varied by activity, and included travel expenses and staff time in the field, time to conduct research and publish results, fundraising costs and grant writing.

Respondents listed 12 crocodilian species for which their institutions provided support. Of the species receiving support, it is not surprising that the most endangered crocodilian species featured in this list.

Table 2. Levels of support (in USD) provided by zoos worldwide for crocodilians, 2009 – early 2014

Species Funded	**$ (USD)**
C. mindorensis	$262,850
C. siamensis	$257,647
G. gangeticus	$172,300
C. intermedius	$94,230
T. schlegelii	$56,008
C. acutus	$48,252
A. sinensis	$37,060
M. cataphractus	$18,740
C. moreletii	$6,320
M. niger	$5,000
C. rhombifer	$3,454
O. tetraspis	$1,000

The IUCN Red List has six species listed as Critically Endangered: the Philippine crocodile (*Crocodylus mindorensis*), the Siamese crocodile (*Crocodylus siamensis*), the Chinese alligator (*Alligator sinensis*), the gharial (*Gavialis gangeticus*), the Orinoco crocodile (*C intermedius*), and the Cuban crocodile (*C rhombifer*).

Another species is currently listed as Endangered, this being the Tomistoma (*Tomistoma schlegelii*). There are a further three species listed as Vulnerable: American crocodile (*Crocodylus acutus*); the mugger (*Crocodylus palustris*); and the dwarf crocodile (*Osteolaemus tetraspis*) (IUCN 2012).

The remaining species are listed as Lower Risk. (It should be noted that several of these Red List accounts are currently in varying stages of revision).

Clearly, looking at the above list, the projects supported by zoos for *in-situ* conservation of crocodilians have focused on Critically Endangered species.

Discussion

Given the mandate from zoo authorities around the world, including AZA and WAZA (AZA 2014; WAZA 2014), and the need for zoos to more and more redefine their commitments to conservation, there is now serious attention to conservation by zoos. Their collection plans are based around the more endangered species. Exhibit designs and interpretive signage attempts to highlight conservation issues and habitats. Their education messages increasingly incorporate status and *in-situ* projects.

For crocodilians, there has been an increase in zoos wanting to house the species that are Critically Endangered, such as the Philippine crocodile, gharial, Orinoco crocodile, Chinese alligator or Siamese crocodile. In Europe, there has also been recent interest in Tomistoma. This could be due to more regular breeding within a number of zoos, and hence more availability, but there is clearly an interest in this species because of its endangered status, unique appearance, and under-representation in zoo collections.

Education messages are incorporating the target species into the habitat/ecosystem information presented to visitors through signs and talks, as well as overall ‘themes’ of exhibit space (e.g., Chester Zoo’s ‘Islands’ exhibit, which will feature Tomistoma in one of the largest developments in UK zoos, as well as Krokodille Zoo’s Black Caiman Swamp, and Paignton Zoo’s Crocodile Swamp).

Given the need for zoos to drive home a conservation message through their exhibits and education programs, there has been an emphasis on developing or supporting *in-situ* projects – putting the conservation dollar where their education message is. Pushed by key staff dedicated to the crocodilian cause, there has been a corresponding commitment to crocodilian conservation projects.

Funding by zoos has become somewhat creative in recent years. It includes:

1. Donations from net profits
2. Donations from funds collected from visitors via voluntary donor bins/buckets
3. Targeted funding taken as a percentage of entry fees – these are normally short-term projects, or aimed at raising a specific amount
4. Legal arrangements that enable a zoo to acquire a certain species on the proviso that they contribute an annual amount toward *in-situ* projects (the Philippine crocodile program is a prime example of this)
5. Zoo conservation funds that are sourced from major donors (local businesses, councils, governments) from the home city of the zoo. Such a scheme has supported gharial conservation via Zoo Praha (Prague Zoo)
6. Special fund-raising events aimed at a particular project/species. These events are many and varied, depending often on a small group of staff to drive the event

7. Zoo projects that include outside funding, but the zoo provides administrative, staffing and salary support as well as technical advice.
8. A special fund, stocked by interested individuals and zoos, solely for the purpose of supporting crocodilian-related projects. Since 2009, $125,000 USD has been donated by zoos and private individuals to the AZA Crocodile Advisory Group's (CAG's) John Behler Conservation fund. Much of this money has been earmarked for specific species, but about $22,000 of it has been donated to the general fund. The CAG has a small grants program and it accepts applications for conservation work with crocodiles. Generally, grant applications have been small – about $2,000 USD.

Implications for the future

An incidental finding as the result of the survey discussed herein was that 97 percent of responding zoos have crocodilians in their collections. Accordingly, it would follow that increasing the number of institutions holding crocodilians would increase annual support for worldwide crocodile conservation. To accomplish this, in the USA, an AZA Professional Development School, called Crocodilian Biology and Captive Management, was instituted. There is little doubt that the AZA "Croc School" has created a generation of personnel that push for crocodilian conservation within their institutions. A 2010 survey on the effects of "Croc School" attendance revealed that 30 of 57 respondents had sent at least one keeper to the course. Seven of these thirty respondents had added new crocodile exhibits as the result of what they had learned; 6 more exhibits were expected to be established. This model has not just provided invaluable training for AZA keepers, but has built a very solid network of support and ideas for conservation of crocodilians within AZA zoos.

There are other established courses that provide similar means by which future crocodile keepers and conservationists can be trained. Based out of Frankfurt, Germany, Ralf Sommerlad's Crocodile Conservation Services Europe offers a variety of training opportunities as well as assistance in procuring crocodilians for zoological (and other) collections. Shawn Heflick, located in West Palm Bay, Florida, USA, now hosts Crocodile University, which offers comprehensive training in crocodile natural history, husbandry and handling. Dr. Grahame Webb, based out of Australia's Northern Territory, has conducted international training on crocodilian conservation, management and farming for many years.

In Europe, there are now a number of crocodile-specific zoos/attractions, as well as large zoos that have high-profile crocodile exhibits (Paignton Zoo, Chester Zoo, Cologne Zoo). Popular television programs over the past decade and more have increased visitor interest in crocodiles. This has helped to support better crocodile exhibits within zoos, and along with the endangered status of certain species, what was once an ignored group has become a major focus for conservation support.

Traditional avenues of conservation funding through NGOs have concentrated on high profile, 'charismatic' species, mainly mammals. Such organizations rely on public donations and these mammal species are an easier sell, given the often limited advertising budgets that must compete in a very tough commercial culture. However it would appear that this extremely mammal-centric culture is slowly changing in favor of crocodilians. In 2013, at the Greenville Zoo in South Carolina, USA, the Philippine crocodile beat a mammal species at their Quarters for Conservation kiosk. The zoo's visiting public was offered the opportunity to "vote" for one of four conservation projects; three of the programs benefitted a mammal species and one benefitted a crocodile. When the votes were counted, two mammal projects came in first and second, but Philippine crocodiles took third place, thereby beating a mammal species for public support!

Conclusion

The modern zoo incorporates conservation into its core philosophy. Animal collections, exhibits, signs and education programs all put wildlife within the context of habitat/ecosystem conservation. With the recent increase in popularity of crocodilians with the general public, there has been a concomitant increase in focus on crocodilian exhibits in zoos. Over 700 million people visit zoos around the world each year. Zoos are in the enviable position of being able to convert visitor interest into conservation funding – provided the conservation message is strong and incorporated into the thematic presentation of the crocodilians in the collection. In the past 5 years, zoos around the world have contributed in excess of $1,000,000 USD toward *in-situ* programs for the most endangered crocodilian species. Given the growing acceptance of crocodilians by zoo managers, it is expected that this figure will continue to increase. Not only has the funding increased, but 'in kind' support is also strengthening, with a number of zoos providing resources and materials to *in-situ* projects. The results of this study show that zoos play a major role in crocodilian conservation programs, with some projects made possible only due to zoo support.

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Zoo/Private Partnerships for Fundraising and Conservation

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Abstract

Over the last five years there has been a marked increase in collaboration between zoos and the private sector in support of crocodile conservation. Several focused fundraising events have rapidly gained popularity, including "CrocFests," "CROCtoberfests," and "Scales and Slime." These festivals have a range of themes, but generally include fun, educational activities for people of all ages along with many different, often creative, ways to raise funds. Driven by zoological institutions or by private conservationists with a passion for crocodilians, effective partnerships have evolved through the organization and hosting of these events. These include local herpetological societies, city parks, non-profit zookeeper associations, herpetoloculture-friendly businesses and nature-loving individuals. The festivals and related outreach events have not only increased awareness of the plight of crocodilians worldwide, but have generated a significant amount of funding for field conservation and research. Here we will discuss some of these collaborative efforts, provide examples of creative fundraising, and provide an overview of the amount of funding raised as well as some of the conservation initiatives these funds have supported.

Introduction

n 2005, a small nature center 35 miles north of Chicago, Illinois (Wildlife Discovery Center) held the first "CROCtoberfest" event in the U.S.A. Despite modest beginnings, and being located in an area where there are no native crocodilians, this event has grown into an important annual community event that has raised thousands of dollars for crocodile conservation. Today, many similar events take place around the U.S.A., in facilities from small nature centers, to private facilities, to world-class public zoos. Despite differences in the event setting and the actual activities that take place, most of the collaborative events between zoos and the public have several things in common: they raise awareness about the plight of crocodiles worldwide; they raise funds that can benefit wild crocodile populations; and, they attract people to the event by offering activities that are fun for both children and adults. All of this generally takes place in an informal setting. As more festivals have blossomed, financial support for crocodile conservation projects has increased. Many organizations, from public zoos, museums and aquariums, to cities, colleges, and herpetological societies have joined in the effort, with partnerships growing exponentially each year.

Forms of Collaborative Efforts for Fundraising and Promotion of Crocodile Conservation

CROCtoberfest, Wildlife Discovery Center, City of Lake Forest Parks and Recreation, Lake Forest, Illinois, USA

This one-day event takes place in October of each year and attracts 500-1000 people from neighboring communities. It partners with the Chicago Herpetological Society, Madison Area Herpetological Society, and the Association of Zoos and Aquariums (AZA) Crocodile Advisory Group (CAG). Local businesses and merchants sell items, serve food, and provide a number of interactive activities for visitors. Each year it hosts a special guest speaker, including Dr. Brady Barr, Rob Carmichael, Jim Nesci, Bob Bavirsha and a number of other scientists who share a passion for crocodiles. Also featured are a number of activities, including: face painting; a crocodile scavenger hunt; crocodile geocaching; pet and learn sessions; scout badge challenges; live crocodilians on exhibit; preschool and early childhood story time; and arts and crafts. Wildlife Discovery Center is now planning a 2015 "Gator Golf" event that will be held at Deerpath Golf Club. All proceeds will benefit various crocodile conservation efforts. The event will feature live crocodilians on display, a special "gator hole," and many animal ambassadors from the zoo mingling with the crowds.

Crocodile conservation efforts supported: Philippine crocodiles/Mabuwaya Foundation;Siamese crocodiles/Cambodian Crocodile Conservation Project; American crocodiles/Jamaican Crocodile Project through Caribbean Wildlife Alliance; and AZA Crocodile Advisory Group (CAG)
Amount of funds raised: $45,000.00 USD

San Diego Zoo and SDAAZK Croctober Fest, San Diego, California, USA

This event was held in San Diego on October 21, 2013 at Ono Grind's Café & Grill. It featured an authentic Hawaiian-style BBQ pig with all the fixings, served buffet style. The silent auction items varied from framed reptile photographs to ZooMed terrariums, to stuffed crocodiles and Sea World passes. Live auction items included a package of California Wolf Center tours, an official commemorative basketball and poster signed by Bill Walton, and an autographed NFL football made all the more special by a San Diego Charger player coming out to support the event. A band, called Steel Parade, came all the way from Long Beach, California, and made the night even more festive. Of course, the good beer helped as well. One hundred percent of the proceeds went to benefit crocodile conservation.

Half of the funds raised at the 2013 event will benefit the Gharial Conservation Fund managed by San Diego Zoo Global. The other half was sent to the AZA Crocodile Advisory Group's John Behler Conservation Fund, and earmarked for helping conservation efforts for the Jamaican crocodile, *Crocodylus acutus*.

Assisting the San Diego Zoo in planning, and partnering on the event, was the local American Association of Zoo Keepers' (AAZK) chapter. This is a local membership-based group of zoo keepers from regional zoos and aquariums, including San Diego Zoo, San Diego Zoo's Safari Park, and Sea World San Diego. This AAZK chapter has many years of fundraising experience, having hosted many such conservation events, including Bowling for Rhinos. Accordingly, partnering with such an experienced and engaged group of fellow "zoo" staff has made for a strong collaborative team. This is a great example of how zookeepers from many disciplines are working together to help crocodiles, and the success of this first year, with over $10,000 raised, is very encouraging. The San Diego Association of Zookeepers has committed to assisting with this event annually.

Crocodile conservation efforts supported: Indian gharial/Gharial Conservation Fund, managed by San Diego Zoo Global; and American crocodiles in Jamaica via AZA's CAG John Behler Conservation Fund
Amount of Funds Raised: $10,636.00 USD

Virginia Aquarium and Marine Science Center, Virginia Beach, Virginia, USA

The Virginia Aquarium partners with the public to raise funds via various means for their Research and Conservation Fund. A good portion of the proceeds is dedicated to supporting crocodile conservation. Tomistoma is a signature species for this facility, and it provides significant support for it. This facility also contributes to other crocodilian conservation efforts, such as those driven by the IUCN-SSC Crocodile Specialist Group (CSG), the Tomistoma Task Force (TTF), the AZA CAG and the Florida-based Summer and Christmas CrocFests.

Means by which the Virginia Aquarium raises funds for their Research and Conservation Fund are as follows:

- Public solicitation
  Every person that enters the aquarium to purchase a ticket is asked if they will contribute $1.00 to the zoo's conservation initiatives. With an annual visitorship of over 600,000, and a good portion of guests making the contribution, a strong, consistent funding stream has been developed.
- Guest speaker lectures for membership
  Funds generated from lectures are either earmarked for a specific project or dedicated to the Research and Conservation Fund. For example, Brady Barr provided a lecture, with all funds dedicated to the TTF. Rob Stuebing, whose facility has worked in Borneo for many years on behalf of Tomistoma, was also a guest speaker.
- Behind the scenes tours of the harbor seal and sea turtle facility
  Thousands of dollars for the Research and Conservation Fund are raised annually from this activity.
- Annual fundraising "Black Tie" event, called "Commotion in the Ocean"
  This is another avenue for raising monies for the Research and Conservation Fund.
- Virginia's largest outdoor Aerial Adventure Park – opening June 2014

A percentage of funds that are generated from photo sales in this park will be earmarked for the Research and Conservation Fund.

Crocodile conservation efforts supported: TTF, CSG, CrocFests
Amount of funds raised (2009-present): $45,900.00 USD

Sedgwick County Zoo, Wichita, Kansas, USA

One creative approach to fundraising for crocodiles implemented by the Sedgwick County Zoo involves the dedication of memorials to crocodile conservation. In lieu of flowers, the zoo sends out donations in the name of a lost loved one to a conservation cause. In this case, Sedgwick submitted memorial donations in the amount of 250.00 each to benefit the conservation of Philippine crocodiles. The funds were dedicated to the Mabuwaya Foundation's CROCS program, whereby school children are sponsored with school supplies. The same children help care for headstarted Philippine crocodiles in San Mariano, Luzon, and after about 18 months, help release the juvenile crocodiles to the wild. Generally the school children name their crocs, but in these cases, the crocs were named for the person being remembered. Gladys Porter Zoo collects the funds and transfers them to the Mabuwaya Foundation.

Crocodile conservation efforts supported: Philippine crocodile/Mabuwaya Foundation

Dallas World Aquarium, Dallas, Texas, USA

The Dallas World Aquarium (DWA) held their first CroctoberFest event on October 19, 2013. Activities were set up throughout the halls of the aquarium in order to reach as many people as possible. The goal was to increase the public's awareness of crocodiles and the need to conserve them. Funds raised were sent to the AZA Crocodile Advisory Group.

There were informative and interactive stations set up with crocodile facts, artifacts, and games. Guests got to see real crocodile eggs, compare the skulls of crocodiles and alligators, and put what they had learned at the various stations to the test. A silent auction featured National Geographic memorabilia as well as artwork produced by representatives of the six critically endangered crocodilian species. Crocodile specialists from the National Zoo, the San Diego Zoo, and Chicago's Brookfield Zoo presented posters on captive-reproduction strategies, field work, and behavioral studies being conducted at their facilities.

DWA also introduced their new mascot at the event – Coco the black caiman. Coco was on hand for photo opportunities, and made some media appearances promoting the event. Other activities included "Meet the Keeper" sessions, during which time zookeepers shared information on DWA's crocodiles and caiman. They also conducted feeding and training demonstrations.

A fundraising luncheon was the main event and Dr. Brady Barr from National Geographic was the keynote speaker. Colette Adams from the Gladys Porter Zoo and DWA’s Luis Sigler opened the lecture series, each discussing the different roles that zoos and aquariums play in the conservation and captive management of endangered species. Carl Franklin from University of Texas at Arlington presented on the American alligator population in the Metroplex, and Brady Barr closed the program with an exciting and entertaining presentation. It was replete with photos and videos of adventures he shared with crocodiles during his career working with National Geographic.

Crocodile conservation efforts supported: AZA Crocodile Advisory Group
Amount of funds raised: $1,700.00 USD

St. Augustine Alligator Farm, St. Augustine, Florida, USA

St. Augustine Alligator Farm (SAAF) has an average annual attendance of 200,000. Donations for crocodile conservation projects are collected via “Big Belly Banks,” placed strategically around the park. Guests are encouraged to drop their loose pocket change into the slot of the banks in lieu of tossing it in the water or throwing it at the crocodiles. The banks are unique and compelling and visitors enjoy introducing their coins into the mouth of the crocodile bank and then watching it follow a wavy course into the “belly” of the bank. These coins are routinely collected and the money is set aside to support various crocodilian conservation efforts.

Crocodile conservation efforts supported: Black caiman project; CAG; Philippine crocodile/Mabuwaya Foundation; Siamese crocodile; CSG; African slender snouted crocodile; African dwarf crocodile
Amount of funds raised (since 2009): $13,721.00 USD

Greenville Zoo, Greenville, South Carolina, USA

Greenville Zoo’s “Quarters for Conservation and Zoo Conservation Fund” helps enhance the zoo’s wildlife conservation efforts. Through the collection of quarters, the zoo and the local community partner to provide much needed funding for new and existing wildlife conservation projects in their region and around the globe.

Money collected through the Quarters for Conservation program is allocated to a restricted account with the sole purpose of enabling the Greenville Zoo to participate in a variety of conservation programs locally, regionally, and globally with an emphasis on field conservation. This restricted account is funded by admissions and membership sales.

- $0.25 from each admission fee
- $3.00 from each annual membership

At each visit, visitors and members will receive a "quarter" token that enables them to vote for one of four selected conservation projects. A centrally located Conservation Kiosk tells the story of each of the four projects via photos and a short written explanation. How much funding each project receives is determined by how many tokens have been placed in each corresponding bank by zoo visitors. In 2013, the Philippine Crocodile captured 21percent of the vote. This was a smaller percentage than Orangutan International and Project Puma, but there is some significance in the fact that it actually got more votes than a civet (another mammal)!

Project	Votes	Percentage
Orangutan International	66,290	35.67
Project Puma	46,961	25.27
Philippine Crocodile	38,777	20.86
Owston Civet	33,832	18.20

Cape May County Zoo, Cape May Court House, New Jersey, USA

An annual evening event, called "Scales and Slime," takes place at the Cape May County Zoo in August of each year. This event is conducted by the AAZK Cape May County Zoo Chapter and features an evening of games, and activities. Then visitors get a behind the scenes tour of the Reptile House. Proceeds help relocate displaced American alligators in New Jersey to a preserve in Florida. Attendance has grown over the past two years, with last year's attendance at 97 (double the first fundraiser).

The Cape May County Zoo also raises money for crocodile conservation through the use of a simple donation box placed at the crocodile exhibits. All donations are matched by the AAZK chapter.

Crocodile Conservation Efforts Supported: Tomistoma; Siamese crocodiles; Cuban crocodiles
Amount of funds raised: $6000.00 USD

Summer and Christmas CrocFests, Florida, USA

What started out as a backyard get together to celebrate Ralf Sommerlad's visit to Florida in 2009 evolved into a biannual event in central Florida that, as of May 2014, has raised over $64,000.00 USD for five species of crocodiles.

From $1,005.00 raised by 30 people in 2010 at the Summer BBQ for Crocs to a regular fiesta that now attracts as many as 185 people per event and raised $26,000.00 for Jamaican crocs in 2013, this has become a very popular event. Attendees, mostly reptile enthusiasts, come from throughout North America and beyond to socialize, eat good food, drink beer, and attend a fun-filled auction – all to raise money for a good crocodile cause.

Zoos contribute by sending auction items, including animal art and items from their gift shops. They also contribute about a third of the total proceeds via cash contributions. The Gladys Porter Zoo collects the money and then transfers it to the CrocFest beneficiary. Attendees to the event pay $25.00 for all they can eat and drink, and many of them bring an auction item as well. Until recently, the organizers shouldered 100 percent of the expenses involved in putting on the CrocFest. However, increased attendance equaled increased expenses, and corporations such as Ship Your Reptiles/The Reptile Report, Shawn Heflick's Crocodile Manor, Flavio Morrissiey's Gator Adventure Productions, Bone Clones, Inc., the Canadian Reptile Breeders Expo and ZooMed have stepped up to help out with either cash sponsorships or top-notch items for the auction.

A celebrity is a good draw for a public event, and Shawn Heflick, of Nat Geo Wild's Python Hunters fame, is one of the organizers. He and his wife, Jen, have hosted Christmas CrocFests for the last three years. Attendees enjoy touring Shawn's facility and visiting with his personal crocodile collection. They also get to kayak on the lake behind his property. To add to the entertainment, Flavio Morrisiey's employees put on exhibition on alligator handling, which is usually followed by many attendees having their picture taken with the gator. Curt Harbsmeier often brings a crocodile from his collection to the event, and does a great deal of the fundraising and clerical work. Colette Adams helps raise funds as well, and generally travels from her zoo in south Texas to help with the auction.

Crocodile conservation efforts supported: Chinese alligators; Philippine crocodiles (Mabuwaya Foundation); Siamese crocodiles (Flora and Fauna International); Orinoco crocodiles, and; American crocodiles in Jamaica (Caribbean Wildlife Alliance)
Amount of funds raised: $64,000.00 USD

Conclusion

Festivals featuring crocodilians are becoming very popular all over the United States and this concept is now being implemented in other countries. In June of 2015, Canada hosted its first CrocFest event to raise money and awareness for croc conservation. Hosted by Reptile Camp, Little Ray's Reptile Zoo and Reptilia, the first year event will raise money for the Indian Gharial Project.

In order for long-term crocodile conservation and research to be successful, awareness building and education are as necessary as fundraising. All must be implemented concurrently. These events also provide unique opportunities to promote public-private partnerships and collaboration. Most of them require minimal direct costs but a great deal of labor, organization and collaboration. Fortunately, they can generate impressive profits that are earmarked for crocodile conservation. Many species of crocodilians are facing challenges due to human encroachment. While humans, in most cases, are the problem, they can also play a significant role in the solution. The events previously described are just a few of the ways to provide much needed awareness and support . . . all to create the synergy needed to give crocodiles a fighting chance.

Behavioral Conditioning to Assist in Crocodilian Conservation

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Abstract

Traditional methods of capture and restraint have been the standard methods used in most if not all crocodilian research and conservation projects. We highlight several examples of the effectiveness of classic and operant conditioning in crocodilians with no compromise to the welfare of the animals or safety of the staff. These methods are now widely used in captive management of crocodilians. Possible application of these methods in *in situ* crocodilian conservation projects is examined through proposed methods and case studies. Success is dependent upon the evolution of the systems implemented for conservation.

Example-1

Omaha's Henry Doorly Zoo and Aquarium is currently harvesting semen from 2 unrestrained male American alligators (15 years old, 3.35m, 117kg and 30 years old, 3.2m, 113kg). This is the pinnacle of years of target training and tactile desensitization work. Individual animals are called onto land and expected to target in various locations and tolerate any tactile manipulation we deem useful to captive management. This includes allowing us to extract their phallus and rinse the penile canal of all semen collected there.

Example -2

Omaha's Henry Doorly Zoo and Aquarium is also harvesting semen from one Philippine crocodile (est. 47 years old, 2.43m, 50kg) with protective contact. The croc is targeted into the opening of a shift area where a sliding door can be closed just enough to narrow the gap without pinching the croc. Staff can then safely perform semen collection and other tactile manipulation on the caudal half of the body of this non-sedated adult male crocodile. 4 female Philippine crocodiles (14 years old, 1.31m, 8kg) are also being conditioned to walk up a ramp and into a crate. The crate is fashioned with small trap doors that can be opened to allow access to specific parts of the croc body, including the vent region. Keeper and Vet staffs have successfully performed endoscopy procedures to determine the exact location of the oviduct for future artificial insemination. Future plans involve using ultrasound to track follicular development through the season to determine the best time for insemination. The hopeful end point is the successful insemination of an unrestrained female Philippine crocodile.

Example-3

Gator Adventure Productions has used desensitization to successfully draw blood from an estimated 15 year old male American Alligator unrestrained in a water situation. The alligator is housed with 4 male alligators, and are all part of a daily training program to better manage them. The alligator that is being desensitized is called over by his name (Blue) by a primary trainer and is cued to station in an accessible position for the secondary trainer. While Blue is being stationed, the secondary trainer is vigorously desensitizing the tail area. The desensitization process continues to become more vigorous with each session, until a needle is applied to skin between scales along the sides of the tail. This is followed by inserting the needle into the muscle of the alligator. The primary trainer is holding the animal in a still position while rewarding the still alligator in increments of 30 seconds. This process is repeated each session for no more than 4 minutes each session. Sessions were conducted on an intermittent schedule with the same two trainers. After 6 sessions over a 4 day period there was a successful blood draw. This quick success was attributed to previous daily training used to manage the alligators. Daily maintenance behaviors consist of calling over to trainer's location for general inspection, name recognition, hold behavior and away behavior. These are base behaviors for any future behaviors to be developed for management.

Increasing People Participation in Crocodile Conservation: Zoos as Agents for Change

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Abstract

Thousands of species around the world are threatened with extinction. The threats are driven by people and the choices we make. The world's zoos attract more than 700 million visitors annually and many more on-line and via social media, and have huge capacity to engage people in conserving wildlife. Zoos Victoria is using social science methodologies to influence positive behaviour change for wildlife. Community conservation campaigns use a Connect-Understand-Act model that links animals in our zoos and visitor-driven threats in the wild, provides actions people can take and measures social change and wildlife outcomes. "Seal the Loop", targets marine entanglement threats to fur seals, resulting in 10km of fishing line placed in collection bins each year rather than the in sea, supported by 59 community groups. "Don't Palm Us Off" links orang-utans in Melbourne Zoo with their 'palm-oil driven decline' and has influenced more than 200,000 people to ask for palm oil to be labelled on all products containing it, stimulated a bill in the Australian Parliament and caused all six major palm oil users in Australia to make time-bound public commitments to only use Certified Sustainable Palm Oil. Key factors in the success of this approach are evidence-based rigour; making people part of the solution and removing the barriers to them taking action; focused messages; and measurable targets. The process complements and enhances field-based recovery programs, and can be applied to threatened crocodilians if the campaign selection criteria are met.

Introduction

Initiatives such as the United Nation Global Compact and the Millenium Alliance for Humanity and the Biosphere make clear that environmental issues now constitute one of the most significant challenges facing humanity (MAHB 2013; Global Compact 2014). Indeed, it could be argued that this is the most urgent challenge, as healthy societies and economies are underpinned by a healthy environment. Reports from the Intergovernmental Panel on Climate Change highlight that human actions are driving climate change, over-consumption of the Earth's resources and a loss of biodiversity (Stern 2007, IPCC 2014).

Human impacts on other species have been especially dramatic, with the latest International Union for the Conservation of Nature's (IUCN) Red List highlighting that more than 11,000 species, or 21% of animal species in the groups assessed are threatened with extinction (IUCN 2013). Further, the pace of threat has increased over recent years, despite increased awareness of the challenge and the best efforts of committed people (St. John *et al*. 2010). For reptiles, the numbers of threatened species in the Critically Endangered, Endangered and Vulnerable categories have increased by an average of 49% from 2008 to 2013 (http://cmsdocs.s3.amazonaws.com/summarystats/2013_2_RL_Stats_Table2.pdf) . Ten of the 23 currently recognized species of crocodilians are listed as threatened, with a further two species considered as Lower Risk-Conservation Dependent (http://www.iucncsg.org/pages/Conservation-Status.html).

If we start from the premise that people are at the heart of the current pressures on the environment in general and species in particular, either directly or indirectly, then engaging effectively people in solutions is critical. Many hundreds of thousands of people around the globe are working hard to do just that. But in the context of the impact of zoos in crocodilian conservation, the question is have zoos influenced people to take conservation action, despite attracting more than 700 million visitors through their gates each year?

Historically, zoos rested on the four pillars of recreation, education, conservation and research (IUDZG/CBSG [IUCN/SSC 1993). With a handful of exceptions, zoos contributed very little to conservation until the late 20th century. That is now changing rapidly and zoos globally are important players in species conservation, at home and abroad (WAZA 2005; Gusset and Dick 2010 & 2012).

Education in zoos has followed a similar path. Traditionally, it was expected that education outcomes in zoos be achieved through viewing animals and their exhibits, reading signs and other interpretive material, and 'structured learning' by school groups and guided tours (Anderson 2003). But there is debate about the effectiveness of that approach in terms of measurable increase in visitor knowledge or understanding of biodiversity and its challenges, let alone leading them to conservation action (Mazur and Clark 2001; Marino *et al*. 2010). Indeed, it is now widely accepted in zoos that the 'information intensive' approach is ineffective at inspiring conservation action (Weiler and Smith 2009). More recent studies point to improved 'educational practices', adoption of new engagement techniques and rigorous evaluation leading to significant increases in visitor awareness and an appetite for taking action in support of threatened species (Moss *et al*. 2014; Pearson *et al*. 2013; Pearson *et a*l. 2014). Critical to successfully engaging zoo visitors and influencing them to take action is understanding their perceptions, beliefs and attitudes (MacDonald and Gavin 2010).

These changes in zoos and their approaches are part of a transformation to becoming zoo-based conservation organisations, which started in 2005 with the launch of the World Zoo and Aquarium Conservation Strategy (WZACS) (WAZA 2005). Following the first World Zoo Conservation Strategy published a decade previously, the core of the WZACS was "integrated conservation", ie. "*when all the activities of a zoo or aquarium are linked to one another conceptually and strategically coordinated internally and externally; with their main aim being the conservation of threatened species, their habitats and their human neighbours*" (WAZA 2005).

Conservation at Zoos Victoria

Zoos Victoria adopted a new 20 year mission/vision in 2009 to become the 'world's leading zoo-based conservation organisation" and is delivering 'integrated conservation' through aligning everything we do under five Action Areas – Conservation, Animals, People (Staff), Visitors and Financial Sustainability (Zoos Victoria 2009). Key to achieving our goal is unification of effort and rigorous evaluation under an overarching banner of Fighting Extinction.

Conservation effort is focused on two fronts, which complement and enhance each other. *Wildlife Conservation* is work to conserve threatened species and support direct conservation activities that have tangible conservation benefits, ie. native threatened species recovery programs, international conservation partnerships and grant program, and a suite of research projects designed to answer conservation questions for native species.

Community Conservation supports conservation and environmental sustainability by engaging with and influencing the behaviour of our visitors, community and stakeholders; and advocating for wild places and wildlife. At Zoos Victoria this is achieved through careful design of zoo interfaces, such as zoo exhibits and their messages, visitor experiences and learning programs. Community Conservation Campaigns extend this focus into the visitor sphere using our Connect-Understand-Act (CUA) model (Lowry 2009). The CUA model was first developed to guide zoo-based 'visitor conservation campaigns' and engagement at ZV, following evaluation of education programs that demonstrated effectiveness at raising awareness, but failed to influence behaviours leading to conservation action (Lowry 2009).

Some campaigns aim to alleviate threats to critically threatened species, whilst others aim to alleviate threats to habitats and species to ensure that they do not reach a dire state. They are selected using criteria that evaluate if will make a difference, capacity for ZV to access the identified target audience, capacity for the relevant ZV property to deliver a rich experience and likelihood of approval from the Victorian Government. A Value-Effort matrix is used to capture the assessment results and a decision is only made to take a campaign proposal forward if it is High Value and Low Effort.

The CUA model is used to guide ZV's work across all community interfaces to ensure that we effectively target attitudes, knowledge and behaviours that are sensitive to conservation needs. The model draws upon the strengths of three disciplines - Conservation Science, Education and Social Science, to determine the threatening processes that ZV visitors can alleviate, and how best to utilise engaging and fun tactics to achieve community conservation outcomes. Applications from Community-Based Social Marketing is are used throughout this process, drawing on its four phases: (1) uncovering barriers to behaviors and then, based upon this information, selecting which behavior to promote; (2) designing a program to overcome the barriers to the selected behavior; (3) piloting the program; and then (4) evaluating it once it is broadly implemented (McKenzie-Mohr & Smith, 1999). Community-based social marketing merges knowledge from psychology with expertise from social marketing (see also Geller, 1989).

Zoos Victoria is operating six Community Conservation Campaigns. Although none target a crocodilian species, the approaches undertaken could equally be applied to a threatened reptile. Two of the campaigns, one having a local focus and other international, exemplify what can be achieved using a community-based social marketing approach designed to achieve behavior changes that benefit wildlife.

"Seal the Loop"

Studies have shown that almost 1,500 seals die annually from entanglement along Australia's coast (Page *et al.* 2004), along with countless numbers of sea birds, reptiles and other marine mammals. Australian pinnipeds are recorded as having amongst the highest documented rates of entanglement in the world (Ceccarelli 2009). Zoos Victoria provides veterinary care for many wildlife entanglement victims each year, with fishing line being a consistent factor impacting rescued marine animals. This includes the Australian Fur Seal (*Arctocephalus pusillus doriferus*), which is part of ZV's Melbourne Zoo animal collection and occurs naturally in Port Philip Bay within 15km of the Zoo.

Zoos Victoria decided to address this issue through the "Seal the Loop" (STL) campaign, with the objectives of:

- Reducing the threat that fishing waste and plastics pose to the marine environment through encouraging recycling behaviours and installing specially designed bins on ports and piers.
- Helping people understand the impact they have on the health of the marine environment.

Don't Palm Us Off"

Orang-utans (*Pongo pygmaeus*) are under severe pressure in the wild and most wild populations will disappear over the next few decades unless current threats are reduced (Meijaard *et al*. 2011). Conversion of tropical forests in Borneo and Sumatra, largely driven by oil palm plantations, is the major factor driving the species current decline (Nantha and Tisdell 2009, Wich *et al*. 2011, WWF 2011).

Zoos Victoria (ZV) exhibits orang-utans at its Melbourne Zoo property. Our visitors contribute to the threat faced by orang-utans through purchasing products containing palm oil – but they do this unknowingly because palm oil is not labelled in Australia. To address this, Zoos Victoria established the "Don't Palm Us Off" (DPUO) advocacy campaign that aims to:

- Change food labelling legislation in Australia and New Zealand, so that labelling of palm oil becomes mandatory in all food products containing it.
- Increase public awareness of the link between palm oil, food products and risks to orang-utan survival.

The campaign is not about saying no to palm oil.

Methods

A. Seal the Loop.

The campaign was launched at Melbourne Zoo in December 2009, coinciding with the opening of the Zoo's Wild Sea exhibit. The campaign targets two audiences – Zoo visitors and fishermen along Victoria's coast (Banks and Sanders 2012). Zoos Victoria partnered with the University of South Australia (UniSA) to survey responses to the STL campaign from visitors to Melbourne Zoo and people using the Victorian coast where STL bins were installed (Mellish in prep., Pearson *et al*. in prep.).

The STL campaign has two main elements:

1. Visitor engagement at Melbourne Zoo.
   The Zoo's daily seal show for visitors promotes natural seal behavior and was redesigned to incorporate the STL campaign. The impact of discarded fishing line and general waste on seals and other marine wildlife was highlighted by the presenters.

   A survey of 164 visitors to Melbourne Zoo was conducted between 30 September and 6 October 2013, to assess (1) the effectiveness of the exhibit and visitor show vs. exposure to the exhibit only, and (2) the call-to-action donation point.

2. Community engagement along the Victorian coast.
   Twenty collection bins were installed at fishing locations in a five month trial along the Victorian coast, starting in November 2010. The trial's results gave confidence in extending the project and additional STL bins were installed around Port Philip Bay on which Melbourne is located, and approximately 400km along the Victorian coast to both the east and west of Melbourne.

   A survey of 213 people was conducted at four sites on the Victorian coast where STL bins had been installed. The research was undertaken from 15-20 January 2013, to measure (1) general public awareness of marine wildlife entanglement and the 'Seal the Loop' initiative, (2) attitudes toward marine animals and (3) self-reported behaviour pertaining to waste in marine environments.

B. Don't Palm Us Off"

The campaign was launched in August 2009, initially using petition-based postcards. Returned postcards were forwarded to Food Standards Australia and New Zealand (FSANZ), the body responsible for mandating labelling on food products in Australia and New Zealand. FSANZ declined to act on consumers' requests to have palm oil labelled, but the cause was taken up by

Australian senators, resulting in the "Truth in Labelling Bill (Palm Oil) (2009)" being passed by the Australian Parliament's Upper House.. An on-line version of the postcard, community service announcements and high profile celebrity support added to the campaign's reach (www.zoo.org.au/palmoil) (Pearson *et al*. 2013).

In Phase 2 of the campaign (2012-13), ZV engaged with stakeholders across the palm oil industry, including the Roundtable on Sustainable Palm Oil (RSPO) and the Malaysian Palm Oil Board, to identify barriers at the supply end.

In May 2013, ZV launched the Zoopermarket (www.zoo.org.au/zoopermarket) in Melbourne Zoo's Orang-utan Sanctuary display. This interactive experience allows Zoo visitors to scan common grocery products to see which companies are using Certified Sustainable Palm Oil (CSPO) or are committed to doing so, and enables the visitor to email the company and urge that palm oil is sustainably produced and clearly labelled.

Connect-Understand-Act

Development and implementation of the CUA model is an 8-step process (Fig. 1):

Step 1. Select the Threatening Process: determine which threatening process to help alleviate. This requires extensive research to ensure that the threat is relevant to the zoo and its visitors.

Step 2. Identify the Ambassador Species: select a suitable ambassador species in the zoo's animal collection that will most effectively engage visitors with the selected threatening process. Zoos Victoria uses a Species Selection & Assessment Tool to guide this, always aiming to choose an Ambassador Species that scores the highest possible value on the Values axis of the Assessment tool. The Tool uses a series of Value and Effort criteria to determine both a qualitative and quantitative assessment of each species in the zoo collection (Embury 2014).

Step 3. Identify a target audience: first ensure that zoo visitors and the broader community can realistically influence this threatening process with the help of the zoo. Then identify which sector of the community is the target audience, e.g. teenage boys, parents with young children, etc. This becomes even more important when applying the CUA in a field program, where it may be one demographic that is driving a threatening process, e.g. adult men hunting wildlife, or young women cutting brush for firewood.

Step 4. Select target behaviour: identify one behaviour (or 'action') that you want the zoo to influence that will help to alleviate the threatening process (and therefore make a difference) through collective community action.

Step 5. Confirm enduring understanding: identify an understanding that compliments your target behaviour (action). This is often an ecological understanding that provides context for why it is important to take a specific action for wildlife.

Step 6. Identify the connection opportunity: zoos have enormous potential to ignite emotional connections between people and wildlife. Consider ways in which visitors can get the opportunity to 'connect' with the selected ambassador species. In a zoo setting, precinct design, exhibit design and program design will all play critical roles in ensuring that visitors have the best opportunity to experience powerful connections with the species and animals involved. Best practice exhibit and interpretive design principles need to be used to maximize this opportunity.

Step 7. Select the appropriate CUA tools: ZV has developed a range of approaches (tools) that are applicable for each of the Connect, Understand, and Act phases of the model. The CUA toolkit is used to decide which tools within each phase will best enable the zoo experience to influence attitudes, knowledge and behaviours of visitors to ignite emotional connections, facilitate enduring understandings and inspire action (Fig. 2). A similar approach applies in the field.

Step 8. Determine measures to enable outcomes to be evaluated: agree on targets and determine the measures to be put in place to enable the impact of the community conservation initiative to be assessed.

Figure 1. Zoo Victoria's Connect-Understand-Act model.

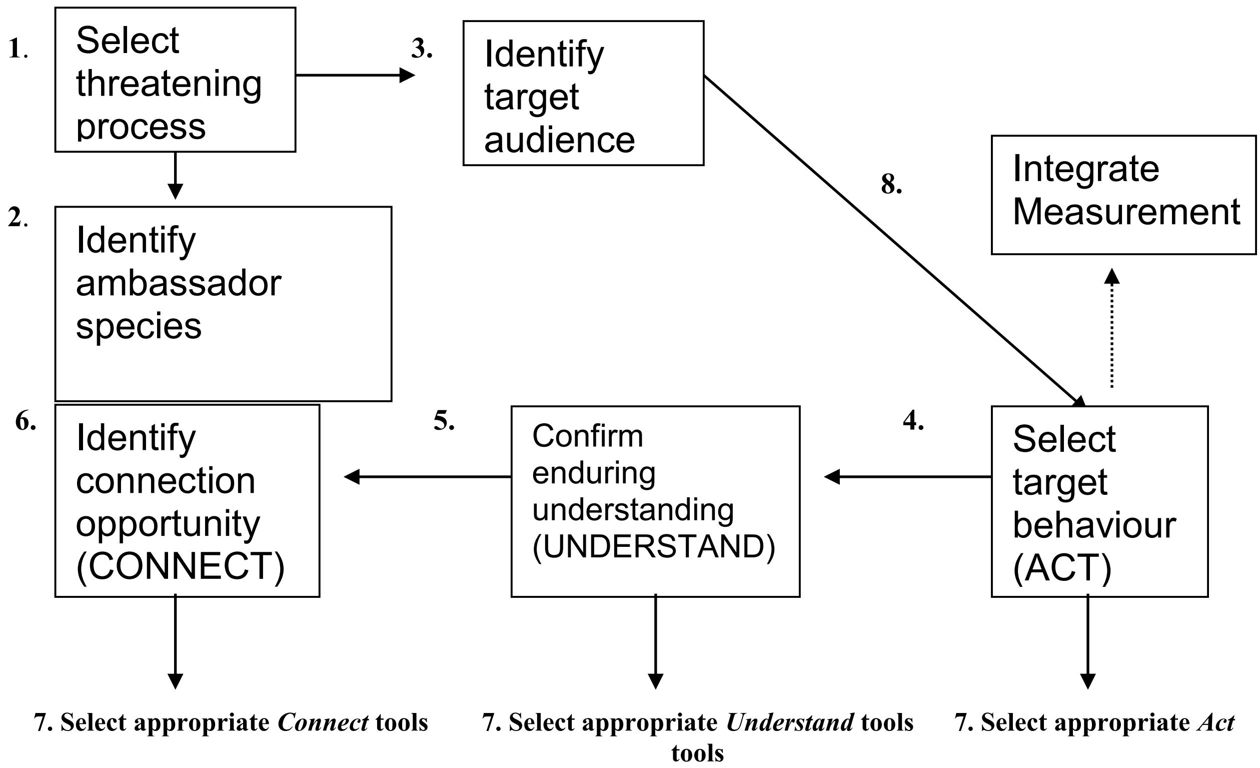

Figure 2. Zoos Victoria's Connect-Understand-Act toolkit.

	CONNECT	UNDERSTAND	ACT
TOOLS	Tactile Close encounter Observation Tell a story (*includes characterising animals)* Get personal Unique insight (*includes discovery, unexpected, surprise)* *Role Play/Drama*	Observation Analogy Provoke Thought Tell a story *(includes Anecdotes)* Props Be Relevant - Location, Location, Location Role Play Get Active/Interactive *(includes Games)* Questions – closed, open & rhetorical	Remove Barriers Incentive Eco-badging Likeness/Social Norms Commitment Prompts Persuasive language *Convenience* *Walk the Talk* *Join others (link)* *Feedback* *Access experts* *Salience* **Targeted Behaviour, Tangible Action*
	Fun – ‘ham it up’ humour or performance, ‘Dr Doolittle’ talk to your animal, fun facts, rhymes		
	Engage all senses	Layered	Themes

Results

A. Seal the Loop

1. Visitor engagement at Melbourne Zoo.

The research focused on three areas:

Participants/satisfaction:

- 18.3% of exhibit & show visitors reported conservation issues as the most interesting aspect of their visit. This was not reported by exhibit-only visitors.

Visitor Learning:

- More than 75% of Zoo visitors who viewed the seal show reported learning something new from their visit, compared to 30.9% of exhibit-only visitors.

2. Community engagement along the Victorian coast.

A. Bin installation:

- Following a five month trial in 2010 in which 20 STL collecting bins were installed, 170 bins are now in place along the entire length of the Victorian coast.
- More than 9km of fishing line is being collected each year (25m per day).
- Bins are collecting 73% of fishing waste vs. general waste (cigarette butts, etc.).
- More than 2,000 hooks, lures and bait bags placed in the bins each year.
- 20 STL bins have been installed in Western Australia.
- 59 Victorian government and community groups monitoring and emptying the bins.

B. Community awareness and attitudes:

Public attitudes toward marine wildlife:

- 98% felt very strongly that all marine species have a right to exist in their natural environment.
- 92% of people agreed it is humans’ responsibility to protect marine animals from extinction.

Understanding of marine wildlife entanglement:

- 70% were able to provide a basic overview of what this means.
- Marine entanglement was viewed as a significant issue by people.
- Fishing and then plastics were perceived as the primary types of waste responsible.
- Fishing activity and ignorance/carelessness by people generally were seen as main contributing factors.

Perceptions of the STL program:

- 12% of the sample had some awareness of STL.
- 56% of the people surveyed indicated that STL had an impact on their waste disposal behaviours.

The campaign's initial success resulted in additional outcomes:

1. Establishment of a Marine Response Unit at Melbourne Zoo: this is a first for the state of Victoria and is funded through a three year partnership between ZV, AGL Energy Ltd and the Victorian Government.

2. Annual STL community action days organized by ZV:
   - In November 2013, 250 community members collected 70 bags of rubbish and 1.4km of fishing line removed from two coastal sites (one close to Melbourne and other 350km to the west).
   - 63% of surveyed participants said that the event changed the way they will dispose of waste near water environments in the future and 81% said that it had a strong impact.

3. Commitment from New South Wales to implement the program in 2014.

B. Don't Palm Us Off.

- In the campaign's first two years more than 160,000 people sent signed postcards.
- Community awareness of the threats to orang-utans increased from 53% to 97%.
- The "Truth in Labelling Bill (Palm Oil) (2009)" was passed by the Australian Parliament's Upper House.
- Five of the six major users of palm oil in Australia made public time-bound commitments to switch to CSPO by 2015.
- More than 24,000 community actions supporting sustainable palm oil and clear labelling were recorded in the first 8 months of the 'Zoopermarket'.
- An additional five Australian companies have committed to using only sustainably sourced, deforestation-free palm oil.
- In September 2013, ZV was invited to present the DPUO campaign internationally at the RSPO European Summit and RT11 meeting.

Discussion

The amount of fishing line and plastic waste being deposited consistently in the STL bins suggest that the campaign's first objective is being achieved, ie. "reduce the threat that fishing waste and plastics pose to the marine environment through encouraging recycling behaviours and installing specially designed bins on ports and piers." There was no pre-campaign data on the amount of discarded fishing line and plastic waste occurring annually on Victorian beaches, but it is reasonable to assume that NOT having 9km of fishing line less and 2,000 hooks and lures, etc. in Victorian waters each year is a benefit to marine wildlife.

The visitor research conducted at Melbourne Zoo indicated that the seal exhibit plus show is effectively mobilising conservation support from the public. Implicit within this finding is that the STL campaign is “helping people understand the impact they have on the health of the marine environment” – the second objective of the STL campaign. The surveys of people using the coast near where STL bins were located indicated an existing high level of care for the marine environment, although less understanding of the extent of marine entanglement. Many people also urged more education of the general community to increase awareness of people’s impact on the marine environment and the need to reduce litter in particular. This will feed into reviews of STL and how it could be extended to other sectors of the wider Melbourne/Victorian community.

The DPUO campaign has not yet resulted in a change to food labelling legislation in Australian and New Zealand, making palm oil labelling mandatory for all products containing it. However, the campaign increased community and political awareness of this goal, and subsequent communication suggests that the goal of mandatory labelling of products containing palm oil has not disappeared and is likely to re-emerge when political conditions are more favourable. The campaign did, however, significantly increase community awareness of the link between palm oil, food products and the risks to orang-utan survival. Whilst these links are understood within zoo and conservation circles, it was very apparent from community responses to DPUO that those relationships are poorly known among the general public.

The attitudinal research of zoo visitors showed strong retention across all measures – knowledge of the issues, support for palm oil labelling, etc. - 12 months into the campaign and six months after it ended. Visitors rated the DPUO experience at the Zoo as very satisfying and enjoyable, and were enthusiastic about being able to take specific actions, rather than only being presented with information about threats to orang-utans. This reinforces the notion that zoo experiences can be both enjoyable and provide ‘education’ that encourages conservation action (Ballantyne *et al.* 2007).

The extensive community uptake of, and participation in these two campaigns were significant factors in the subsequent additional outcomes that were not foreseen when the campaigns were initiated. Seal the Loop enabled establishment of Victoria’s first Marine Response Unit and a major zoo-government-private partnership; whilst DPUO resulted in changed buying practices by 10 national/global companies and invitations to ZV to participate in global workshops on palm oil (Banks and Dunstan 2014). These outcomes demonstrate the significant external reach of zoos when they are innovative and committed to species outcomes in the wild.

Zoos Victoria’s Community Conservation Campaigns draw heavily on behavior change approaches such as community-based social marketing (McKenzie-Mohr 1999; McKenzie-Mohr *et al*. 2012). This is based on research demonstrating that behavior change is most effectively achieved through initiatives delivered at the community level that focuses on removing barriers to an activity while simultaneously enhancing the activity’s benefits (Andreasen 1995, McKenzie-Mohr *et al*. 2012). Social marketing also underscores the importance of strategically delivering programs so that they target specific segments of the general community and overcome the barriers to that segment engaging in the behavior. Adopting these elements in the ZV campaigns demonstrated that use of appropriate tools will increase the likelihood of successfully connecting with people, strengthen understandings and influence behaviours – the CUA model.

Human behavior and its relationship with biodiversity conservation in the field is not a new concept and its significance has been recognized by various authors, e.g. “conservation is primarily not about biology, but about people and the choices they make” (Balmford and Cowling (2006); and “conservation can only be achieved by changing behavior” (Schultz 2011). However, it is only relatively recently gaining traction in mainstream conservation journals (Mascia *et al.* 2003; Ehrlich and Kennedy 2005; Shultz 2011). The use of social marketing techniques is also starting to appear, an example being to enhance conservation outcomes in land-use planning in South Africa highlights the potential for this approach benefit *in situ* species conservation (Wilhelm-Rechmann *et al.* 2013).

Zoos Victoria is also adapting the CUA model to apply in the field. A pilot eco-social project is underway at one of ZV's international conservation partnerships in northern Kenya with the Northern Rangelands Trust and its Melako Community Conservancy (B. Squires pers. comm.).

But what about crocodilians? Every species is held in zoos around the world, in a combined total of more than 340 institutions in March 2014 (ZIMS 2014). Many species are in zoos situated within the species natural range, including the Crocodile Specialist Group's seven species currently most in need of urgent conservation intervention, ie. *Alligator sinensis, Crocodylus intermedius, C. mindorensis, C. rhombifer, C. siamensis, Gavialis gangeticus* and *Tomistoma schlegelii* (CSG 2014). The threats to crocodilian species are well-understood, including habitat loss, direct killing and human-crocodile conflict. The latter issue is a particular focus of the Crocodile Specialist Group, as evidenced by a CSG Working Group for Human-Crocodile Conflict and 10 papers presented on this topic at the 2012 regional meeting (see CSG 2013).

The ZV campaigns address the same broad range of threats as those faced by crocodilians. They also target critical underlying factors such as low community awareness of the species, negative attitudes, and poverty. Dealing with these underlying causes rather than just the symptoms of human-wildlife conflict, etc., is essential if we are to save species, particularly in developing countries where the human populations are also under severe pressure.

It is not difficult to see zoos effecting the Connect and Understand components of ZV's Connect-Understand-Act model. Many zoos holding crocodilians already deliver Connection and Understanding through interpretation and on-site 'crocodile shows', although some adjustment may be required to enhance a more empathetic approach rather than one based more on shock and fear. Act is the element most widely missing, but I am sure than innovative thinkers can find ways to address this and develop meaningful outcomes for crocodilians and the people who live with them.

Use of social science-behaviour change processes rarely appears in published literature on crocodilians. One exception is a project to understand knowledge of and attitudes towards crocodiles and their interactions with people in southern Sri Lanka, as the first step in addressing human-crocodile conflict (Samarasinghe 2013). People were also surveyed about barriers to implementing solutions and a range of solutions were presented. However, the abstract included in the CSG Proceedings did not elaborate on the processes used, nor how proposed solutions addressed or aligned with survey outcomes. Notwithstanding this, the project would appear to be a good start and suggests the potential for positive outcomes for people and crocodiles in the project area. Moreover, could it be a model for addressing human-crocodile conflict elsewhere in Sri Lanka?

In the context of this CSG 'zoo session' on the role of zoos in crocodile conservation, it should be noted that Sri Lanka has four zoos. Only one, however, is a WAZA member – the National Zoological Gardens in Colombo (WAZA 2014). The ZV campaigns outlined above suggest the potential for a program linking crocodiles in, and visitors to the National Zoo; people and crocodiles along the Nilwala River in southern Sri Lanka; and other external partners such as the Young Zoologist's Association (YZA) of Sri Lanka. Moreover, noting that the YZA is based at the National Zoo, it may be that this notion is further advance than the presented abstract suggests.

Zoos globally are already contributing to preventing the extinction of the world's crocodilians, but the use community-based social marketing by zoos to effect positive behavior change offers great potential for zoos to expand their conservation outcomes for threatened crocodilians.

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Collaborative Efforts for Captive Breeding and Reintroduction of *Crocodylus siamensis* in Cambodia

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When you think of the collaboration among organizations over the last 20 years that have worked together to save the Siamese crocodile you think of Government, non-Government conservation groups, zoos, individual donors, etc. At the heart of this collaboration is the indigenous Khmers and the people of Cambodia. Looking closer at this collaboration it really boils down to a collaboration of values. As conservationist, zoo managers, keepers, government and non-government organizations we value the Siamese crocodile as a species once thought to be extinct, rediscovered and a species to protect. For the Khmers they believe that when someone dies their spirit turns into a crocodile. So they value the crocodile as an ancestor, relative or member of the family. This value dates back over 1700 years.

Almost 20 years ago after the fall of the Khmer Rouge, conservation groups like Fauna and Flora International (FFI) began hearing rumors from indigenous Khmers of crocodiles in the areas where they were surveying. It was during a rapid survey assessment when FFI recorded the image of a single Siamese crocodile (Fig. 1). Until then the only place thought to see Siamese crocodiles was through cravings found on the walls of temples. The discovery of this single animal began a series of intensive surveys over the next few years to see if there were other populations in the wetland habitats around Cambodia. Once rediscovered there was a collaborative effort formed between the local Khmer mountain people and FFI to save this species. The local villages were included in conservation strategies and some even employed as Cambodian Crocodile Conservation Wardens. From the results of these surveys roughly 200 animals had been identified with most being found in the heart of the Cardamom Mountains. Conservation groups, primarily FFI working with the Forestry Department formed the world's first crocodile sanctuary in the Cardamom Mountains.

Figure 1. The first documented Siamese crocodile caught in a camera trap by FFI.

In the meantime a number of crocodiles were being held at the Phnom Tamao Zoo, some as part of the zoo's collection and offspring and some as confiscated animals. These animals would become the nucleus of a captive breeding program to head-start and restock in suitable habitat where Siamese crocodiles had been found or where numbers were low. Every animal was DNA-tested and genetically pure animals were selected for breeding. A group of animals were selected from this group to be the first of the restocking effort. A site had been selected for the initial release after a habitat assessment had been done and a soft release pen built so they could recover after the transport. Eighteen animals were equipped with VHS transmitters for post-release monitoring. And then they were transported deep into the Cardamom Mountains for release (Fig. 2).

Figure 2. Sam Han (FFI) and Lonnie McCaskill (Disney's Animal Kingdom) release the first Siamese Crocodile.

Back in 2004 I joined the coalition to help with different projects in the area. I have been assisting FFI in surveys of wild populations, captive husbandry, relocation and reintroductions. A couple of years ago I became the primary studbook keeper for *C. siamensis* and helped coordinated several breeding populations in the United States. As the AZA Studbook Keeper I began to think of ways to utilize the US populations as a resource to help support the efforts in Cambodia. At this time it had been extremely difficult to place offspring when they were produced in captivity since this species is what is considered a medium-sized crocodile, not particularly distinctive in color or body shape as a Gharial or Tomistoma. In zoos, species compete for space. Another issue that is presented is that *C. siamensis* is a CITIES Appendix I species and "For-profit" organizations are only allowed to house these animals under restrictive permits. This means we may have institutions that might be interested in helping the species that are unable to do anything. One way we can help address those issues is by moving animals around and create open exhibits in "Non-profit" zoos.

Zoos have the issue that they need to bring people to their facilities and keep them interested in what they are doing. Guests are the main funding force for most zoos and they have the task to keep people coming back. In general it is the mega vertebrates such as elephants, beautiful dangerous animals such as tigers or the cuddly species like pandas. In terms of crocodile conservation that makes it a little more difficult, because zoos can only house a certain amount of animals. This causes a condition called B.A.C. (Big Ass Croc). Zoos want to exhibit the biggest crocodiles they can. This usually means they are searching for the largest Nile crocodile and/or a Saltwater crocodile. That is an issue for the Siamese crocodile because they generally only grow up to 7-9 feet long and are not as impressive. Due to zoos wanting "sexy animals" and some zoos not being able to house animals it presents some different issues that we need to look at and make some changes. To make the Siamese crocodile more appealing to zoos is the fact they can be kept in relatively small space, they breed fairly easily in captivity and there is a direct link to *in-situ* conservation that they can market as a part of their conservation efforts. Hopefully, over the next couple of years US zoos holding Siamese crocodiles will have their animals DNA-tested so I can make better breeding recommendations so hatchlings could go back to Cambodia and other range countries where they could be used to enhance wild populations.

The collaboration does not end there however! We need to continue to educate and involve the next generation of Cambodians, conservationist and zoo keepers so they also will share the value of this species so that the temple walls around Angkor Wat is not the only place to see them in Cambodia.

Louisiana's Nuisance Alligator Program

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Abstract

The Louisiana Department of Wildlife and Fisheries manages the American alligator (*Alligator mississippiensis*) as a commercial, renewable natural resource. The goal of the Department's alligator program is to manage and conserve Louisiana's alligators as part of the state's wetland ecosystem, providing benefits to this keystone species, thus aiding the fish and wildlife that depend upon alligators. The Department's sustained use program is one of the world's most successful conservation efforts. This success has increased the statewide alligator population, but because of this success, the occurrence of human – alligator conflict has also increased statewide. The Department commonly receives over 2,000 nuisance alligator complaints annually. Approximately 3,000 nuisance alligators are harvested in peak years, and an additional number of smaller sized nuisance alligators are relocated annually by state licensed nuisance alligator hunters. Habitat loss and human encroachment are increasing in Louisiana, and as the human population increases, so will the occurrence of human – alligator conflict. The nuisance alligator program continues to strive to minimize alligator and human conflicts throughout the state. The analysis of the 2012 – 2013 nuisance alligator data will be discussed. Number and location of complaints received by parish, month, and nuisance hunter will be reviewed. The number and size of alligators harvested or relocated and the time to complete the complaint assignment will be analyzed. Management implications developed from this analysis will also be discussed.

Introduction

The Louisiana Department of Wildlife and Fisheries (LDWF) manages the American alligator (*Alligator mississippiensis*) as a commercial, renewable natural resource. The Department's sustained use program is one of the world's most recognizable examples of a wildlife conservation success story. Louisiana's program has been used as a model for managing various crocodilian species throughout the world. Louisiana's alligator management programs include a wild harvest of sub-adult and adult alligators, a nuisance alligator program, a commercial farming program including egg ranching, and research. Conservative estimates have indicated these harvest programs generate over $60 – 70 million dollars of revenue to landowners, hunters and farmers annually, providing significant, direct economic benefit to Louisiana.

Historical Perspective

Alligators have been used commercially for their valuable leather since the 1800s. This harvest was generally unregulated throughout the 1900s, until a gradual population decline resulted in severely reduced harvests in the early 1950s. In 1962, alligator season in Louisiana was closed, and research studies, focusing on basic life history factors, were undertaken, leading to the development of a biologically sound management program. Of tremendous importance was the establishment of a rigorous survey method to estimate and monitor population trends.

From 1962 through August 1972, alligators were totally protected. During this time numerous state and federal laws regulating harvest distribution and allocation of take, and methods of harvest, possession, transportation and export of live alligators, alligator skins and their products were enacted. Similarly, in 1970 the Louisiana Legislature recognized that the alligator's value, age at sexual maturity, and vulnerability to hunting required unique consideration and passed legislation providing for a closely regulated experimental commercial harvest.

The goals of the Department's alligator program are to manage and conserve Louisiana's alligators as part of the state's wetland ecosystem, provide benefits to the species, its habitat and the other species of fish and wildlife associated with alligators. The basic philosophy was to develop a sustained use management program which, through regulated harvest, would provide long term benefits to the survival of the species, maintain its habitats, and provide significant economic benefits to the citizens of the state. Since Louisiana's coastal alligator habitats are primarily privately owned (approximately 81%), our sustained use management program provides direct economic benefit and incentive to private landowners and alligator hunters who lease land, to protect the alligator and to protect, maintain, and enhance the alligator's wetland habitats. One of the most critical components of the management program was to develop the complex set of regulations which required individual applications for each property to be considered for tag allocation, landowner permission, documentation of proof of ownership and detailed review of habitat quality related to alligator abundance, all of which combined to equitably distribute the harvest in relation to population levels.

During the period of total protection (1962-1971) alligator populations increased quickly and by 1972 the Department was ready to initiate its new sustained use management program. In 1972 the alligator season was reopened in Cameron Parish and a total of 59 hunters harvested 1,350 alligators. The season was expanded to include Vermilion Parish in 1973, Calcasieu Parish in 1975, and an additional nine coastal parishes were added in 1979. The alligator season opened statewide in 1981.

Oversight by the U.S. Fish and Wildlife Service

Five years after Louisiana closed the alligator harvest season, the alligator was listed in the federal Endangered Species Act in 1967. At this time the alligator was considered an endangered species throughout its range. In March of 1974, Louisiana petitioned the Secretary of the Interior, requesting that populations of the alligator in Louisiana be removed from the list of threatened and endangered species in Cameron, Vermilion, and Calcasieu Parishes. In subsequent years, similar petitions sought to reclassify the alligator, first in nine additional coastal parishes in 1978 and then statewide in 1981. Each of these petitions was based on results of detailed scientific study and the demonstrated success of the early harvest programs.

Export of alligator skins and products out of the United States is regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This treaty, which became effective in 1975, regulates the international trade in protected species; its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. The U.S. Fish and Wildlife Service (USFWS) administers CITES requirements and controls for the United States. The species covered by CITES are listed on one of three Appendices, according to the degree of protection needed. Currently, the alligator is listed on Appendix II of CITES, because of their similarity of appearance to other crocodilians that are truly endangered or threatened.

The USFWS, through a series of rulemakings, has developed a complex set of CITES requirements with which the individual states, including Louisiana, must comply in order to be granted export approval for harvested alligators skins and products. The most critical component in these requirements is that the Department must certify, on an annual basis, that the harvest programs we administer will not be detrimental to the survival of the species. The "no detriment" finding is predicated on our assessment of the current condition of the alligator population, including trends, population estimates or indices, data on total harvest, harvest distribution and habitat suitability evaluation. Additionally, the management program must provide for a rigorously controlled harvest with calculated harvest level objectives. All alligators and eggs harvested must be taken from specifically identified properties and all hides must be individually tagged (with approved, serially marked CITES export tags furnished by the USFWS). The USFWS requires strict accountability for each tag allocated to the harvester, requiring that all unused tags are returned at the close of the season.

Wild Alligator Management/Harvest Program

In 1970, the Louisiana State Legislature (Act 550) gave the Department of Wildlife and Fisheries full authority to regulate the alligator season in Louisiana. Since that time, the Department has annually inventoried alligator nest production throughout coastal Louisiana in order to assess the status of alligator populations. Results of annual alligator nest surveys are compiled to provide estimates of nest density (acres per nest) by parish and by habitat type (brackish, intermediate, or fresh). Private and publicly owned lands (State and Federal Refuges, and Wildlife Management Areas) are compiled separately. Each summer over 2,800 miles of transects are flown, surveying 135,000 acres of wetland habitat. The sampling intensity covers approximately 3.4% of 2.3 million acres of private coastal wetlands, and 3.4-10.8% of some 622,000 acres of public coastal wetlands.

Nest density and alligator population estimates are combined with a detailed review of harvest parameters and a general assessment of environmental factors observed during each survey to determine final harvest level objectives. Over 50 individual alligator harvest quotas are developed annually in order to distribute the harvest in relation to alligator abundance in the various habitats across the state. In the best habitat one alligator is harvested per 55 acres, while in the poorer habitats one alligator is harvested per 400 acres.

Before alligator tags can be issued on a specific property, the potential alligator hunter must submit a description of the property on which they have permission to hunt. The Department assesses the habitat quantity and quality and determines if the property qualifies for alligator harvest, and then the number of alligators that can be harvested by each hunter is determined.

This methodology ensures that alligators are harvested in proportion to their population levels and that the harvest will not negatively impact populations at any location.

The annual harvest takes place in late August and September to specifically target the adult males and immature segments of the alligator population. Adult females, which typically inhabit interior marshes in September, would be more susceptible to harvest if the season was scheduled during the spring or summer.

Nuisance Alligator Program

As outlined previously in Boundy's (2004) report, the LDWF is authorized to control nuisance alligators through the "Nuisance Alligator Program" (RS 76.701.10). A nuisance alligator is defined as "a specific alligator that poses a threat to human life or property" (RS 76.701.2). Specifically, Johnson et al. (1985) outlined three situations in Texas which alligators are considered a nuisance and warrant removal. Similar situations occur in Louisiana.

The first nuisance situation occurs when an alligator has been encountered outside of its natural habitat. Most complaints of this type are received from people residing in or near coastal marshes or swamp and find alligators in yards, roadways, drainage ditches, work areas, or swimming pools. Natural alligator dispersal is often the driving factor of these complaints. These issues often occur during high or low water conditions, spring territorial aggressiveness, or dispersal of older pods of young alligators. The second nuisance situation involves alligators in natural habitats that have become acclimated to the presence of humans due to repeated human contact. These alligators are often considered nuisances because they approach private property along a body of water, fishermen, and other recreationists, likely because they have been fed in the past by other individuals. The third nuisance situation occurs when an alligator is residing in an area managed for a specific resource, but the management of this area may not be compatible with normal alligator behavior and feeding habits. These problems typically occur where a recreational fishery or aquaculture operation is taking place, thus normal feeding activities of alligators negatively affect commercially valuable species or inhibit recreational activities.

After alligator populations recovered in the early 1970s, problems with human – alligator conflicts began. The nuisance program is designed to remove problem alligators in order to avoid potential human – alligator conflicts. Initially, nuisance alligator complaints were handled by LDWF employees (Linscombe 1975); in 1975 some 127 complaints were received and 77 alligators were captured and relocated, and in few instances led to disposal of dead alligators. As the alligator population continued to recover over time, more complaints were received than could be handled by LDWF staff, and nuisance alligator hunters were licensed to assist with managing the problem. In 1979, a nuisance alligator removal program was initiated in six coastal parishes (counties) where problem alligators could be harvested or relocated. Then then the nuisance program was expanded statewide in 1981with nineteen nuisance control hunters involved (Joanen et al. 1984). In the early years relatively small numbers of nuisance alligators were harvested, and did not exceed 225 alligators until 1986 (Figure 1).

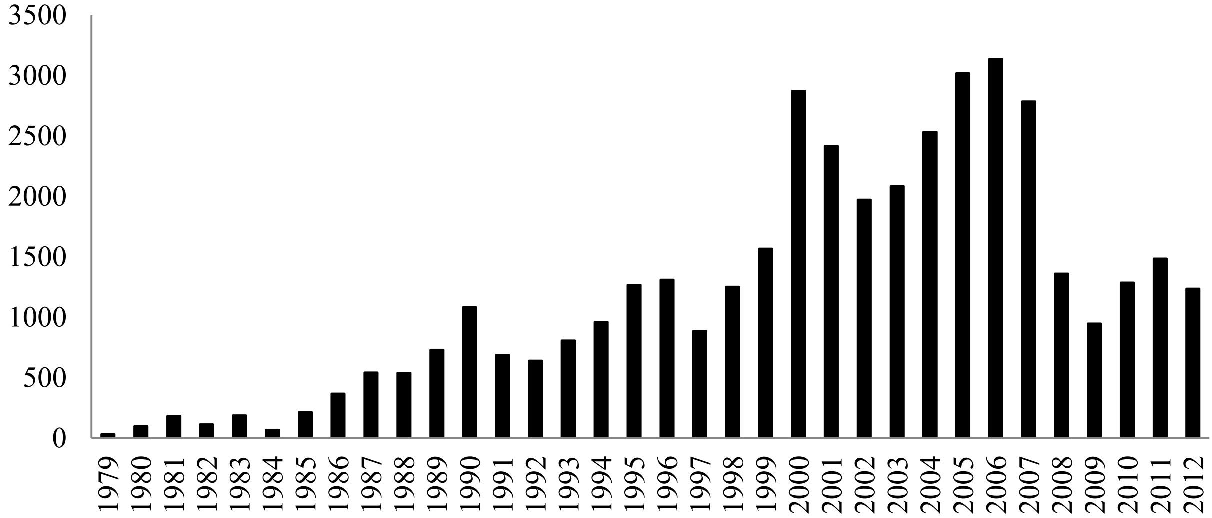

Figure 1. Number of nuisance alligators harvested from 1979 to 2012.

Nuisance alligators in Louisiana are removed by licensed alligator hunters who are appointed by the Secretary of the Department. Appointments are made as needed on a regional, nuisance complaint basis, and remain in effect as long as appointed hunters conduct their operations in a manner that is satisfactory to the Department. Appointees are screened by the Department's Enforcement Division, and preferably have experience trapping alligators (Boundy 2004).

Through the process of nuisance alligator hunter appointments and annual license renewals, the Department maintains a statewide network of qualified nuisance alligator hunters who generally have several years of experience trapping wild alligators. Nuisance alligator complaints are phoned into various Department offices, where complaints are recorded, assigned a complaint identification number, and then forwarded to a nuisance alligator hunter in the vicinity of the complaint. Nuisance hunters respond promptly, capture and remove the alligator as deemed necessary. Hunters are allowed to harvest the nuisance alligator and process the meat and skin for commercial sale (assigned CITES tags must be used for each harvested alligator, smaller alligators are generally relocated alive to appropriate habitat). This process provides an immediate response to problem alligators and payment to the nuisance alligator hunter, thereby minimizing the program operating costs to the Department. Louisiana nuisance alligator hunters are governed under a rigid set of rules to curtail any issues associated with the benefits of being a state licensed alligator hunter.

Licensed alligator hunters greatly benefit the Louisiana nuisance alligator program. LDWF employees are not capable of dedicating the time and resources needed to perform the duties involved in nuisance alligator removal. Hines and Woodward (1980) determined that nuisance hunters in Florida did not select for smaller, easier to remove and higher quality alligators. They also determined that hunters often harvested more alligators per complaint than wildlife officers because the hunters were more experienced, efficient, economically motivated, made more attempts to remove nuisance animals than wildlife officers. Our nuisance alligator hunters are extremely efficient, as 45% of the individual complaints were resolved in one day or less. One nuisance hunter dedicated 120 days to resolving a nuisance issue, showing the dedication and perseverance our nuisance hunters possess. All of these factors make nuisance hunters more likely to successfully remove the alligator(s) than wildlife officers. Hines and Woodward (1980) also determined that the hunters responded to all complaints in a timely manner, whereas wildlife officers often had higher priority law enforcement matters with which they had to attend. Beginning in 2009, when the worldwide economic crisis led to low prices for alligator hides, nuisance alligator hunters in Louisiana were allowed to charge (at their discretion) a fee not to exceed $30 to the complainant for removal of alligators less than 6 feet in length. This was further motivation for a nuisance hunter to respond to a complaint when alligator hide prices were not sufficient to cover operating costs.

This paper will review recent nuisance alligator harvest results and focus on more detailed analyses of complaint logs in the last two years (2012 – 2013). We recognize that data records are incomplete, and were collected using varying levels of detail by nuisance hunters assigned to numerous regional offices over the years; many records were undoubtedly lost or discarded through time. Recently we tried to encourage more complete record keeping by hunters and devoted more staff time to data entry of records from past years. The most complete data we have are for the years 2012 and 2013; trends and data available for earlier years will be addressed as well.

Data collected includes information on the number of complaints received, dates/months of nuisance alligator complaints, details on each case (concern for human safety or safety of pets/livestock, road hazard, etc.), size of alligator(s) involved, and ability of complainant to estimate the size of the problem alligator.

Methods

Information was obtained by review of nuisance alligator complaint logs maintained by each regional LDWF office and by review of nuisance complaint forms submitted by nuisance hunters after a complaint has been resolved. Each complaint is assigned a number, and nuisance hunters are required to report the disposition of each complaint routed to them. Data are now sent from each regional office to the LDWF office at Rockefeller Refuge in Grand Chenier for compilation and entry into a database. Initial information received by the complainant (location of problem alligator, estimated size, etc.) and a follow up summary information provided by the assigned nuisance hunter (actual size of alligator harvested, time required to handle complaint, CITES tag used, etc.) was entered for each complaint received, if adequate information was provided.

Results

Results of the internal LDWF nuisance alligator survey done in 1975 showed the majority of the 127 nuisance complaints occurred in the months of May and June. In this early phase of the nuisance alligator program, problem alligators were nearly always caught and relocated alive, rather than being harvested. As expected, problem alligator complaints began slowly in March and April as warmer spring temperatures began, and complaints tapered off in August and September (Linscombe 1975). The size of the nuisance alligators ranged from the 1 foot total length (TL) size class to the 12 foot TL size class (Linscombe 1975). Interestingly, an opinion survey suggested nuisance alligator complaints were about four times more numerous in 1974 (Linscombe 1975); possibly in part because in 1975 the Louisiana Wildlife and Fisheries

Commission adopted a position that only in an emergency situation would an alligator be moved. With the increase in population across the state came an increase in human – alligator conflict.

There are ten LDWF Regional Offices that receive nuisance complaints throughout the year, these include Baton Rouge (BR), Communications (COM), which is also located in Baton Rouge, Lake Charles (LC), Minden (MIN), Monroe (MON), New Iberia (NI), New Orleans (NO), Pineville (PINE), and Rockefeller (ROCK). When no office was reported on a complaint, then no office (NO OFF) was used. A total of 3995 complaints were received in the 2012-2013 study period. Complaints vary greatly between offices, with the Communications section within the Enforcement division of LDWF receiving the most filed complaints, with a total of 1507 total complaints filed in 2012 and 2013 combined. The Communications division receives the most complaints because it is centrally located and functional 24 hours a day, every day of the year. Rockefeller had the lowest total of filed complaints, at 46 complaints combined for 2012 and 2013 (Figure 2). Occasionally, local sheriff offices receive nuisance alligator complaint calls as well.

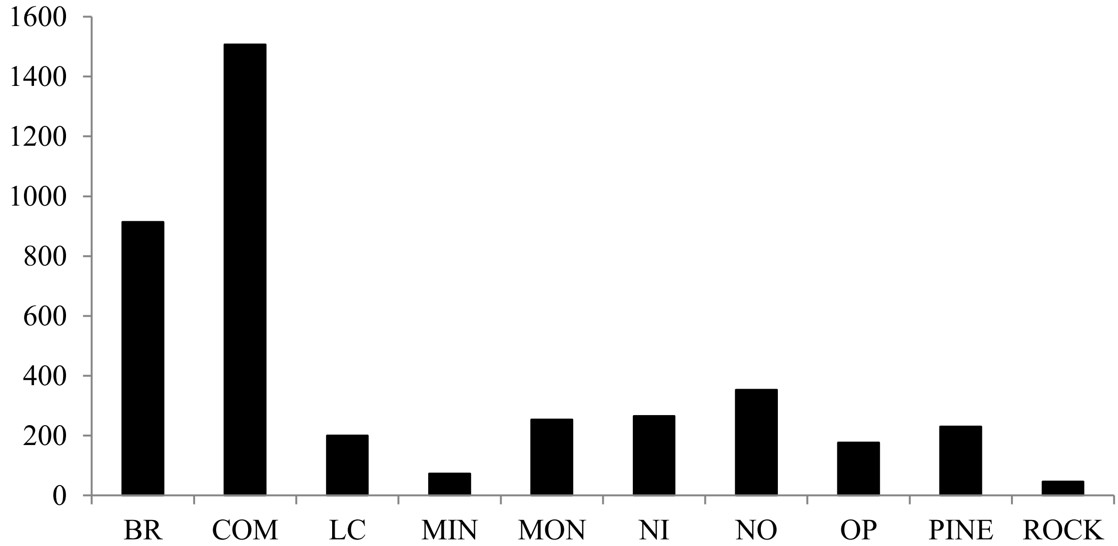

Figure 2. Total complaints filed by office for 2012 and 2013 combined.

One issue associated with Louisiana's nuisance alligator program is the return rate associated with nuisance complaint forms submitted after a complaint has been closed. Overall, only 42 % of nuisance complaint forms are returned after a complaint has been resolved, however we recently encouraged more complete record keeping by hunters and devoted more staff time to data entry of records. Alligator hunters may have thought that a completed nuisance complaint form was required if an alligator was not harvested in response to the complaint. We anticipate more complete records will be obtained in the future. (Table 1).

Table 1. Total complaints filed vs. total complaint forms submitted.

Office	Total Complaints Filed	Total Forms Submitted	% Complaint Forms Submitted
Communications	1507	573	38.02
Baton Rouge	914	325	35.56
New Orleans	353	79	22.38
New Iberia	265	117	44.15
Monroe	254	92	36.22
Pineville	230	124	53.91
Opelousas	177	29	16.38
Lake Charles	175	94	53.71
Minden	73	41	56.16
Rockefeller Refuge	47	24	51.06
No Office Reported	N/A	188	N/A
Grand Total	3995	1686	42.20

The following data has been compiled from the complaint forms that have been submitted. As with any large scale program where multiple entities are collecting data for a common goal, data may be lost, incomplete, inaccurate, or misinterpreted. These were the challenges we faced in compiling and analyzing this data. Despite these challenges, we were able to discern some interesting trends in the data collected in 2012 and 2013.

We see a general trend in nuisance alligators handled, where total nuisance issues slowly increase in March and April then peak in May, then decrease slowly from June to December (Figure 3).

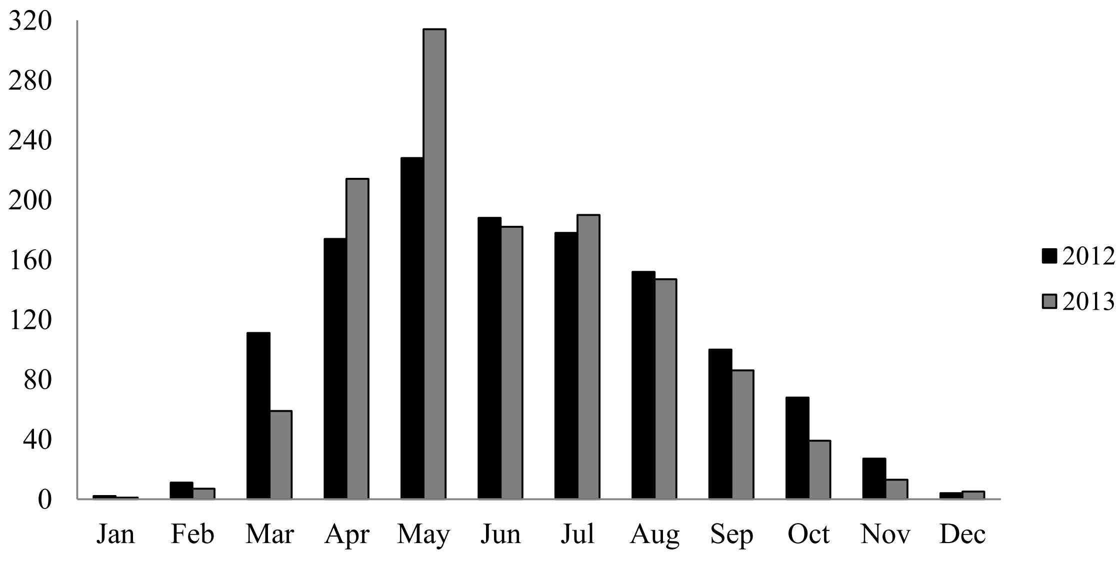

Figure 3. Total alligators handled by year and month.

As expected, we see a difference in the amount of reported alligators harvested (n= 1763) vs. relocated (n= 464) across the state for both 2012 and 2013 (Figure 4). Hunters are allowed to harvest the nuisance alligator and to process the meat and skin of the alligator for commercial sale, thus providing a financial reimbursement to the nuisance alligator hunter and minimizing the program operating costs to the Department.

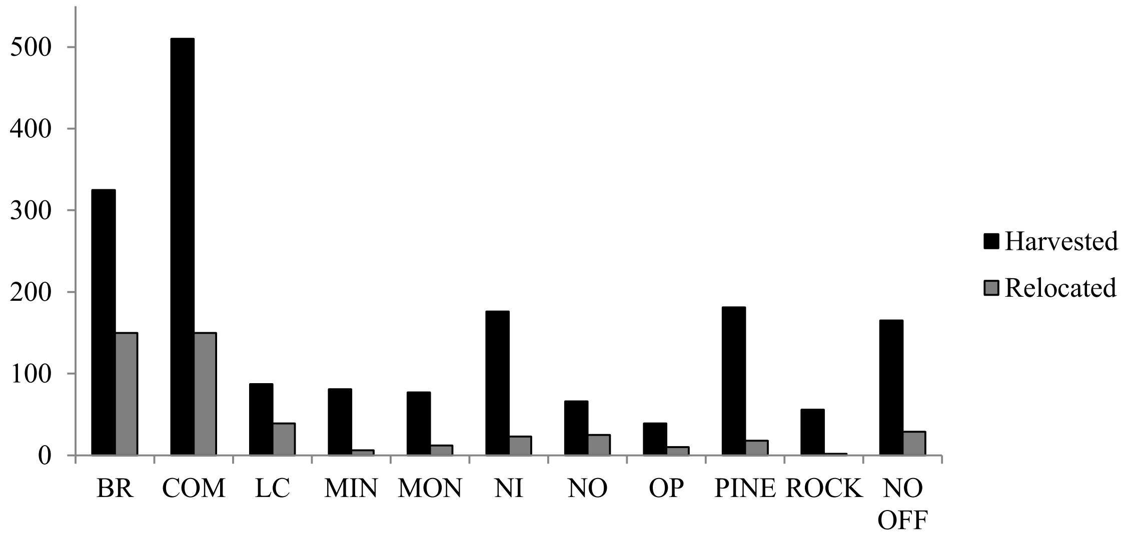

Figure 4. Total harvested vs. relocated by office for 2012 and 2013 combined.

There is a notable difference in the number of harvested nuisance male and female alligators throughout the year for both 2012 and 2013; however sex was not reported for 1425 of the harvested alligators. Of the total 1763 harvested for 2012 and 2013, males were reported harvested 14% of the time, while females were reported harvested 5% by nuisance hunters. Given that sex was only reported for 19% of the time for harvested alligators, this data must be interpreted with caution. When sex was reported for harvested alligators in 2012 and 2013 (n=338), approximately 74% were male (Figure 5).

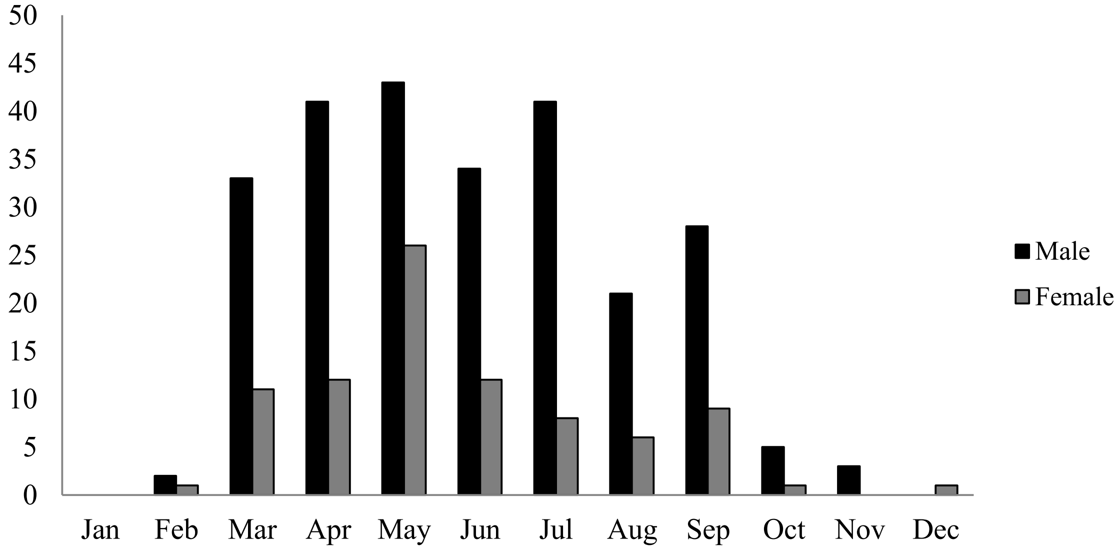

Figure 5. Reported harvested male vs. female for 2012 and 2013 combined.

The number of nuisance alligators handled by year and size indicate that the general size of nuisance alligators, approximately 6 feet, is smaller than the statewide average length of 7.28 feet TL harvested by commercial alligator hunters during the annual autumn harvest (Figure 6).

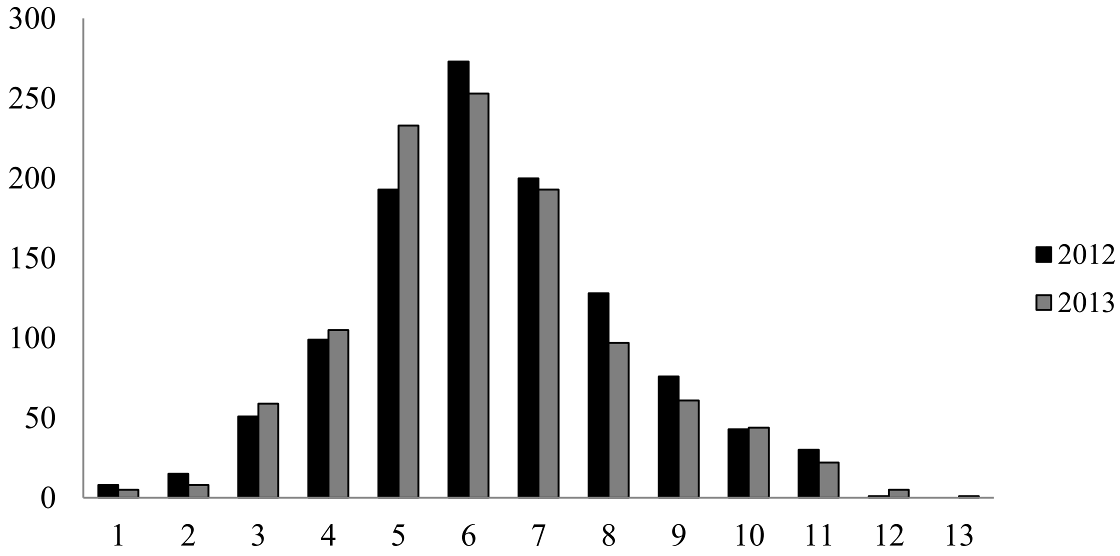

Figure 6. Reported nuisance alligators handled by year and size class (total length in feet).

Harvested nuisance alligators often fall into the 5-7 foot size classes, with the majority of the nuisance alligators falling in the 6 foot TL size class, similar to Hines and Woodward (1980). We see a trend in the number and size of nuisance alligators harvested versus relocated in 2012 and 2013. In general, a nuisance alligator hunter is more likely to harvest an alligator in the 5 foot TL size class or larger, while relocating alligators in the 4 foot TL size class or lower (Figure 7). One alligator in the 13 foot TL size class was relocated in 2012 for unknown reasons.

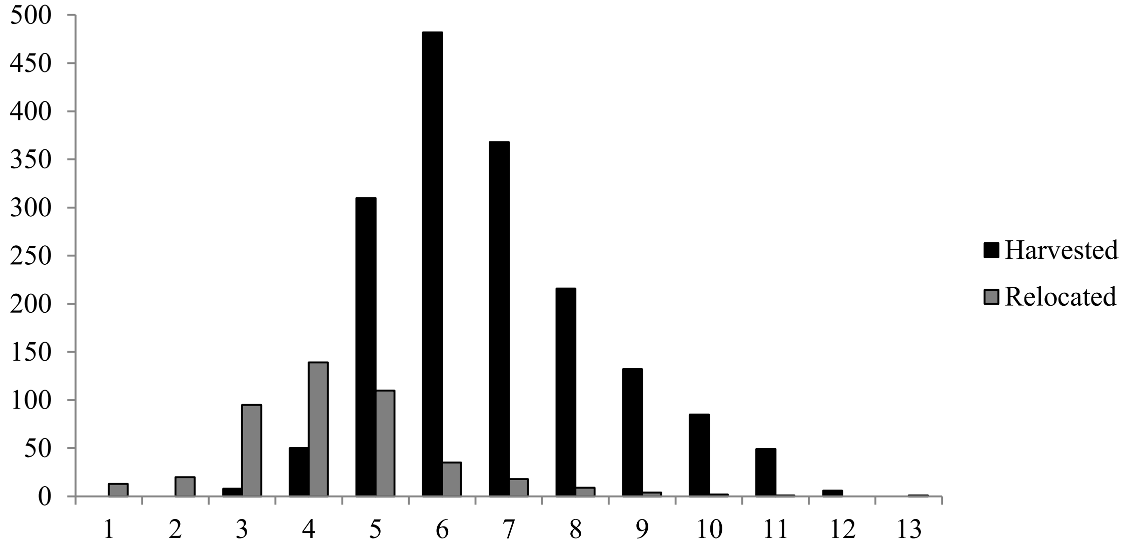

Figure 7. Number of nuisance alligators harvested vs. relocated by size class for 2012 and 2013 combined (total length in feet).

An interesting variable we were able to analyze from this dataset was the ability of the complainant to estimate the actual length of the nuisance alligator. We designated an alligator as underestimated if the estimated length was at least 1 inch smaller than the actual length of the alligator. We designated an alligator as overestimated if the estimated length was at least 1 inch longer than the actual length of the alligator. We then averaged the inches underestimated or overestimated by size class, which is represented in Figure 9. This gave us an idea about how many inches on average an alligator was overestimated or underestimated within a given size class. We concluded that, in general, alligators in the 1 foot TL to the 8 foot TL inch sizes classes were more often overestimated in length, while the alligators in the 9 foot TL size class to the 13 foot TL size class were drastically underestimated (Figure 8).

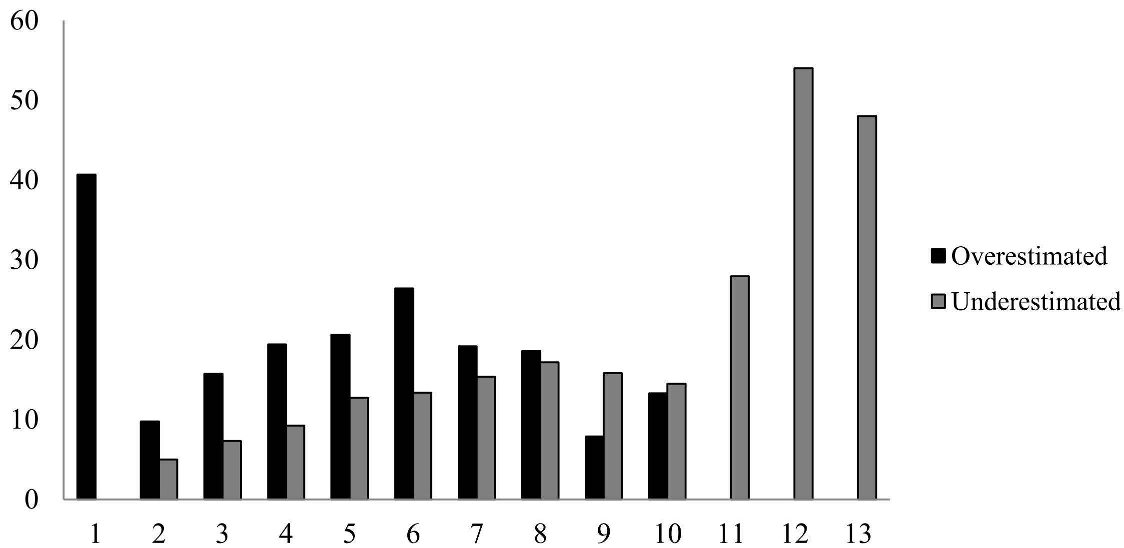

Figure 8. Average inches overestimated vs. underestimated by TL size class (total length in feet).

The most frequent locations at which nuisance alligators were reported was in unspecified ponds for both 2012 and 2013. Approximately 17% of the incidents were in unspecified ponds, similar to Boundy's (2004) findings. Bayou/canals followed in rank, at approximately 13% for 2012 and 2013 combined. (Table 2).

As expected, nuisance alligators are harvested 71% of the time because there is financial reimbursement associated with harvesting the alligator. Interestingly, of the complaints reported, the hunters only failed to capture the nuisance alligator approximately 0.50% of the time (Table 3). Boundy (2004) found that handling of alligators varied widely among hunters, with one individual surprisingly capturing 82% of his alligators alive; from 1995 – 1998 some 4687 alligators were harvested by nuisance hunters and about a third of nuisance alligators caught by 14 hunters in Region 7 (Baton Rouge and surrounding area) were released alive, whereas in 2012 and 2013 combined, only about 19% were release alive statewide.

Table 2. Nuisance complaints by site type, year, and percent occurrence.

Complaints by Site				
Site Type	2012 Total	2013 Total	Grand Total	% Occurrence
Unreported	271	218	489	19.56
Pond	183	230	413	16.52
Bayou/canal	151	167	318	12.72
Residence (pond)	144	167	311	12.44
Residence (yard)	128	109	237	9.48
Lake	75	86	161	6.44
Roadway	65	44	109	4.36
Industrial site (pond/canal)	39	45	84	3.36
Ditch	31	51	82	3.28
River	39	23	62	2.48
Industrial site (parking/work area)	20	37	57	2.28
Camp	20	10	30	1.20
Pit	9	19	28	1.12
Commercial/stock pond	21	3	24	0.96
Culvert	10	12	22	0.88
Under car	9	11	20	0.80
Pasture	11	6	17	0.68
Marina	4	5	9	0.36
Water (unspecified)	3	5	8	0.32
Business	4	3	7	0.28
Golf course or park	3	3	6	0.24
Swimming pool	3	1	4	0.16
Beach	0	1	1	0.04
Swamp/“Low area”	0	1	1	0.04
Grand Total	1243	1257	2500	

Table 3. Nuisance complaint outcomes by year and percent occurrence.

Complaint Outcome	2012 Total	2013 Total	Grand Total	% Occurrence
Harvested	899	864	1763	70.52
Relocated	211	253	464	18.56
No alligator present/seen	77	102	179	7.16
Unreported	32	14	46	1.84
Dead already	17	9	26	1.04
Failed to capture	3	9	12	0.48
Deemed non-nuisance	4	6	10	0.40
Grand Total	1243	1257	2500	

Discussion

The results discussed in this paper are based on incomplete records, but recent attempts to analyze our nuisance program data have provided some interesting information.

Of the ten LDWF Regional Offices that receive nuisance complaints throughout the year, Communications section, located in Baton Rouge, received the most complaints in 2012 and 2013 combined. The Communications division receives the most complaints because it is centrally located and functional every day of the year. Rockefeller had the lowest total of reported complaints, at 46 complaints combined for 2012 and 2013, possibly because Rockefeller is far from any metropolitan or suburban area where more human – alligator conflicts likely occur.

We faced several challenges in compiling and analyzing this data. We have multiple entities are collecting data for a common goal, so data is often lost, incomplete, inaccurate, or misinterpreted. These challenges, including low return rate of nuisance complaint forms, made compiling and analyzing this data difficult, but we were able to discern some interesting trends in the data collected in 2012 and 2013. We used the complaint forms as our primary data source because most of the pertinent information for each individual complaint is located on the complaint forms. This information includes the location of the alligator, time to work the complaint, the complaint outcome, size of the alligator, CITES tag number, and sex of the alligator, if the fee was charged, and if the alligator was a recapture from our statewide farm release program.

We see a general pattern in seasonal nuisance complaints that follows the same trend in Linscombe (1975) and Hines and Woodward (1980), where nuisance complaints slowly increase in March and April then peak in May, then decrease slowly from June to December. Boundy (2004) also found that more complaints were received during warmer months, and only 6% were logged from mid-October through mid-March. This trend follows the yearly fluctuations in temperature and alligator activity, with alligators becoming active in early spring, beginning courtship and mating in early summer, then nest construction and incubation occur in late summer, followed by a reduction in activity going into fall and winter (Joanen and McNease 1970).

The number of nuisance alligators relocated and harvested by year and size indicate that the general size of all nuisance alligators is smaller than the statewide average length of approximately 7 feet TL for alligators harvested during the autumn alligator season. This indicates that nuisance hunters generally relocate smaller alligators and harvest the larger alligators, simply due to the fact that a larger hide will provide greater compensation. This is beneficial for the hunter, but it also benefits the nuisance program. By harvesting larger alligators, the hunter reduces the chance of recapturing alligators that are repeatedly a nuisance. Hines and Woodward (1980) discussed the biological implications of relocating nuisance alligators, specifically large alligators. In their review, they stated that alligator populations can reach carrying capacity in a short period of time. Addition of several nuisance alligators into a balanced system can increase competition within a population of alligators. There is also evidence that alligators will return to their previous location if not relocated a significant distance from their previous location. Relocation of a nuisance animal that has acclimated to humans can also cause issues with recreationists that utilize the area.

As expected, we see a notable difference in the amount of nuisance alligators harvested (n= 1763) vs. relocated (n= 464) across the state for both 2012 and 2013. Hunters are allowed to harvest the captured nuisance alligator and to process the meat and skin of the alligator for commercial sale, thus providing a financial reimbursement to the nuisance alligator hunter and minimizing the program operating costs to the Department. Beginning in 2009, when the worldwide economic crisis led to low prices for alligator hides, nuisance alligator hunters were allowed to charge a fee not to exceed $30 to the complainant for removal of alligators less than 6 feet in length. This fee was initiated to assist the hunter in undertaking the operating costs associated with nuisance alligator removal. Despite the rising operating costs, hunters reported that only 5% of the complainants were charged a fee for removal of the alligator in 2012 and 2013, while hunters reported that 45% were not charged a fee, however in 50% of the cases it was not reported if the fee was charged or not.

There is a notable difference in the number of reported nuisance male and female alligators captured throughout the year for both 2012 and 2013; however sex was not reported in 83% of the complaints where the alligator was handled (harvested, relocated, or dead already). Of the total nuisance alligators handled with sex reported, 263 were males, while only 97 were females. When sex was reported when harvested in 2012 and 2013, approximately 74% were male. Our results were comparable to Hines and Woodward (1980), who reported 77% males harvested during their study.

Harvested nuisance alligators often fall into the 5-7 foot TL size classes, with the majority of the nuisance alligators falling in the 6 foot TL size class. We saw a trend in the number and size of nuisance alligators harvested versus relocated in 2012 and 2013. In general, a nuisance alligator hunter is more likely to harvest an alligator in the 5 foot TL size class or larger, while relocating alligators in the 4 foot TL size class or lower. Boundy (2004) found that between 1995 – 1998 in Baton Rouge, the average size of nuisance alligators harvested was 6.70 feet (n = 409) while the average size of the 203 nuisance alligators relocated alive was 3.67 feet.

An interesting variable we were able to analyze from this dataset was the ability of the complainant to estimate the actual length of the nuisance alligator. It is difficult for even the most experienced crocodilian biologist to estimate the precise length of a crocodilian from a distance, so we realize that it would be even more difficult for the general public to estimate the length of a crocodilian from a distance. We concluded that, in general, alligators in the 1-8 foot TL size classes were more often overestimated in length, while the alligators in the 9-13 foot TL size classes were drastically underestimated. Overestimation of length of smaller alligators may be accidental, as most people that are concerned with the presence of a nuisance alligator may have an undue fear of the alligator, therefore unconsciously overestimating its length. Underestimating the length of an extremely large alligator could be a public safety concern, however. Although alligator attacks on humans are rare in Louisiana, if a person underestimates the length of an alligator, he/she may feel that it is safe to swim or wade in the water near the large alligator. This obviously increases a chance of an attack.

The most frequent locations at which nuisance alligators were reported was in unspecified ponds for 2012 and 2013 combined. Approximately 17% of the incidents were in unspecified ponds, similar to Boundy's (2004) findings. Bayou/canals followed in rank, at approximately 13% for 2012 and 2013 combined. Residential ponds followed with approximately 12% occurrence. An alligator in a public rather than private location is likely to be seen by more people, thus having a higher likelihood of being reported. Alligators in public areas tended to be reported when they were near a particular area frequented by people (marina, beach, etc.), but in many instances, such as generic reports for "pond" or "lake", proximity to people was not indicated (Boundy 2004).

LDWF keeps records when we are made aware of human – alligator incidents. Fortunately these have been very limited and in general injuries have been relatively minor. The two most recent incidents with which we are aware were more serious (Table 3), in one case a young boy had a traumatic arm amputation and in the other case, a young woman was bitten on the arm, sustaining several bone fractures. In both cases, the victims reportedly had observed the alligator involved in the water prior to the incident. Of note, both of the two recent (July 2008 and July 2010) serious human – alligator incidents of which we are aware occurred where alligators were seen and/or harassed (throwing rocks at the alligator known to inhabit the pond where victim then went swimming) before the attack occurred. The incident in 2010 occurred near areas where tour boat operators routinely feed alligators, despite our repeated requests to

Table 3. Documented alligator incidents in Louisiana.

Date	Site in Louisiana	Age, sex of victim	Size of alligator	Remarks
10/8/1734	Natchitoches	adult male	N/A	body recovered on river bank, alligator bites post-mortum
7/1/1966	Little Chenier	juvenile female	estimated 4'	girl bitten on index finger of left hand while pulling melons in yard
6/1/1978	Hackberry	8 year old male	9'9"	bitten on right leg, required two surgeries, chest scratched
7/1/1992	French Settlement	32 year old male	estimated 8-10'	bitten on hands, back scratched; required over 200 stitches
5/25/1996	Venetian Isles (N.O.)	11 year old female	estimated 4'	bitten on upper arm
2002-2003?	Lafourche Parish	adult male	sub-adult alligator	bitten on the hand
5/8/2003	Concordia Parish	11 year old female	estimated 7'	bitten on upper left thigh

Summer 2004	Lake Maurepas	adult female	estimated 4-5'	bitten on upper leg; wound not serious
7/20/2004	Constance Beach	10 year old female	estimated 6'	bitten on right hand, required 10 stitches
6/13/2005	St. Bernard Parish	50 - 55 yr old male	estimated 7-9'	bitten on hand and arm; lacerations, no sutures needed
7/25/2005	Venice	12 year old female	estimated 7-9'	distal two phalanges of right middle finger and had thigh lacerations left open to heal
7/16/2007	Lake Charles	30 year old female	estimated 4'	bitten on buttock
7/30/2008	near Slidell	11-12 year old male	11'	left arm amputated at shoulder
7/28/2010	JLNHP, Marrero	29 year old female	estimated 7'	5-6 broken bones in hand/arm

discourage this dangerous activity that habituates alligators to people and perhaps makes them associate human activity with feeding.

Linscombe (1975) suggested nuisance complaints appeared to correlate with either high alligator populations in areas of low or moderate human populations (rural), or low to medium alligator populations in areas of high human populations (urban cities). It was also suggested tolerance of human – alligator contact is generally higher in rural areas and influenced by attitude and education concerning alligators (Linscombe 1975). The same trend is likely seen today.

Management Implications

Many factors contribute to alligator attacks on humans. A decline of unregulated alligator hunting and poaching from protective legislation and the increase of humans using alligator habitat for recreational opportunities has assisted in the rebound of alligator populations. Since 1970, an increase in human population in the southern states, residential development of waterfront property, and growing popularity of water related recreational activities have increased alligator human interactions. State wildlife agencies have responded to the expanding alligator populations by implementing nuisance alligator management through removal of nuisance alligators and public education programs about alligators (Conover and Dubow 1997). Our sanctioned autumn harvests of 34,000 – 35,000 sub-adult and adult alligators annually undoubtedly helps limit human – alligator conflicts. Many state Wildlife Management Areas and state and federal

Refuges specifically target their harvest efforts in areas of high public use (recreational fishing, crabbing, shrimping, etc.) to remove larger alligators from areas of high public use.

The ultimate goal of Louisiana's nuisance alligator program is to continue to reduce the occurrence of human – alligator conflicts within the state. Historically, Louisiana has had a low occurrence of alligator attacks compared to other states. Conover and Dubow (1997) found 236 recorded cases of alligator attacks on humans going back as early as 1948 to the end of 1995, and only one attack (0.4% of the total surveyed area) occurred in Louisiana. Fortunately, the nuisance program has been successful in its attempts to protect human lives and property by handling each complaint on a case by case basis with experienced, qualified individuals. The rigorous screening performed before a nuisance alligator hunter license is issued has insured that the state of Louisiana maintains a list of individuals that handle each complaint safely and thoroughly. We are fortunate that many of Louisiana's residents are familiar with alligators and the potential danger associated with attempting to handle a nuisance situation themselves. Realistically, the threat of unprovoked alligators to human life is low. An alligator seen from the shoreline or a boat does not pose a threat to humans; however exceptions include those that are in popular fishing or swimming areas such as beaches and camps, or very large alligators inhabiting public use areas. It is at these areas that people come into close contact with alligators, and people will often attempt to feed the alligator to capture a photo or get a closer look. Alligators exhibit an opportunistic hunting strategy, and when fed, they will become acclimated to being fed and lose their tendency to avoid humans. Because of this opportunistic feeding strategy, they will readily consume anything from bread and marshmallows to crawfish and frogs to dogs and other alligators. The threat of alligators to small domestic animals and aquaculture species is present, however. When an alligator is located near a residence or farm with domesticated waterfowl, aquaculture species, small children and pets, caution should still be exercised. Given enough time, generally an alligator will leave the area if feeding opportunities are not available. In some cases, such as aquaculture settings, the feeding opportunity cannot be removed; therefore the alligator is depredating on the crop. This particular situation warrants a nuisance compliant. Some instances may not warrant a complaint. If an alligator is inhabiting an isolated area on a bayou, river, or lake and is occasionally encountered by a fisherman or boater, then it poses no threat to human life or property if avoided or viewed from a distance.

An important factor in any nuisance wildlife programs is public awareness. In most situations, the nuisance problem itself is created by inappropriate human behavior, either from feeding or harassing the alligator. An effective nuisance alligator program can both educate people about the dangers associated with approaching and/or feeding alligators and familiarize people with alligator behavior. Education through public outreach can reduce the number of potential nuisance alligator encounters and occurrence of human injury, alleviate unnecessary aversion to alligators, and encourage appreciation for alligators and their niche as a keystone species in wetlands (Johnson et al. 1985).

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Human Alligator Conflict in Florida, USA

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Abstract

We evaluated the trend of American alligator (*Alligator mississippiensis*) bites during 1971-2013 and examined patterns associated with bites on humans in Florida documented during 1948-2013. We excluded provoked bites and used 307 non-provoked and 55 unintentionally provoked bites for our analyses. The estimated frequency of bites resulting in major injury to the victim increased (P= 0.026) during 1971-2013, but the number of bites per Florida resident did not show a significant trend (P= 0.255). Most victims were Florida residents (93.5%) and 57% were familiar with the site of the incident. Bites generally occurred in residential areas (72.6%) and during daylight hours (86.7%). Monthly frequency of bites was positively correlated (r= 0.946) with mean maximum air temperatures in central Florida and not correlated (r= -0.065) with testosterone concentrations in adult male alligators, suggesting that bites are more related to temperature than territorial defense. Most alligators were males (76.9%). We found only one instance where a bite was prompted by defense of eggs or young by an adult female alligator. Victims were predominantly male (81.8%), and we saw no differences in the proportion of victims in 5 general age classes of people. About half of the victims were alone (51.1%) and in the water or at the waters edge (87%) when bitten. Alligators were not observed prior to biting the victim in 79% of bites, suggesting that alligators usually used stealth when approaching humans. Evidence of humans feeding alligators prior to the bite was documented in 34.7% of bites. Dogs were present in only 10% of bites. Twenty-two fatalities were attributed to alligator attacks, but no pattern in ages of victims could be discerned. Alligators involved in fatal attacks were in good condition with few deformities or injuries. Alligator bites in Florida appear to be feeding attempts, although in just over half of the incidents (53%), the event consisted of a single bite followed by a release, suggesting that alligators were unsure about their prey in these cases. The risk of alligator bite can be contained by selectively removing problem alligators and continuing education of humans likely to interact with alligators. Increasing harvest pressure of alligators in human residential and high recreational use areas may be the only means of significantly reducing the risk of alligator bites.

Introduction

The Problem

American alligators (*Alligator mississippiensis*) inhabit nearly all freshwater habitats in the coastal plain of the southeastern United States. In Florida, they are found in all 67 counties and they inhabit freshwater lakes, streams, marshes, wooded swamps, canals, reservoirs, brackish coastal estuaries, and tidal streams. Many of Florida's 19 million human residents and the 95 million out-of-state tourists that visit Florida every year either reside on fresh water or participate in fresh water-related activities such as swimming, wading, diving, or boating. This attraction to water puts people in potential conflict with the state's estimated 1.3 million alligators, of which an estimated 300,000 are adult-sized (≥1.8 m) and capable of delivering severe injuries to humans.

Although Nile crocodiles (*Crocodylus niloticus*) and Saltwater crocodiles (*C. porosus*) are recognized as "notorious man-eaters" (Pooley *et al*. 1989; Wallace *et al*. 2011; Caldicott, *et al*. 2005), it is only since the early 1970s that American alligators have been considered a significant threat to human beings (Hines and Keenlyne 1976, 1977; Pooley *et al*. 1989). In general, early naturalists believed alligators to be non-threatening to humans unless provoked or threatened (Kellogg 1929; Audubon 1931; Neill 1971). Several attacks by alligators on humans during 1948-1958 caused some naturalists, state officials, and the general public to reconsider this notion (Carle 1948; Bothwell 1962; Neill 1971). Some naturalists speculated that differences in aggression of alligators appeared to be associated with temporal and regional variation in persecution of alligators by humans, and consequent variation in wariness (Allen and Neill 1952; Neill 1971). Suppression of illegal alligator skin trade in the early 1970s resulted in a rapid recovery of the Florida alligator population (Hines 1979; Woodward and Moore 1994). Complaints by the public about alligators increased immediately after protection (Schemnitz 1974) and continued to rise through the 1980s and 1990s. The number of complaints has leveled off in recent years (Fig. 1).

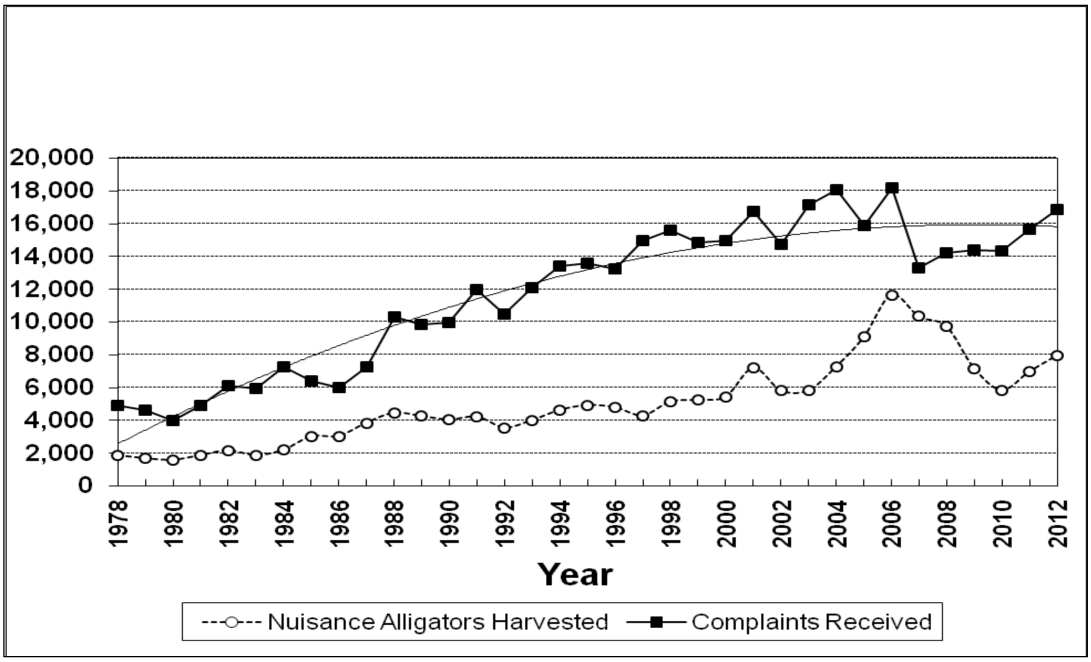

Figure 1. Number of alligator complaints received and nuisance alligators harvested in Florida during 1978-2012.

Alligator bites on humans increased concurrently with rising alligator populations and complaints during the early 1970s (Hines and Keenlyne 1976) (Fig. 2), and a nuisance alligator control program was implemented in 1978 to manage problem alligators (Hines and Woodward 1980). Bites have continued since 1978 but long-term trends have not been clear. Conover *et al*. (1997) concluded that "Alligator bites increased dramatically in the 1980s and from 1990-1995…" throughout the alligator's range but they drew this inference from incomplete data and included provoked bites in their assessment. They also pointed out that improvements in reporting of bites may have contributed to apparent recent increases in the frequency of reported incidents.

We should mention American crocodiles (*C. acutus*), which are also found in south Florida but behaviorally, they are considered a relatively timid population of *C. acutus.* However, non-provoked bites of American crocodiles on humans in Florida have never been documented. Their presence does make some waterfront residents and salt and brackish recreational users uneasy, and both complaints from the public and translocations have increased exponentially in recent years (L. Hord, pers. comm.).

The Current Situation

Alligators and crocodiles are managed by the Florida Fish and Wildlife Conservation Commission (FWC) in Florida. The FWC is a constitutional agency, and no other government entities are allowed to manage or handle alligators without a permit from the FWC. Prior to 1978, the FWC [then the Florida Game and Fresh Water Fish Commission (GFC)] dealt with problem alligators by capturing and translocating them to more remote areas. It became apparent that many translocated alligators either returned or tried to return to their removal site, and the costs of live-capturing several thousand alligators per year was becoming unfeasible (Hines and Woodward 1980). The GFC instituted a nuisance alligator control program in 1978 to combat the increasing number of complaints about problem alligators and to reduce the risk of bites (Hines and Woodward 1981). Hines and Woodward (1980) found that selectively harvesting nuisance alligators after receiving a complaint was the most effective means of reducing the immediate risk that alligators posed to people or their domestic animals. This research indicated that the most cost-effective approach was to offset the expense of removing alligators by allowing contracted nuisance alligator trappers to sell the skins and, later, the meat from harvested alligators (Hines and Woodward 1980, 1981; Jennings *et al*. 1989). Except for a few minor adjustments (Woodward and Cook 2000), this program was virtually unmodified until 2006. Following 3 fatal alligator attacks in 2006, the statewide nuisance alligator program instituted new procedures to improve response time of trappers to complaints and allow proactive removal of alligators under certain situations.

Attitudes of people in Florida about alligators range from full acceptance of living with alligators to complete rejection of living with them. However, when polled in 2009, the majority of people thought there were about the right amount of alligators in non-residential areas, and attitudes were evenly split on whether there was the right amount or too many alligators in residential areas (Hayman 2011). Interestingly, people who lived near water or conducting activities in or around fresh water felt less at risk from alligators than those that did not live near or recreate in fresh water habitats (Hayman 2011). So, people in Florida generally accept living in the close proximity of alligators, given the state of the alligator population over the last decade and the existence of the nuisance alligator program. However, we suspect attitudes would be substantially different if problem alligators were not removed from human use areas on a regular basis.

Whether the nuisance alligator program has reduced the risk of alligator bites has not been clear because the FWC was not able to conduct an experiment comparing harvested with non-harvested sites. However, in this paper we examine trends in the frequency and rate of alligator bites in hopes of shedding some light on long-term changes in risk of alligator bites. We also classify alligator bites, analyze the characteristics associated with alligator bites, and assess hypotheses posed over the years as to why alligators bite humans and the circumstances associated with alligator bites. The results of this latter analysis will hopefully provide insight into how people can reduce the risk of being bitten by alligators.

Hypotheses Examined

Over the years, there has been much conjecture about the trend in alligator bites and many hypotheses have been put forward regarding the reasons for alligators biting humans. We evaluated the following:

1. The frequency of alligator bites has been increasing since 1970 and since 2000.
2. The risk to Florida residents of being bitten by an alligator has been increasing since 1970 and since 2000.
3. Alligator bites are correlated with the number of complaints received about problem alligators.
4. Alligators are more likely to bite people during the April-June alligator mating season.
5. People are more likely to be bitten by alligators during the April-June alligator mating season and that this is caused by elevated testosterone levels in male alligators.
6. People are more likely to be bitten by maternal female alligators during the June-26
7. Alligators that bite people have usually been fed prior to the incident.
8. The majority of alligator bites are cases of "mistaken identity", where alligators mistake a human for a normal prey species.
9. Alligators are more likely to bite small children than adults.
10. People in the presence of a dog are more likely to be bitten than those without dogs present.
11. People on land are at significant risk of being bitten by alligators.
12. The frequency of alligator bites tends to increase with lower water levels.

Methods

Protocol for investigating and compiling human-alligator incidents

- **Who interviewed victim and witnesses?** Since 1971, incidents involving a bite by an alligator on a human have usually been reported to the FWC by telephone by the victim or their family, the medical caregivers who treated the injuries, or by local law enforcement agencies. Prior to 1971, reporting was inconsistent, particularly for bites resulting in minor injuries. In most cases after 1970, officers with the FWC Division of Law Enforcement conducted the investigation and interviewed the victim and witnesses. Biological staff usually assisted with the removal of suspected alligators, recovery of victims' body parts, and physical examination of the alligators in cases involving severe injury. We relied on published or newspaper accounts of incidents prior to 1971 (Kellogg 1929; Carle 1948; Bothwell 1962; Neill 1971; Hines and Keenlyne 1977; DeVane 1978).

- **What questions were asked of the victim and witnesses?** The victim, witnesses, and local residents were questioned as to what they observed during the incident. Specific questions asked were: Was the alligator observed prior to, during, or after the incident?; Had alligators been fed in the general or immediate area of the incident?; Were dogs present at the time of the bite?; Were other people near the victim at the time of the bite?; Was the bite provoked?; and, What activities was the victim engaged in prior to the bite?

- **Who was responsible for catching and removing alligators?** Prior to 1978, GFC wildlife officers or biologists were responsible for catching and removing alligators. After 1977, nuisance alligator trappers assisted GFC/FWC staff in removing alligators associated with a bite.

- **How was the perpetrating alligator determined?** In cases where the victim or witnesses observed the incident, we used their size estimates of the alligator to target a likely culprit. If several alligators in the area of the bite were $\geq$1.8 m, alligators would be removed until the area was cleared of alligators or the remaining alligators were rendered wary. If bite marks on the victim were discernible, we used the bite pattern as an indicator of alligator size. In cases where the alligator ingested body parts of the victim, alligators of a likely size would be removed from the general area of the incident and their stomachs examined until the alligator responsible for the attack was caught.

- **How was the validity of incident determined?** In some cases, people sustained injuries non-indicative of an alligator, such as a single laceration or a puncture wound, and never observed an alligator but felt certain that they were bitten by an alligator. In those cases, FWC law enforcement and biological staff examined photos of the injuries to determine the likelihood that the injury was caused by an alligator. These incidents were included as a confirmed bite only if the weight of evidence indicated the most likely cause of injury was an alligator.

- **Has the reporting of incidents been consistent over years?** Prior to 1971, reporting of alligator incidents to the FWC was inconsistent and no formal record-keeping system was maintained. Since 1971, records of bites resulting in injuries that required some advanced medical treatment have been received, maintained, and recorded on the Alligator Bite Database maintained by the FWC's Alligator Management Program. It is likely that all severe bites since 1970 have been documented and included in the database. However, bites requiring minor medical care or first aid may not have been reported.

<u>Classification of incidents</u>

- **What is considered an attack?** We defined an attack as an encounter where the alligator approached the victim, the bite was sustained, the alligator bit the victim multiple times, or the alligator consumed body parts of the victim. In some cases, which we will discuss later, an incident resulted in minor wounds from a brief bite. We consider those as bites rather than attacks. In many cases, it appeared as though the victim unknowingly approached the alligator and/or bumped the alligator and may have been bitten in a defensive response by the alligator. We consider these cases as unintentionally provoked bites, and we included those cases in most analyses.

- **Were all bites included or just those that were clearly an aggressive attack by a wild alligator on a human?** We were primarily interested in the risk of being bitten by a wild alligator when engaged in normal daily activities. Therefore, we excluded bites on humans that occurred while people were trying to handle or move alligators. These were considered to be provoked bites and were not used in any of our analyses.

- **How was the severity of bite classified?** Injuries from incidents that resulted in scratches, superficial lacerations, shallow or small puncture wounds (usually inflicted by small alligators), abrasions, or bruises were considered as minor injuries. Injuries of moderate severity included deep puncture wounds (usually alligators ≥1.8 m) and/or deep lacerations requiring medical treatment (sutures or extensive bandaging). Bites that resulted in loss of appendages, broken bones, life-threatening lacerations or puncture wounds, or damage to internal organs were considered to be severe injuries.

- **In cases of deceased victims, what forensic procedures were used to determine if bite was ante- or post-mortem?** The FWC has relied on county medical examiners to make a determination of cause of death of corpses that have been bitten by alligators, particularly incidents where there were no witnesses. The knowledge and thoroughness of examinations varied over time, with a gradual improvement in later years. However, it was apparent that the prior knowledge and of medical examiners about alligator behavior was important in making a determination about cause of death and forming their conjectures about the course of events leading up to death when no witnesses were present. In many cases, alligators seize and drown the victim, and the cause of death is determined to be "drowning" by the medical examiner. In these cases, we examined the medical examiners report for evidence of hemorrhaging or contusions around bite marks to confirm whether there was blood flow at the time of the initial bite, indicating that the victim's heart was pumping when first bitten.

Human-alligator conflict reduction and methods used to measure results

- **Problem alligator removal program and disposition of animal (killed, translocated, moved into captivity, other).** In Florida, problem or nuisance alligators are removed either alive or dead from the capture site. Live alligators are dispatched at an alternate site and alligators are usually processed for skins and/or meat. Nuisance alligator trappers are allowed to transfer live alligators to a permitted alligator exhibit or farm. Typically, demand by exhibits and farms for nuisance alligators has been limited to a very few large specimens.

- **Public education.** The FWC has historically provided news releases during late winter and early spring to alert the public that alligators will be moving and feeding more as the weather warms, and that people should be alert for alligators when children and pets are near fresh water. News releases are disseminated by the media at their discretion, and sometimes they are not considered important enough to publish. The FWC also distributed paid public service announcements to Florida network and cable television channels during April-June in 2007, 2008, 2010, 2011 and 2014, which insured that the announcement would be broadcast.

- **Structural separation of alligators from (fences, exclosures, etc.).** In certain circumstances, the FWC recommended that people install fences or bulkheads to keep a safe separation between alligators and people and their domestic animals.

Analysis

We used only those records with estimates of hour of bite data for time of day analyses. Time of bite was rounded to the nearest hour. We used mean monthly air temperatures in Orlando, Florida (Florida Climate Center, Florida State University, www.coaps.fsu.edu/climate_center/), which we considered to be centrally located to most bite sites, for correlation with monthly bite frequency. We used mean monthly male testosterone concentrations from the Merritt Island area of Florida (Hamlin *et al*. 2011) to correlate with monthly frequency of bites.

To examine the probability of various human age classes being bitten according to various categories, we grouped victims in age and freshwater user activity groups when available from surveys. We used ages 0-14, 15-24, 25-44, 45-64 and ≥65. Activities were categorized by the activity in which the victim was engaged immediately prior to the incident: swimming (water activities in which victims were over 50% submersed in water), wading (water activities where victims were standing or crouching on the bottom and less than 50% submersed), diving or snorkeling, fishing (sport-fishing, trot-lining, or cast-netting), boating (riding in or using a boat or raft), walking (walking or standing on dry land), landscaping (mowing, weeding, pruning, etc.), or other. We also examined whether victims were involved in golf course-related activities and classified those as retrieving golf balls (not golfing), golfing or golfers retrieving golf balls, and non-golfing use of aquatic habitats on golf courses.

We regressed annual frequency of severe alligator bites on both mean annual rainfall and mean annual water runoff rates for Florida to assess the effects of water availability on the frequency of bites. To assess the trend in per capita risk we divided the annual frequency of severe alligator bites by the number of Florida residents.

Results

Frequency and Temporal Trends in Alligator Bites

The Florida alligator incident database includes 619 alligator-human incidents, of which 553 resulted in bites of 1 or more persons, 30 did not result in a bite, 7 were determined to be post-mortem feeding by alligators on persons that died of accidental causes not associated with an alligator bite, and 7 involved alligators feeding on deceased persons with undetermined cause of death. The alligator incident database includes bites from 1948 through 2013 (Fig. 2). Of the 553 alligator bites, 307 were non-provoked, 55 may have been unintentionally provoked and 210 were provoked. Provoked bites usually involved handling of alligators (79%), and were not included in further analyses. Analyses of trends and bite characteristics included 362 bites (307 non-provoked and 55 unintentionally provoked) (Fig. 2).

We were not able to verify any alligator bites prior to 1948, although Dowler (1846) refers to a Jacksonville, Florida newspaper article describing an attack on a man in 1835 and Neill (1971) mentioned a reported fatal attack in 1928. The first well-documented alligator attack was on a woman in Weekiwatcheee Springs in 1948 (Carle 1948). We found records of three bites and one incident that is under review during 1950-1958, but we found no reports of bites during 1959-1970. Alligator bites occurred in all years from 1971 to 2013.

The frequency of non-provoked alligator bites resulting in severe injuries increased from 1971-2013 (P= 0.026) but showed no trend from 2000 to 2013 (P= 0.417) (Fig. 3). The number of bites resulting in severe injuries per 1 million Florida residents showed no significant trend during 1971-2013 (P= 0.255) (Fig. 4). We found no discernible trend in frequency of fatal bites, although from 2001-2007, 12 fatal attacks occurred in 7 years (Fig. 2). The frequency of alligator bites was not significantly associated with the frequency of alligator complaints (P= 0.085). There has been no significant increase in frequency of overall bites since the nuisance alligator program in 1978 (P= 0.139).

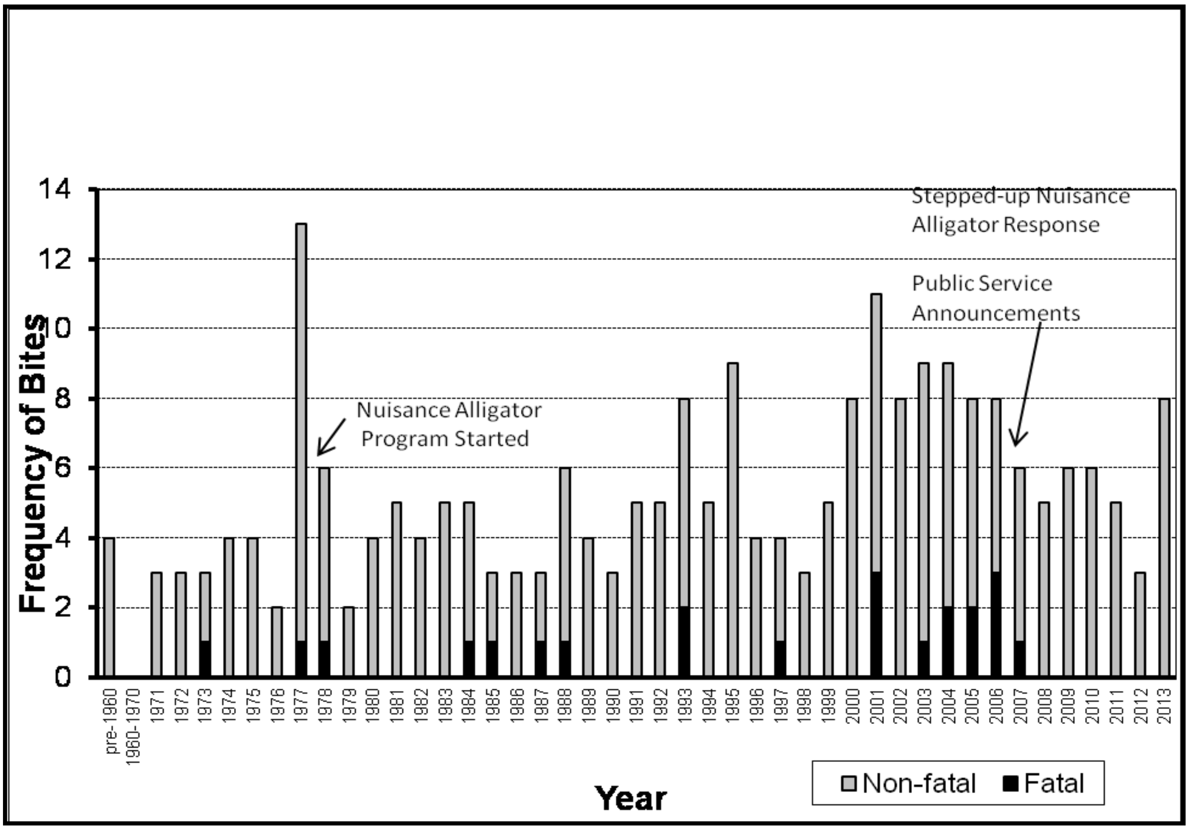

Figure 2. Non-provoked alligator bites in Florida by severity of injury during 1948-2013.

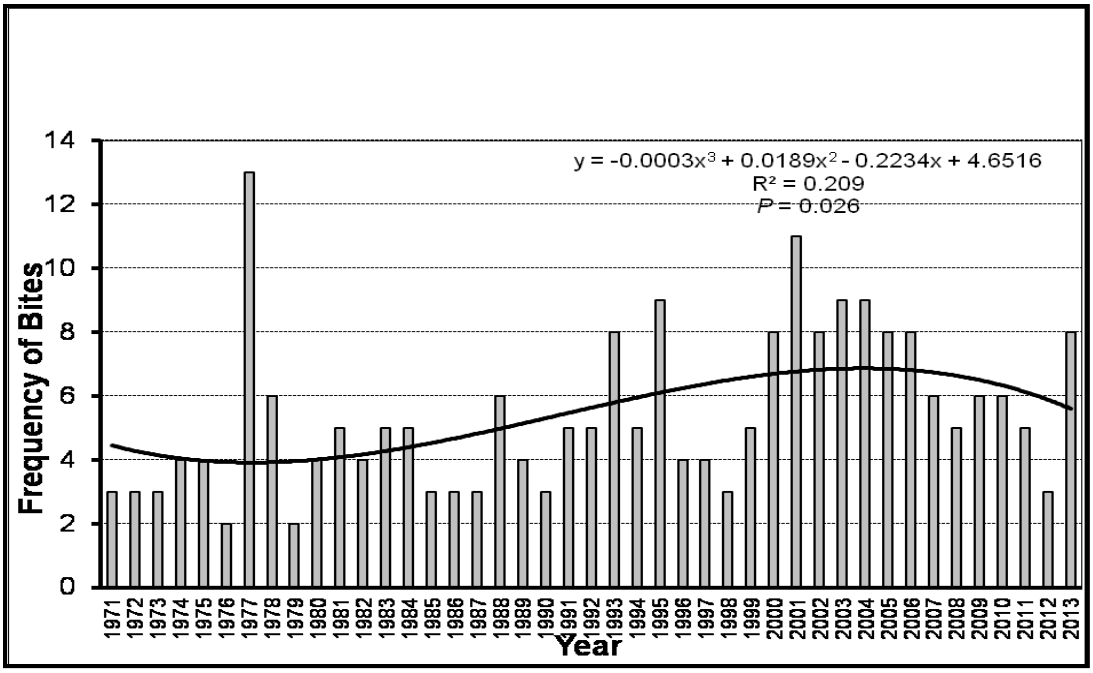

Figure 3. Trend in non-provoked alligator bites in Florida resulting in moderate to severe injuries.

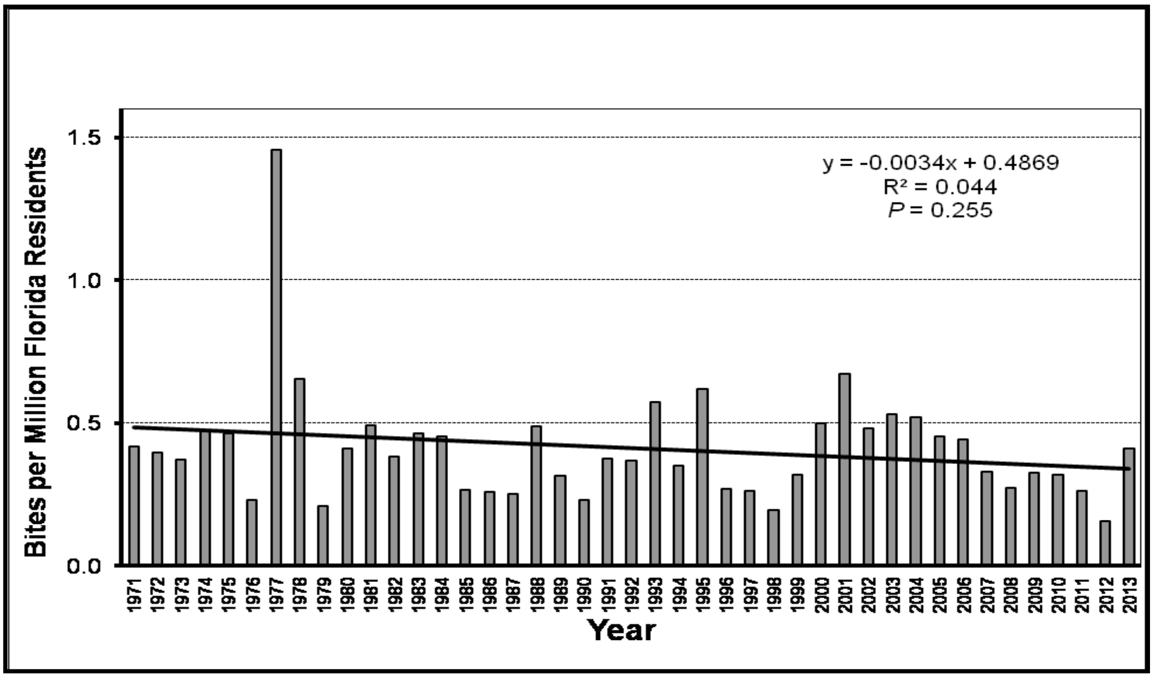

Figure 4. Number of alligator bites per 1 million Florida residents during 1971-2013.

The monthly frequency of alligator bites exhibited a bell-shaped curve with bites peaking during the summer (Jun-Aug) months and few bites during the winter (Dec-Feb) months (Fig. 5). Alligator bites occurred in all months, but most bites occurred during the warmer months (Fig. 5). The monthly frequency of bites was not correlated with mean monthly male alligator testosterone levels (r= -0.178) but was positively correlated with mean monthly air temperatures (r= 0.946) (Fig. 5). Alligator bites occurred during all hours, but most bites (83.8%) occurred during 1000-2000 hours.

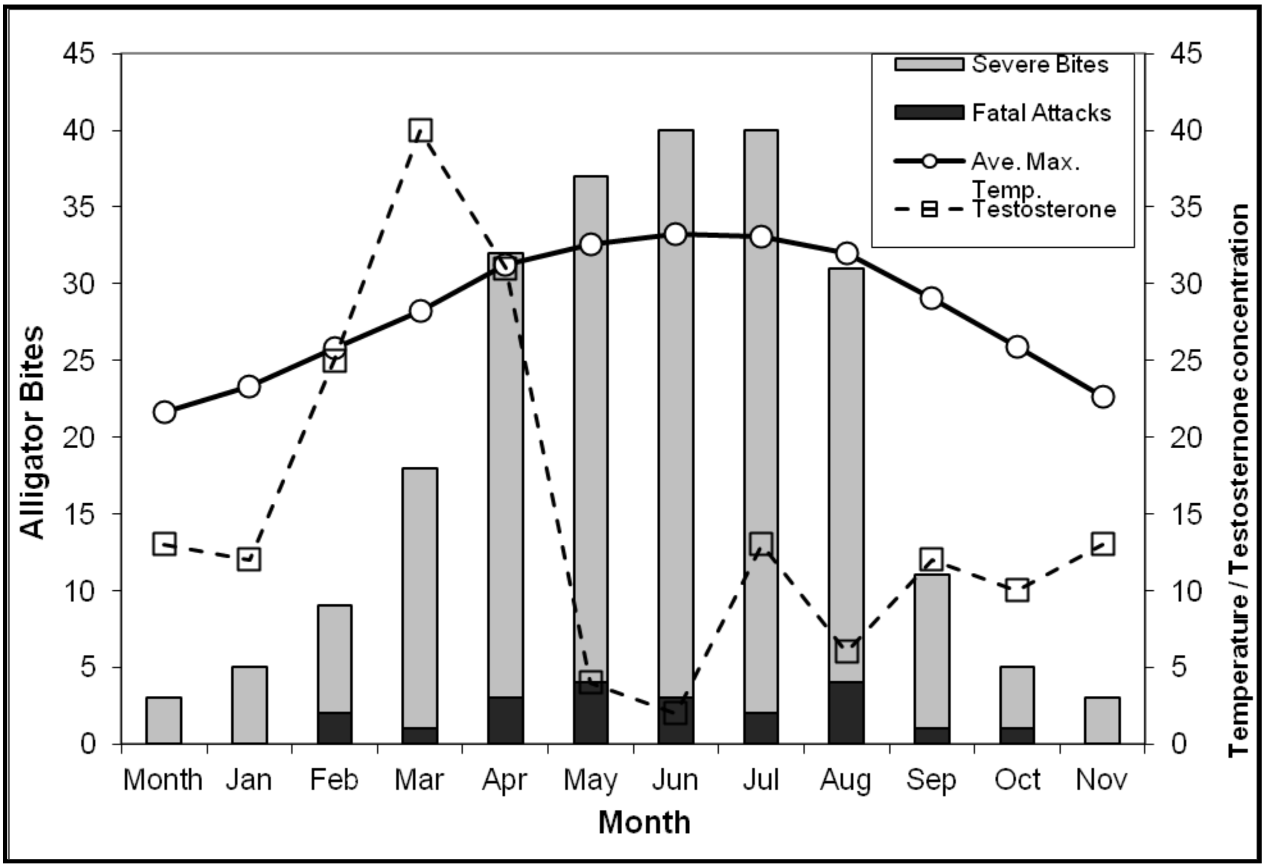

Figure 5. Association of mean ambient temperatures (C) and mean monthly testosterone concentrations (ng/ml) with monthly frequency of alligator bites resulting in severe injuries to humans in Florida during 1948-2013.

Spatial Trends

We documented alligator bites in 52 of Florida's 67 (77.6%) counties in Florida. Lee County in southwest Florida experienced the most bites (34). Bites occurred throughout peninsular Florida but were concentrated in the coastal areas of the southern region and the central and north-central regions of Florida. Only 3 bites were reported for the Florida panhandle west of the Apalachicola River. The Lakeland metropolitan area experienced the greatest number of bites (13), with Fort Myers (11), Orlando (10), Sanibel (9) and Venice (9) comprising the remaining top 5 frequencies of bites. We found no great concentrations of bites on any given water body. The greatest number of bites (5) occurred on the Withlacoochee River (South), Alexander Springs and Juniper Creek each had 3, and the remaining areas had 1-2 bites. Nineteen bites occurred on areas with managed hunts for larger alligators. Bites occurred most often in areas classified as urban (69.5%) as compared to rural (30.5%), although bites tended to be more severe in rural locations (72.2%) than urban sites (62.6%).

Victims

Of those victims of alligator bites with known residency status, 93.5% were Florida residents. Twenty victims were from 14 other states in the USA and two victims were from foreign countries. Most victims (57.1%) were local residents, who were familiar with the area where the incident occurred. Use of alcohol by the victim prior to the bite was confirmed in only 5% of cases. Males (81.8%) were much more likely to be victims than were females. Ages of victims of alligator bites ranged from 2-90 years. There was no significant difference in the frequency of bites among the 5 different age classes we established (χ^2= 7.032, P= 0.134).

Activity

Most bites (92.4%) occurred in or near (<1 m) permanent or semi-permanent wetlands (eg ponds, lakes, streams, swamps, canals, or drainage ditches). Twenty-two bites (6.2%) occurred in upland locations (≥1 m from water). Of the upland bites, 13 were severe and 9 resulted in minor injuries. Interestingly, 41 bites occurred at public or private golf courses, 22 of which resulted in severe injuries. Of the 41 victims, 29 were retrieving balls from a pond or lake, 11 were golfers searching for lost balls, and one was wading in a water hazard. One victim was bitten on 4 different occasions while retrieving golf balls. Nine of the bites occurred after the divers or waders bumped into alligators, and were considered unintentionally provoked.

Victims were most often (68.2%) in the water when bitten; 96 were in ≤1.0 m depth, 133 were in >1.0 m depth, and 13 were in an unknown depth. Ninety-one victims were bitten while swimming. One victim was bitten while swimming in two separate incidents at the same location; first in 1976 and, again, in 1977. Thirty-three victims were snorkeling or scuba diving, 83 were wading, and 15 were boating.

Slightly over half (51.1%) of victims were alone when bitten. The victim was in the presence of other persons in 48.5% of incidents. In 5 incidents, a second victim was bitten by an alligator while aiding the first victim. A dog was reported to be in or near the water in 9.7% of incidents. Alligators had been fed in the immediate area of the incident in 25.6% of bites. In 57.7% of bites, there was no indication that alligators had been fed in the immediate area. Most victims (78.5%) did not see an alligator in the area until they were bitten. Some (10.8%) victims did not observe the alligator that bit them before, during, or after the bite because of murky water or darkness.

Injuries

Most victims (82.1%) were bitten only once during the incident and 17.4% were bitten ≥2 times. Most bites involved a single bite followed by immediate release (53.3%). However, 46.2% of bites involved prolonged holds or multiple bites. The initial bite on most victims (80%) was either on an upper extremity (hand or arm) or on a lower extremity (foot or leg). Twenty percent of victims were bitten on the torso, buttocks, neck or head.

Physical injuries were reported for 354 of 362 incidents. Of victims that received no injuries, eight were bitten on clothing (ie wetsuit, swim fin, boot) but not injured. Of those victims injured during an incident, 34.4% received only minor injuries and 65.6% sustained moderate to severe injuries.

Fatalities

Twenty-two human deaths were attributed to alligator bites, and all appeared to be predatory attacks. One incident in 1957 is still under review. One fatal attack occurred in each of years 1973, 1977, 1978, 1984, 1985, 1987, 1988, and 2007. Two fatal attacks occurred in 1993, 2004, and 2005, and three occurred in 2001 and 2006. Thirteen victims were male and 9 were female. Seven victims were 2-14 years of age, 3 were 15-24 years old, 5 were 25-44 years old, 3 were 45-64 years old, and 3 were ≥65 years old. Nine victims of fatal attacks were swimming when attacked, two were snorkeling, one was wading in shallow water, 2 were walking along the shoreline, one was landscaping, and the attack site of 3 victims was uncertain but probably near the shoreline. The landscaping victim was trimming plants near the shoreline (investigators estimate about 3 m) when she was seized by an alligator that had emerged from a nearby pond and was dragged back to the pond.

The sizes of alligators determined to have been responsible for fatal attacks ranged from 2.0-3.7 m. The 2.0 m alligator was responsible for killing a 2-year-old girl. Two victims had survivable injuries but subsequently died of bacterial infections. Ten of the alligators responsible for fatalities fed on the victim following the initial attack.

The Alligator

The TL of 332 alligators presumed to be responsible for bites was measured by FWC staff or agents after they were captured and killed. TL of all estimated and measured alligators ranged from 0.7 to 3.7 m (mean= 2.1 m). The mean TL of alligators responsible for bites with severe injuries was longer (2.4 m) than the mean TL of alligators responsible for minor injuries (1.7 m). Most (71.4%) alligators found responsible for bites were of adult size (≥1.83 m TL).

The sex of the alligator was listed on 149 records. Male alligators (76.5%) were more likely to be responsible for a bite than were female alligators (22.2%).

None of the 57 alligators examined showed obvious signs of debilitating disease or had a major physical disability. Three alligators were reported to be under-weight for their size, one was missing an eye, and the teeth of one large alligator were worn close to the gums (a condition common for older individuals). No definite pattern of injuries, abnormalities, or diseases could be discerned in necropsy reports of 10 alligators examined by veterinarians.

Although cause of bites was preliminarily attributed to adult female alligators defending their nests or young by field investigators or local officials in 11 cases, we were able to substantiate this behavior on only 1 case. In 10 of the cases, the bite was not during the nesting season, or the sizes of the observed young indicated they were older than 1 year, or the alligator was a male.

Water Levels

We found no significant association between the frequency of bites and the mean annual rainfall (P= 0.579, R^2= 0.010) or mean water runoff rates (P= 0.833, R^2= 0.002).

Discussion

The alligator population in Florida increased an estimated 170% (Woodward and Moore 1994; C. Carter, pers. comm.; A. Brunell, pers. comm.) and the human population in Florida increased 188% during 1971-2013. Thus, the prospects of human-alligator encounters more than doubled during that 43-year period. Although the annual frequency of alligator bites has increased over the 42-year period, the frequency of alligator bites has remained stable since 1999. Further, the number of bites per Florida resident showed no significant trend during 1971-2013. Although we were not able to test several hypotheses about the reasons for this, we believe that the static rate of per capita alligator bites during this period of rapidly increasing human and alligator populations primarily resulted from the selective removal of potentially dangerous alligators through the nuisance alligator program (Jennings *et al*. 1989; Woodward and Cook 2000). This program culls alligators that are habituated to humans, show no wariness, show aggressive behavior, or are in situations that present a threat to people and pets. It is a reactive program, in that it relies on the public to contact the FWC to have an alligator removed. We attribute the stable frequency of bites and of bites/capita in recent years primarily to improvements in the performance of nuisance alligator trapper agents, which has reduced the time lapse between when a complaint was received and when the alligator was removed.

Increasing educational efforts and public service announcements aimed at public groups likely to interact with alligators are also thought to have helped people better understand the risks associated with alligators and may have reduced human-alligator conflict. Paid public service announcements, begun in 2007, are also thought to generally improve the knowledge and awareness of the public about the danger of alligators. We were not able to test the effectiveness of these announcements but it is likely that they played a part in reducing human-alligator encounters.

To a lesser extent, the expansion of the recreational alligator harvest program to a county quota system may have reduced alligator densities on areas adjacent to high human use areas. Hunting can increase wariness of the remaining alligators and lower densities can reduce the likelihood of alligators moving from wild areas into areas frequently used by people. The apparent inverse relationship between hunting pressure and incidence of attacks was previously noted by Allen and Neill (1952), Neill (1971) and Hines and Keenlyne (1976). Hunting may selectively remove the least wary alligators from populations while increasing the wariness of remaining individuals. We are unable to explain the mechanism by which an increase in wariness can occur, but Neill (1971) suggested that a combination of artificial selection for shier individuals, and auditory and olfactory cues might lead to increased wariness. This connection between hunting pressure and wariness was also suggested by Kushlan and Kushlan (1980), who found that nesting female alligators in the protected Everglades National Park were more aggressive than nesting females in areas where they were more prone to harassment by humans.

Why do alligators bite human beings? To answer this question, it is helpful to examine alligator biology and behavior. Alligators are carnivores and prey exclusively on animals. They eat a broad variety of prey and tend to select size of prey items in proportion to their size (Wolfe *et al*. 1987; Delany *et al*. 1999; Rice *et al*. 2006). Based on the habitat preferences of species found in the stomachs of alligators and on anecdotal observations, alligators primarily prey on aquatic animals. Alligators, like several other crocodilians, will take terrestrial species if they enter the water or approach the water's edge (Pooley *et al.* 1989). In Florida, there is a popular notion that alligators can run "as fast as a racehorse" and that they are capable of running down prey on land. Although alligators are capable of surging out of the water and onto land to size prey, there is no verifiable evidence to support that they will pursue mammalian prey on land at top speed for distances in excess of 2-3 m. Alligators have evolved as aquatic predators, and, although they are capable of bursts of speed, they are not adapted for pursuing and catching prey on land. We are not aware of a measured land speed for running American alligators, however, the maximum land speed of a galloping Johnston's crocodile, *C. johnstoni*, has been measured at 17 kph going downhill in an escape response (Webb and Gans 1982; Zug 1989:46). Alligators are considered to be more sluggish than crocodiles and, therefore, we would expect their maximum land speed would be <18 kph. Although they are capable of a burst of speed, this is usually used as an escape behavior when water or other cover is near. We saw no evidence in our data of attacks in which an alligator was observed to run more than 1-2 m on land to seize a person.

Alligators are heterothermic - their body temperature varies with environmental temperature. Therefore, metabolic rate and appetite also vary with temperature (Coulson *et al*. 1983). Alligators substantially reduce feeding at 21°C and are reported to cease feeding altogether when ambient temperature drops below 15.5°C (Coulson *et al*. 1983). In Louisiana, captive adult alligators maintained in outdoor pens refused food from mid-October through the end of February (Joanen and McNease 1971). In Florida, active feeding months vary depending on temperature clines. There is no published information on seasonal feeding patterns of alligators, but movement patterns should be an indicator of activity rates and feeding. Adult alligators tend to move least during the winter (Dec-Mar), increase movements as temperature rise in the late winter (Feb-Mar) and early spring (Apr-May) and achieve peak movement during late-May through August. Movements are reduced in the fall (Sep-Nov) as winter (Dec) approaches (Joanen and McNease 1970, 1972;

Goodwin and Marion 1979; Taylor 1984; Rootes and Chabreck 1993). Therefore, our findings that alligator bites were correlated with ambient temperatures in Florida support the hypothesis that most bites are related to feeding attempts.

Based on the predominantly secretive behavior of alligators when approaching victims during human-alligator incidents, we attributed most bites to predatory bites. The exceptions were 55 (15%) incidents where people were bitten by alligators in what appeared to be defensive bites or retaliation against unintentional provocation by humans. These bites were most common when people were wading or diving and bumped into alligators. Most bites that resulted in superficial injuries appeared to be feeding attempts, albeit meager efforts. The tendency for alligators to bite a single time then release, even when they could easily subdue the victim, suggests an uncertainty by the alligator about the prey. Our interpretation that alligator bites are predominantly predatory concurs with those of Hines and Keenlyne (1976, 1977) and Pooley *et al*. (1989). The predatory nature of most alligator bites is further supported by the finding that, if given time, most alligators responsible for fatalities and amputations fed on the victim's body parts following the initial attack.

We found sparse evidence that female alligators bit humans in the act of protecting their eggs or young; only one incident was documented. Accounts of female alligators biting intruders that threatened their eggs or young apparently were based on conjecture by investigators. Ross Allen, the famous Florida herpetologist and expert on alligators during the mid-1900s, was quoted in 1957 as saying that the "conditions under which alligators would attack people are baiting, teasing, and invading the nest." This general sentiment prevailed until the early 1970s when Hines and Keenlyne (1976, 1977) presented information that indicated that most attacks were predatory. Although brooding females occasionally make sustained charges at intruders (Kushlan 1973; Deitz and Hines 1980), such behavior is usually preceded by vocalization and display which is likely meant to discourage the intruder (Garrick and Lang 1977; Kushlan and Kushlan 1980; Pooley *et al*. 1989; Hunt and Ogden 1991).

Alligator attacks have been attributed to "territorial defense", a behavior generally considered to be protection of a space from conspecifics for critical resources (food, shelter, water, etc.) or mating advantages. Alligators and most other crocodilians tend to visually display when defending against conspecifics (Garrick and Lang 1977), and this has lead to the presumption by some people that this behavior would be similar when defending a territory against other species. We could find no instances when victims were bitten following displays by alligators. However, in at least 2 instances alligators displayed after delivering bites resulting in severe injuries to the victim. Thus, except for retaliatory bites resulting from unintentional provocation, bites could not be attributed to territorial defense.

Contrary to general supposition, bites did not occur more frequently during the Mar-May courtship season. The frequency of bites during the non-breeding, September-November, season was similar to bites during the March-May mating season. Monthly frequency of bites throughout the year was strongly related to ambient temperature, peaking during July. This can be explained by increased water use by people during Jun-Aug because of hot weather and summer water activities, coupled with higher metabolic rate and an elevated feeding frequency of alligators during warmer months. Bites occurred most frequently during mid-late afternoon, generally the warmest hours of the day. This also probably coincides with peak water recreation activities by humans.

The predominance of alligator bites in peninsular Florida is probably related to denser concentrations of humans and alligator populations in that region relative to the Florida panhandle and the very southern part of the state.

Victims were bitten while participating in a variety of water activities. Few victims were bitten ≥1 m from the water's edge, and most of those bites appeared to be the result of people bumping into alligators while walking at night or alligators walking up to people who were either crouching, sitting, or lying on the ground. Most of the latter were involved in landscaping activities and intent on their work. A high percentage of victims were male. This may be more a matter of males tending to spend more time in the water and taking greater "risks" (swim, wade, or snorkel in alligator habitat) than females, rather than differences in morphology or odor. There was no obvious tendency for alligators to bite any particular age groups. However, young people may put themselves at greater risk by participating more in deep water activities in or near preferred alligator habitat than older people. Fatal attacks occurred on a wide range of sizes and ages of victims with no apparent tendencies.

Drought conditions tend to concentrate alligators in remaining wet areas. Further, as water levels recede, alligators tend to move around looking for more permanent water in which to reside. This may result in alligators moving into areas where they had not previously been and posing a new risk. We did not find any relationship between water availability (using mean Florida rainfall and runoff as indicators) and the frequency of bites. However, water availability conditions can vary considerably from north Florida to south Florida and this may have masked any association.

Alligators were not observed prior to most (78%) unprovoked bites, indicating a stealthy approach by alligators, and suggesting a predatory attack. However, in the majority of cases, encounters resulted in a single bite then a release, implying that alligators were either unsure of their prey, or the prey was too large or unmanageable. As expected, the severity of injuries was positively correlated with alligator size. We saw no tendency for alligators involved in bites to be underweight nor did necropsies of alligators involved in bites resulting in severe injuries reveal a pattern of injuries or abnormalities to the alligator that would suggest that they were compelled to attack humans as a last resort. It is our opinion that the motive for most alligator bites on human was feeding, but that the severity of the bite depended on the size of the alligator, the size of the victim, and the location of the initial bite.

Management Implications

To reduce the risk of alligator bites, people should be aware that alligators can be found in almost any fresh or brackish water habitat in Florida. They should be alert for alligators when they or their children or pets are involved in activities near water. People should avoid water activities (except boating) in areas inhabited by large alligators. They should refrain from activities such as feeding alligators, exercising dogs, and cleaning fish, which may attract or reduce wariness of alligators in areas where people conduct water-recreational activities. Non-wary alligators should be removed from areas with frequent human use.

Alligators pose a threat to humans involved in freshwater recreational activities. Alligators also provide aesthetic enjoyment to humans and are an important component of most wetlands ecosystems (Mazzotti and Brandt 1994). Unfortunately, the only ways to eliminate the threat of alligator bites on humans would be to reduce recreational use of fresh water by people or substantially reduce alligator populations in areas that are likely to have human/alligator conflicts. Alligator bites can have an adverse affect on public attitudes regarding alligators and can have negative ramifications for the conservation of alligators. The FWC has tried to achieve a balance between public safety and maintaining alligator populations near natural densities. Florida's statewide nuisance alligator program currently strives to maintain this balance and appears to be reasonably successful.

The FWC currently distributes to tourists, civic groups, alligator complainants, and other interested individuals up to 50,000 copies per year of the brochure, "Living with Alligators", which warn of the potential danger of alligators and provide guidelines for minimizing risk when living near alligators. In addition, with the onset of alligator feeding and movement activities in the March-

April, the FWC issues news releases that caution the public about the potential danger of alligators. We believe that by educating the portion of the public exposed to a greater risk of bite we were able to increase awareness of the potential danger of alligators, enhance the public's ability to recognize potentially dangerous situations, and reduce the probability of alligator bites. Although the heightened public awareness of alligators frequently leads to the removal of selected alligators, from a conservation perspective, this seems to be preferable to the alternative; a rapidly increasing number of bites and a deterioration of public attitudes toward alligators.

Acknowledgements

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Human-Crocodile Conflict in the Australia and Oceania Region

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Abstract: The incidence of human-crocodile Conflict involving Saltwater crocodiles in the Australia-Oceania region is increasing, and it is becoming a key political issue in Timor Leste and the Solomon Islands, where the species is listed on CITES Appendix I, and where management programs have yet to be developed. Management programs need to reflect the cultural and social characteristics of these small island nations, as one model does not fit all.

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.

The Region

The CSG's "Australia and Oceania" region comprises the six (6) range states for crocodilians - Australia, Papua New Guinea, Solomon Islands, Palau, Timor Leste and Vanuatu (Fig. 1). Vagrant *C. porosus* have been reported from the Eastern Carolines (Allen 1974), Yap State (Buden and Hagelham 2010), Nauru (Webb 1994) and the Marshall Islands (Manolis 2005), but these are not considered to be in the natural range of the species, and are thus not considered further in this paper.

Figure 1. Range states for crocodilians in the Australia and Oceania region.

Species

Three species of crocodilian, the Saltwater crocodile (*Crocodylus porosus*), the New Guinea freshwater crocodile (*C. novaeguineae*) and the Australian freshwater crocodile (*C. johnstoni*), are distributed in the region. *Crocodylus porosus* is distributed in each range state, *C. novaeguineae* is restricted to Papua New Guinea, and *C. johnstoni* is restricted to mainland Australia.

Attacks by *C. johnstoni* are rare, and the species is considered harmless to humans (Caldicott *et al.* 2005; Webb and Manolis 2010). No attacks by *C. novaeguineae* on humans are reported in the CrocBite database (www.crocodile-attack.info), in either Papua New Guinea or Indonesia, but it is possible that attacks by *C. novaeguineae* have been attributed to *C. porosus* (Brandon Sideleau, pers. comm.) - the two species share many habitats and adults are large (Webb *et al.* 2010; Cox 2010).

Vanuatu

The size of the *C. porosus* population in Vanuatu (12,200 km^2 total land area) is unknown, but it is considered to be very small, and restricted to the island of Vanua Lava. Messel and King (1992a) undertook population surveys in 1992, and sighted only two adult crocodiles. HCC has not been reported, and crocodiles are considered as "vermin". A 3.6 m long *C. porosus* that spent one year at the heavily populated island of Maewo. was captured in 2003 and relocated to the Selva River on Vanua Lava (160 km north of Maewo) (www.internationalcrocodilerescue.com.au/about_rescue_unit/vanuatu.html#pressrelease).

Palau

With a relatively small land area of 459 km^2 (Fig. 1), Palau has limited freshwater habitat. Lake Ngardok is an important area for *C. porosus* nesting, and is afforded protection through a management plan for the area (Melekeok State 2010).

Crocodiles were extensively hunted for skins in the 1960s, 1970s and 1980s, with an estimated 1370 crocodile being taken between 1966 and 1981. Following a fatal attack on a man in 1965, there was a deliberate policy to eradicate crocodiles. The Saltwater crocodile population was systematically surveyed in 1991 by Messel and King (1992b) who recorded 42 sightings in 112 km of waterway. More recent surveys (2005-2008) indicate that the population has increased significantly since the 1990s, and is probably now stable (Joshua Eberdong, pers. comm.). Brazaitis *et al.* (2009) estimated the population to be 500-750 individuals based on surveys undertaken in 2003, and interviews with hunters (Matthews 2003) support the view that the *C. porosus* population has increased. A draft management recovery plan was being drafted with assistance from the US Fish and Wildlife Service (Joshua Eberdong, pers. comm.), but it has yet to be completed (P. Brazaitis, pers. comm.).

Attempts are made to capture problem crocodiles, and some adults are maintained in facilities in the main island of Koror. Some captive-bred hatchlings have been released back into the wild. A privately-run facility in Koror is open to visitors, and serves to promote public awareness of crocodiles, but crocodiles are generally “disliked” by the local people, who consider them to be pests.

Two fatal attacks (1930s, 1965) and one non-fatal attack (2012) have been recorded for Palau.

Timor Leste

The ex-Portuguese colony of Timor Leste was governed by Indonesia between 1975 and 1999, and crocodiles were hunted for their skins during this period. Since Timor Leste’s independence in 1999, *C. porosus* has been effectively protected (on CITES Appendix I), and no trade has occurred. The population is considered to have increased, although no surveys have been carried out to quantify its current size.

The Saltwater crocodile is of particular cultural significance to the people of Timor Leste. Legend is that Timor was created when a crocodile died, and the eastern part of the island represents the head of that crocodile. Crocodiles are revered by the people - the national animal and the mascot of the army is the Saltwater crocodile, etc. Because of these beliefs, management of crocodiles to reduce HCC must be tailored accordingly. Timor Leste has economic and other ties with the Northern Territory of Australia, and some training has been provided to Government personnel.

With a total land area of 14,874 km^2, Timor Leste has few freshwater habitats, and these are restricted to the eastern part of the country. During the dry season, rivers on the north coast contain little/no water. The CSG maintains contact with the Timor Leste Government, and a preliminary mission was undertaken in 2009. Consideration is currently being given to the development of a management program.

Since the early 2000s, the incidence of attacks on people has increased. Between 2007 and mid-2014 there were some 41 attacks recorded (www.crocodile-attack.info), most of which had occurred in coastal areas. Kaiser *et al.* (2009) reported that crocodiles do not appear to be as wary of humans relative to countries where they are hunted (eg Papua New Guinea), perhaps reflecting the cultural ties with the people, and no hunting in Timor Leste. Public education is limited to signage at some areas.

Solomon Islands

The Solomon Islands is an extensive archipelago state of 28,400 km^2 land area. Saltwater crocodiles were hunted for the international skin trade until 1989, when hunting was banned. In 1989 the *C. porosus* population was estimated to comprise around 720 individuals (Messel and King 1990).

Due to civil unrest in the country, the Regional Assistance Mission to Solomon Islands (RAMSI) was deployed in 2003, and one of the first actions was the disarming of civilians. Without firearms, people have been forced to go back to traditional hunting methods.

Since 2007 the frequency of attacks on humans has increased (www.crocodile-attack.info; 22 attacks between 2007 and mid-2014), and crocodiles are now a key political issue. The responsibility for dealing with "problem" crocodiles has fallen to RAMSI personnel. Government recognises that a management plan needs to be developed, in order to provide economic incentives for long-term conservation. But efforts to undertake surveys to quantify the status of the *C. porosus* population (currently on CITES Appendix I) have been stifled by a lack of finances and capacity. Some assistance on capture methods has been provided by Australia, but it did not appear to be tailored to the local situation.

The relationship between crocodiles and people varies between clans in the Solomon Islands. Some clans revere crocodiles and believe that crocodiles will not attack "their people", and crocodile callers are considered to be able to "talk" to crocodiles.

Papua New Guinea

Covering some 462,840 km^2, Papua New Guinea has extensive river and wetland habitats that are occupied by *C. porosus* and/or *C. novaeguineae*. Both species are on Appendix II of CITES, and have been utilised for trade through ranching (eggs, hatchlings/juveniles) and wild harvest programs. Crocodiles are viewed as a resource, and provide the only cash income for many rural people.

The CrocBite database reported 51 crocodile attacks between 2007 and mid-2014, but it is unclear whether there is an increasing frequency of attacks over time or not. Population monitoring indicates that the *C. porosus* population is increasing, and the *C. novaeguineae* population is at least stable.

River transport is very common in Papua New Guinea, and many people still use traditional canoes to carry out various activities (eg fishing). People rely on wetlands for food and daily chores (eg bathing, washing), bringing them into close contact with crocodiles and their habitats. Little/no public education about the dangers of crocodiles is delivered in the country (Eric Langelet, pers. comm.).

Australia

The most detailed database on crocodile attacks in the Australia-Oceania region is for northern Australia.

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. That most (69.2%) attacks occurred in the state of Queensland is considered to reflect the larger human population there relative to the sparsely populated Top End of the NT and Western Australia at the time, although a lack of reporting may also be implicated. Attacks were biased towards males (86.0% of victims; N= 207), and most (61.7%) attacks were fatal.

1946-1970

Between 1946 and 1971/74, commercial unregulated hunting of *C. porosus* 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 (Western Australia), 1964 (Northern Territory) and 1974 (Queensland)]. By the time of protection the *C. porosus* population had been greatly reduced. In the Northern Territory it had been reduced to <5% of its historical abundance (Fig. 2) and <1% of its historical biomass. This trend is also considered to reflect the situation in Western Australia and Queensland, except that the levels of recovery in those States is not the same as the Northern Territory, 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%).

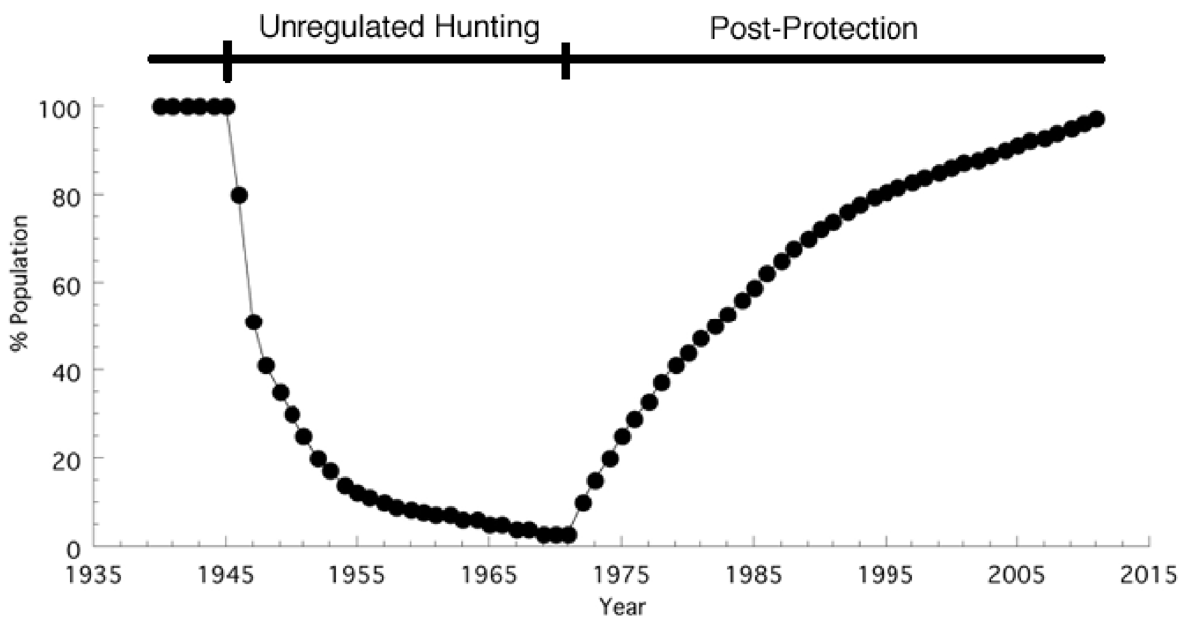

Figure 2. Estimated population trends for Saltwater Crocodiles in the Northern Territory following unregulated hunting (1946-70) and protection (1971 onwards).

<u>1971-2013</u>

Since protection in the NT (1971), more detailed information has been available on crocodile attacks in Australia. Since 1971 there have been 108 *C. porosus* attacks, most of which occurred in the Northern Territory (62%); Queensland accounted for 25% and Western Australia for 13%). One hundred and four attacks involved one person being injured or killed, and four attacks involved two people being killed/injured - a total of 112 victims.

Manolis and Webb (2013) summarised HCC *C. porosus* for Australia since 1971, and their results can be summarised as:

1. Fatality rate: since 1971 around one-third of attacks have been fatal.
2. In cases involving adults, 21% involved the victim consuming alcohol around the time of attack.

3. Most victims have been males (74.5%). Mean age of victims was 32.0 years (range 5 to 75 years).
4. A high proportion of attacks (34%) involved indigenous people.
5. Most attacks have involved local residents (85%), rather than visitors (15%).
6. Crocodiles involved in attacks have ranged in length from 0.8 m to 5.1 m (mean= 3.2 m). The majority of fatal attacks are disproportionately caused by large male crocodiles (>4 m TL), that have comprised an increasing proportion of the total population of crocodiles (see Fukuda *et al.* 2011).
7. The probability of surviving attack decreases markedly with increasing crocodile size, and the difference in size between victim and crocodile is a significant variable (Fukuda *et al.* 2014).
8. Most attacks occurred during the day (78%), reflecting the activity of victims.
9. Attacks have taken place in every month, but the majority (85%) have occurred in the warmer months (August to April).
10. Most (86%) attacks have occurred in the water or on land at the water's edge.
11. Most (90%) attacks occurred while people were engaged in recreational activities.
12. Considering the number of boats involved in recreational activities in northern Australian rivers, there have been very few directed attacks on people in boats.
13. The frequency of attacks has increased significantly over time.

Active public education programs operate in northern Australia (eg BeCrocWise).

Discussion

The recovery of wild populations of Saltwater Crocodiles in the region has resulted in increasing frequencies of HCC in Australia, Timor Leste and the Solomon Islands. Similar trends have been reported in other Range States (eg Sarawak, Sabah, Indonesia).

Interestingly, fatality rates in Timor Leste, Solomon Islands, Palau and Papua New Guinea (67-83%) have been much higher that recorded in Australia (31%) (see Table 1). The reasons for this difference are unclear, but may reflect the non-reporting on non-fatal attacks (especially if medical attention is not sought), access to medical care, and differences in size structure of crocodile populations. Large individuals are not commonly sighted in Palau, but data are lacking for Timor Leste and the Solomon Islands.

Table 1. Fatality rate for *Crocodylus porosus* attacks in the Australia and Oceania region. * data obtained from the CrocBite database; ** considered to be underestimated, and may also include attacks by *C. novaeguineae.*

Country	Period	No. of Attacks	Attacks/Year	% Fatal
Australia	1855-1945	214	2.38	62%
Australia	1946-1970	19	0.79	32%
Australia	1971-2014	108	2.51	30%
Australia	2007-2014	36	4.80	31%
Palau	1930-2014	3	0.04	67%
Palau	2007-2014	1	0.13	0%

Papua New Guinea *	2007-2014	51 **	6.80	76%
Solomon Islands *	2007-2014	22	4.00	73%
Timor Leste *	2007-2014	41	5.50	83%
Vanuatu	1970-2014	0	0.00	-

Management programs involving use are in place in Papua New Guinea and Australia. Timor Leste and the Solomon Islands have recognised the need to develop a management program, and to assess options through which incentives for conservation could be generated. It is also recognised that programs need to be tailored to the local situation, particularly with respect to cultural relationships between people and crocodiles (eg as exist in Timor Leste). The involvement of multiple ministries with crocodiles may also be an impediment to the development and implementation of effective management programs.

Palau, Timor Leste and the Solomon Islands are relatively small in area, and may never have had or be expected to have very large populations of *C. porosus*. Nonetheless, even low levels of use (eg trophy hunting; IUCN SSC 2012) may be sufficient to counter the negative impact that HCC has on people's attitudes to crocodiles.

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Human-Crocodile Conflict in South Asia and Iran

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Abstract

Culture, poverty and a growing human population present unique challenges to conservation and wildlife management within the South Asian region. The three crocodilian species here are the saltwater crocodile, the Mugger, and the Gharial. Although each species is recovering across parts of its range, the loss of habitat combined with human expansion into previously wild areas is causing increased reports of conflict. This sharing of an essential, but a limited resource, has resulted in an increase of Human-Crocodile Conflict (HCC). Cultural and social reliance on natural and man-made water resources has always been a source of HCC. Here, we look at the extent of HCC, the consequences of conflict, and how it is currently dealt with across the region. We also make recommendations for mitigating HCC within the South Asia and Iran region as part of some much-needed management plans.

Introduction

With growing crocodile populations and expanding human populations and activities, it was inevitable that conflict would arise - largely as competition for a shrinking crocodile habitat. Almost as a consequence of successful conservation programs since the late 1960s-early 1970s, the management of crocodile populations around the world now has to address the growing number of conflict incidents, and to come up with solutions to mitigate against these incidents. Human-crocodile conflict (HCC) is a significant driver to establishing sustainable management programs for crocodilians.

The region

The region we are addressing comprises the following nations, all largely based around the Indian subcontinent: Bangladesh, India, Iran, Pakistan, Nepal, Sri Lanka and Bhutan. This region is bounded by the Bay of Bengal, the Arabian Sea, and the Indian Ocean to the south (Fig. 1).

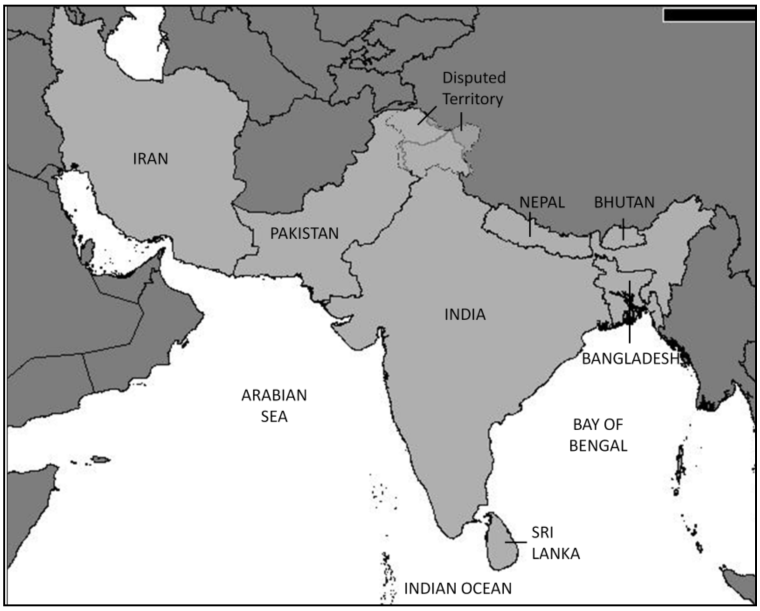

Figure 6. South Asia and Iran region (light shading)

Within this region, three crocodilian species are now extant: the saltwater crocodile, *Crocodylus porosus*; the mugger, *Crocodylus palustris*; the gharial, *Gavialis gangeticus*. Of these species, only the Mugger and the saltwater crocodile are responsible for attacks on people and livestock. Although the Gharial attains large sizes (5 m+ for males), their long and narrow jaws are much more effective at securing fish via sideways thrusts of the head than they are at attacking large mammals (Stevenson and Whitaker 2010).

Within the South Asia and Iran region, the populations of all three crocodilian species are increasing (although some of these populations continue to be supplemented from head-start programs, so figures will be inflated by animals released prior to the survey). A questionnaire was provided to CSG vice-chairs and members within each country in the region to determine how HCC was being addressed overall, what attitudes of local people were toward HCC, and what mitigation projects had been tried, in order to get some idea of effectiveness of these ideas. Data from these forms was then set alongside data from the CrocBITE online database (http://www.crocodile-attack.info) in order to determine the extent of HCC in this region. An important point of the exercise was to also illuminate the response protocol to conflict.

The problem

At a very broad level, the problem can be viewed in the following scenario: crocodile populations were critically reduced through unregulated hunting in the late 19th and early to mid-20th centuries mainly for the leather industry; human populations subsequently expanded into areas previously occupied by crocodiles; legally-protected crocodile populations began to stabilise, then grow; as crocodile numbers increased, local people began seeing crocodiles more frequently; and, crocodile populations and sizes of crocodiles continued to increase and naturally expand into areas now occupied by people. The problem is perhaps that a generation or two of people are no longer accustomed to living with crocodilians (Manolis and Webb, 2013). Humans are unforgiving creatures: once we are habituated to an area and lifestyle, any threat to that is not tolerated. This is the situation that many crocodile populations now face around the world. Addressing this conflict is a critical part of developing our management plans for crocodiles.

There has long been a strong media response to attacks on people by wild animals (Davis and McLeod 2003), and the reporting can be somewhat misleading. Even so, response to attacks can generate significant negative publicity that is detrimental to conservation programs. This is a key factor in developing comprehensive management plans for crocodiles.

Because of the dramatic and spectacular nature of attacks on people by large predators, HCC is too often seen as crocodiles attacking people. However, when management plans truly address conflict between people and animals, they must consider the damage done to the animals by people - for example, mortality associated with often illegal fishing practices throughout this region. Indeed, the present threats to wildlife species are all anthropogenic in origin. In general, such considerations are addressed as part of the traditional conservation solution based around wildlife laws and protected areas.

However, it is important to remember that human-wildlife conflict is a two-way street. Whenever conflict occurring in either direction becomes excessive (itself an often nebulous value) there is a management problem that must be accorded some priority. Conflict between humans and wildlife can also be a result of human-human conflict (Dickman 2010), and conservation programs are now recognising that there is clearly a socio-political/economic role in addressing ‘wildlife conservation’ problems (Webb 2013; Stevenson 2013; Hoban and Vernesi 2012).

When investigating how HCC was addressed within the region, we wanted to first of all understand how HCC is understood in the region - how do the people define HCC? Although livestock and pets are taken, the general attitude within the region is that this is expected as a natural consequence of living next to large predators. Indeed, some areas experience loss of livestock to leopards, tigers, as well as crops to elephants (Chowdhury 2008; Pokhrel and Shah 2008). So to a large extent loss of livestock to crocodiles was not the main definition of conflict. It is noted that this attitude varies across the region, and in future, crocodiles may not enjoy such tolerance.

Overwhelmingly, in the South Asia and Iran region, conflict in this context is defined by a crocodile attacking a human being.

Given that attacks on human beings are the definition of conflict within the region, we need to understand the species distributions within the area.

Saltwater crocodile

This large and widely distributed species occurs in Sri Lanka, India and Bangladesh. Within India, there are three main populations: Orissa, the Sundarbans and the Andaman & Nicobar Islands. Within these areas, attacks are known. In fact, a chart of saltwater crocodile attacks in this region accurately depicts the current distribution of the species (Fig. 2):

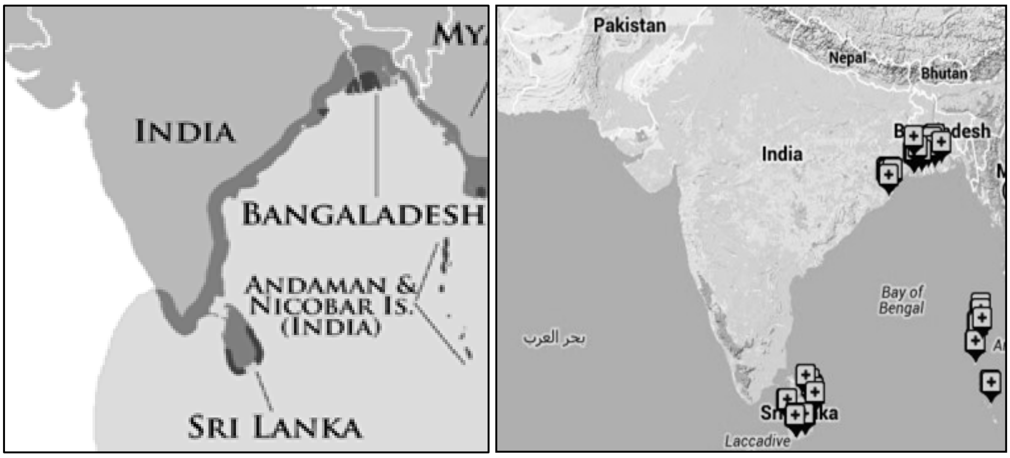

Figure 2. Distribution (black) of the saltwater crocodile within the region on left, dark grey shading is historic range within region; the distribution of saltwater crocodile attacks on the right. *(images courtesy of crocodilian.com, and crocodile-attack.info.*

According to the CrocBITE database, there were 131 saltwater crocodile attacks in the area. These refer to those attacks recorded in the database thus far. The frequency of attacks varies across years (Fig. 3), and shows no increasing trend, although the figure for 2014 is only up until time of report (May 2014):

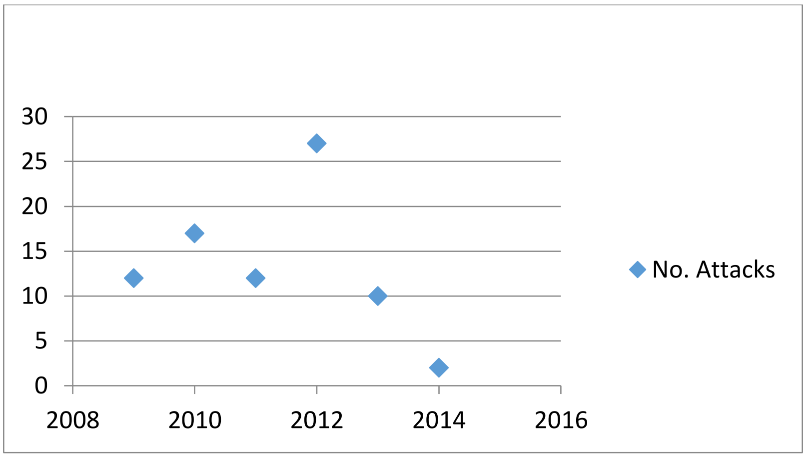

Figure 3. Frequency of saltwater crocodile attacks since 2009 in the region.

Of the 131 attacks listed in the database, 79 were fatal and 52 were non-fatal (Fig. 4).

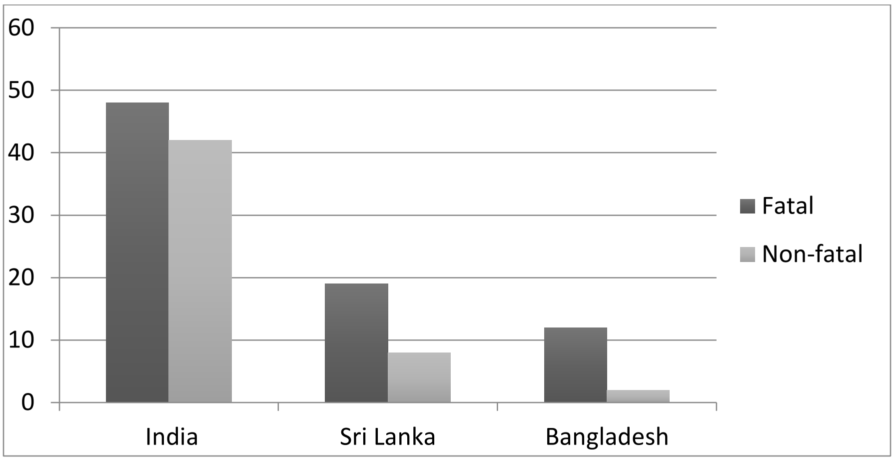

Figure 4. Outcome of saltwater crocodile attacks in the region.

The main population of saltwater crocodiles in the region is within Bhitarkanika Wildlife Sanctuary in Orissa, on the northeastern coast of India. Perhaps the most significant recovery of crocodiles in the region has occurred here. From encounter rates of 0.87 per km in the early 1970s, the figure is now over 5.0 crocodiles per km (Gobi and Pandav 2009). Estimated numbers increased from 96 in 1976 (Gobi and Pandav 2009) to 1640 in 2012 (Pandav 2012). The increase here is largely due to the rear-and-release program established under the Indian Crocodile Conservation project.

Within the Andaman and Nicobar Islands, saltwater crocodile populations have increased from an estimate of only 31 animals in the 1970s (Andrews 1999). Surveys by Madras Crocodile Bank Trust have been planned for the islands to quantify the current crocodile population.

Saltwater crocodile populations are stable or increasing slightly in Sri Lanka and Bangladesh. Although specific data on current numbers is lacking in these areas, in Sri Lanka the *C. porosus* population was assumed at 'no greater than 300' in 2001 (de Silva 2013). The Nilwala River *C. porosus* population in Sri Lanka has increased during the past 40 or so years, and the Nilwala River is the hotspot for saltwater crocodile attacks in the country (de Silva 2008, 2009, 2013).

Mugger crocodile

Muggers have a wide distribution across the region, from Sri Lanka through to Iran. Their main stronghold is India, where the species occurs across much of the country. It is a species that adjusts to disturbed or modified habitats particularly well, and is found in close proximity to human settlements. Within the state of Gujarat, this species is found in water bodies within a major city. Recent estimates for the IUCN Red List assessment put the current Mugger population at up to 8700 animals across its range (Choudhury and de Silva 2013).

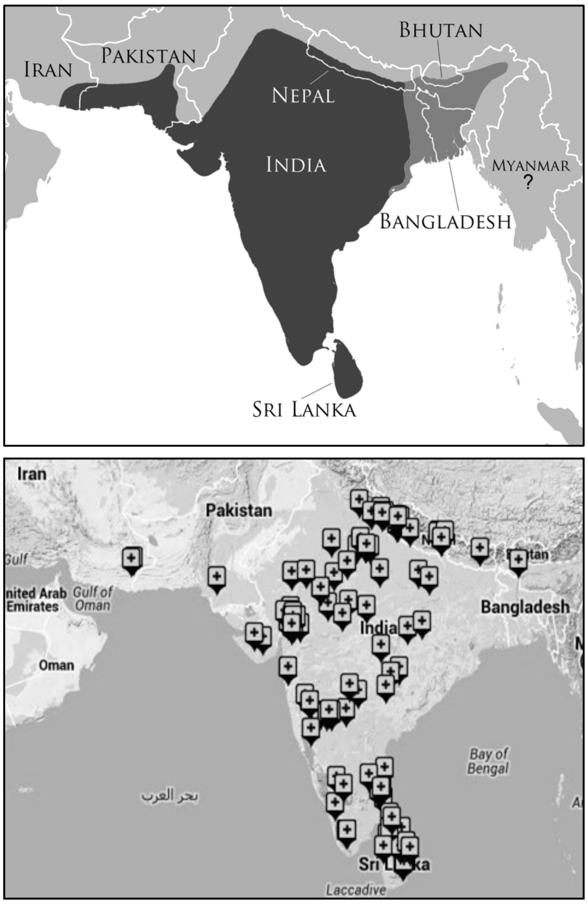

Figure 5. Distribution of the mugger across the region in dark shading (left); distribution of mugger attacks. (Images courtesy of crocodilian.com and www.crocodile-attack.info.

Recorded in the CrocBITE database are 161 Mugger attacks as of May 2014 (Fig. 5). Of these, 82 were fatal, and 79 were non-fatal (Fig. 6). The frequency of Mugger attacks is clearly increasing (Fig. 7), particularly in areas such as Gujarat, where 5 fatal attacks occurred in April 2014.

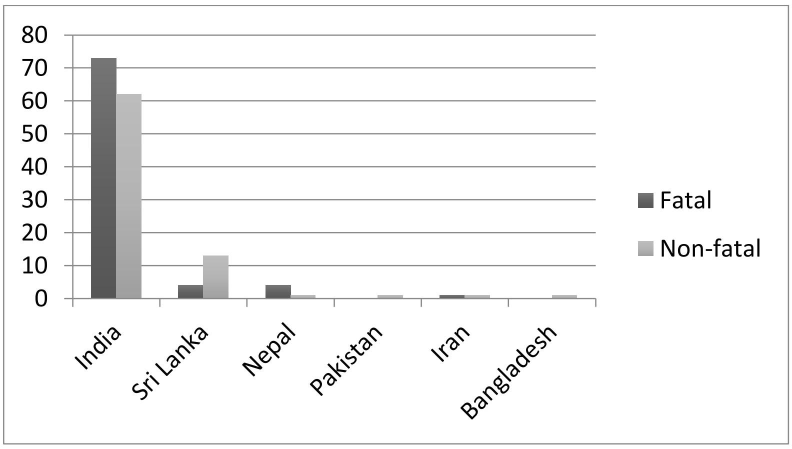

Figure 6. Outcome of attacks by Muggers in the region.

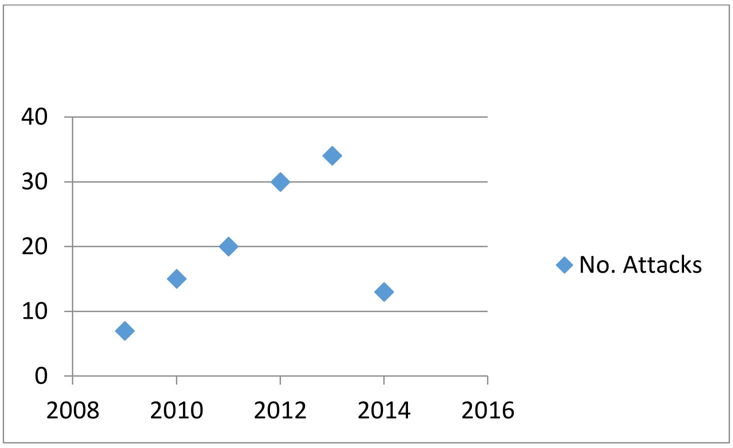

Figure 7. Mugger attack frequency since 2009 in the region (2014 figures are up to May).

Culture of Conflict

The population of South Asia is largely rural, and poverty and associated socio-economic problems is widespread. Public infrastructure is poorly developed and civic amenities are mostly absent. Hence, there is a high dependence on natural and man-made water-bodies in the locality. The adaptable Mugger is often present in these water-bodies and regularly interacts with people and their livestock. While mutual avoidance is the norm, the potential for HCC is significant because of the fore mentioned problems combined with the lack of awareness, a blatant disregard for basic precautions and religious fatalism. In many areas, conflict with wildlife can go unreported.

India

In 1976, the Indian Government initiated the FAO/UNDP-supported Project Crocodile. This program was aimed largely at breeding and releasing head-started crocodiles of all three species back into newly-created protected areas. Without question, this project was responsible for not only reversing the decline of crocodiles within the country, but also establishing sanctuaries and developing expertise within the country (ENVIS 1999). Despite the mixed success of this project, there is no current management program for the country.

Within India, there is little concerted effort at mitigating conflict between humans and crocodiles. An attack may result in retaliatory killings, or conversely, no response at all. Varying by area, different agencies may be deemed responsible for investigating attacks: normally it is the Forest Department, but may also be the police. In some areas, there may be efforts to capture and relocate the crocodile responsible. Over the years, many cases attributed to crocodile attack were very likely death by other causes - drowning, murder and suicide. Validity of attacks reported is often poorly investigated. When investigating crocodile attacks there is usually no effort to identify whether the attack was provoked or unprovoked, or to identify the perpetrating crocodile.

Victims of animal attack (or their family) are granted compensation, however even this varies from zero to INR200000 /$US3200 (Times of India, 26 September 2012). Often, this compensation can amount to little more than $US160. Corruption clearly plays a part in the compensation mechanism. The point is, there is no established protocol for compensating victims of HCC.

The rigid caste system in India - especially in the north - contributes to the problem in that lower castes are often not granted access to public infrastructure such as water pumps and crocodile exclusion enclosures. This exposes these members of society to unprotected sites.

Disposal of dead bodies (human and animal) in rivers is common in parts of India. Crocodiles often feed on these remains. There is speculation that this could encourage crocodiles to associate people with food, thereby encouraging HCC.

Within the Andaman and Nicobar Islands, the most recent surveys indicated a small number of saltwater crocodiles. In recent years, numbers appear to be increasing, as are attacks, with at least 5 fatal and 3 non-fatal attacks in a 12-month period during 2011-2012 (Saxena 2012). Compensation paid to victims on these islands ranged from INR3000 for injury to INR1,00,000 for death; the victim's family must claim for compensation (Saxena 2012). Some attacks are blamed on illegal dumping of chicken waste and other animal products into waters, thus attracting crocodiles close to areas used by humans (Andaman Chronicle 2012). The Andaman and Nicobar Islands also have a large immigrant population from mainland India, many of whom have never lived in close proximity with *C. porosus* and therefore do not exercise the necessary level of caution near water bodies when in the Islands.

Recent efforts on the Andaman and Nicobar Islands to raise awareness of saltwater crocodiles includes a new and impressive display at Port Blair, and Madras Crocodile Bank Trust has carried out training of Forest Department staff in crocodile capture, as well as developing awareness and education materials. Continued training of staff is carried out by Zoological Survey of India. Some of the warning signs on the islands use wording that many feel contribute to the hostility toward crocodiles (Chandi 2012). Such wording includes 'this river infested with crocodiles', although this wording may well be a translational issue, as the signs are in English (rather than in the local languages - itself, a bit of a problem to campaign effectiveness).

Although attacks occur on the Nicobars, the Nicobar islanders themselves remain relatively isolated, and retain traditional knowledge, with more tolerance of crocodiles. Certain districts also hunt crocodiles (Chandi 2012).

Within Orissa, the Bhitarkanika Wildlife Sanctuary holds the largest saltwater crocodile population within the region, estimated at over 1600 crocodiles (Pandav 2012). Attack on both humans and livestock occur mainly during the monsoon period. Compensation for victims' families has increased from INR100,000 to INR200,000 in recent years, however, compensation claims are not always processed in a timely manner (ToI 2012). In response to a dramatic increase in HCC reports, authorities for the Sanctuary employed local fishermen to use traditional methods to remove problem crocodiles - essentially chasing the animals away from human settlements (CSG 2008).

Pakistan

Within Pakistan, Muggers occur in the southern regions of the country (see Appendix I). The Gharial is considered extinct in Pakistan. The estimated Mugger population in the country is around 600 individuals: approximately 430-450 in Sindh Province; 120-150 in Balochistan Province. Wild populations are extirpated from the Punjab area.

Crocodile breeding facilities exist in the country, but as of 2014, commercial use had not commenced.
HCC in Pakistan is low, but fear of attack on humans and livestock is entwined with tribal customs and traditions. Attacks on humans are rare, but conflict arises from loss - or *perceived* loss - of livestock and fish and the economic impact of such losses.

In recent years, dead crocodiles have been found, clearly killed by people, but suspicions that they were killed for their skins is unfounded as the carcasses were found intact. These are retaliatory killings, or intentional killing in response to the fear of the threat crocodiles pose.

One custom involves killing the crocodile responsible for attack on a human. Not doing so would be considered *'Zan Talaq'* - a derogatory term that infers poor social status ('divorced') on the widow/widower. This tradition is changing as awareness grows.

Crocodiles are now found in areas that do not come under jurisdiction of wildlife departments, hence many attacks are unreported. Lack of funds and resources in wildlife departments also reduces monitoring of crocodile incidents.

The main form of mitigation in Pakistan was the World Wildlife Fund (WWF) program of public awareness campaigns and community-empowerment projects in the River Dasht region. The WWF program in this area has now stopped, but clearly there was a positive impact on the local communities with regard to reducing conflict and improving awareness of crocodiles. The WWF program is now being implemented in the Sindh region, again with positive impacts. There is no use of crocodile exclusion enclosures in Pakistan.

With the new breeding centres being established in the country, there are now reports of the illegal capture of young crocodiles for sale to the private sector breeding centres.

Iran

Iran holds the western-most population of mugger crocodiles, where they are found in Sistan and Baluchistan Province. The area is designated as a Protected Area (Gandou Protected Area), with Muggers found in a range of natural and artificial water bodies that are in close proximity to human settlements.
Fortunately, local people in crocodile areas hold cultural beliefs that do not permit killing of crocodiles, and the animals are afforded high respect.

However, when Muggers move between habitats during dry seasons, they are struck by vehicles as they cross roads. Periods of drought and flooding are the major threats to the crocodiles of the area.

The last survey in May 2012 indicated a direct count of 326 crocodiles.

Although there is a cultural taboo against harming crocodiles, loss of livestock and the fear of crocodiles which stray into villages does exist. Livestock loss appears to be tolerated by the local Baluchi tribes, and compensation for losses due to crocodiles is given. However, despite use of water bodies for washing, bathing and swimming, serious conflict is not reported.

The main form of mitigation is the use of warning signs at water bodies used by local people. Due to the low incidences of HCC, there is little impetus to introduce further measures.

Sri Lanka

Both saltwater crocodiles and Muggers inhabit Sri Lanka: saltwater crocodiles are mainly confined to the southwest and northeast of the islands; Muggers are found in the south east and many parts of the north, north-central and northeast of the country. Both species are responsible for attacks on people and livestock. Sri Lanka has identified the main areas of conflict, and the patterns of crocodile attack in the country (de Silva 2013; Grametz 2008). When crocodiles do attack, there are often retaliatory killings of several crocodiles in the area. Five cases of poisoning of crocodiles are recorded in the Matara Nilwala. The response by authorities is varied and does not follow any standard protocol.

There is a long tradition of mitigation measures used in Sri Lanka. These include:
- Crocodile repellents, consisting of plant toxins (often accompanied by rituals) placed in the water
- Charms and talismans, whereby granite blocks are inscribed with a talisman and are believed to offer protection against crocodile attack within the water body (see plate 6)
- Charms and mantras that are prescribed for use prior to entering the water
- Crocodile Exclusion Enclosures, which are placed at the edge of the water to allow safe washing and bathing (see plates 1, 2 and 3)
- Crocodile Fences (metal fences between the river and domestic animal pens) are sometimes used to protect domestic pets from crocodiles at night (see plate 4)
- Warning Signs have been under-utilised even in areas with high conflict.
-

Crocodile Exclusion Enclosures (CEEs)

These traditional enclosures are made of thick palm or hard wood poles driven deep into the river bed, with each end of the enclosure meeting the river bank. More recent enclosures are constructed of metal and wire mesh. These enclosures are known in Sri Lanka as *'kimbula kotuwa'*, which simply means 'crocodile enclosure'. Along the Nilwala Ganga, these are common, and consist of both private and public enclosures. Private ones are smaller, and are used by the owners of property on the river. Larger public enclosures are communal property.

Interestingly, although many of the enclosures examined by de Silva (de Silva 2013) were not secure and were enclosed on only 3 sides, crocodile attacks that occurred during the survey period all took place outside of enclosures, or in areas that had no enclosures. Recently, a young boy was killed when he bathed just a few metres from a CEE in Matara, and a young girl was killed as several poles of a personal CEE were missing, allowing the crocodile to enter (de Silva, pers. comm.). It appears that these facilities offer a very real benefit to avoiding crocodile attack in Sri Lanka.

The way forward for Sri Lanka includes expanding the CEE program, increasing the use of Crocodile Fences and warning signs in crocodile areas, and introducing an education and awareness campaign.

Nepal

Two species of crocodilian are found in Nepal: the Gharial and the Mugger. There is a strong Gharial project in Nepal, based on head-starting, chiefly in the Royal Chitwan National Park. The Mugger population is small in the country, numbering perhaps 200 animals, but is considered to be growing (Choudhury and de Silva 2013).

Muggers occur in the southern terai region of marshy grasslands and savannas (Bhatt *et al*. 2012), and there are at least 5 attacks by Muggers on people recorded for the last 10 years - of which 4 were fatal. Most of the victims were reported to be fishing at the time of the attacks.

Between 1981 and 2008, 164 Muggers were released from rearing stations, but they were not monitored at all (Goit and Basnet 2011).

Most of the work on crocodilians in Nepal has focused on the Gharial, and given the small populations of both species in the country, little work on HCC mitigation has been carried out.

Recent studies indicate that Muggers exist in isolated populations within protected areas. Human-wildlife conflict within Nepal is concerned more with elephants and tigers (Shrestha 2007), although sloth bears and leopards also attack people (Pokhrel and Shah 2008) - in this report crocodiles were not mentioned as a species causing conflict with humans.

However, Pokrel and Shah (2008) report that 9.5% of injuries caused by wild animals on people within the Bardia National Park were by crocodiles, and that these occurred as people fished or bathed in the Rapti River. Again, though, little information is given about mitigation measures or response protocols for HCC.

The Mugger population in Nepal is still too low to have a significant number of HCC incidents. Most studies call for protection measures, including awareness programs, and involvement by the local people in aspects of protection such as nest monitoring (Goit and Basnet 2011; Wagle 2010; Siwakoti and Karki 2009).

Bangladesh

The Mugger is no longer considered to survive in the wild in Bangladesh, and the Gharial is reported in very small numbers that indicate stray animals. No breeding population exists for Gharials in Bangladesh, despite occasional reports (Stevenson and Whitaker 2010). There is a small captive group of Muggers at the Khan Jahan Ali Shrine at Bagerhat (southwest of Dhaka). Here, people come to worship and feed the crocodiles. There was one fatal attack in 2008 at the shrine. Another incident involved a group of men beating the crocodiles - the men later being sentenced to two years in prison with hard labour (BBC News), according to Bangladesh law. The main crocodilian remaining in the country is the saltwater crocodile, found along the coastal region, particularly the Sundarban mangrove region.

Within this vast network of mangrove forests that straddles the India-Bangladesh border, saltwater crocodiles and tigers are reported to take a serious toll on local fishermen. Although the CrocBITE database records only 15 attacks over the past decade, reports often indicate that tigers and crocodiles collectively have killed around 200 people in the past decade (New Age 2012). Considering the isolation and poverty of the villages within this region, clearly most attacks would go unreported. Given the terrain, many would consist of missing persons, presumed killed by tigers, crocodiles or sharks.

The mangrove forest is a valuable resource to over 10 million people, who are either directly or indirectly dependent upon it, from fishing and agriculture to cattle rearing, settlement and as a food resource (Islam and Wahab 2005). Recently, shrimp farming and tiger prawn seed collection have been a major source of income, as well as controversy, in the region (Badola *et al*. 2011; Jalais 2010; Chowdhury *et al*. 2008). Given the proximity to and the reliance of the local people on the Sundarban mangrove forests, attacks by crocodiles remain a constant threat, although tigers appear to be more of a concern (Vyas 2012). Most of the recent crocodile attacks seem to be confined to areas where tiger prawn seed collection is carried out (Vyas 2012; Islam and Chuenpagdee 2013).

Despite significant numbers of HCC incidents in the Sundarbans, there is no protocol to deal with this in Bangladesh. Fatal attacks by tigers and crocodiles are certainly under-reported, as only deaths of officially registered forestry workers are documented (Islam and Chuenpagdee 2013). Compensation is normally around 100,000 BDT ($US1240), but obtaining this compensation can involve bribery and long delays (Islam and Chuenpagdee 2013).

Discussion

That crocodile numbers are increasing and available habitat is decreasing is the favoured reason for increased HCC incidents.
However, the pattern of water use in this region clearly shows the true cause of the high HCC incidents. In all areas within the region, most attacks were whilst people were bathing, washing, crossing rivers, collecting edible and non edible plants and fishing (de Silva 2013; Vyas 2013). Contrasted with a developed country such as Australia, the patterns of water use are quite different, with water bodies there used often for leisure, and attacks much less frequent. Within the developing world, rivers, lakes and ponds are essential for daily life, so local people are forced to share crocodile habitats on a daily basis.
Compounding this problem are habitat degradation, polluting of rivers, hydrological issues such as dams and water extraction/diversion, which reduces not only crocodile habitat, but also availability of prey.
Reliance on natural and man-made water bodies places people at a higher risk of crocodile attack. In many areas, these people are poorly educated, unemployed and facing extreme poverty. For them, survival means risking crocodiles and other predatory animals. Disposal of animal by-products into local waterways in some areas, such as the Andaman Islands, serves to attract crocodiles to these areas.

In Sri Lanka, there is evidence that the use of Crocodile Exclusion Enclosures is effective in reducing crocodile attacks on people, and the Crocodile Fences have a similar positive effect for pets and livestock.
Throughout the region, there is a universal call for education and awareness programs, training of Forest Department staff, and for a protocol for responding to HCC incidents, dealing with problem crocodiles (Kumar *et al.* 1999; Vyas 2013; de Silva *et al*. 2013; Rao and Gurjwar 2013; Kar and Patnaik 1999). The lack of any comprehensive crocodile management programs requires serious consideration. The Government of India/FAO/UNDP Project Crocodile successfully rebuilt crocodile populations within the country, and although discontinued, the mindset remains set that crocodile conservation equals head-starting programs. Current management plans for Protected Areas address the protection of wildlife, and do not adequately address conflict with wildlife. These plans need to be updated to recognise that wildlife populations need to be *managed*, as well as protected.

During a Human-Crocodile Conflict symposium in Bangalore, India, in 2012, a panel discussed the necessity for India to contemplate a limited sustainable use model to allow for removal of problem crocodiles. As discussed, crocodiles are sometimes translocated after HCC incidents, but this is haphazard and often not effective, with the crocodile either returning to the capture site, or moving into other human-occupied areas. There are few captive facilities that can cope with these crocodiles due to their capacity already having been reached, and it is difficult to retain the support of local people who see only a danger to themselves and their families from the crocodiles. Sustainable use of crocodiles, particularly within India, would have been a natural result of Project Crocodile: with many breeding farms established around the country, some felt that the opportunity to develop sustainable use as a key component of an on-going crocodile management plan was lost (see Whitaker 1999; Singh 1999).

Another option that has not been explored except within Sri Lanka (and in some Protected Areas within India) is ecotourism, with crocodiles being a focal species. In Sri Lanka, wildlife tourism is well-established, but crocodiles are an added extra. Eco-tourism based around crocodiles is a vital part of the economy in Northern Territory in Australia and Florida in the USA, as examples. The potential for such an industry in this region is strong, and the call for such is not new (ENVIS 1999).

Wildlife conservation today is as much about human welfare and support as it is about protecting wildlife populations (Webb 2014; Berkes 2007; Stevenson 2013). Progressive and successful conservation programs recognise that by developing the economy and livelihoods of local villages, a reduction in behaviours and practices detrimental to the local environment results (Mehta and Heinen 2001; van Weerd and van der Ploeg 2012; Dickman 2010). It also opens up possibilities for education and awareness programs at the local level.

One failing of crocodile conservation programs within the region is that they have not included local people in the conservation solutions - although reports on the Bhitarkanika program indicate relatively good support from locals (Kar 2013), but there are clear problems even here (Badola *et al*. 2012). There is a lack of value assigned to crocodiles by local people, and without this support, long-term conservation will be difficult, and require regular mitigation efforts (see van Weerd and van der Ploeg 2012, for more on this). Local people often see the conservation programs as a direct threat to their way of life (de Vos 1984). Such approaches will never succeed long-term.

Recommendations

Given that the cases of HCC being reported are increasing within the region, governments - both local and federal - should begin taking the issue seriously. To significantly impact HCC will require long-term commitment from both government and NGOs working within areas that have crocodile populations.
The recommendations in this report are realistic actions that can be taken to help mitigate HCC. However, there are some immediate steps that could have a rapid and positive impact on HCC. These are:

1. Committed trial of Crocodile Exclusion Enclosures within HCC ‘hotspots’
2. Committed trial of Crocodile Fences within areas of attacks on livestock and household animals
3. Immediate use of warning signs in areas known to hold crocodile populations, and that are used frequently by local people
4. Immediate development of education and awareness materials

There is a financial cost to implementing these, as local people could not be expected to bear the cost of installing fences or enclosures themselves. In Sri Lanka, local government, Disaster Management and NGO bodies install CEEs.

Long-term strategy requires a comprehensive crocodile management plan. Such a plan would need to cover:

1. Regular monitoring of crocodile populations
2. Protocol for dealing with problem crocodiles - removal/relocation/captive/culling.
3. Training of wildlife/Forest Department staff
4. Protocol for investigating attacks on humans - including compensation mechanism
5. Provision to link with government-run socio-economic programs that deal with basic humanitarian issues within local villages
6. Enforcement of Protected Area/Wildlife laws
7. Eco-tourism proposals that will benefit local people
8. Education and Awareness programs for schools, villages, communities

The emphasis in developing such a plan must be on building these communities, not in forcing them to change their lifestyle, making things more difficult for the people. They must see the conservation of wildlife as a part of an overall solution to their own problems. If they can benefit by either eco-tourism or alternative livelihoods that are realistic and based on the skills they already have or those that they are willing to develop, then there can be an expectation of support from these people.

There are many programs around the world that can be used as a basis for developing these crocodile management plans (eg Leach *et al*. 2009), and there is ample expertise within the region, as well as access to IUCN specialists.

Conclusions

HCC should not be treated as an independent issue, but dealt with in a comprehensive management plan for crocodiles. Whether such a plan is completed at a local or federal level is not as critical as the actual development of these plans. It is clear that supporting lifestyle changes and reliance on water bodies for basic activities such as bathing and washing is the key to the reduction of HCC in these areas. Use of crocodile exclusion enclosures and crocodile fences have been effective in Sri Lanka and less so in India. Properly implemented and monitored, these clearly can be a part of the solution. Long-term solutions to HCC require developing a management plan that will incorporate socio-economic realities and suit local sensibilities to gain local community support. Behaviours detrimental to the environment in these areas are often a result of limited livelihood options for local people.

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Plate 1: Insecure Crocodile Exclusion Enclosure

Plate 2: Personal Crocodile Exclusion Enclosure

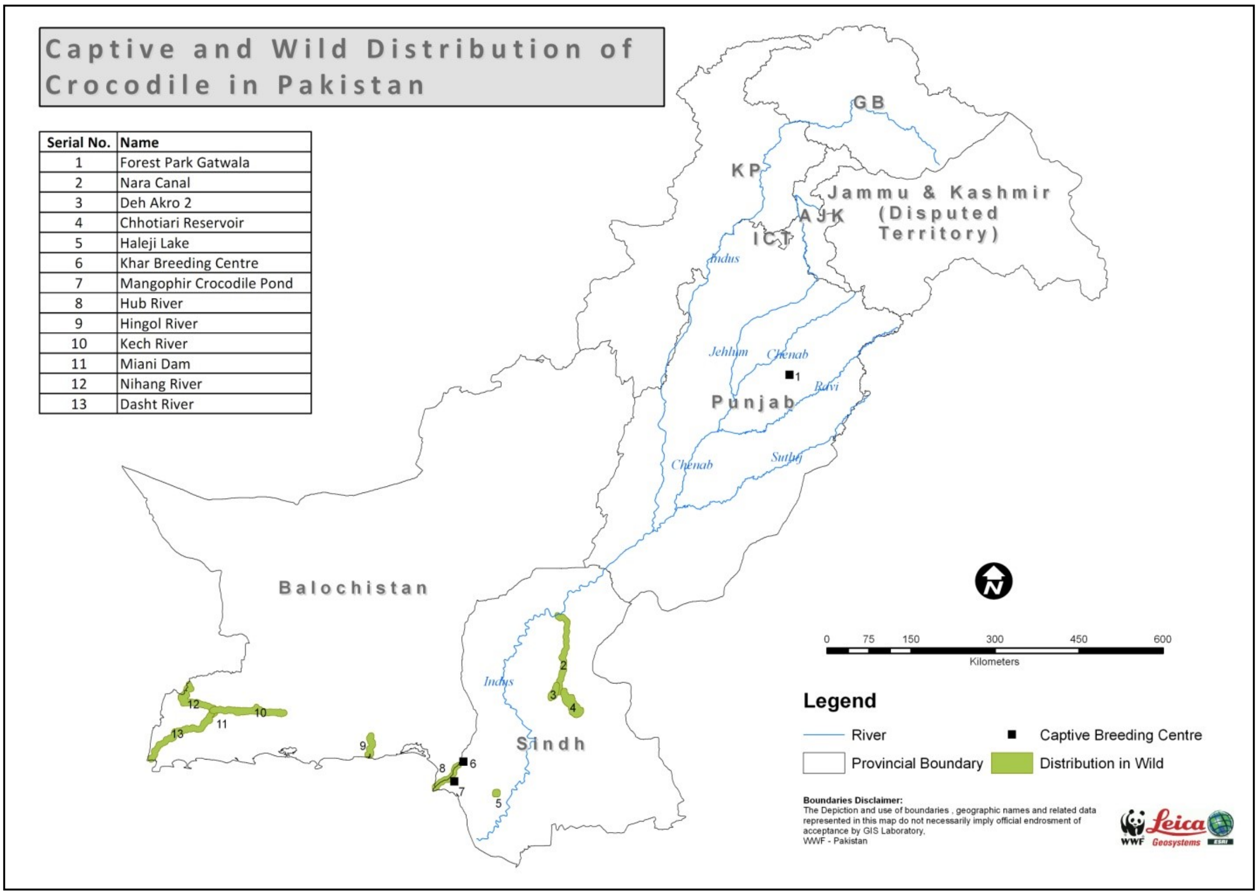
Plate 3: Secure Kitul palm (*Caryota urens*) CEE

Plate 4: Crocodile Exclusion Fence, Matara

Plate 5: Mugger near houses

Plate 6: 14-15 century granite talisman for crocodiles

All photographs from Sri Lanka, and © Anslem de Silva.


Captive and Wild Distribution of Crocodile in Pakistan
Serial No. Name
1 Forest Park Gatwala
2 Nara Canal
3 Deh Akro 2
4 Chhotiari Reservoir
5 Haleji Lake
6 Khar Breeding Centre
7 Mangophir Crocodile Pond
8 Hub River
9 Hingol River
10 Kech River
11 Miani Dam
12 Nihang River
13 Dasht River
GB
KP
Jammu & Kashmir (Disputed Territory)
AJK
ICT
Indus
Jehlum
Chenab
Ravi
Punjab
Chenab
Sutlej
Balochistan
Indus
Sindh
0 75 150 300 450 600
Kilometers
Legend
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Provincial Boundary
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Boundaries Disclaimer:
The Depiction and use of boundaries , geographic names and related data represented in this map do not necessarily imply official endrosment or acceptance by GIS Laboratory,
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A Roadmap for Crocodile Conservation in Sarawak

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Abstract

In Sarawak, the mention of crocodiles spews an air of love and hate – more of hate at present. Despite the current irritability with crocodiles which by a large population are regarded as vermin, the culture of the various tribes in Sarawak has always heralded crocodiles as a protector with divine strength and power. Sarawak's football team has a crocodile as its mascot, instilling its team with an aura of invincibility. Protection by the law for over twenty years had allowed the once near-threatened population to recover, so successful was the recovery that Sarawak is now faced with an increase in Human-Crocodile conflicts. Incessant public outcries propelled the State Cabinet to issue a directive to conduct statewide crocodile culling exercise. The management authority, however, has convinced the cabinet to review this directive holistically and scientifically, resulting in the approval of the Strategic Crocodile Management in Sarawak to ensure win-win coexistence between human and crocodile. This paper reports on the up-to-date development and implementation of a roadmap towards a comprehensive crocodile conservation and management in Sarawak.

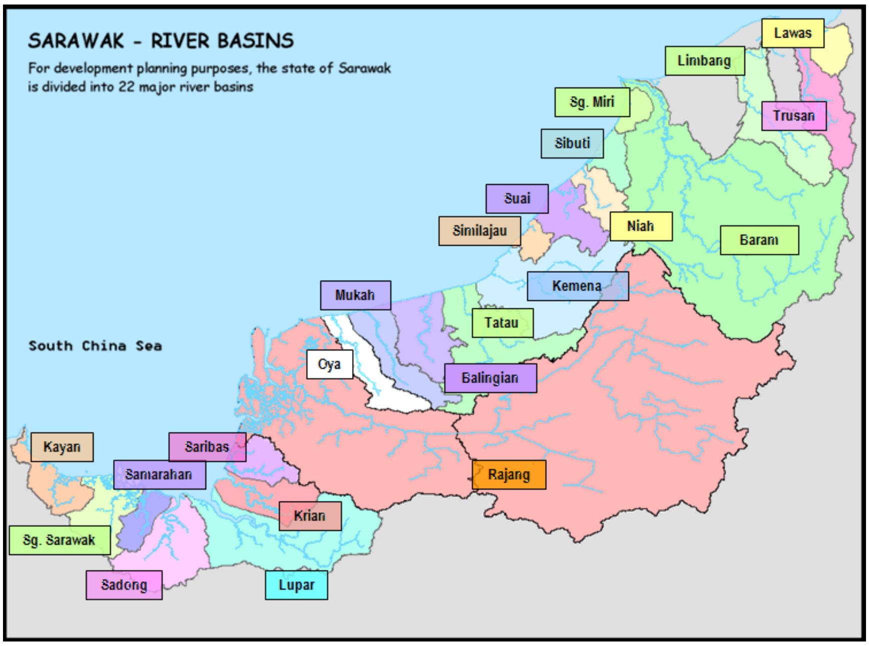
Introduction

Crocodylus porosus is one of the most widely distributed of all crocodilians, ranging from southern India and Sri Lanka, throughout southeast Asia, east through the Philippines to Micronesia, and down through Indonesia, Papua New Guinea and the Solomon Islands to northern Australia (Webb, Manolis and Brien, 2010).

As such, Sarawak, the largest state in Malaysia, located on the north-eastern part of Borneo, falls within the distribution range of *Crocodylus porosus*. Sarawak is geographically separated from Peninsular Malaysia by the South China Sea, and shares the island of Borneo with the Sultanate of Brunei Darulsalam, Indonesian's Kalimantan and another Malaysian state of Sabah. Sarawak lies 0.5° - 5° north of the Equator and thus possesses a hot and humid climate with an average rainfall of more than 3000mm/year and average temperature of 26°C (Map 1).

Map 1: Sarawak, Malaysia within the *C. porosus* range

Sarawak has always been referred to as the 'Land of many rivers'. It is divided into 22 river systems based on the major rivers draining the areas (Map 2). The topography is generally flat closer to the coast to gently undulating hills and rugged mountains towards the borders in the east and south. The tidal portions of the rivers are lined with mangroves and the rivers meander through great distances over broad flood plains with oxbow lakes, giving rise to extensive crocodile habitats such as mangrove estuaries, the large river systems, and the inland freshwater swamps (Tisen, Gombek, Ahmad and Ubang, 2013).



Map 2: Sarawak's *River basins (Source: Department of Irrigation and Drainage)*

Whitaker, (1984) suggested that the highest crocodile densities in Borneo are usually found in mid-river areas of medium-sized to large rivers. Stuebing *et. al*., (1993) reported that crocodiles were also found to have occurred far up rivers as far as Kapit, a town in the Rajang River Basin, which is more than 160 kilometres from the Rajang River mouth and is not affected by tidal influence.

Crocodiles have coexisted with the people of Sarawak since time immemorial, a relationship which in recent years had been something akin to that of 'love and hate'. Crocodiles are integral to the belief and tradition of most ethnics groups in Sarawak. They are feared at as they could exert and seek revenge if they are disturbed or killed and the vengeance will last for generations. The once-notorious 19 footer white-back in Batang Lupar (Lupar River), called '*Bujang Senang*' (the male in the Senang tributary of Lupar) was believed to be the paramount leader of crocodiles in Sarawak possessing supernatural powers and thus could not be captured or killed. The much-feared 'Bujang Senang' was believed to be on its avenging rampage when it attacked and killed a number of people (Tisen and Lading, 2001). Interestingly there seem to be a tit-for-tat thing going on about that tradition, the local people, particularly those residing along the river banks, would kill a crocodile as an act of revenge if the crocodile had killed someone especially a relative.

During the White Rajah's (Brooke's) era and later the British Colony from 1841 to 1963, crocodiles were considered as vermin that needed to be eradicated. The government offered bounties at the rates of 15 cents per inch of head length and 5 cents per egg brought in to the authorities. However, this had little impact on the wild population. Aggressive hunting for skins during the late 1950s through early 1970s had resulted in significant depletion of Sarawak's crocodile population (Whitaker, 1984). Skins exports plummeted by over 90% in one decade from 7,245 kgs in 1961 to only 692 kgs in 1970 and great concern was expressed that hunting for skins would cause extinction of the wild population (Cox and Gombek, 1985).

The first comprehensive survey of crocodile population in Sarawak was conducted by Cox and Gombek (1985). Their survey covered a distance of 1,043 km of main rivers and some of their tributaries. The survey results showed the density of crocodiles in Sarawak's rivers was at 0.054 individual per kilometre. They also noted that crocodile habitats were seriously disturbed and degraded. Waterways were fairly intensively used for fishing and transport. They observed that the use of cross-netted fishing techniques caused not only entanglement and drowning but also halt mobility and recruitment of crocodiles. This report spurred the Special Select Committee for Flora and Fauna to recommend that crocodiles be protected under the Wild Life Protection Ordinance in 1990.

Cox and Gombek (1985) reported that harvesting of wild crocodile ceased in the 1980's as it was no longer profitable as the number of crocodiles had plummeted. The protection of crocodile under the state's law further discouraged the killing or hunting of crocodiles. Rapid development of roads connecting the small towns and villages has significantly reduced the use of rivers as the main mode of transportation. These developments had also reduced the dependence on rivers as the source of food as it is easier to get provisions from major towns. Land developments and change of land use such as agriculture, despite being initially thought of as disturbances to crocodile habitats, upon regeneration could result in formation of habitat conducive to crocodile. Stuebing *et al*., (1993) suggested that such recovery created a type of vegetation called 'padang', a stable community of secondary growths of grasses and herbs, used by female crocodiles for nest construction, thus creating a suitable nesting habitat. Thus, the combinations of legal protection, diminishing usage of rivers and change of land use have contributed to the recovery of Sarawak's estuarine crocodile population.

Recent surveys in Sarawak showed that crocodile populations had recovered in most rivers (Engkamat, 1997; Tisen and Ahmad, 2010). This had also led to the increase in human-crocodile conflicts (Landong and Mohd Kasyfullah, 2010). The ~~positive~~ reports on the crocodile population recovery in Sabah and Sarawak presented during the Crocodile Conflict Workshop in Kota Kinabalu, Sabah, Malaysia in 2010 led to Dr. Grahame Webb, Chairman of CSG making the following the closing remark:

> *"Sabah and Sarawak should be proud today as crocodiles in the wild have recovered in the two states. However, this has created a new set of problems, i.e., the increase in human-crocodile conflict. The challenge now is how to sustain what we have succeeded to protect as now we have a new problem to address."*

In Sarawak, crocodile attacks, averaging ten per year, have raised outcries from the public and politicians demanding the management authority to take urgent actions. Subsequently crocodiles also became a favorite subject by the media. In 2011, nine attacks were recorded with three fatalities; in 2012, eight attacks also with three fatalities while in 2013 there were seven attacks with three fatalities.

The Sarawak State Cabinet meeting on 16th August 2012, after considering the outcries from the public and politicians, had directed the crocodile management authority to carry out state-wide culling of the crocodiles in response to the recent spates of crocodile attacks. However, on 20th September 2012, the management authority made a strong representation on the plight of the crocodiles in Sarawak so much so that the Sarawak State Cabinet agreed to withdraw the sweeping culling directive and opted for the management authority to manage Sarawak's crocodiles holistically and scientifically. The Sarawak State Cabinet thus approved the "Strategic Crocodile Management Plan", among which include various components of a holistic crocodile resource inventory, to ensure win-win coexistence between humans and crocodiles.

Strategic crocodile management in Sarawak

The Sarawak State Cabinet approval on the 20th September 2012 of the Strategic Crocodile Management in Sarawak includes the following matters:

i. The Cabinet agreed that crocodiles can be conserved but the level, extent and location for conservation need to be determined;

ii. Establish crocodile-free zones at major population centres (Kuching City, Miri City, Sibu, Bintulu, Sri Aman, Limbang, Niah) and popular recreation areas (Pasir Panjang, Damai Beach, Siar Beach, Wind Cave). The presence of crocodiles in these areas will not be tolerated and will be killed or captured and removed;

iii. Prepare for crocodile down-listing from CITES Appendix I to Appendix II by 2016 for Sarawak;

iv. Fast track a state-wide crocodile survey covering all major river systems to be completed by end by 2013 by engaging volunteers, universities and experts to complement SARAWAK FORESTRY personnel. Priorities to be given to surveys along the following rivers: Salak, Sadong/Sebangan,Samarahan and Batang Lupar. Survey cost is estimated at RM800,000;

v. Swift Wildlife Action Team (SWAT) to be appropriately equipped including undergoing specialized training, e.g., handling and carrying suitable firearms. Specialized training, equipment and gadgets with crocodile deterring frequency could also be looked into. The Cabinet directed sourcing of fund for the purpose from the Federal Ministry of Natural Resources and Environment;

vi. Expand the "3M Buaya" awareness programme state-wide by way of involvement of relevant government agencies (e.g. Resident & District Offices, Police, Fire & Rescue Department and Civil Defence) and other stakeholders; and

vii. The Cabinet has no objection to the establishment of crocodile chair in Universiti Malaysia Sarawak (UNIMAS) as a centre of excellence for crocodile research in

Malaysia, the proposal is considered premature at this stage. Instead the Cabinet directed a comprehensive study should first be conducted relating to food/resources balance for crocodile vis-a-vis human being to determine what crocodile population level can a river system sustainably support without adversely affecting human safety and economic activities. This study could be conducted as per item (iv).

The State Cabinet decision served not only as a directive but also as an action plan and work plan. Other efforts which are already in place to further enhance the conservation of crocodiles include:

i. Regional Meeting (Borneo) and information sharing between Malaysia, Brunei and Kalimantan, planned for in 2014. Crocodiles found in these countries could be of the same stock and facing similar threats. Concerted efforts by these countries would be possible to address these issues;
ii. To enhance capacity building through training and workshops dealing with human-crocodile conflict, crocodile survey techniques (practical) and awareness programme;
iii. Guidelines for Safe Practice of River Usage;
iv. Installation of warning signages to indicate danger;
v. Advocating media and NGOs roles;
vi. Establishing working groups on crocodile businesses especially on community-based tourism (current programme have been carried out in Bako, Niah and Sibuti; and
vii. Formulation of legal framework to promote crocodile businesses (farms).

Action Areas

Following the Sarawak State Cabinet decision, efforts have been intensified in the following areas:

Holistic Crocodiles Resource Inventory for Sarawak.

The objectives of the holistic crocodile resources inventory are:

a) To determine the population status of crocodiles in Sarawak;
b) To determine and map the crocodile distribution and habitats in various river systems in Sarawak;
c) To inventory the availability of crocodiles' food sources within their habitats;
d) To determine the carrying capacity of the river systems to support crocodiles;
e) To determine the extent of human-crocodile coexistence/conflicts.

The sub-objectives of the project are:

a) To identify and establish crocodile-free zones;
b) To identify priority areas for the establishment of crocodile sanctuaries;
c) To develop proposal to downgrade the Sarawak's crocodile population status from CITES Appendix I to Appendix II;
d) To develop centralised database using Geographic Information System (GIS);
e) To develop Strategic Crocodile Management Plan for Sarawak.

3.2: Formation of Swift Wildlife Action Team (SWAT).

3.3: Awareness Programme and Media (3M Buaya).

3.4: Establishment of Crocodile Protected Areas.
3.5: Community-based ecotourism initiatives.
3.6: Training and Human Capital.
3.7: Down-listing crocodile from Appendix I to appendix II.
3.8: Engaging Stakeholders in Crocodile Conservation.

Achievements

4.1: Holistic Crocodiles Resource Inventory.
Crocodile surveys were conducted in all the 22 river systems in Sarawak. Information generated will be used to develop a strategic crocodile management plan for Sarawak.

4.2: Formation of Swift Wildlife Action Team (SWAT)
The SWAT of SARAWAK FORESTRY was formed on 4 May 2012 with the objective of, among other things, managing human-crocodile conflicts/crises. Since then, SWAT had been in the forefront in engaging the public and aggrieved parties when crocodile attacks occurred.

4.3: Awareness Programme and Media Engagement (3M Buaya).
A specific crocodile awareness programme called "3M Buaya" has been designed with the aim to raise public awareness on crocodiles. The 3Ms stand for "*Mengenali, Memahami* and *Memelihara"* which means to Know, Understand and Conserve while *Buaya* is the Malay word for crocodile. This programme is being conducted statewide in areas having high human-crocodiles conflict such as the Niah, Suai, Sibuti areas in Miri, Bako-Santubong in Kuching, Kabong in Betong and Seduku in Sri Aman. The events were attended by some 200 villagers including pupils at each venue and were graced by the Member of the State Assembly and Member of the Parliament of the respective areas. The programmes were well-covered by the media.

4.4: Establishment Protected Areas for Crocodiles.

The Lupar River is well known for harbouring high population of estuarine crocodiles including the infamous *Bujang Senang* that terrorized the local population in the 1980's. Pulau Seduku, an island in the Lupar River was identified as a favourite place for crocodiles and is probably a breeding place. The island is now in its early stage of establishment as a Protected Area (Crocodile Reserve), mainly as a sanctuary for crocodiles and also potentially a good venue for crocodile research and tourism.

4.5: Community-based ecotourism initiatives.

The potential of community-based ecotourism having crocodiles as part of the attraction have been identified in areas where crocodiles are abundant. This initiative has been carried out at Bako Village, Niah district, Sibuti district and Similajau National Park.

4.6: Training and Human Capital

SARAWAK FORESTRY have already developed and implemented a structured module for human-crocodile conflict training covering the aspects of legal, scientific and biological, community use of resources and perception, and dealing with crocodile attacks. A protocol in handling crocodile attack has been developed and put to use.

SARAWAK FORESTRY is also collaborating with an institute of higher learning, in particular, Universiti Malaysia Sarawak (UNIMAS), in developing a home-grown expert on crocodiles. To date we have a few postgraduate students researching on crocodiles in Sarawak.

Dr Charles Manolis, the Scientific Officer of CSG conducted a 7-day training workshop in October 2013 for SARAWAK FORESTRY covering topics on survey techniques and data analysis in.

4.7: Down-listing Sarawak's *Crocodylus porosus* from CITES Appendix I to Appendix II.

Sarawak aspires to have the down-listing of its *Crocodylus porosus* population from CITES Appendix I to Appendix II to be ratified at the 2016 Conference of Parties to allow for sustainable utilisation of the wild population. This initiative would emulate the examples of Australia and Papua New Guinea the models of which promote conservation through wise use of the crocodilian resources.

4.8: Engaging Stakeholder in Crocodile Conservation.

Sarawak plans to host the Borneo Crocodile Forum 2014 aimed at establishing networks and synergising efforts towards a holistic crocodile management in Borneo knowing the fact that crocodiles do move long distances beyond political boundaries.

Summary

True to Dr. Webb's statement in 2010, today Sarawak faces a major challenge to maintain what we have achieved as there are very strong demands from some quarters for the government to remove dangerous crocodiles from our rivers.

Conflicts with crocodiles will always be present and could escalate in the future as the crocodile population increases. Culling and relocating crocodiles are temporary "fire-fighting" measures that are not only expensive but questionable in its effectiveness. Risk of crocodile attacks can be reduced by minimising exposure to crocodiles. This can be done through public awareness campaigns, media campaigns and change of public attitude and behaviour. Negative issues about crocodiles may change if people can benefit from crocodiles. Most of the people who became victims of crocodile attacks are the poor that depend on the rivers for fishing and bathing. Sustainable harvesting and ranching in Australia and Papua New Guinea has proven to be successful in conserving wild crocodiles while providing benefit to local communities, and this practice need to be emulated here in Sarawak particularly in areas with high crocodile density. The authority, in particular the Controller of Wildlife, with the advice from crocodile experts, has to play a major role in regulating harvest activities of estuarine crocodile from designated areas once the species has been downgraded from CITES I to CITES II. Local consumption of crocodile resources do not require CITES approval and thus it is advisable that surplus crocodile population and nuisance individuals be removed from certain areas be placed in licenced crocodile farms throughout the State. Those interested in crocodile business are urged to apply for permit to harvest individual crocodiles from certain areas and to apply for licence to set up crocodile farm from the Controller of Wild Life, Sarawak. Community-based tourism could also deliver benefits to the locals to support the conservation of crocodiles. At the same time, there is also need to remove nuisance or rogue crocodiles that are known to attack humans and livestocks. All of the work and plans that were discussed and detailed in this paper are preamble to the formulation of a "Crocodiles Management Plan for Sarawak". It is hoped that the management plan will be able to change the negative perception on crocodiles and provide a positive value to it.

Acknowledgements

We are thankful to the State Government for providing the fund for the holistic crocodile project. Special thank from us also extended to all our field staff and researchers from SARAWAKFORESTRY and the Forest Department, Sarawak for their effort to make the project a success. Without their concerted effort the project wouldn't have been completed in time.

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An Historical Overview of Human Crocodile Conflict in South Africa and Swaziland, 1949-2014

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Introduction

We are often told that Nile crocodiles (*C. niloticus* in particular) kill more humans than any other crocodilian species, but this is based on very little data, or very little published data. There are several published smaller-scale regional studies from across continental Africa, notably those by Patrick Aust *et al*. on northeastern Namibia, Kevin Wallace on the lower Zambezi in Zambia, several reports by Richard Fergusson, and Georgina Hatch's unpublished thesis on HCC in the Okavango. Crocodile HCC is mentioned in several books treating the human-animal conflict more broadly, notably in East Africa, Zimbabwe and Mozambique, but no coherent accessible database exists incorporating these scattered sources, archival materials or nature conservation records. It is not the purpose of this paper to review these. [1]

Broad statements are made, for example "63% of attacks in mainland Africa are fatal". However, in addition to possible behavioural differences between the two species formerly known as the Nile crocodile, there are of course considerable differences in the social, economic and ecological contexts within which human-crocodile interactions occur across the continent. This paper aims to make a contribution towards the admittedly herculean task of assembling some long-term data for a specific region, to help us to begin to make more careful and regionally specific statements about Nile crocodile attacks in Africa.

Crocodylus niloticus is the only species to naturally occur in South Africa in historical times, and was widely distributed across the warm, seasonally well-watered low-lying northeastern regions of South Africa and Swaziland, extending as far south as the Eastern Cape. Settlement and habitat transformation along the coast, chiefly for sugar cane and timber, meant that by the 1950s very few crocodiles were sighted south of the Tugela River, the southern border of Zululand.

The three major concentrations of wild crocodiles remaining in the country are in the St. Lucia lake system and Ndumo Game Reserve and surrounding waterways in KwaZulu-Natal, and the waterways of Kruger National Park in the former Eastern Transvaal Province, now Limpopo and Mpumalanga Provinces.

Methods

Attack data were sourced from my father Tony (A.C.) Pooley's personal archive, media reports (print and electronic), interviews and correspondence with conservationists, mission hospitals and rural clinics, and several archives. Tony worked for the Natal Parks Board and handled or advised on crocodile attack incidents in Zululand (northern KwaZulu-Natal from the mid-1960s until 1984).

I included attacks by wild crocodiles that resulted in fatalities or actual harm to persons, as well as a handful of attacks on canoes where the craft was damaged. If no witnesses or evidence were forthcoming, attributed attacks were excluded. Several attacks on snake park curators, crocodile farmers or their staff were also excluded. Only one attack was deliberately provoked, when two Swazi men tried to kill a crocodile alleged to be a ‘man-killer’. If it wasn’t before, it was after. Both were killed.

The remote and rural nature of most of Zululand, Swaziland and parts of the interior meant attacks on Africans were poorly recorded until the 1950s. This was compounded as a result of the prevailing attitudes to black South Africans. From the 1950s, attacks on Africans as well as ‘white’ South Africans were reasonably well reported in provincial newspapers. This was to support a public and media campaign against crocodiles in Zululand in the mid-1950s (see Pooley 2013).

The 18 recorded cases I have for Swaziland clearly miss most of the actual incidence. I include Swaziland because I was interested in regional information on biophysical factors (seasonality, etc.) and because two key rivers for crocodile attacks (Komati and Usutu) flow from Swaziland into South Africa. Mick Reilly of Big Game Parks estimates a minimum of 5 crocodile attacks per year in Swaziland. Thus an unknown number of incidents - and likely those involving (relatively) minor injuries - went unreported, at least until the proliferation of regional print and online news resources in recent decades. This is something to bear in mind when considering the analyses offered here.

On the other hand, over-reporting is possible: references in the media to ‘numerous’ attacks with no precise dates or evidence have been omitted. Examples include the allegation that 30 people were eaten by crocodiles in the Nkundusi area of Zululand between 1988 and 1998, and that 26 people had been killed in the Makuleke Dam near the Kruger National Park between 2004 and 2011. The few documented cases for these locations were included (see Mathye 2011; Mbuli 1998).

Results

Most of the recorded attacks by Nile crocodiles on humans in the study region were on locals or regular visitors to the locale where they were attacked. Only six were first-time visitors (and two were not South African nationals). The situation is similar to that in northern Australia in this respect.

Attacks by location

The majority of attacks occurred in the water (58%) or at the water’s edge (33%), similar to attacks by American alligators, but not Saltwater crocodiles in Northern Australia (Langley 2010; Manolis and Webb 2013). Although attacks in the water were more likely to prove fatal, this was only very marginally the case (see Fig. 1). Most attacks in the region occurred in rivers or streams (67%), followed by lakes or pans (20%), and dams (7%).

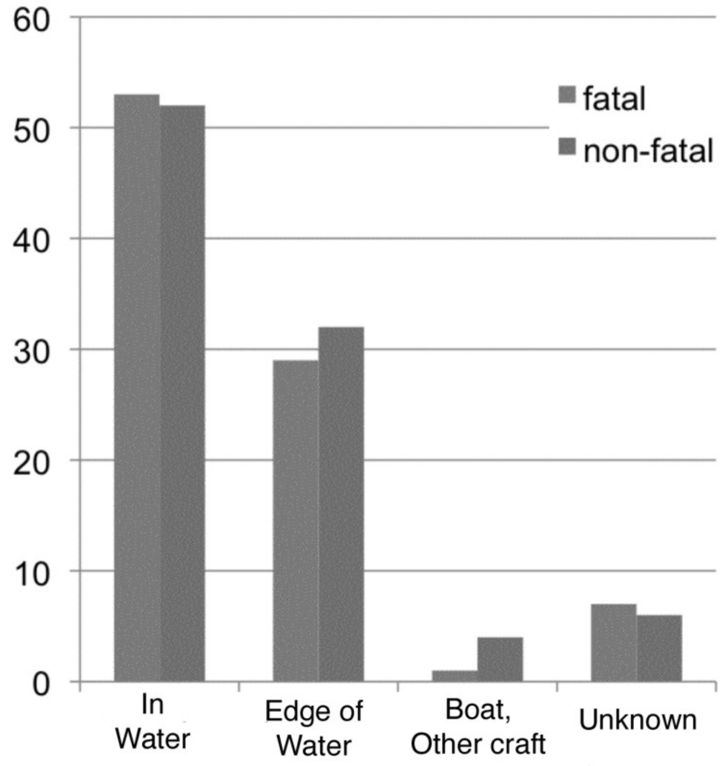

Figure 1. Outcome of 185 crocodile attacks by location. One far from water is not shown.

Attacks by activity

The major activities being undertaken by victims when attacked were swimming or bathing, fishing, crossing a river or stream, and domestic chores (collecting water, washing clothes, etc.). The only activity for which there was a high proportion of fatalities was fishing (63%). There are age and gender differences in major activities of victims when attacked (Table 1).

Table 1. Top 2 activities when attacked, by gender and age categories.

Category	Activity of Majority When Attacked	Next Highest Activity Category
Men (20+ y)	Fishing (31%)	Swimming/bathing (20%)
Women (20+ y)	Domestic chores (46%)	Crossing (20%)
Boys	Swimming/bathing (53%)	Fishing (18%)
Girls	Swimming/bathing (25%)	Crossing, and domestic chores (both 22%)

It is sometimes assumed that ‘in Africa’ females are disproportionately at risk of attack by crocodiles because their domestic tasks put them in constant danger of attack. This is not supported by this data, which shows 61% of the recorded attacks were on males (Fig. 2). It is rather true that a greater proportion of women are attacked while performing domestic chores.

Of those victims for whom we have exact age information, most victims were in the 11-20 year age group (42%), and within this age group, the 11-15 year group was most at risk. Next most vulnerable were children aged 6-10 years.

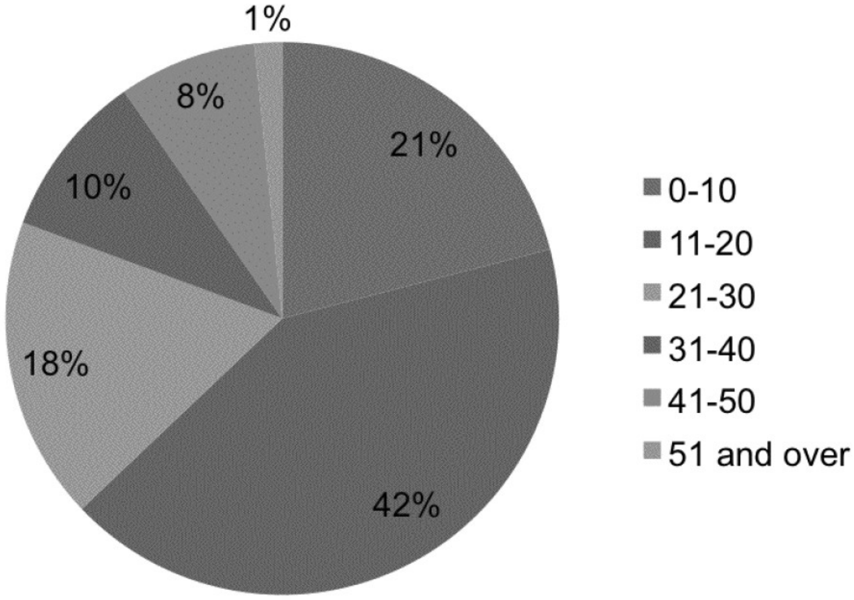

Figure 2. Crocodile attack victims by age group (N= 124).

This is in marked contrast to statistics for *C. porosus* attacks in Northern Australia, where only 9% of attacks were in the 11-20 year group, and 24% of victims were in the 31-40 year group. This contrast in age profiles of victims between regions and countries is indicative of social and demographic differences, and demonstrates the need for focussed analyses and properly informed region-specific mitigation measures. There seems to be a clear relationship between age (and hence strength and size) and the chances of surviving a crocodile attack (Fig. 3).

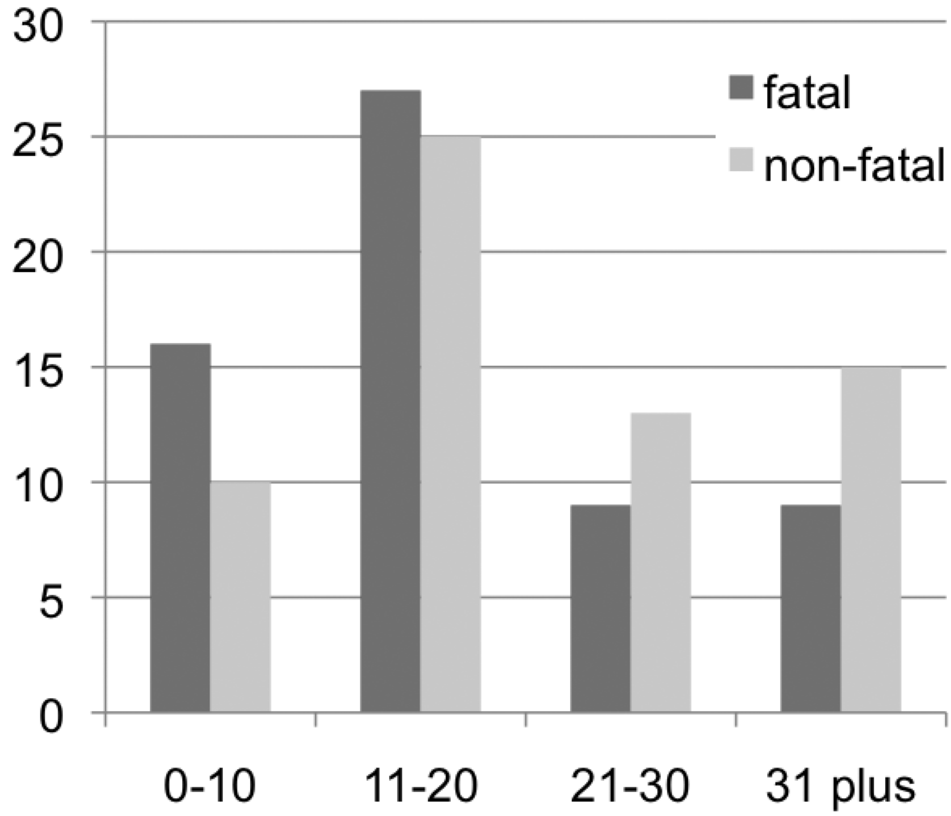

Figure 3. Outcomes of crocodile attacks by victim age (N= 124).

Size of crocodiles

Reliable data on the size of crocodiles involved in attacks is hard to come by. I found only 16 measurements and 16 more credible estimates. Mean size of crocodile (from this insignificant sample) involved in fatal attacks was 3.5 m (11'). The smallest crocodile involved in a fatal attack was a 2.5 m (8') animal that killed a seven-year-old boy. The two victims who survived attacks by >3 m (>9.8') crocodiles were rescued, or they would most likely have proved fatal. In all but one case, non-fatal attacks where the victim escaped without assistance were carried out by crocodiles of 2.5 m or less. These figures on the influence of size on outcome of attack accord well with data from the USA and Australia.

Seasonality of attacks

As has often been remarked, the seasonality of attacks is usually very marked (Fig. 4). Taking into account three variations in duration of regional wet and dry seasons, I found that 90% of attacks occurred in the wet season, going by long-term average rainfall figures. I am currently working on gathering historical data on actual water levels. In the period of low attack incidence, minimum ambient temperatures dip below 15°C (59°F). Xander Combrink's data on temperature and activity levels in the St. Lucia system are interesting for thinking about the possible relationship between attacks and ambient temperature. The breeding season also falls in the period of high attack incidence. We are currently playing with statistical approaches to trying to disaggregate and test these three overlapping explanations for peak attack incidence.

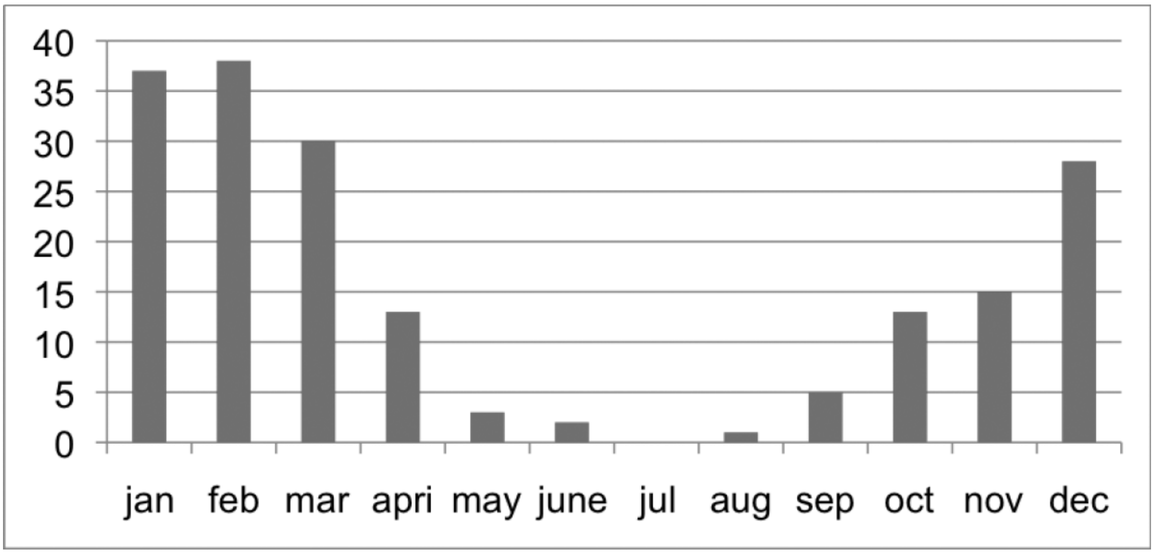

Figure 4. Crocodile attacks by month, Swaziland and South Africa, 1949-2014 (N= 185).

<u>Historical frequency of attacks</u>

The period 1957-72 is the period of highest incidence, with the peak years occurring in 1967-72 (Fig. 5). The annual average for attacks for the entire period is 2.8, with an egregious decadal high of 4.6 in the 1960s and only 1.8 in the 1990s. For the two decades since 2000 there have been on average 3 attacks per year.

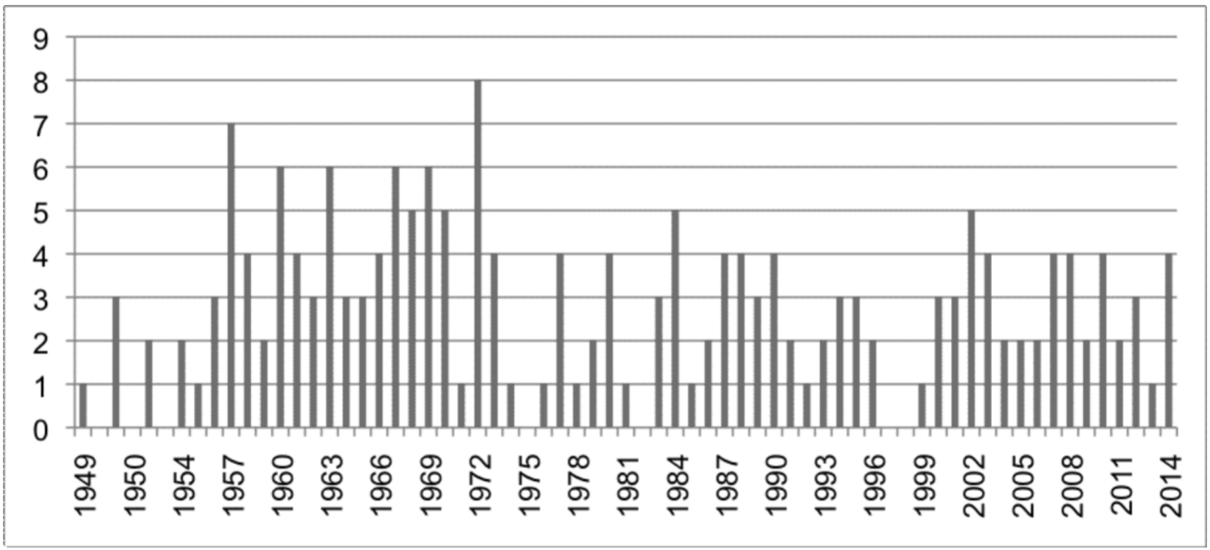

Figure 5. Crocodile attack incidence by year, 1949-2014.

In most decades more recorded attacks were fatal than non-fatal (see Fig. 6), which may reflect reporting bias in rural areas. The 1980s are the big anomaly here. The fatality rate is 50% overall for the period 1949-2012, which is significantly lower than the 63% reported by Ferguson (2004) for mainland Africa. However, 58% of attacks on children up to 16 years of age proved fatal in comparison with 39% of attacks on adults. During the period of high incidence in the 1960s, 68% of recorded attacks occurred in the lake St. Lucia system and its feeder rivers, and the Ndumo area including surrounding floodplains and the Pongolo and Usutu Rivers, which flow through Ndumo Game Reserve into Mozambique.

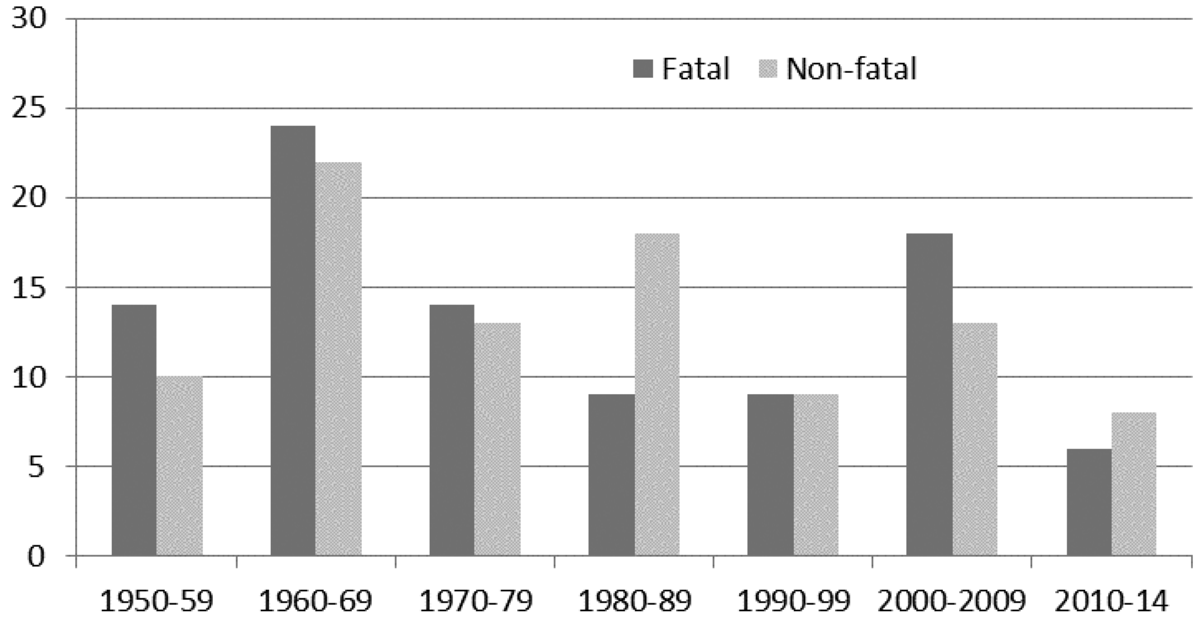

Figure 6. Fatal and non-fatal crocodile attacks by decade.

<u>Crocodile populations</u>

Crocodile population data are patchy, but we know that in Zululand crocodiles were in serious decline from the 1950s into the early 1970s, with a recovery noticeable from the 1980s. Thus there appears to be no obvious relationship between overall crocodile population levels and attack incidence in KwaZulu-Natal, though there may be such relationships at the very local level.

In the former Transvaal outside of the Kruger Park, the Limpopo, Lower Olifants and Levhuvhu Rivers harboured the most and the largest crocodiles. These rivers, together with the Letaba, all had breeding populations outside Kruger. Until the late 1980s the Komati was also a good river for crocodiles. Most attacks have occurred in the Levuvuhu River, the Sabie River inside Kruger, and along the Komati. Many illegal immigrants were rumoured to be eaten while crossing the Limpopo from Mozambique into South Africa, but there are few documented cases of this.

<u>Management of HCC</u>

KwaZulu-Natal Province

Tony Pooley began to handle and advise on crocodile attacks from the mid-1960s, and it would be nice to think his efforts achieved the significant reduction in attacks over the next decade but there are no doubt many reasons for this (Fig. 7).

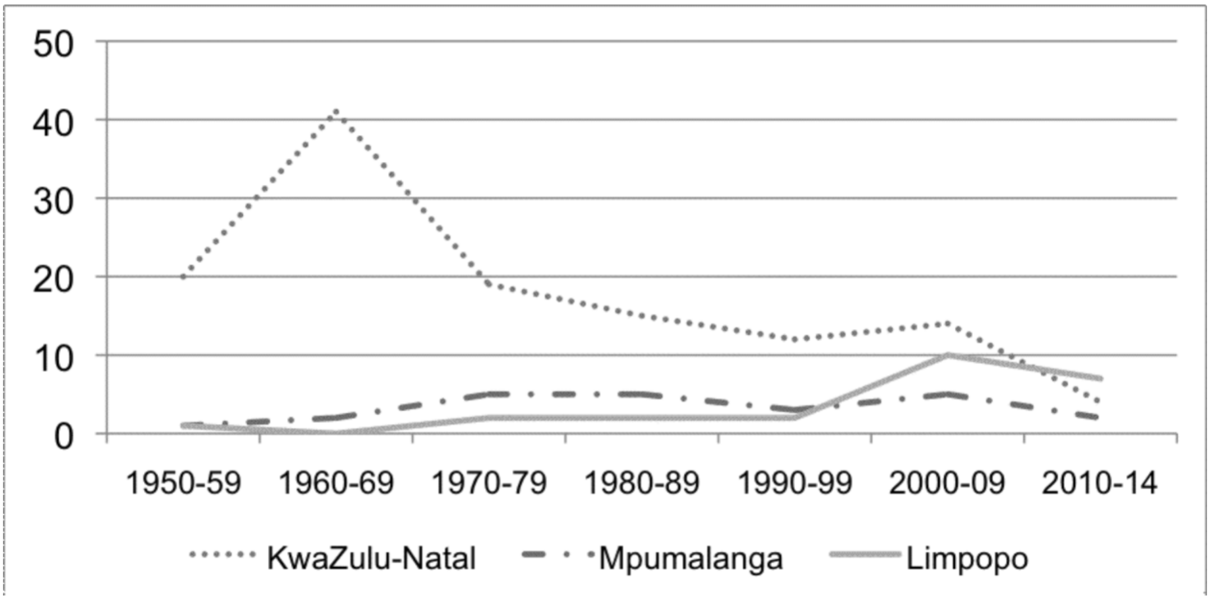

Figure 7. Trends in crocodile attack incidence by region.

The first formal protocol for handling incidents of HCC in KwaZulu-Natal was drawn up in 2005 by Ricky Taylor *et al*. of Ezemvelo KZN Wildlife. It was drawn up to manage crocodiles in the St. Lucia (now called Isimangaliso) Wetland Park. These recommendations remain the guiding ones for Ezemvelo today.

The guiding philosophy of this management approach is that adequate human management should prevent crocodiles becoming problem animals. If habituated crocodiles are deemed a potential hazard, and cannot be scared off, they are captured and removed, ideally (in order of preference) to another safe area of the lake system, to private landowners who want to stock crocodiles on their land, or failing that, are sold to commercial crocodile farms.

Crocodiles may only be destroyed - by an authorised staff member - if they pose an imminent threat to human life. If the risk is not imminent, destruction should only be considered after 21 days of unsuccessful attempts to trap the animal. Only a crocodile seen attacking a victim, or actively feeding on human remains following an attack, should be destroyed. Neither relocation nor destruction should be considered if the victim had intentionally antagonized the crocodile. Procedures are outlined for handling incidents, including dealing with victims, witnesses and crocodiles.

Ezemvelo have a generic incident form, and there is also a HCC data sheet in circulation, but these forms have been little utilised or archived. No systematic records of attacks are kept. Ezemvelo will not erect or maintain protective structures nor pay compensation for attacks outside protected areas.

Swaziland

There was little effective protection of crocodiles outside the kingdom's 6 protected areas until the Game Act was amended for the second time, in 1993, making crocodiles Royal Game under Schedule 2. The private company Big Game Parks (BGP) is mandated to enforce the Game Act and manage wildlife nationally. According to Mickey Reilly, BGP Head of Conservation and Security, their policy in problem crocodile management is as follows:

- When a problem crocodile presents itself, complaints should be reported to BGP or the police;
- BGP will investigate the complaint;
- If valid, BGP will advise complainants on avoidance of conflict with crocodiles, or capture and remove the animal. They seldom destroy a crocodile;
- Regular 'croc warnings' appear in the *Times of Swaziland* newspaper, usually in spring or early summer, to sensitise the public;
- Compensation for crocodile attacks is not paid. Avoidance advice is given, but communities must build their own protective structures.

Mpumalanga and Limpopo

The relevant authorities in the former Eastern Transvaal are South African National Parks (SANParks) for national parks, the Mpumalanga Tourism and Parks Agency, and Limpopo's Department of Economic Development, Environment and Tourism. The Transvaal Nature Conservation policy (pre-1994) made no mention of crocodiles, and at present there appear to be no protocols specific to HCC in this region, and no systematic attack records are kept. Hannes Botha of Mpumalanga Tourism and Parks has drafted a protocol for his province, but this has not yet been submitted for official approval.

The South African Police Service deal with fatal attacks, and may shoot the problem crocodile, but they usually request the assistance of the relevant conservation authority, to capture and relocate the problem animal. Commercial crocodile farms may capture problem animals outside protected areas.

SANParks won't pay compensation for crocodile attacks outside the Kruger National Park (KNP), as they dispute custodianship of such animals. Inside the park, people should know better. KNP rangers may no longer handle incidents outside the Park without prior authorisation from the provincial authorities, as they used to do in the past.

The Mpumalanga Tourism and Parks Authority can capture and sell large problem crocodiles to commercial farms. The Limpopo authorities on the other hand are a government department and cannot sell crocodiles. They have issued tenders licensing trophy hunters to control damage causing animals, including crocodiles (very few have been destroyed in this way). Limpopo seems to be experiencing a slight increase in crocodile conflict (Fig. 8), and fences have been built to protect humans who use dams with significant crocodile populations.

Conclusions

Crocodile attacks are not on the increase in South Africa, but an average of three reported attacks per year since 2000 is not insignificant, particularly in light of an apparent decline in the country's major crocodile populations. There have been several controversies over alleged crocodile attacks on people and livestock outside of protected areas in recent years. Ezemvelo KZN Wildlife appears to be the only organisation in the region that has a protocol for handling problem animal incidents specific to crocodiles. All the conservation organisations favour capture over destruction of wild animals. It is fortunate that at least in the Kruger National Park, Mpumalanga and Ezemvelo conservation organisations, there are at present knowledgeable and motivated individuals who care about conserving crocodiles.

Although education and outreach are recommended, I could find no evidence of current programs trying to achieve this. Even though incidents are investigated and problem animals removed, and some community-oriented follow-up is undertaken, many communities remain hostile to crocodiles. The lesson of history is that it only takes a spate of crocodile attacks such as that of the mid-1950s to persuade the public, politicians and local administrators to advocate mass culling.

No-one keeps systematic records of crocodile attacks. A national database and regionally-specific mitigation and education advice based upon the kind of data presented in this paper is certainly achievable. Spatially explicit information on attacks which disaggregates data by age group, gender and activity at time of attack (among other variables) will enable targeted mitigation measures including education and information, and provision of facilities for safer water use as relevant. International databases on the major crocodile-inhabited rivers (notably those flowing through Swaziland, South Africa and Mozambique) would complement this, and the CrocBite database developed by Adam Britton and Brandon Sideleau could provide a great resource here.

Finally, in the absence of organisational resources to reduce HCC, I recommend making easily interpretable visualisations of such data freely accessible to managers as well as lay persons online. I'm developing a prototype called Croc Digest with this in mind. The interface allows users to explore the data, without requiring any advanced programming, software or research skills to do so. The aim is to motivate busy conservation managers and the public to both collect, and use, crocodile attack data to save human and crocodilian lives.

Acknowledgements

This paper is dedicated to my late father Tony (A.C.) Pooley who pioneered crocodile management in KwaZulu-Natal, South Africa, and tirelessly spoke up for a widely persecuted species when few did. I wish to acknowledge Imperial College London, for funding my fellowship on the history of crocodilian conservation, and my convivial institutional home, Imperial College Conservation Science. Thanks also, for data, access to records, and insights, to: Hannes Botha (Mpumalanga Tourism and Parks Agency); Xander Combrink (Ezemvelo KZN Wildlife); Charlie Manolis for *C. porosus* attack data in advance of publication; Danie Pienaar (SANParks); Mark Robertson (Ezemvelo KZN Wildlife); Mickey Reilly (Big Game Parks, Swaziland); Ricky Taylor (formerly Ezemvelo KZN Wildlife); and, J. Perran Ross (Rocky Point Consulting LLC).

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Human-Crocodile Conflict with *Crocodylus acutus* in Mexico, with Comments on *Crocodylus moreletii* and *Caiman crocodilus*

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Abstract

Human-Crocodile Conflict (HCC) involving *Crocodylus acutus* is reported from 11 countries. Information is presented up to 2010 in order to determine the most common causes. A database for HCC in this region, including common Caiman and Morelet's crocodile, is under preparation for Mexico. HCC related to *C. acutus*, shows trends and percentages by age and sex of persons involved, and the most common causes of conflicts. Finally, hot spots, the most "dangerous" places for people, are presented. México has the greatest number of HCC reports, primarily along the Pacific coast where there is the greatest concentration of *C. acutus*. Costa Rica has the greatest number of deaths recorded, which may be related to the large size of *C. acutus*. Regression analysis shows increasing incidence over years (P>0.05), with a similar trend at a state (Jalisco), country (México), and species distribution level. The increase is suggested by the recovery of the species, habitat reduction and habitat use by humans. The highest proportion of incidents was associated with rustic and local fisheries, at least in México. Deaths by *C. acutus* are recorded from 10 countries. In México deaths are recorded from all of the coastal states where species is distributed, except Nayarit, where one possible death case is under investigation. Deaths related with *C. moreletii* in Mexico are recorded from the gulf coast in Tamaulipas, Veracruz, and Quintana Roo. Deaths related to *Caiman crocodilus* have not been reported.

Introduction

This work started in 1993-1994, when the author advised the wildlife service about Human-Crocodile Conflicts (HCC) in Jalisco State, Mexico. Information was continuously updated and presented at several meetings, congresses, as well as universities and to wildlife service in Jalisco and at national level in México (Ponce-Campos and Huerta-Ortega 1997; Huerta-Ortega and Ponce-Campos 2001, 2002, 2004; Ponce-Campos 1999, 2006, 2007; Ponce-Campos *et al*. 2011). The earliest known information published about HCC in México is by Navarro and Navarro (1995) and Lazcano (1996), the latter had a program of HCC in Can Cun since then. The first information at state level was presented by Ponce-Campos and Huerta-Ortega (1997), as part of the Action Plan for conservation of *Crocodylus acutus*. Martínez (1997) reported on HHC with *C. acutus* and *Caiman crocodilus* and Sigler (2000) reported an attack by *C. acutus* in Chiapas. Since 2001, the mention of terms related with HCC started to sound by several groups, also new activities related to HCC started in Jalisco (Cupul *et al*. 2001; Gómez *et al*. 2001; Gómez and Cupul 2002). Huerta-Ortega and Ponce-Campos (2002) updated and presented the status of *C. acutus* attacks in Jalisco State. Wildlife authorities were involved again into actions related to HCC in Jalisco, when they asked the author to analyze a case, then Ponce-Campos (2006) made a report on it and updated HCC in Jalisco and presented a new technique to evaluate the size of the implicated crocodile in HCC superimposing the calibrated tooth print of the crocodile over the calibrated photo of the victim. Wildlife authorities continue into actions. Again authorities ask for help to catch a large crocodile in Tomatlán, Jalisco. Then Ponce-Campos (2007) made a report on the capture of a 3.67 m crocodile that killed a 5-year-old boy in Jalisco, and updated data on HCC in the state. Later, Cupul *et al*. (2010) added 5 more cases to the state.

At a national level, activities increased after the mid-2000s, when it was common to see reports related to HCC (Hernández-Hurtado *et al*. 2006; García-Grajales and Brandon-Pliego 2008; Ovando-Hidalgo *et al*. 2008; Cupul *et al*. 2010). Information on HCC at a state level is available from the states of Jalisco (Ponce-Campos 1996, 1997; Huerta-Ortega and Ponce-Campos 2002; Cupul *et al*. 2010; Ponce-Campos *et al*. 2011), Tabasco (Ovando-Hidalgo *et al*. 2008; they mention HHC without numbers), and Quintana Roo (Javier Carballar and Marco Lazcano, pers. comm.) Reports on the states of Colima and Chiapas are in preparation (Hesiquio Benitez report, México, 2014) and information related to Nayarit State, and other states are included in this report.

Nowadays more information on HCC is being published (García-Grajales and Buenrostro-Silva 2013; García-Grajales *et al*. 2013). The author, thanks to initiative of Manuel Muñiz, gave a lecture on HHC from Jalisco and Latin America to the director of (DGVS) wildlife management Authority in Mexico (Martín Vargas, Dirección General de Vida Silvestre, SEMARNAT), and other people related in the government agency on 2010 and 2011, in order to start actions against HHC. As a result, I was invited to a HCC National Meeting in Campeche in 2010, in order to present the information cited above and on the basis to a HHC National Protocol. During this meeting, a national action Group on HCC was established, called "SOS Cocodrilo" (SOS Crocodile) which would be into action just after wildlife department in Mexico developed a National Protocol, which they ask me to review. National protocol is in process to publish, but some actions (SOS Crocodile) groups started in Colima, Jalisco-Nayarit, and Oaxaca. Quintana Roo, have a specific plan for many years, because is a touristic area (Marco Lazcano and Javier Carballar, pers. comm.). In Nayarit State, wildlife authorities have been actively solving problems of HCC for many years (Jesús Romero Villarruel and Carlos Villar, pers. comm.). In Costa Rica there are biologist (Juan Bolaños and Laura Porras) who are very active on this subject, and in the USA, biologist undertake actions to diminish HCC with *C. acutus* (Heller 2005).

Objectives

The objective of this paper is to analyze: the most common situations related to HCC with *C. acutus* up to 2010 throughout its range; and total cases in the range of the species up to 2014, including *C. moreletii* and *Caiman crocodilus* in México.

Methods

The information presented came from a database initiated since early 1990s, as a result of interviews with fishermen and locals in the States of Nayarit, Jalisco, Colima, Michoacán, Oaxaca, Chiapas, Campeche and Quintana Roo, during fieldwork or short trips. Information was also obtained from locals, people involved in HCC or witnesses, biologist, papers, notes in newspapers and on the internet (including the CrocoBite website; www.crocodile-attack.info/). The analysis of the information presented is updated to 2010 but the total number of cases of HCC is updated to 2014, through the range of *C. acutus* in 12 countries. Some information is updated to 2014, including *C. moreletii* and *Caiman crocodilus* in México.

Analysis of several cases is still in progress. Information from *C. acutus* was filtered in order to obtain as much information as possible, but not all the cases had enough information to allow analysis (up to 2010). It is important to note that in many cases it was not possible to determine if the attack was made by *C. acutus* or *C. moreletii* in the Yucatan Peninsula (Quintana Roo) where both species coexist. Something similar happened in Belize and Guatemala. In Chiapas, Mexico, some cases would be related to *C. acutus* and *Caiman crocodilus,* or *C. moreletii* depending on the distribution. For this reason, some information is presented as "undetermined species" depending on its distribution, in between the validation of species attacks is being made when possible.

Every case was reviewed in order to determine the size of the crocodiles (not all cases had this information), depending on the situation of the conflict. The approach of the size is relative, since the size chosen is from 2.8 m to a larger size. Even though, is well known that crocodilians of 2 m are capable of taking an adult's arm. For that reason, in this approach it is important to relate the size of incidents in order to know how frequent is the size related to the HCC. This is taking into account the relation pray size in every case (when possible) and also to the deaths in some cases. Several cases have not been included because the information is not confirmed or validated, as an example, Colima or Tabasco States, where many cases occurred, but are in process to confirm the validation, or compile. Finally, many cases related to researchers, people who had crocodiles as pets, and those related with captivity are not included in this manuscript.

Results and Discussion

Up to April 2014, 187 cases of HCC with *C. acutus* were reported in 12 countries (Fig. 1), with México having the largest number of cases (N= 111), followed by Costa Rica (N= 33), Panama (N= 14), and Guatemala, United States and El Salvador with two cases each.

In México, Jalisco State had 44 cases (4 deaths) between 1958 and 2014, Quintana Roo had 18 cases (44 cases if *C. moreletii* and undetermined species are included), Oaxaca had 17 cases, Colima had two cases (several cases are under revision) and Sinaloa had one (Fig. 2). For the three species in México, data are updated to 2014, with 153 cases of HCC including undetermined species [*C. moreletii* N= 31; *Caiman crocodilus* N= 2(?); undetermined species (N= 19) and *C. acutus* (N= 111)].

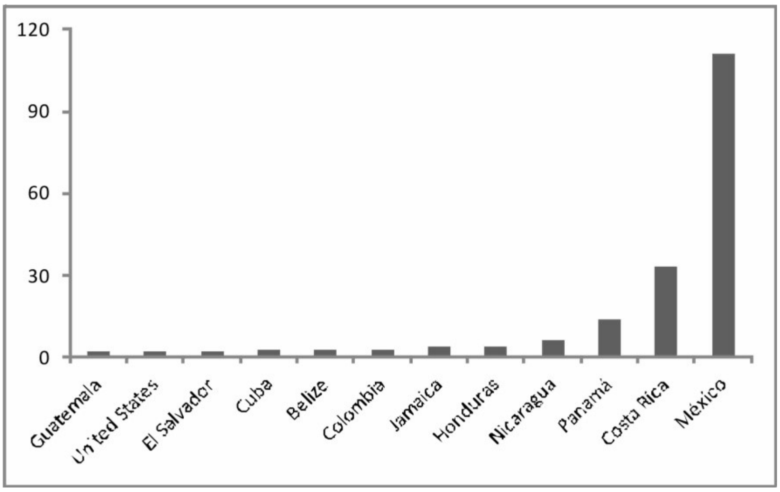

Figure 1. Number of HCC cases with *C. acutus* in 12 countries (updated to 2014).

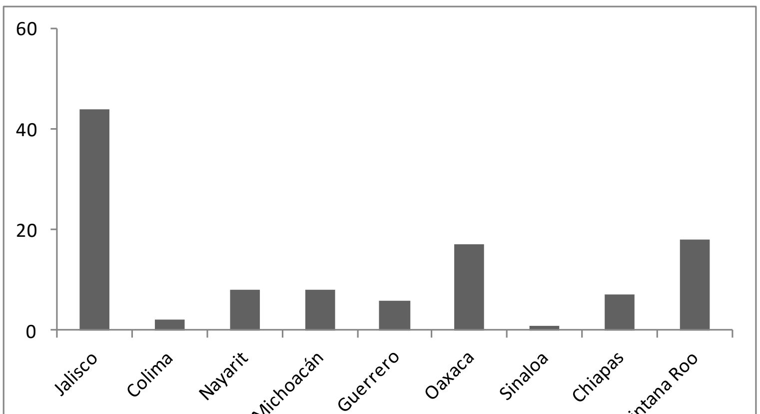

Figure 2. Number of HCC cases with *C. acutus* by state in Mexico (updated to 2014).

For *C. acutus* there was a total of 138 HCC cases were recorded up to 2010, in 11 countries (many cases in process of validation), where 117 (84.8%) involved males (included 12 boys), and 20 (14.5%) involved females (including 6 girls). At least 95 (68.8%) victims were locals.

Crocodiles of around 3 m TL or more were involved in at least 70 (50.7%) cases. Fatalities were recorded in at least 33 cases (17.6% of 187 records; 67.3% of the total of deaths). In 93 cases (67.4%), (including the parents when children were involved) the persons involved knew about the presence of crocodiles in the site of the incident. A total of 82 men were involved (59.4%), 7 women (5.1%), 13 boys (8.7%) and six girls between 2 and 13 years old (4.3%); 11 men between 14 and 19 years old (8.0%); 20 men between 20 and 30 years old (14.5%); 21 men (15.2%) between and two women 31 and 45 years old (1.4%); 7 men between 46 and 55 years old (5.1%); 4 men (2.9%) and one women between 56 years old or more. At least 45 are related to fishing (32.6%), and 27 were doing local recreational activities (19.6%).

At least 49 deaths in 12 countries (26.2% N= 187) are recorded throughout the distribution of *C. acutus*, with Costa Rica having the largest number of deaths (18; 9.6%), and México had 11 deaths (5.9%). No fatalities were reported for the United States and El Salvador (Fig. 3). Deaths caused by *C. moreletii* in México are from the states of Tamaulipas, Veracruz, and Quintana Roo. Deaths related to *Caiman crocodilus* have not been recorded in México.

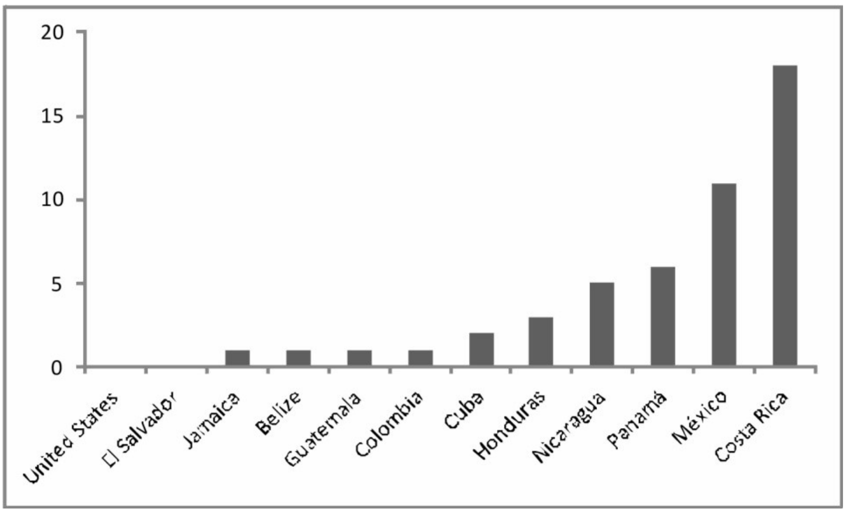

Figure 3. Number of human fatalities caused by *C. acutus* in 12 countries (updated to 2014).

The results show that more of the cases occur with adult males, local people, and people who are aware of the presence of crocodiles in the site. Also fisheries and recreational activities are factors that have important influence on HCC. Size of the crocodile is an important factor for HCC. There are other factors involved in the incidents, such as feeding large crocodiles for tourists (a common practice in the Mexican Pacific), habitat reduction, increase of human activities in crocodilian habitats, and the recovery of crocodile populations over the time. For the last two points, the total number of crocodilians and number of adult crocodilians sighted in Boca Negra estuary, and number of HCC cases recorded in Jalisco up to 2010 were plotted against year (Fig. 4). Even, many factors as stated below, are related, this information shows that the recovery and size increasing of crocodiles is related to the HHC incidents. Also is important to note that rustic fisheries have as important a proportion as tourist and local recreational activities. (Note: information sometimes is not available or sometimes differs depending on the source, even names or ages of the persons involved).

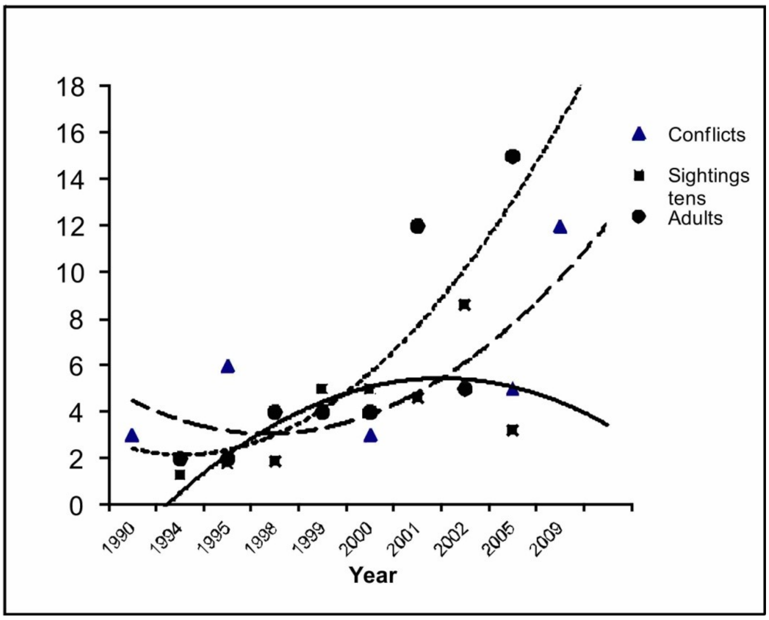

Figure 4. Relationship between the number of HCC cases in Jalisco State (dashed line), total sightings of crocodiles sighted (divided by 10) in Boca Negra estuary (solid line) and number of adult crocodiles sighted in Boca Negra estuary (dotted line) and year.

The distribution of HCC cases in 5-year periods since the 1950s in Jalisco State, Mexico, and 12 countries are on Figures 5, 6 and 7. These figures show gaps in HCC from the 1960s to 1990s, which is related to the populations of *C. acutus* being reduced due to past exploitation, from the late 19th century to the 1960s (Casas and Guzmán 1970). This is also related to the lack or few large crocodiles being present. At least two of the HCC incidents in Mexico from late 1950s or early 1960s involved crocodile hunters.

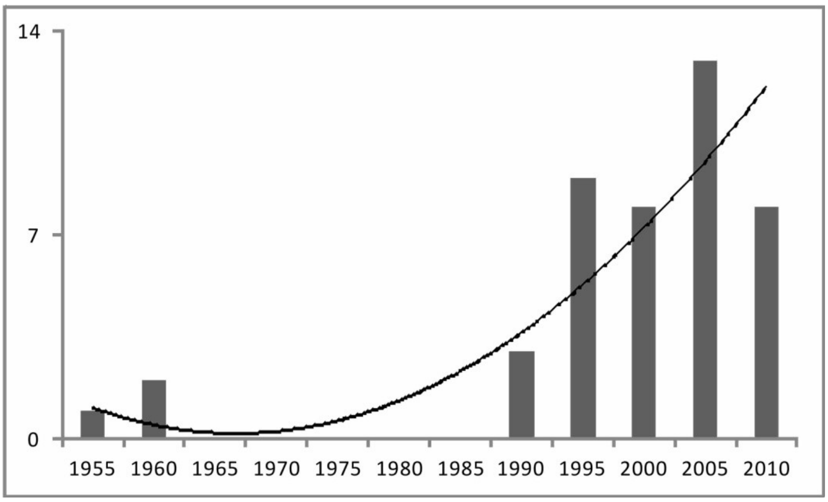

Figure 5. Numbers of HCC cases involving *Crocodylus acutus* in 5-year periods in Jalisco State, Mexico (P>0.05; N= 44 cases) (updated to 2014).

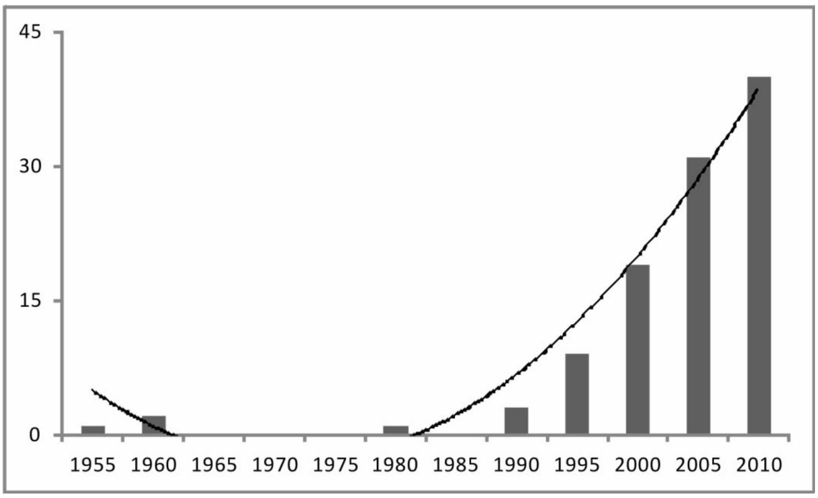

Figure 6. Numbers of HCC cases involving *Crocodylus acutus* in 5-year periods in Mexico (P>0.05; N= 106 cases) (updated to 2014).

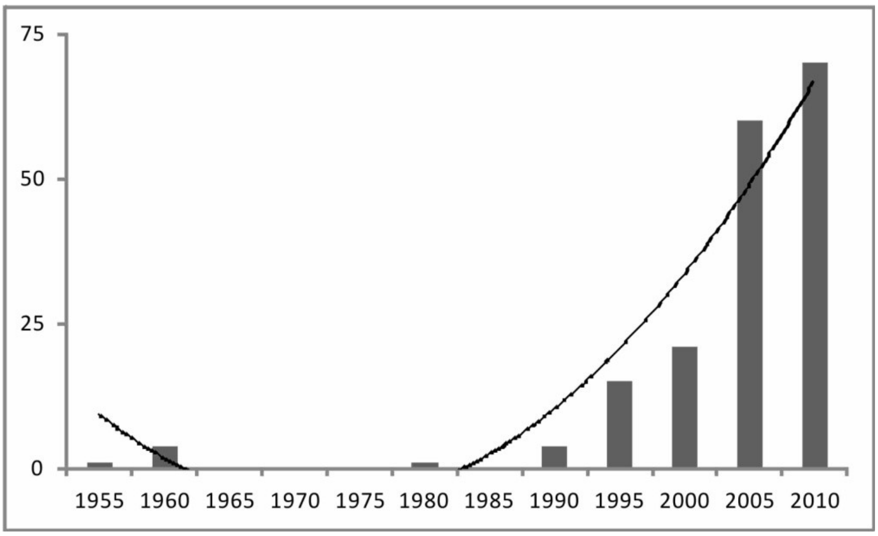

Figure 7. Numbers of HCC cases involving *Crocodylus acutus* in 5-year periods in 12 countries (P>0.05; N= 176 cases) (updated to 2014).

Hot spots or areas where more cases of HCC with *C. acutus* occurred in México are the southern coast of Nayarit and the northern coast of Jalisco States. Also the middle and southern coast of Jalisco. The coast of Colima and northern coast of Michoacán, the central and southern coast of Guerrero, the coast of Oaxaca, and especially the southern coast of Chiapas, and finally Cancun area in Quintana Roo. Hot spots for *C. moreletii* are in Tamaulipas (Tampico and Cd. Madero areas), Central Veracruz, the coast of Campeche and the central Chiapas. For *Caiman crocodilus* the coast of and central part of Chiapas. The most important areas or states related with HCC in México are Jalisco and Quitana Roo principally Cancun area, where many cases are associated with international tourists.

The most important range states for HCC with *C. acutus* are Mexico, Costa Rica and Panamá. Also the coast and central Belize have to be taken into account for *C. moreletii* and *C. acutus* (coast).

With this information we can see that the most risk for people in Mexico is in the southern coast of Nayarit and the northern coast of Jalisco, central coast of Jalisco through Northern coast of Michoacan to Oaxaca, and the southern coast of Chiapas, and also Tampico area. The most risk area in México, especially for tourist, is in Cancun area, in Quintana Roo. Costa Rica where most deaths are recorded and Panamá, are the most risks countries after Mexico.

Conclusions

HCC is increasing in recent times, and is related to habitat use and habitat reduction for humans. Recovery of the species and increasing in size it also an important factor. Most of the incidents are related to people who know about the presence of crocodilians in the site, even if they were children, the parents knew about the presence. Most of the HCC cases are related with locals. Rustic and sport fisheries have an important impact on HCC. Finally the size of the crocodiles related in many cases as well as deaths, are an important factor in HCC.

This information show the most common factors related with HCC occurred with *C. acutus* in Jalisco, México and along its distribution in 11 countries. It is important to know that most of the data is underestimated, because not all the sources of the information have data to analyze. A database is under revision and/or validation, for this reason many cases are not included. HCC with *C. acutus* will increase after validation of many cases, as mentioned below.

Recommendations

The only way to live in a better relation between humans and crocodilians is with knowledge. We have to inform to the people about crocodilians, their habits and prevention of HCC in order to diminish these terrible situations.

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Management of Human-Crocodile Conflict in the Northern Territory, Australia: Review of Crocodile Attacks and Removal of Problem Crocodiles

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Abstract

Rebuilding of depleted crocodilian populations leads to increased Human-Crocodile Conflict (HCC), and the focus of management changes from conservation to mitigation of HCC. As the largest and most aggressive extant crocodilian species, saltwater crocodiles (*Crocodylus porosus*) are of particular concern, although they are an important natural resource for commercial harvesting, tourism, and customary use. We quantified HCC in the Northern Territory of Australia by reviewing the historical records of saltwater crocodile attacks and the removal of saltwater crocodiles. Between 1977 and 2013, a total of 5792 problem crocodiles were caught, of which 69.04% were males. The most common size class was 150-200 cm and their mean size did not change significantly over years. Between 1971 and 2013, 18 fatal attacks and 45 non-fatal attacks occurred. About 60% of these attacks occurred around human population centers including remote communities. The number of attacks, particularly non-fatal cases increased over years. This increase was strongly related to the increase in both human and crocodile populations, and the increasing proportion of larger (>180 cm) crocodiles. The peak of problem crocodile capturing and crocodile attacks was in the beginning (Sep.-Dec.) and end (Mar.-Apr.) of the wet season. However, fatal attacks occurred almost all year around. Attacks by >400 cm crocodiles often resulted in death of the victim (73.33%). Crocodiles in 300-350 cm class were more responsible for attacks than any other sizes. Proportions of indigenous and non-indigenous victims did not differ greatly. Local and male victims were much more common than visitors and females, respectively. The most common activity of victims was swimming and wading. It is essential that the public receive messages about crocodile awareness and risks through education programs.

Introduction

Depleted populations of large carnivores represent a particularly difficult conservation challenge, because success in increasing wild populations can come with the social, political and economic cost of increased conflict with people (Treves and Karanth 2003; Treves *et al.* 2006; Dickman 2010). The rebuilding of wild crocodilian populations has often resulted in increased Human-Crocodile Conflict (HCC) (Stuebing 1983; Conover and Dubow 1997; Aust *et al.* 2009; Gopi and Pandav 2009; Wallace *et al.* 2011; Webb 2012), and with larger and more aggressive crocodilians, conflict involves people being severely injured or killed (Nekisic and Wardill 1992; Scott and Scott

1994; Caldicott *et al.* 2005; Gruen 2009; Wamisho *et al.* 2009). Saltwater crocodiles (*Crocodylus porosus*) are of particular concern, because 1) they are the largest of extant crocodilians and can exceed 6 m in length and 1000 kg in weight (Britton *et al*. 2012), 2) they feed on large prey items including people and domestic stock (eg cattle, horses, and water buffalo), 3) they are widely distributed in the Indo-Pacific region (Webb and Manolis 1989; Webb *et al.* 2010), and 4) they occupy a variety of water bodies, including marine and freshwater wetlands critical to the livelihoods of many people.

The Northern Territory of Australia represents the southern part of the range of saltwater crocodiles. Wild populations in the Northern Territory were severely depleted by unregulated commercial harvesting (1945-70), were eventually protected (1971), and have increased in abundance and biomass since then (Messel *et al.* 1981; Webb *et al.* 1984). They are now considered almost fully recovered in the core habitats of tidal rivers and associated floodplains (Webb *et al.* 2000; Fukuda *et al.* 2011), but are still expanding into upstream sections of rivers (Letnic and Connors 2006) and the sea (Nichols and Letnic 2008). In some of these areas there is no institutional memory of crocodiles being present and their re-appearance poses a risk to public safety where the types of recreational water activities undertaken assume the absence of crocodiles. Crocodiles that appear in or near human settlement are considered a risk to people and/or livestock and defined as problem crocodiles (Leach *et al.* 2009).

Despite the risk to public safety, saltwater crocodiles are an important and valuable natural resource in the Northern Territory, exploited through commercial farming and ranching (Leach et al. 2009), tourism (Ryan 1998) and customary use (Lanhupuy 1987). Crocodiles and their eggs are harvested in a sustainable manner for commercial use and land owners receive royalties for these harvests (Leach *et al*. 2009). This incentive-driven conservation system adds economic value to the species and motivates the community to tolerate and conserve wild populations of crocodiles (Webb and Manolis 1993; Hutton *et al.* 2002). Consequently, management goals are somewhat diametrically opposed, improving public safety by removing problem animals and educating the public about the risk, while encouraging crocodile population growth to support ongoing commercial uses by people.

In this study, we describe 1) HCC with a particular reference to the dynamics of human and crocodile populations, 2) the development of public safety programs including education and the removal of problem crocodiles, and 3) patterns and trends in problem crocodiles and attacks on humans in the Northern Territory of Australia. After quantifying HCC and its relationship with human and crocodile populations, we provide a series of recommendations to guide the management programs to reduce HCC.

Study area

The study area was the northern, coastal regions of the Northern Territory, Australia (Fig. 1), encompassing the natural historical distribution of *C. porosus* in the Northern Territory, where it inhabits a range of freshwater and saline water bodies, including beaches, billabongs, floodplains, lagoons, lakes, mangroves, rivers, swamps, and waterholes (Webb and Manolis 1989; Fukuda *et al.* 2007). The climate is monsoonal with distinct wet (Nov.-Apr.) and dry (May-Oct.) seasons. The dry season is characterised by the coldest (May-Aug.) and the hottest (Aug.-Nov.) periods of the year (Webb 1991). The mean minimum and maximum temperature typically ranges between 22 and 32°C and the annual rainfall is around 1700 mm (Station Number 14015, Darwin Airport; Bureau of Meteorology 2014). During the wet season, heavy rainfalls flood water bodies and floodplains, enabling more extensive movement of saltwater crocodiles (Webb 1991; Campbell *et al.* 2013). Courtship and mating for saltwater crocodiles begin in the late dry season, and nesting occurs during the wet season (Webb and Manolis 1989; Fukuda and Cuff 2013). During the cooler times of the dry season, the activity of saltwater crocodiles may be reduced, but they will continue to feed to some degree throughout the year (Webb *et al.* 1978; Taylor 1979).

The study area covers several townships (Table 1), including the state capital, Darwin, and many large and small indigenous communities. The main land use is indigenous use (any land uses by indigenous or Aboriginal groups in their lands to which access is controlled by authorities or land councils), pastoralism, conservation (national parks and reserves), and tourism (Fig. 1). Local communities, including indigenous and non-indigenous groups, hold diverse perceptions towards crocodiles as a culturally or ecologically significant species, natural resource, and predator of humans and livestock (Lanhupuy 1987; Webb and Manolis 1989; Fijn 2013).

Australian freshwater crocodiles (*Crocodylus johnstoni*) also inhabit the study area, mainly in freshwater bodies upstream of tidal influence (Webb *et al.* 1983; Webb and Manolis 1989). We did not include *C. johnstoni* in this study because this smaller species poses few HCC issues (Webb and Manolis 1989; Delaney *et al.* 2010) and its attacks on humans are rare and reported elsewhere (Hines and Skroblin 2010; Somaweera 2011).

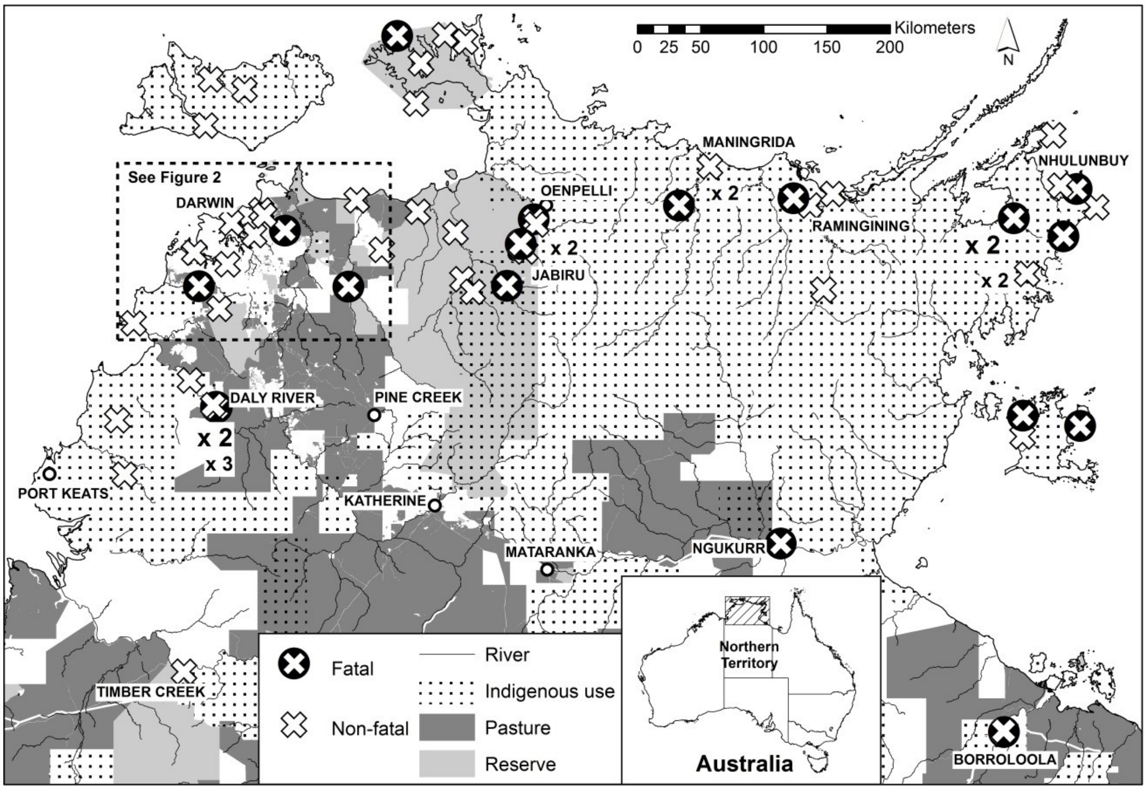

Figure 1. Study area in the Northern Territory, Australia, with approximate locations of saltwater crocodile attacks between 1979 and 2013 (N = 63).

Table 1. Population centers in the study area of the Northern Territory, Australia, and their human population size, the number of saltwater crocodile attacks between 1979 and 2013, and estimated saltwater crocodile breeding habitat within 50 km buffer around each of the population centers. Note that the three attacks in Oenpelli were also contained within the 50 km proximity of Jabiru.

Population center	Human population (2011)	Crocodile attacks (1971-2012)	Breeding habitat (km^2)
Borroloola	926	2	481
Daly River (Nauiyu)	625	6	1123
Darwin	120,586	7	460
Jabiru	1129	7	1685
Katherine	5798	0	0

Maningrida	2292	3	980
Ngukurr	1056	1	513
Nhulumbuy	4072	8	145
Oenpelli (Gunbalanya)	1171	3	1358
Wadeye	2111	0	1224
Ramingining	833	3	1857
Timber Creek	231	1	239

Methods

Human population

The Northern Territory has a relatively small human population (approximately 234,800 in 2012), concentrated within the Greater Darwin Region (approximately 131,900 people in 2012) that includes, Darwin, Darwin Harbour, and its surrounding urban and rural residential areas (ABS 2013). Towns and communities in the study area have different human population sizes (Table 1) and approximately 30% of the entire population in the Northern Territory are indigenous (ABS 2006). The human population in the Northern Territory has been constantly increasing and the increase is expected to continue (ABS 2013). We derived the human population in the Greater Darwin Region from ABS (2013) and described the trend by fitting a linear regression to the mean population in five-year periods for 1979-2013 with 1971-1978 grouped as one period.

Crocodile population

At the time of protection in 1971, saltwater crocodiles in the Northern Territory were considered commercially extinct due to uncontrolled hunting, and the population was estimated to be between 3000-5000 non-hatchlings (Webb *et al.* 1984; Richardson *et al.* 2002). Extensive monitoring programs since protection showed consistent increases in crocodile populations across the Northern Territory (Messel *et al.* 1981; Webb *et al.* 2000; Fukuda *et al.* 2011). Although the degree of recovery differs between sub-populations due to intrinsic habitat quality (Fukuda *et al*. 2007, 2011), the overall population, now estimated to be 80,000-100,000 non-hatchlings (Y. Fukuda, Northern Territory Department of Land Resource Management, unpublished data), is considered to be approaching carrying capacity and the abundance level that existed in 1945, before the period of uncontrolled hunting (Leach *et al.* 2009; Fukuda *et al.* 2011). The monitoring surveys of crocodile populations showed that as the number of crocodiles recovered, the mean individual size of individuals in the population also increased (Fukuda *et al*. 2011). Using data derived from Fukuda et al. (2011) and the historical surveys of crocodile populations in twelve tidal rivers monitored between 1971 and 2013, we described the trends in the relative density of saltwater crocodiles (sighting/km of river) and the proportion of crocodiles >180 cm total length (TL) by fitting linear regressions to the mean of these indices in five-year periods, except for 1971-1978 which was grouped as one period.

Public safety program

Public safety is one of the priorities in the management of saltwater crocodiles in the Northern Territory (Leach *et al.* 2009; Fukuda *et al.* 2012). The Northern Territory Government's public safety program consists of two major components, education for safety awareness and the removal of problem crocodiles.

The public education program for crocodiles started in the late 1970s with the goal of raising the awareness of the risk of crocodile attack (Butler 1987), and was sustained at different levels of intensity depending on the public concern triggered by occasional crocodile attacks (G. Webb, Wildlife Management International, unpublished data). It also involved the installation and maintenance of warning signs in crocodile habitats with frequent human access, providing information exhibits and talks at local events and schools, and advertizing public notices in a variety of media (eg television, radio, newspaper, and website). During the 1990s less effort was expended on media and school outreach, but in the last decade, government revitalized the public education program ("Be CROCWISE") with dedicated staff and funding to deliver the message about crocodiles and efforts to maintain public safety in the Northern Territory (Leach *et al.* 2009; PWCNT 2014).

The removal of problem crocodiles began in the late 1970s as government started receiving reports from the public about crocodiles considered a risk to people, livestock or domestic animals. As the crocodile population continued to recover, the concern spread across the Northern Territory, and the removal of problem crocodiles, especially around human settlements, became a permanent feature of the crocodile management program. Since the inception of the problem crocodile program in the early 1980s, the removal of problem crocodiles has concentrated on Darwin and its environs. This area was defined as the Darwin Crocodile Management Zone (DCMZ; Fig. 2) in 2009 as a management response to increasing crocodile populations and HCC around the urban areas (Leach *et al.* 2009; Fukuda *et al.* 2012). The DCMZ encompasses the Greater Darwin Region that contains approximately 56% of the human population in the Northern Territory (ABS 2013), and around 70% of the population in the study area (TNRM 2013). Captured problem crocodiles are not returned to the wild, because *C. porosus*, particularly males, have a strong homing instinct (Walsh and Whitehead 1993; Read *et al.* 2007; Campbell *et al.* 2010). Instead, they are transported to crocodile farms in most cases to be utilized as stock (Leach *et al*. 2009). Outcomes of the problem crocodile management such as the location and number of problem crocodiles removed are reported regularly to the public through the media and government reports (Leach *et al.* 2009; Fukuda *et al.* 2012; PWCNT 2014).

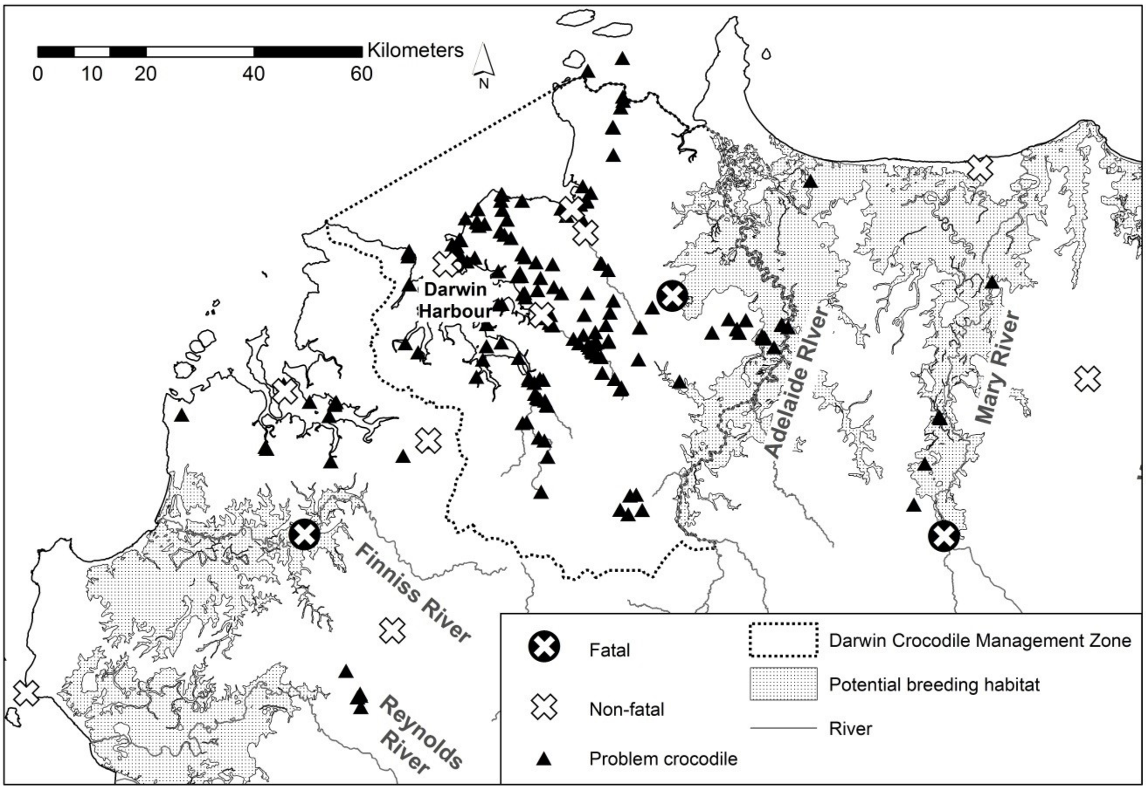

Figure 2. Saltwater crocodile attacks, problem saltwater crocodiles captured, and saltwater crocodile breeding habitats in and around the Darwin Crocodile Management Zone (DCMZ) in the Northern Territory, Australia.

We compiled the historical data for saltwater crocodiles caught as problem crocodiles between 1977 and 2013 from internal government databases. We did not include the data for crocodiles captured 1) primarily for commercial or traditional use, 2) in Kakadu National Park, because they were relocated within the park rather than removed (Lindner 2004; G. Linder, Parks Australia, unpublished data), and 3) by non-government staff, because these crocodiles were also used for commercial purposes and the distinction between problem crocodile and commercial use was not clear. We excluded data for 1998 from the analysis because they were incomplete. We also excluded hatchlings (<0.6 m) that were rarely captured as problem crocodiles. The detail of each problem crocodile record included the date and location of the capture, and the species, sex, and TL of the crocodile.

We analysed the historical data on problem saltwater crocodiles with respect to 1) numbers caught annually and mean total length in each year over time, using ANOVA, 2) TL distribution in 50 cm categories using chi-square test, 3) sex difference in the size distribution, using chi-square test, 4) seasonal (monthly, Jan.-Dec.) distribution of captures, using chi-square test, and 5) correlation between number of problem crocodiles and mean rainfall in each month [rainfall data derived from Weather Station Number 14015, Darwin Airport (Bureau of Meteorology 2014) nearest to the DCMZ where most problem crocodiles were captured]. We did not test the correlation between the number of problem crocodiles and the rainfall in each year because the capture effort was not standardised, but rather has been increasing over time [eg the number of traps used to catch problem crocodiles in the DCMZ increased from 33 in 2009 to 65 in 2012 (T. Nichols, Northern Territory Department of Land Resource Management, unpublished data)].

Crocodile attacks

We compiled historical records of crocodile attacks in the Northern Territory since 1971 by 1) collating the internal reports and databases kept by the Northern Territory government agencies and police, 2) interviewing victims, witnesses, police officers, or rangers involved in the incidents, 3) searching the media such as archived newspapers and websites, and 4) consulting with an independent database (C. Manolis, Wildlife Management International, unpublished data). We excluded attacks 1) involving escapees from crocodile farms, 2) that occurred on people working with crocodiles (eg handling crocodiles or collecting eggs), 3) that did not result in any injury or death of humans, and 4) which were not confirmed as crocodile attacks (eg victims went missing without witnesses or evidence). Details collected for each incident included 1) the date, time, location, and severity of attack, 2) TL of the crocodile, and 3) age, sex, origin (local or visitor), race (indigenous or non-indigenous), and activity of the victim at the time of the incident.

We grouped crocodile attacks into five-year periods between 1971 and 2013, but 1971-1978 was grouped as one because there were no crocodile attacks during that period. We then calculated the mean number of attacks (fatal, non-fatal and combined) in each period and compared the means between periods using ANOVA. Where there was a significant effect, a linear regression was fitted to further examine the trend.

We examined the seasonal distribution of crocodile attacks by dividing the crocodile attack data into months (Jan.-Dec.) and performing a chi-square test. We also tested the similarity of the monthly distribution between crocodile attacks and problem crocodiles, using chi-square test.

To examine trends with regard to the size of crocodile involved in attacks, we grouped the TL data into 50 cm increments and examined their distribution using a chi-square test. We summarised the detail of the victims (age, sex, local or visitor, indigenous or non-indigenous, day or night, activity, and position) to identify patterns and trends.

To explore potentially important areas for future HCC management in the study area, we performed a spatial analysis, in which we identified the human population centers in the Northern Territory and drew a 50 km buffer around each center to calculate the number of the historical crocodile attacks and the total area of the habitat predicted suitable for *C. porosus* within each buffer. We obtained the human population size from ABS (2013) and the spatial data for the breeding habitat from Fukuda *et al*. (2007).

To examine the relationships between the frequency of crocodile attacks and the human and crocodile populations, and the proportion of large individuals in the crocodile population, we fitted Generalized Linear Models (GLM). We used the number of crocodile attacks (fatal and non-fatal combined) as the response variable, and the densities of human and crocodile populations and the proportion of crocodiles >180 cm TL as a single explanatory variable in each model. All the variables were grouped at every five years between 1971 and 2013, except for 1971-1978 that was grouped as one period, as in the other analyses. We used the log link function in the Poisson family for GLM because the response variable was count data and the data showed non-linear relationship (Fig. 3). We compared the model fit by calculating the deviance explained by each model (1-residual deviance/null deviance) and Akaike Information Criteria corrected for small sample size (AICc).

We used ArcGIS (version 10.0, Esri) for the spatial analysis and producing maps, and R (version 2.12.0, CRAN) and Microsoft Excel 2010 for all the statistical analyses.

Results

The density of the human population in the Greater Darwin Region increased constantly between 1971 and 2013 (r^2 = 0.99, P<0.01; Fig. 3A). On the other hand, a logistic regression was the best fit for the crocodile population density (residual standard error= 0.05, df= 5; Fig. 3B) and the proportion of >180 cm long crocodiles (residual standard error= 0.05, df= 5; Fig. 3C).

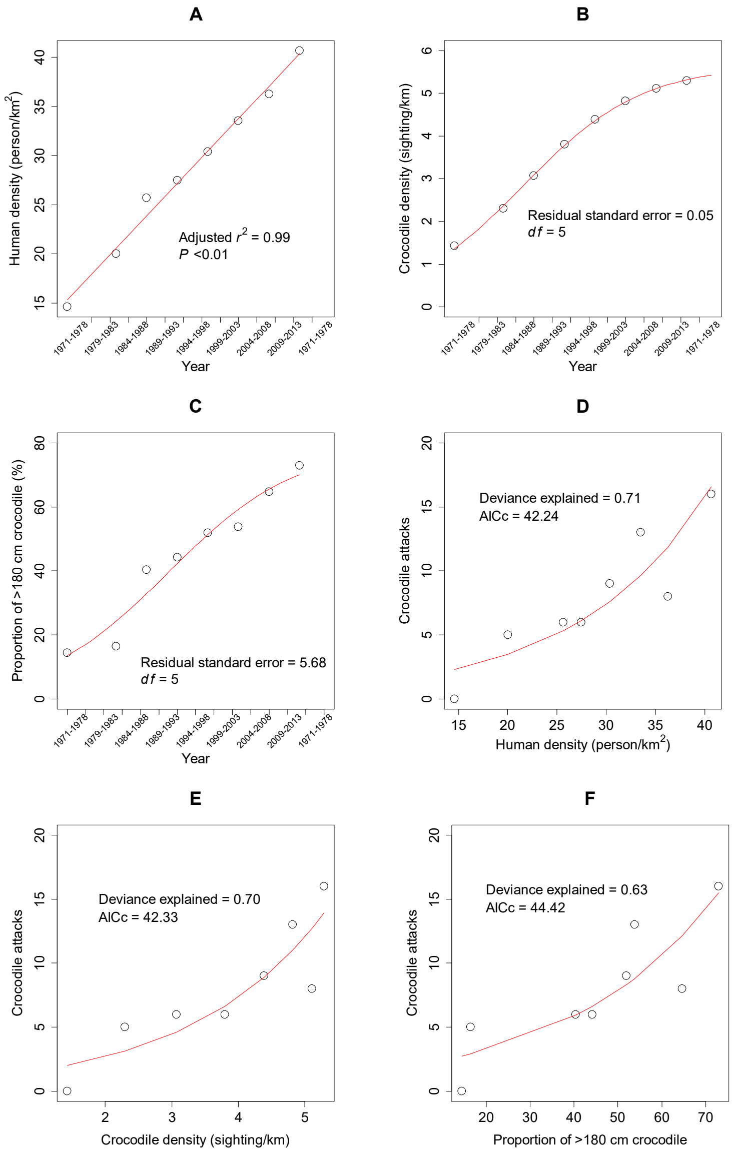

Figure 3. Changes since protection (1971) in A) human population density in the Greater Darwin Region of the Northern Territory, Australia, B) saltwater crocodile density in the 12 monitored rivers, C) proportion of saltwater crocodiles larger than 180 cm in the 12 monitored rivers, and changes in the number of crocodile attacks against D) human population density, E) saltwater crocodile density, F) proportion of saltwater crocodiles larger than 180 cm. Linear regression was fitted in A, logistic regression was fitted in B and C, and generalized linear model (Poisson family with log link) was fitted in D, E, and F.

Between 1977 and 2013, 5792 non-hatchling *C. porosus* were recorded as being caught as problem crocodiles in the Northern Territory, mostly (4910 crocodiles, 83.01%) in the DCMZ. The actual number of crocodiles caught in 1998 remains unknown (thus, excluded from the analysis), but it is estimated that an additional 32 crocodiles may have been caught. For capturing method, trapping accounted for 71.22% of all captures, harpoon for 24.04%, hand catch for 2.21%, and others for

2.52%. Of total problem crocodiles, 69.04% (3,999 crocodiles) were male, while 27.92% (1617 crocodiles) and 3.04% (176 crocodiles) were females and unknown sex, respectively. The total number of problem crocodiles increased from 2 in 1977 to 317 in 2013. The mean TL for each year ranged from 149.0 to 240.19 cm, but it did not change significantly over years [F(1, 5790)= 2.664, P= 0.10] (Fig. 4).

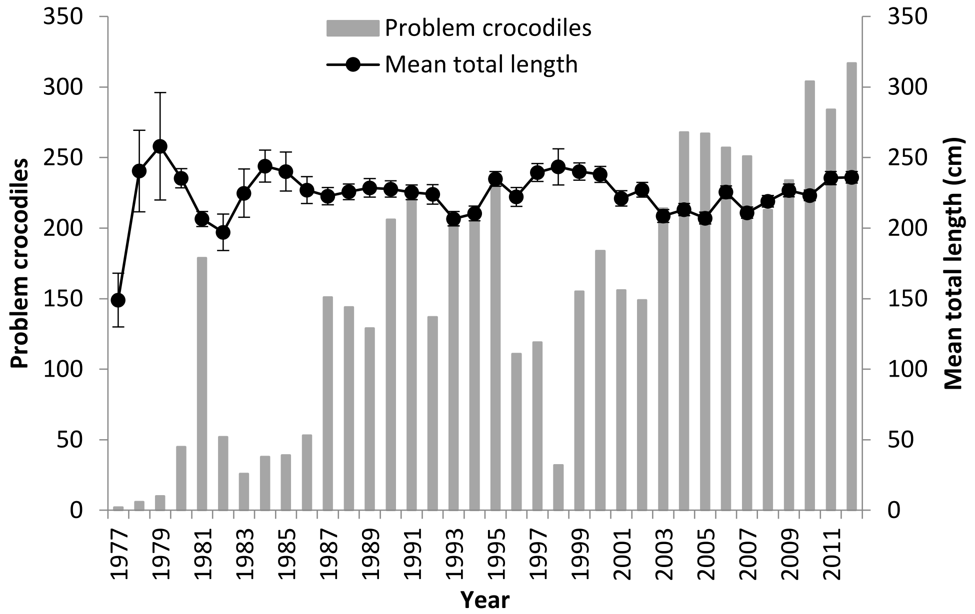

Figure 4. Number of problem saltwater crocodiles caught between 1977 and 2013 (N = 5792), and the mean TL for each year in the Northern Territory, Australia. Bars on mean total length show standard errors.

The TL of males ranged from 70 to 541 cm, and for females from 95 to 370 cm. The proportion in each TL class was not equally distributed between males and females (χ^2 = 443.98, df= 9, P<0.01), although the most common TL class was 150-200 cm for both males and females (Fig. 5). When males and females were combined, the TL classes were not equally distributed (χ^2 = 6,164.53, df= 9, P<0.01).

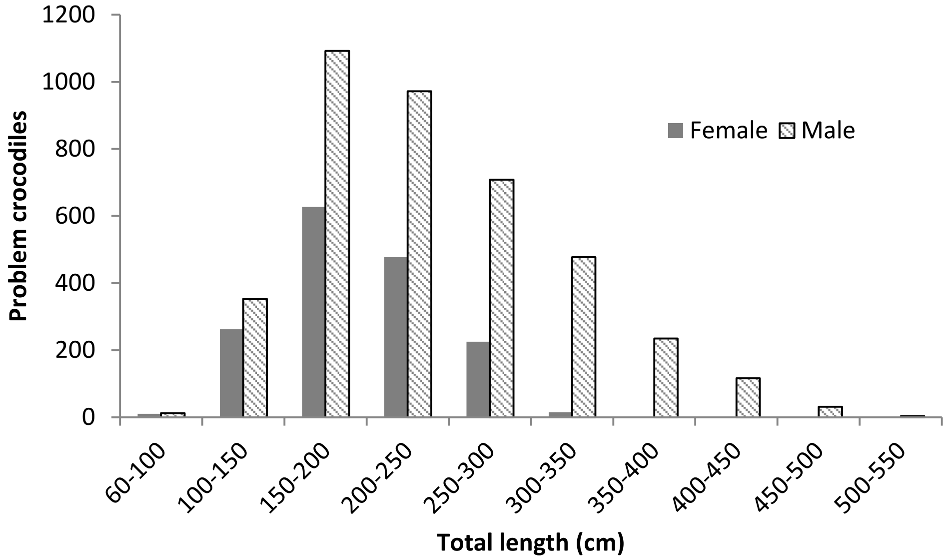

Figure 5. Number of male and female problem saltwater crocodiles in different total length classes caught between 1977 and 2013 in the Northern Territory, Australia (N= 3999 for male and N= 1617 for female).

The number of problem crocodiles also differed between months (χ^2 = 215.60, df= 11, P<0.01), with the highest number in April and the lowest number in January (Fig. 6). There was no significant correlation between the number of problem crocodiles caught in each month and the mean monthly rainfall (r= -0.25, P= 0.36). However, the monthly distribution of problem crocodiles showed significant correlation with the monthly rainfall two months earlier (r= 0.82, P<0.01) (eg problem crocodile numbers in April were related to the mean rainfall in February).

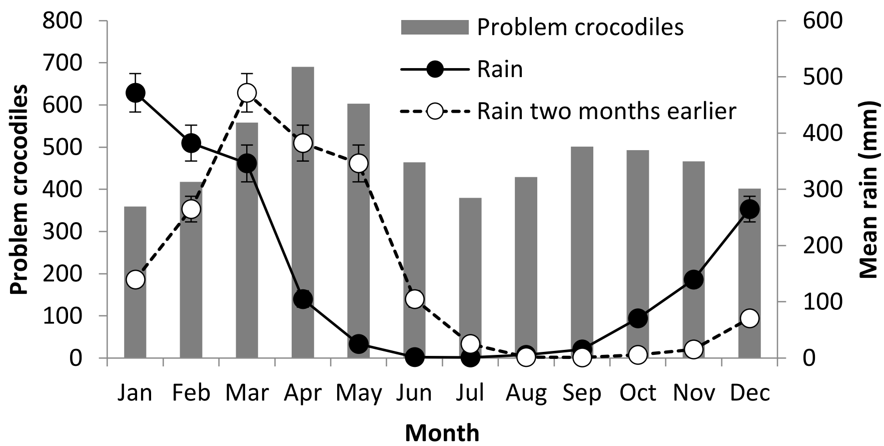

Figure 6. The number of problem saltwater crocodiles caught in each month (N = 5,763), and mean monthly rainfall at Darwin (closed symbols with solid line) between 1977 and 2013 in the Northern Territory, Australia. The open symbols with dashed line are the mean monthly rainfall shifted later by two months. Bars show standard errors.

The first crocodile attack in the Northern Territory after protection of the species occurred in 1979. Between 1971 and 2013, a total of 63 attacks on humans by wild *C. porosus* were recorded, of which 28.57% (18 attacks) were fatal and 71.43% (45 attacks) were non-fatal. The mean number of crocodile attacks (fatal and non-fatal combined) was significantly different between the five-year groups [$F(1, 41)= 32.35$, $P<0.01$] (Fig. 7) and showed a linear increase over year-groups at a rate of 0.36 ($r^2 = 0.76$, $P<0.01$). There was a more profound difference between year-groups for the mean number of non-fatal attacks [$F(1, 41) = 20.53$, $P<0.01$] than fatal attacks [$F(1, 41)= 6.46$, $P= 0.01$], and the mean of non-fatal attacks showed a linear increase over year-groups at a rate of 0.27 ($r^2 = 0.67$, $P<0.01$).

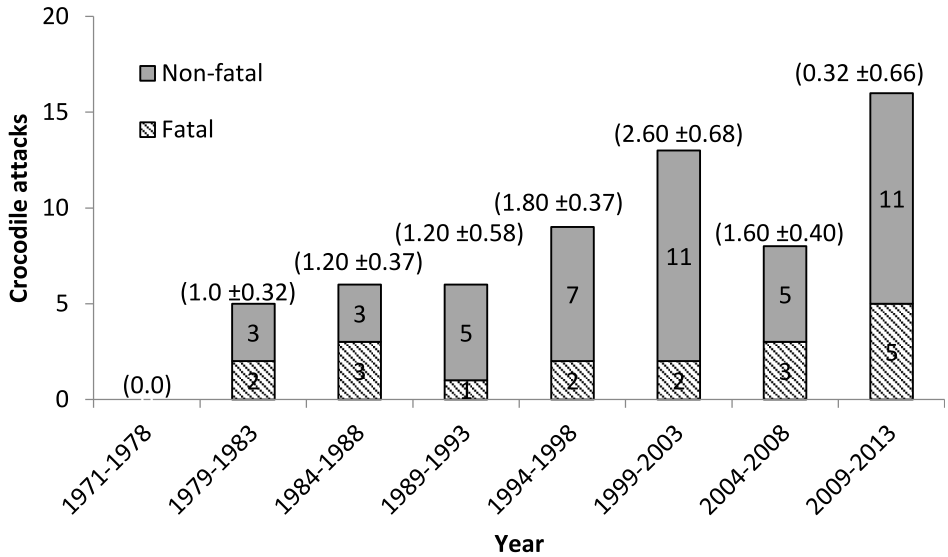

Figure 7. The number of fatal and non-fatal saltwater crocodile attacks in the Northern Territory, Australia divided into five-year periods between 1979 and 2013 (N= 63); 1971-1978 was grouped as one because there were no attacks. In brackets is the mean annual number of total crocodile attacks (± standard error).

Although there was apparent variation between months in the number of crocodile attacks (fatal and non-fatal combined) (Fig. 8), the difference between months was not statistically significant ($\chi^2 = 17.19$, df= 11, P= 0.11). The difference in monthly distribution between crocodile attacks and problem crocodiles captured was not significant ($\chi^2 = 17.22$, df= 11, P= 0.10).

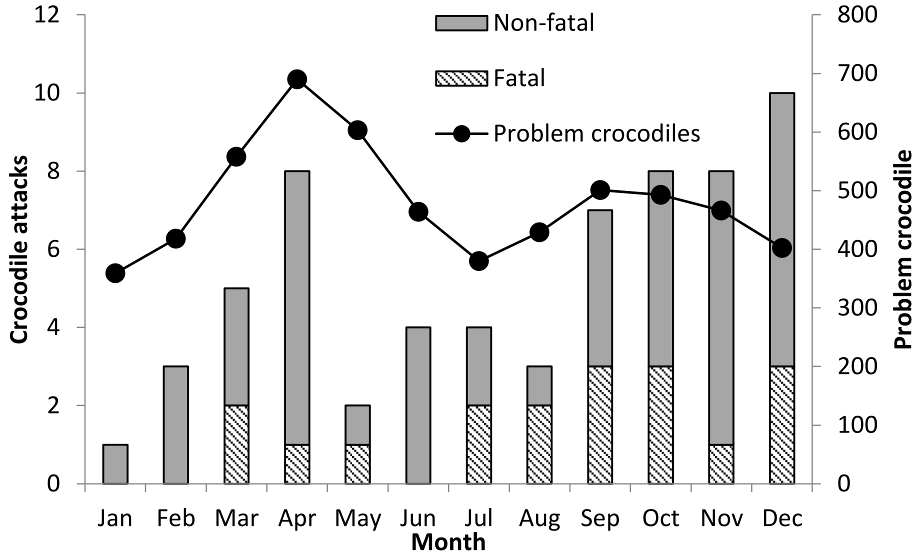

Figure 8. Number of saltwater crocodile attacks between 1979 and 2013 (N= 63) and the number of problem saltwater crocodiles captured between 1977 and 2013 (N= 5763) by month in the Northern Territory, Australia.

The TL of 54 crocodiles, representing 85.71% of all attacks, was known (Fig. 9). The proportion of attacks differed significantly between TL classes (χ^2 = 26.96, df= 9, P<0.01) with the most common TL in the 300-350 cm class (Fig. 9). The most common TL for non-fatal attacks was also 300-350 cm, while for fatal attacks it was 400-450 cm. Attacks by very large (>400 cm) crocodiles were mostly fatal (73.33%). The TL of crocodiles responsible for non-fatal attacks ranged from 80 to 450 cm, but ranged from 320 to 510 cm for fatal attacks. In the case of two non-fatal attacks involving 4.0 m long crocodiles, the victims were able to escape due to assistance from other people, and the result of the attack would have been different otherwise.

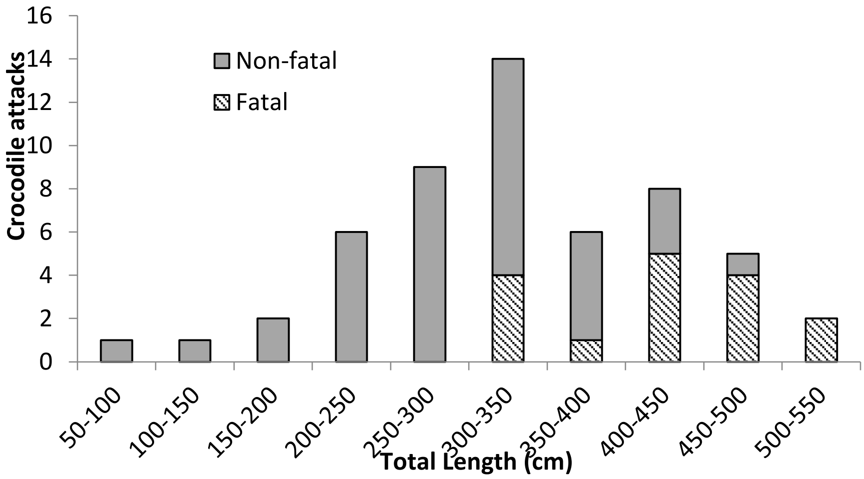

Figure 9. Number of fatal and non-fatal saltwater crocodile attacks in the Northern Territory, Australia between 1979 and 2013 in different total length classes (N= 54).

Most attacks (56 attacks; 88.89%) occurred while victims were in the water or on land at the water's edge; two attacks (3.17%) involved crocodiles leaving the water and walking on land to attack people, in one case even entering a tent in which occupants were sleeping, and five attacks (7.94%) were directed at people sitting in boats. Fatal attacks mainly occurred in deep water (>0.5 m depth; 83.33%), but non-fatal attacks were more common in shallow water (<0.5 m; 42.22%) (Table 2). Both fatal and non-fatal attacks occurred more commonly in daytime (61.11% for fatal and 66.67% for non-fatal). The most common activities at the time of fatal attacks were swimming and wading (77.78%), diving (16.67%), and fishing (5.56%). The most common activities at the time of non-fatal attacks were swimming and wading (37.78%), fishing (20.0%), and hunting (20.0%) (Table 2).

For both fatal and non-fatal attacks, male victims were more common than female, and local people were much more common than visitors (Table 3). The number of indigenous victims was slightly lower than non-indigenous victims in non-fatal attacks, but the proportions were equal in fatal attacks. The age of victims ranged widely (7-55 years for fatal attacks and 5-75 years for non-fatal attacks) with a mean of 26.28 years for fatal attacks and 32.98 years for non-fatal attacks.

Within the study area, 12 major population centers were identified (Table 1). Within the 50 km buffer of these centers, 38 crocodile attacks (60.32% of total attacks) occurred between 1971 and 2013. Darwin, Katherine, and Nhulunbuy had the largest human populations, while Nhulunbuy, Jabiru, and Darwin had the highest number of attacks. The largest amounts of breeding habitat were predicted in Ramingining, Jabiru, and Oenpelli.

The number of crocodile attacks showed an exponential increase as a function of the density of human population, the density of crocodile population, and the proportion of >180 cm crocodiles (Fig. 3). The models showed similar support for these variables (difference in deviance explained <0.08 and ΔAICc <2.18), but the fit did not improve greatly when these variables were combined in one model (deviance explained= 0.79, AICc= 55.01).

Discussion

Despite the current population size of saltwater crocodiles being similar to that estimated before 1945 (Webb *et al*. 2000; Fukuda *et al.* 2011), our results showed a higher frequency of attacks in recent years (3.20 attacks/year for 2009-2013; Fig. 7) than was estimated by Manolis and Webb (2013) for northern Australia between 1855 and 1945 (2.38 attacks/year). The greatly increased human population relative to pre-1945 is considered to be a key factor contributing to this difference. Improved communication may also contribute to a higher number of crocodile attacks reported in recent years.

The increasing frequency of crocodile attacks in the Northern Territory since 1971, as the *C. porosus* population has increased, is also evident in other countries such as Timor Leste, Malaysia, and Solomon Islands where protection and conservation actions have led to depleted *C. porosus* populations recovering (Lading 2013; Sideleau and Britton 2012; C. Manolis, Wildlife Management International, unpublished data). In these cases, as with other successful crocodilian programmes, the focus of management changes from conservation to mitigation of HCC (CSG 2014).

Crocodile attacks occurred across the study area, but there were concentrations of attacks around or near remote communities such as Daly River, Jabiru, and Nhulunbuy (Table 1). Given that these rural communities contain a high proportion of indigenous residents (ABS 2006) and their traditional livelihood requires access to water bodies (eg fishing and hunting), public education may need to focus more attention on this segment of the population. However, the proportions of indigenous and non-indigenous victims did not differ significantly (Table 3), suggesting that both groups conduct the risk-associated activities (Table 2) at similar rates and public education should be applied to both sectors. A strikingly high proportion of attacks involved local residents (Table 3), and in view of the highly transient nature of the human population in the study area (Morgan 2011), public education should be maintained as a continuous process.

Despite the extremely large size of human population in the DCMZ (>56% of the Northern Territory), that only six attacks (one fatal and five non-fatal) have occurred since 1971 is considered to reflect to a large degree the effectiveness of the public safety programs including education and the removal of problem crocodiles. Given that the frequency of crocodile attacks is strongly related to the increasing human population (Fig. 3) there could have been more crocodile attacks taking place without the intensive removal of crocodiles within the DCMZ.

The most common class of problem crocodiles were 150-250 cm males (Fig. 5), and the mean TL of captured crocodiles did not significantly change over years (Fig. 4). Thus, these immature juvenile males have always been the major contributor to the problem crocodile issue within the DCMZ where most problem crocodiles were caught (83%). This is consistent with observations that smaller male *C. porosus* show greater range of movement than larger, more dominant males (Campbell et al. 2013). The crocodiles caught in the DCMZ are migrants from adjacent rivers, because *C. porosus* are highly mobile (Read et al. 2007, Campbell et al. 2010) and there is no major breeding habitat within the zone (Table 1, Fig. 2) to account for their origin. Likewise, in areas outside the DCMZ (e.g., Flora and Katherine Rivers), problem *C. porosus* have migrated from downstream habitats into upstream freshwater areas with no breeding habitat. However, the average TL of problem saltwater crocodiles in the Katherine River is remarkably large (eg >3.1 m; Letnic et al. 2011).

The peaks in problem crocodile capture and crocodile attacks in Mar.-Apr. and Sep.-Dec. (Fig. 8) mark the beginning and end of the wet season (Fig. 6) and coincide with the species' nesting season (Nov.-Apr.). Early rains in Nov.-Dec. fill up rivers and associated freshwater floodplains, triggering increased dispersal of crocodiles (Webb 1991; Campbell *et al.* 2013). Crocodiles move back to permanent water bodies as the floodplains dry out in Mar.-Apr. A number of other factors may also contribute to higher encounter rates with crocodiles in these periods, such as seasonal human activities (eg swimming in hotter months of Oct. and Nov., and recreational fishing when fish flush into the floodplains in Nov. and Dec.). The effort put into catching problem crocodiles also increases in these months (D. Best, Northern Territory Department of Land Resource Management, unpublished data). Lower numbers of problem crocodile captures and crocodile attacks in May-

Aug. may relate to decreased activity of crocodiles during the coolest time of the year (eg reduced appetite and feeding), although this period also coincides with the peak of tourist visitation and associated human activities around water (Tourism NT 2012).

It is unclear why there was no significant change in the number of fatal attacks over years, whereas there was a steady increase in the number of non-fatal attacks (Fig. 7). The increase in the latter is strongly related to key factors for which our models show similar support (Fig. 3), namely the increasing human and crocodile populations and the increasing size of individuals in the crocodile population. The rate of crocodile attacks may continue to increase, as both human and crocodile populations are expected to keep increasing although the rate of increase in both may slow over time (Fukuda e*t al.* 2011; ABS 2013). This is consistent with the number of non-fatal attacks by American alligators (*Alligator mississippiensis*) being higher in Florida, USA, where the populations of humans and alligators are much larger than those of humans and *C. porosus* in Australia (Langley 2005, 2010), and where there is greater encroachment of urban expansion into alligator habitats. However, fatal attack by *A. mississippiensis* is much less common than that by *C. porosus*, due to the less aggressive behaviour and smaller size of the former (Harding and Wolf 2006; Langley 2010; Brien *et al.* 2013).

In *C. porosus*, 73.33% of attacks by very large (>400 cm) individuals resulted in death (Fig. 9). Combining fatal and non-fatal, the 300-350 cm TL class was responsible for more crocodile attacks than any other size classes. According to the size-age relationships derived for wild *C. porosus* in the Northern Territory (Webb and Messel 1978), 300-350 cm crocodiles most likely born after protection in 1971. These post-protection crocodiles may be less wary of humans than the survivors of intensive hunting that hatched before protection (Webb and Messel 1979). For crocodiles less than 300 cm TL, an adult human may represent a prey size that is simply too large to handle.

Fatal attacks commonly occurred in deeper water (Table 2), possibly reflecting the habitat preference of very large crocodiles (>400 cm TL), but also the greater difficulty of escape for victims. In contrast, non-fatal attacks associated with smaller crocodiles occurred more commonly in shallow water or at the water's edge, where crocodilians catch most of their prey (Webb and Manolis 1989). In only a few cases were victims not in direct contact with the water (eg fishing on a boat, sleeping on beach, or camping near the water's edge). Crocodiles also attack people for self-defence or to exclude intruders from their territory (Caldicott *et al*. 2005).

Swimming and wading in crocodile habitats clearly poses a high risk of attack (Table 2), and were also the most common activity of victims of attacks by *A. mississippiensis* (Langley 2005, 2010) in the USA and Nile crocodiles (*C. niloticus*) in Africa (Fergusson 2004; CSG 2014). Consumption of alcohol by victims is noted as a factor contributing to crocodile attacks (Caldicott *et al*. 2005) as it may cause people to undertake activities that they would not otherwise have done. In this study, of 44 adult victims outside of Aboriginal lands where alcohol is largely prohibited, 10 (22.73%) were known to have been drinking alcohol prior to the attack. These numbers are likely to be underestimated as intoxication status was not often reported. Non-fatal attacks happened more commonly in daytime (Table 2), presumably because some activities such as fishing and hunting were more commonly conducted during daylight hours. Also, a higher rate of fatal attacks than non-fatal attacks at night may indicate that crocodiles generally feed more actively at night (Webb and Manolis 1989)

Management implications

We provide the following recommendations to reduce HCC. Given that most problem crocodiles are relatively young males migrating from other river systems, the management of problem crocodiles can be more strategic and efficient by examining their movement patterns and concentrating capture effort in areas where crocodiles enter and exit the management zones. The removal of problem crocodiles and safety awareness education should be maintained year round. Increasing management effort in areas with a high number of crocodile attacks such as Jabiru, Nhulunbuy, and Daly River may be beneficial. Attacks occur throughout the year and caution should be exercised at all times whilst in crocodile habitats. Increasing number of crocodile attacks is strongly related to the increasing human and crocodile populations, and the increasing proportion of >1.8 m crocodiles. This indicates that the management of problem crocodiles 1) should continue to incorporate components on both human (eg public education and safety awareness) and crocodile (eg population monitoring, removal of problem crocodiles) and 2) may be most effective if 300-350 cm TL crocodiles are strategically targeted as the most likely perpetrator. Public education through a range of the media is the most effective means of informing the public about the potential danger of water-related activities in crocodile habitats, particularly swimming and wading that should be avoided where a safety sign is not present. Public education programs need to apply to both indigenous and non-indigenous sectors. However, cultural values of crocodiles as a totem to some indigenous people should be taken into consideration. In the long-term the ability of authorities to conserve and maintain large populations of a predator such as the saltwater crocodile will rely on the ability to create positive incentives (eg through sustainable use and tourism) for conservation.

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Table 2. Activity and position of fatal and non-fatal crocodile attacks in the Northern Territory, Australia, between 1979 and 2013.

	Activity					Position				
Attack	Swimming and wading	Fishing	Hunting	Diving	Other	Deep water	Shallow water	Water's edge	On boat	Other
Fatal (*N* = 18)	14 (77.78%)	1 (5.56%)	0	3 (16.67%)	0	15 (83.33%)	2 (11.11%)	1 (5.56%)	0	0
Non-fatal (*N* = 45)	17 (37.78%)	9 (20.0%)	9 (20.0%)	3 (6.67%)	7 (15.56%)	14 (31.33%)	19 (42.22%)	5 (11.11%)	5 (11.11%)	2 (4.44%)

Table 3. Detail of the victims of fatal and non-fatal crocodile attacks in the Northern Territory, Australia, between 1979 and 2013.

	Age (years)		Sex		Origin		Race	
Attack	Range	Mean	Male	Female	Local	Visitor	Indigenous	Non-indigenous
Fatal (N= 18)	7-55	26.28 ± 3.08	13 (72.22%)	5 (27.78%)	15 (83.33%)	3 (16.67%)	9 (50.0%)	9 (50.0%)
Non-fatal (N= 45)	5-75	32.98 ± 2.59	36 (80.0%)	9 (20.0%)	42 (93.33%)	3 (6.67%)	19 (42.22%)	26 (57.78%)

Comparison of electrical immobilization with manual capture in farmed Nile crocodiles (*Crocodylus niloticus*) by monitoring stress-related physiological parameters

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Abstract

Electrical immobilization is nowadays a frequently used tool on most commercial farms in South Africa to safely handle Nile crocodiles. Although this capture method has been substantially evaluated for the Australian saltwater crocodile (*C. porosus*), its capability and restrictions have not been examined for Nile crocodiles. The aim of the project was therefore to compare electrical immobilization with manual capture in farmed Nile crocodiles (*Crocodylus niloticus*) by monitoring stress-related physiological parameters. Randomly selected study animals (n = 45) were housed in communal pens on a farm in northern Kwazulu-Natal, South Africa. Crocodiles were captured by either e-stunning (n=23) or noosing (n=22) and serum lactate, glucose, corticosterone, alanine aminotransferase, alkaline phosphatase, aspartate aminotransferase and creatinine kinase concentrations determined in serum samples collected immediately after capture as well as four hours post-capture. In addition, individual capture time was recorded for all animals. Comparison of the parameters revealed significantly higher lactate concentrations in noosed animals ($P < 0.001$) if compared to e-stunned crocodiles. Otherwise, there was no significant difference in the parameters monitored between the two capture methods ($P > 0.05$). It took longer to restrain crocodiles with the noosing method compared to immobilizing animals via e-stunning. This could be an explanation for the higher concentrations of blood lactate. In conclusion, e-stunning is recommended as the preferred capture method for Nile crocodiles, from a physiological perspective, as well as an animal welfare and human safety viewpoint.

Introduction

During the past 15 years crocodile farming has become more important, and sophisticated all over the world. In South Africa there are currently an estimated 600 000 Nile crocodiles (*Crocodylus niloticus*) on commercial farms mostly for skin production. These animals are handled intensively on an everyday basis (Blake 2005; personal communication Robert Reader, SACFA 2011). An average South African commercial crocodile farm accommodates between 2 000 and 10 000 crocodiles which are kept in ponds of 200 to 1 000 individuals, graded according to their size (personal communication Robert Reader, SACFA 2011; Huchzermeyer 2003). If the crocodiles are not used for breeding, animals are usually slaughtered for their skins between two to four years of age. The management, especially of crocodiles that are nearly ready for slaughter, is intensive as the skins of these animals have to be in immaculate condition to achieve a good price on the international market (Davis 2001).

Immobilization of crocodiles for management purposes is usually carried out by means of an electric stunner (e-stunner), a technique first introduced in Australia during 2000 (Davis *et al.* 2000). The use of the stunner has led to a logistical improvement in the handling of crocodiles worldwide. With this technique as many as 60 animals may be captured within an hour (Franklin *et al.* 2003). Previously, crocodiles had to be shot in their ponds or otherwise physically restrained, and skins evaluated only after the animals had been culled. With the use of the stunner only animals with excellent skin quality will be culled, while the others are left behind to be slaughtered at a later stage once skin quality has improved (Davis *et al.* 2000). The e-stunner has been approved to handle farmed crocodiles in South Africa (National Standard on Crocodiles in captivity; SANS 631: 2009). However, this method has only been scientifically evaluated in *C. porosus* (Davis *et al.* 2000; Franklin *et al.* 2003). As crocodilian species might react differently to the stunning procedure, it was suggested by SACFA (South African Crocodile Farmers Association), that the e-stunning technique, as used on South African crocodile farms, should be evaluated for Nile crocodiles. This is important to justify the use of the stunner technique from an animal welfare point. This project was conducted in order to scientifically determine the physiological effects of electrical stunning by comparing it to manual capture. Special emphasis was put on physiological stress parameters by measuring serum corticosterone and blood glucose as well as on blood lactate concentrations which are an indicator of physical exertion. Changes in blood enzyme concentrations of alanine aminotransferase ALT), alkaline phosphatase (ALP), aspartate aminotransferase (AST) and creatinine kinase (CK) were also examined as an indication of which organs might be affected by the different capture methods.

Methods

The crocodile farm where the project was carried out was situated in a suitably warm climate near Pongola in KwaZulu-Natal where crocodiles could be farmed in large outside ponds without any extra heating. The enclosure accommodated a total of about 365 crocodiles. Animals were used to human activity around the ponds. Forty-five randomly chosen captive bred Nile crocodiles from this population were utilized for the study. The animals were around four years of age with a total length of 160 to 210 cm.

Individual sampling took place on two days that were two weeks apart to insure independency of the respective data sets. During the first sampling day (D1), 19 January 2012, twelve animals were stunned and thereafter eleven animals were physically captured with a noose. On the second sampling day (D2), 2 February 2012, eleven animals were physically captured and thereafter eleven animals were stunned. This alternate design (flip-over) was chosen in order to account for external presumably stress - inducing factors, like prolonged presence of handlers during the capture operation. After restrain, the first blood sample was collected from each crocodile (T0) as quickly as possible. The crocodiles were then immediately moved to a quiet climate controlled house (± 30ºC), to minimize further exposure to stressors. After four hours another blood sample was collected (T4) from each crocodile. Thereafter crocodiles were tagged with different color tags according to the capture techniques and dates. This was done to prevent capture of the same crocodiles on day two of the project; it also facilitated the post-trial monitoring of the affected animals. After the procedure, crocodiles were released back into the pond.

E-stunning was carried out by an experienced crocodile handler who has carried out electrical immobilization on many thousands of crocodiles. An electric charge of 135 V was delivered to each crocodile for five to 11 seconds to the back of the neck. This caused immobilization with unconsciousness for about five minutes. Straight after stunning the snout and eyes were closed with insulation tape and crocodiles were taken to the examination table for immediate sample collection and further examination.
The stunner consisted of a pair of electrodes at the end of a forked, isolated aluminium wand. The electrodes were connected to a modified 120 Watts, 50 Hz DC-AC inverter, which ran on a 12V battery and allowed a choice of different voltages (D7 Electronics, Pongola) (Figure 1 and 2).

Figure 1: The battery operated crocodile stunner used in this study

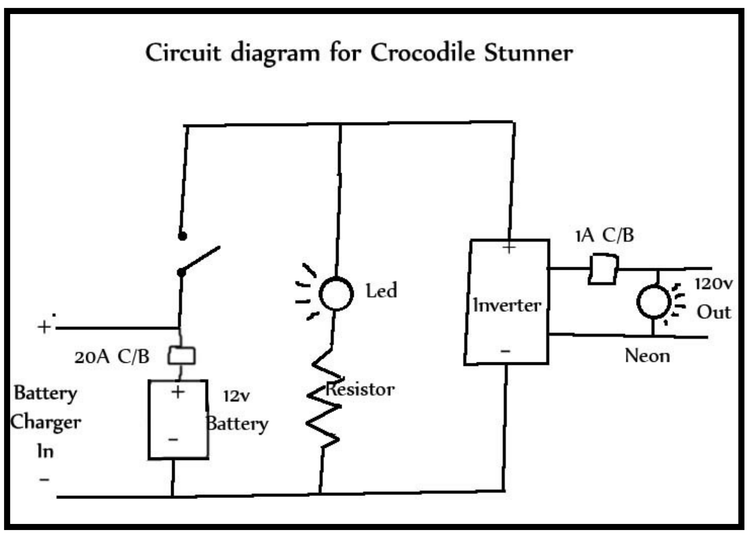

Figure 2: Circuit diagram of the battery operated e-stunner

The manual capture was carried out by gently moving a standard self-locking 3S-72” Thompson steel snare over the head of the crocodile and positioning it over the neck area. The steel snare was pulled tight with the help of a 15 mm heavy duty braided rope attached by a steel coupling. The snare was prepared for the catching procedure by loosely attaching it to the end of a 5 m aluminium pole. Animals were pulled out of the water and subsequently, the animals were restrained, the snout and eyes were closed with insulation tape and they were carried to the examination table for immediate sample collection.

Blood was collected from the post-occipital spinal venous sinus using the technique reported by Myburgh *et al.* (2014). Serum was stored in Cryotubes in liquid nitrogen until further analysis.

Sample analysis

Immediately after collection, a drop of blood was used to determine lactate and glucose concentrations using a hand held Cobas® glucose and lactate meter (Accutrend® Plus, Roche Diagnostics). The measurements base on reflectance photometry and sensitivity for the monitored parameters range from 1.1 to 33.3 mmol/L for glucose and 0.8 mmol/L to 22 mmol/L for lactate, respectively. Serum corticosterone levels were determined by using a Coat-A-Count© Corticosterone Radio-Immunoassay (Diagnostic Products Coat-a-Count Rat-Corticosterone). In brief, 50 µl standards, controls, and samples were transferred in duplicates into coated tubes. 1 ml ^{125}L corticosterone solution was added, and the tubes were incubated for two hours at room temperature. Subsequently, the liquid was removed; the tubes patted dry, and counted for one minute in a gamma counter (Wallac Wizzard, Perkin Elmer) using MULTICALC software. Sensitivity of the assay was 5.7 ng/ml and major cross-reactivities, as given in the manufacturer's pamphlet, were corticosterone, 100%; 11-deoxycorticosterone, 2.86%; progesterone, 0.83%; and cortisol, 0.35%. Blood enzyme concentrations (ALT, ALP, AST and CK) were determined via absorbance photometry using the Cobas Integra 400 plus (Roche Diagnostics 2008).

Data analysis

Data were assessed for normality by assessing histograms, calculating descriptive statistics and using the Anderson-Darling test (MINITAB Statistical Software, Release 13.32, Minitab Inc., State College, Pennsylvania, USA). Data violating the normality assumption were modified using the natural logarithm or square root transformation prior to statistical analysis. The effect of capture method was evaluated using a repeated measures ANOVA with sample time (first capture versus subsequent capture four hours later) as a within subject effect and capture method as a between subjects effect. Sampling day, study duration, capture time, and the interaction between capture method and sample time were included in all statistical models to adjust for potential confounding. Study duration was defined as the time from when the research team first entered the ponds until the time blood was successfully collected from each individual animal. Capture time was defined as the amount of time from when an individual animal was targeted for capture until successful collection of the blood sample. Capture time was further compared using a two-way ANOVA including sampling day and method of restraint as fixed factors. Statistical modelling was performed using IBM SPSS Statistics Version 21 (International Business Machines Corp., Armonk, NY, USA) and results interpreted at $P < 0.05$.

Results

After adjusting for sampling day, study duration and capture time, a comparison of respective corticosterone, glucose, ALT, ALP, AST and CK levels revealed no significant difference ($P > 0.05$) between the two capture methods (Table1). However, lactate concentrations were significantly higher in noosed animals compared to e-stunned animals ($P < 0.001$).

Table 1: Comparison of blood parameters of either captured by stunning or noosing on two different days (D1 and D2).

		e-stunned		**noosed**		
		T0	**T4**	**T0**	**T4**	
Variable	**Day**	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**	**P Value**
Lactate (mmol/L)	1	4 (3.6, 5.4)	5.7 (4.4, 6.4)	10.2 (9, 11.3)	5.7 (5.7, 9.3)	<0.001
	2	3.8 (2.1, 4.8)	3.4 (2.9, 5)	9.8 (8.2, 12.3)	8.2 (5.8, 13.1)	
Corticosterone	1	42 (19, 48)	67 (48, 95)	32 (21, 46)	68 (62, 79)	0.117

(ng/ml)	2	40 (32, 83)	123 (85, 126)	33 (25, 58)	96 (53, 128)	
Glucose	1	2.7 (2, 3.2)	6.1 (5.1, 6.8)	3.8 (3.5, 4)	6.1 (5.7, 6.5)	0.696
(mmol/L)	2	3.8 (3.6, 4)	6.3 (6.1, 6.9)	4.4 (3.7, 4.9)	5.5 (4.9, 5.8)	
ALP	1	48 (29, 77)	48 (37, 67)	41 (38, 50)	77 (61, 87)	0.142
(U/L)	2	36 (32, 45)	35 (30, 45)	55 (45, 66)	49 (35, 111)	
AST	1	35 (28, 38)	44 (37, 48)	34 (32, 39)	51 (46, 63)	0.097
(U/L)	2	26 (18, 31)	37 (31, 40)	33 (26, 35)	43 (39, 62)	
CK	1	460 (286, 3033)	1051 (575, 2125)	479 (436, 985)	1116 (665, 1903)	0.967
(U/L)	2	190 (149, 384)	422 (258, 609)	327 (230, 528)	1012 (834, 1471)	

IQR = interquartile range

Although statistically not significant, there was an overall positive relationship between corticosterone levels and the duration of the trial with regards blood collection at T0 (R = 0.330, P = 0.027) as respective corticosterone values were comparatively higher in animals which experienced a longer disturbance due to the on-going trial (Figure 3).

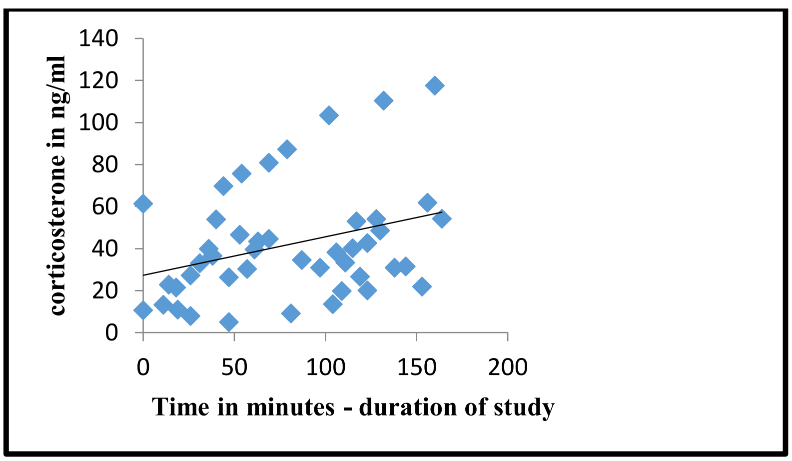

Figure 3: Corticosterone at T0 of nosed and stunned crocodiles on D1 and D2 in relation to trial duration in minutes

Overall median individual capture time, was 101 seconds (s) (range: 67 to 359 s) for stunned animals and 177 s (range: 123 to 380 s) for noosed crocodiles and the difference was statistically significant ($P < 0.001$).

Discussion

In general, T0 blood biochemistry results compared favorably with the normal reference ranges for the Nile crocodile published by other authors (Table 2)

Table 2: Comparing blood chemistry results of our study with results cited in literature (a = C. niloticus; b = C. porosus)

Parameter	Range in this study	Mean in this study	Mean concentrations and ranges reported in literature	References
Serum corticosterone ng/ml	4.80 - 201	63.8	Range: 4.0 - 6.0	Balment & Loveridge 1989[a]
Blood lactate mmol/L	0.80 - 19.10	7.13	Mean: 21.0 in manually captured crocodiles and 10.7 in stunned crocodiles	Franklin *et al.* 2003[b]
Blood glucose mmol/L	1.40 - 8.90	4.86	Means: 3.87 - 5.68 Mean: 3.8; Range: 1.8 - 4.8 Mean: 5.68	Botha 2010[a]; Lovely *et al.* 2007[a]; Swanepoel *et al.* 2000[a]
ALT U/L	7.00 – 90.0	40.0	Means: 13.0 – 30.0 Mean: 43.9, Range:15.0 – 63.0 Mean: 13.1 Range: 9.0 - 20.4	Botha 2010[a] Lovely *et al.* 2007[a] Foggin 1987[a]
ALP U/L	16.0 – 263	57.1	Means: 9.18 – 28.0 , Mean: 21.1 Range: 3.0 – 72.0 Mean: 64.2 Mean of 437 when chronically stressed if healthy	Botha 2010[a] Lovely *et al.* 2007[a] Watson 1990[a]
AST U/L	14.0 -75.0	39.4	Means: 24.0 – 47.0 Mean: 66.5 Range: 14.0 – 211 Mean: 16.6 Range: 6.7 - 22.7	Botha 2010[a] Lovely *et al.* 2007[a] Foggin 1987[a]
CK U/L	93.0 – 7075	1 014	Mean: 211 Mean: 9 187 when chronically stressed	Watson 1990[a]

Median T0 corticosterone values in this study ranged from 32 to 42 ng/ml. This seems much higher than values given for crocodilians in literature (Table 2). However, this discrepancy most possibly has to do with different research models and test methods. Species of crocodilians, laboratory procedures as well as environmental factors could also have a lot of influence on absolute values in each study (Romero 2004). The main interest for this study was in the difference of corticosterone concentrations between the two capture methods.

In accordance with Franklin *et al*. (2003) this investigation revealed significantly higher lactate concentration in manually captured crocodiles compared to e-stunned Nile crocodiles. Median lactate concentrations at T0 of noosed crocodiles were 9.8 and 10.2 mmol/L respectively, while median lactate concentrations of e-stunned crocodiles at T0 were 4.0 and 3.8 mmol/L respectively. The most likely explanation for this difference was that crocodiles struggled less when they were immobilized with the e-stunner. The median individual capture time by noosing was 76 seconds longer compared to e-stunning during which time crocodiles thrashed around vigorously until they could be overpowered and restrained well enough manually to take the first blood sample. Lance *et al.* (2001) reported that the rise of lactate in blood is a reaction to physical restraint. If manual capture takes too long, crocodiles can potentially suffer from lacto-acidosis and muscle damage and will take a long time to recover (Bennet *et al.* 1985).

When working 100 crocodiles, using an e-stunner, the time saving of 76 s per crocodile translates into 126 minutes. Therefore this would not only save crocodiles from exposure to stress due to capture activity inside the pond but the e-stunner would also save 126 minutes of labor. E-stunning also ensures that crocodiles are motionless when handled and therefore the risk is lower for crocodile handlers to be bitten.
Misuse or use of a malfunctioning stunner can lead to heart failure, fracture and trauma of the animals (Grandin 1997). It is therefore imperative that only well-trained handlers operate the stunning device and that it is well maintained and locked away when not in use.

Of concern is, whether e-stunning simply immobilizes crocodiles or if it also causes unconsciousness and thus produces a short term “electrical anaesthesia”. It is accepted that, based on experience in man, a grand mal type epileptiform activity in the brain is indicative of unconsciousness (Gregory 1994). The confirmation and duration of epileptiform activity and unconsciousness is an important factor and would indicate if stunning might be painful per se or if painful procedures could be carried out while crocodiles are under the influence of the electric stunner. Further, while it seems that crocodiles recover from electric head stunning without any identifiable animal welfare issues, the question still remains whether repeated head stunning over a period of several months – as it is carried during the finishing period of crocodiles for slaughter – does not cause brain lesions.

In conclusion, the most significant physiological difference between the two capture methods was the higher blood lactate concentrations of noosed crocodiles. For this reason, we propose that capture by means of e-stunning compares favorably with the traditional manual capture method by noosing and that the additional advantages of e-stunning make it the method of choice for Nile crocodiles on commercial farms. At the same time we propose more international collaboration and research into various issues with regards to the functionality and repeated use of crocodile e-stunners and to standardize these tools and facilitate handler training to insure animal welfare.

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Although, many people have helped with this work and we are thankful for their input and practical assistance, we would like to dedicate this article to Dr. Fritz Huchzermeyer who was a mentor to most of us. We would further like to thank Wildlife Ranching South Africa (WRSA) and the Department of Production Animal Studies, Faculty of Veterinary Science, University of Pretoria for making this presentation possible with their generous financial support.

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Determining Variability in Average Organ Mass/Body Weight of Select Organs in Finishing *C. porosus* and Any Relation to Finishing Age and Perceived Health Status

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Abstract

Relatively few reference materials are available to aid the clinician/layperson in determining normalcy with regard to crocodile visceral characteristics. Even less information is present when one is to further inquire about organ characteristics relative to individual variables. The objective of this endeavor was to identify average organ mass of select organs in overtly healthy finishing *C. porosus* and to further analyze these averages against common variables within finishing crocodile cohorts. The viscera of 114 finishing *Crocodylus porosus* was grossly examined immediately following slaughter. The weight and length of selected organs from each individual were recorded and any apparent external/internal gross lesions were described and photographed. Relation of organ size to animal mass was determined; variability in organ size relative to animal mass was then compared to animal age and animal health status in attempt to identify any apparent relationships/patterns. Across sampled individuals, notable variability exists in specific organ size relative to body mass: Large variability is noted in thyroid mass, steatotheca mass, and gallbladder mass; moderate variability in spleen mass and gonad mass; and relative uniformity in heart mass and kidney mass. In individuals with lesions noted, average spleen mass and thyroid mass was larger. Individuals from older cohorts that presented for slaughter correlated with smaller heart mass. Patterns appear to exist in variability of organ size relative to body weight across organ type, animal age, and concurrent gross lesions. The clinical relevance of such patterns remains unclear; however, potential exists that such patterns may be used to ascertain the health status/normalcy of individual animals and individual organs and perhaps warrants further investigation.

Introduction

Very little published text specific to the disease, pathology and health of crocodiles exists. When faced with disease, even the most basic of reference materials are difficult to obtain for the clinician and producer alike. Regardless of species of interest, in veterinary medicine the clinician must learn to identify that which is abnormal, and it is only after a firm understanding and recognition of normalcy has been established can the clinician begin to astutely and confidently identify that which may indicate a problem. Post-mortem examination of crocodiles found dead/euthanized/slaughtered can provide the clinician and producer with incredibly important information relative to the health of a population. Therefore, necropsy on individuals found dead should always be performed. Likewise, post-mortem examination of slaughtered individuals should be conducted as a form of 'quality control' in attempt to identify and monitor any possible underlying disease conditions within an otherwise healthy-appearing population. Information obtained from the post-mortem examination is often used as the basis for the diagnostic and treatment plan thereafter, and again, because basic reference guidelines relative to organ size, appearance, and allometry are scarce, information taken from the post-mortem examination is sometime difficult to interpret.

This endeavor was started strictly for personal observation and exposure to normal crocodilian gross anatomy. Over time, however, a collection of recorded data developed relating organ size to animal mass from a strong sample size. The objective, then, shifted towards observing which organs varied most considerably in size relative to the mass of the animal and if any relationship between the slaughter age or perceived health status of an animal with regard to organ size was recognizable. What follows is an anecdotal summary of these findings that may offer some use to veterinarians and producers alike.

Methods and Materials

The population sampled was finishing *Crocodylus porosus* on a large farm in the Philippines with a belly width of at least 38 centimeters. From this population the internal viscera of 114 crocodiles that presented for quarterly slaughter was grossly examined in a systematic fashion as described by Huchzermeyer 2003. The internal viscera were tagged with the corresponding individual tail cut number before leaving the processing floor for observation. Using the tail cut number, individual animal weight, length, and hatch year were obtained (Chart 1). During gross examination, any observations that appeared abnormal were recorded and photographed (Graph 1). Following gross examination of each organ, the length of the steatotheca (internal fat body), left ventricular height, ventricular width, and splenic length were recorded using measuring calipers (Chart 2). The weight of the steatotheca, heart (including the auricles), spleen, left and right thyroid glands, gall bladder, right kidney, and the right gonad were obtained using a calibrated electronic gram scale. The weights of each organ were then divided by the body weight of the individual animal. Variance of organ wt/bw was calculated for each organ type; to more accurately compare variance the individual organ wt/bw values were converted to whole numbers of three significant figures (in attempt to 'magnify' the values obtained from each organ group to the same 'level'). The sample group was then subdivided based on finishing age and perceived health status; animals that showed any external or internal abnormalities that could possibly be interpreted as lesions were designated to a 'lesioned group'. Overtly healthy animals, then, were designated to a 'non-lesioned' group.

Results

A large degree of variability was observed in individual organ size relative to body mass in sampled individuals. Category cut-off points in variance measures were assigned loosely for sake of organization: High variability in average organ size per body weight was observed in the steatotheca, gall bladder, and thyroid glands. Moderate variability in average organ size per body weight was observed in the spleen and gonads; low variability in average organ size per body weight was noted within heart and kidney. (fig. 1)

When comparing average organ size/bw of 'lesioned' animals to overtly health animals, it was found that the average weight per body mass of the spleen and thyroid glands was larger within the 'lesioned group'. It is important to note, however, that the designation of the groups is subjective and based upon individual current veterinary skill level. (fig. 2)

Based on tail cut records, individuals from 2009, 2008, 2007 and 'pre-2007' clutches all presented for slaughter, with the 'pre-2007' individuals being referred to as the slower growers. Within the 114 crocodile sample size, 35 individuals were indicated to have been from a 'pre 2007' clutch. Interestingly, These 35 'slow growing' crocodiles, while having a larger average body weight than the other age groups sampled, had a lower average heart weight per body weight than the crocodiles from later clutches. (fig. 3)

Chart 1: Gross Lesion Descriptions

Scute#	Notes
2-1-9	'tail rot';diffuse, progressive necrotic penetrating dermatitis of distal 6” of tail
45-18-12	(refer to lesion photos)
2-17-19	bilateral diffuse enlargement of thyroid glands
5-23-45	bilateral diffuse enlargement of thyroid glands
2-49-49	bilateral enlargement of thyroid glands
3-57-17	bilateral enlargement of thyroid glands
6-36-7	bilateral enlargement of thyroid glands
5-67-39	Bilateral large (approx 6-7cm), firm pulmonary masses present within parenchyma of caudodorsal lungs; cut surface reveals foul-smelling, thick, heterogeneous exudate within alveolar tissue and cranioventral bronchioles; removal of exudate reveal circumferential fibrinous capsule; contralateral lesion similar. Parenchyma juxtaposition to abscess appears grossly normal. Cytology taken. Diffuse greenish discoloration of hepatic parenchyma; left liver lobe notably smaller than right.
3-7-23	bilateral, notable enlargement of thyroid glands
2-25-4	buphthalmous OU (refer to lesion pictures)
45-23-48	buphthalmous OU (refer to lesion pictures)
3-27-9	buphthalmous OU. Severe bilateral enlargement of thyroid glands (refer to lesion pictures)
2-78-0	Diffuse greenish discoloration w/ locally-extensive areas of pallor within hepatic parenchyma
4-45-5	diffuse splenomegaly; multifocal, variably-sized pliable, pale nodules invade splenic parenchyma (refer to lesion pictures)
4-2-4	diffuse, bilateral greenish discoloration of hepatic parenchyma
2-79-27	diffuse, uniform deep red hyperemia of steatotheca; cut surface also reveals diffuse hyperemia. Pericardial sac distended with approx 60-70 mls of clear , viscous fluid
7-68-89	focal firm mass within jejunal mesentary approx 2 cm; contains firm, friable brownish exudate. Bilateral diffuse enlargement of thyroid glands
6-37-24	focal, firm mass within caudodorsal steatotheca, approx 2 cm in length, containing firm, friable brownish material. Bilateral enlargement of thyroid glands
2-46-3	Focal, firm, brownish mass within visceral fat; cut surface reveals slightly heterogeneous, friable but firm brown material; Steatotheca absent (refer to pictures)
3-17-36	Focal, firm, brownish mass within visceral fat; cut surface reveals slightly heterogeneous, friable but firm brown material; Steatotheca absent (refer to pictures)

2-69-3	Locally-extensive area of hemorrhagic,slightly necrotic tissue on left lateral mid-tail region;lesion does not affect underlying muscle
4-1-6	Locally-extensive areas of hyperemia on pleural surface of lungs; multifocal areas of dark discoloration within lung parenchyma. Pericardial sac distended w/ approx 100 ml of green-tinged, slightly viscous fluid; fibrinous strands connect apex of ventricles to pericardial wall. Multifocal soft, pliable pale nodular lesions within splenic parenchyma. Steatotheca diffusely hyperemic (refer to pictures)
7-34-56	Locally-extensive areas of pallor within hepatic parenchyma
5-26-39	Locally-extensive areas of pallor within parenchyma of left hepatic lobe (refer to lesion pictures)
6-67-78	Locally-extensive hemorrhagic lesions on parietal surface of lungs; Right auricle grossly enlarged; epicardial surface of rt auricle diffusely pale and wrinkled in appearance. Additional locally-extensive areas of pallor of epicardial surface of left auricle and ventricles. (refer to lesion photos)
4-1-59	Locally-extensive hyperemia of pleural surface of lungs; multifocal, variably-sized dark discolorations within parenchyma
7-37-48	Multifocal pale, pliable nodular lesions within splenic parenchyma; diffuse splenomegaly (refer to lesion pictures)
7-59-19	Multifocal pale, pliable nodular lesions within splenic parenchyma; diffuse splenomegaly (refer to lesion pictures)
7-67-15	splenomegaly; multifocal soft, pale nodular lesions within parenchyma
x-25-38	tailrot, cystic testicle OD buphthalmous
2-410-67	unilateral enlargement of thyroid gland
4-56-29	yellowish, gel-like substance lateral to tracheal bifurcation

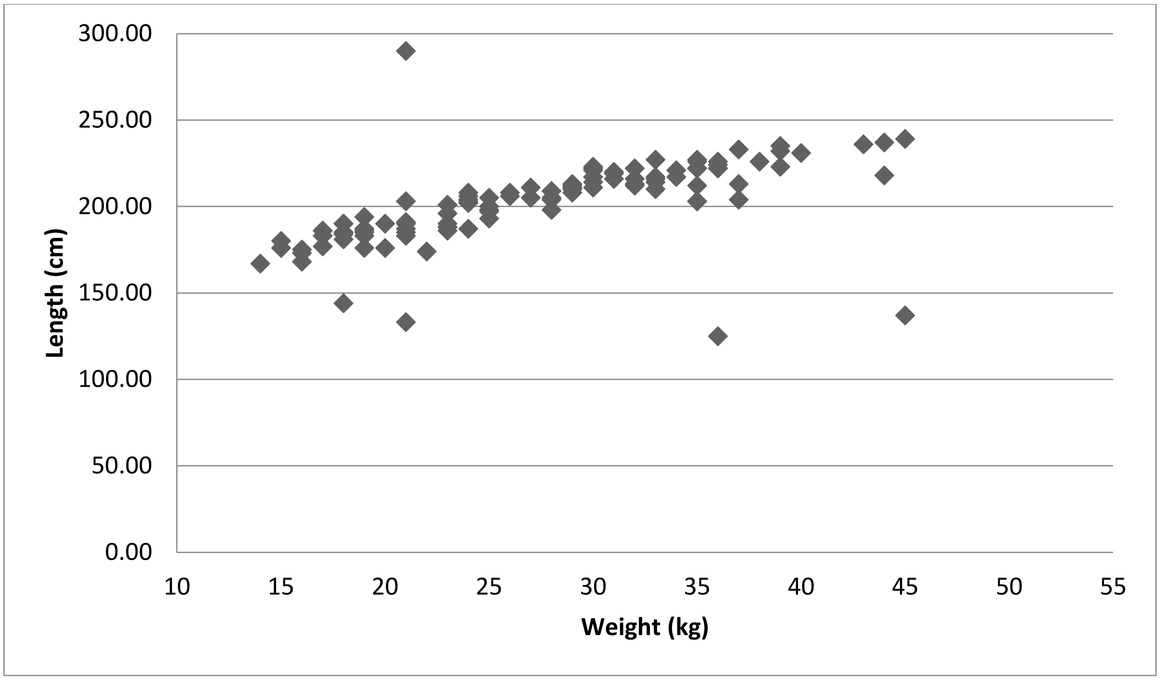

Chart 1: Weight and Length of sample group

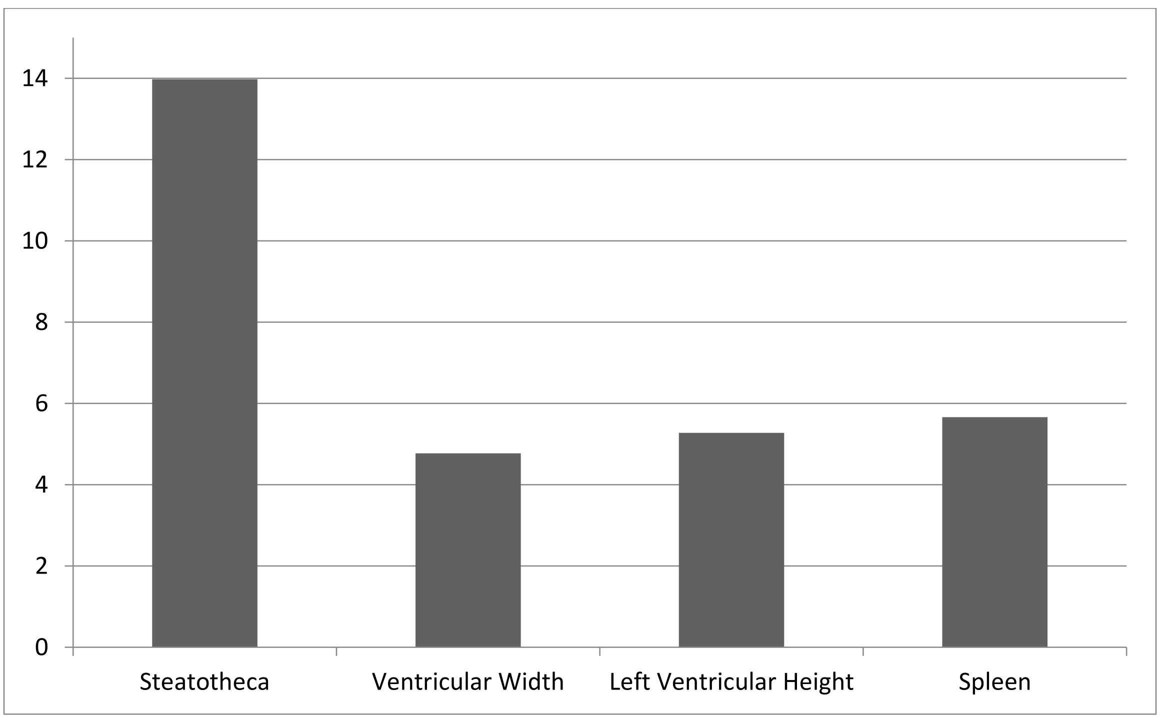

Chart 2: Average length (cm) of select organs

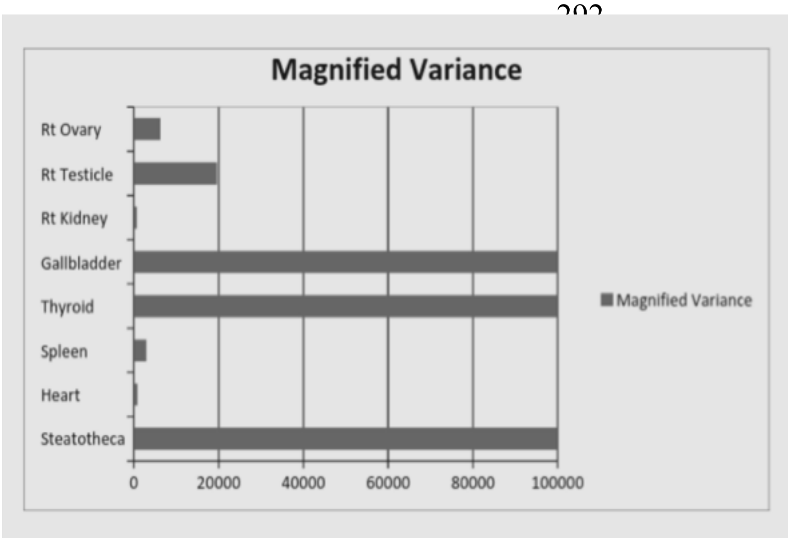

Figure 1: 'Magnified' variance of select organs

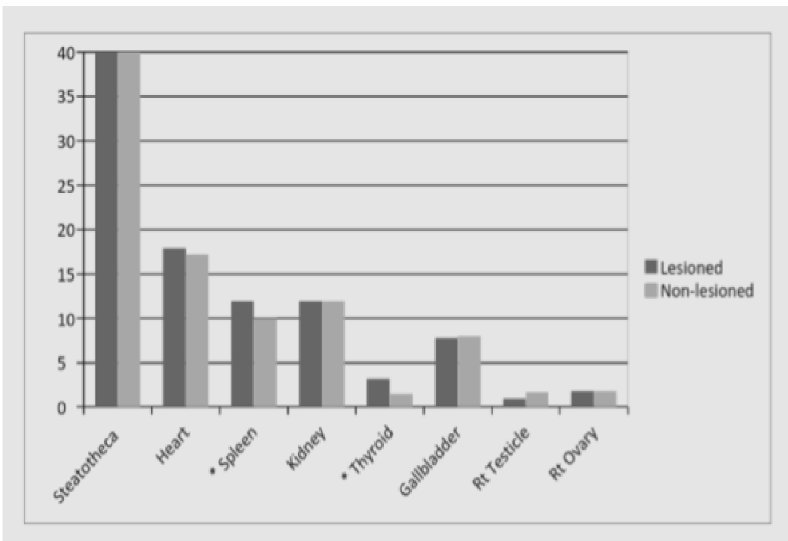

Figure 2: Average organ wt/body wt ($x10^{-4}$) of lesioned and nonlesioned subgroups

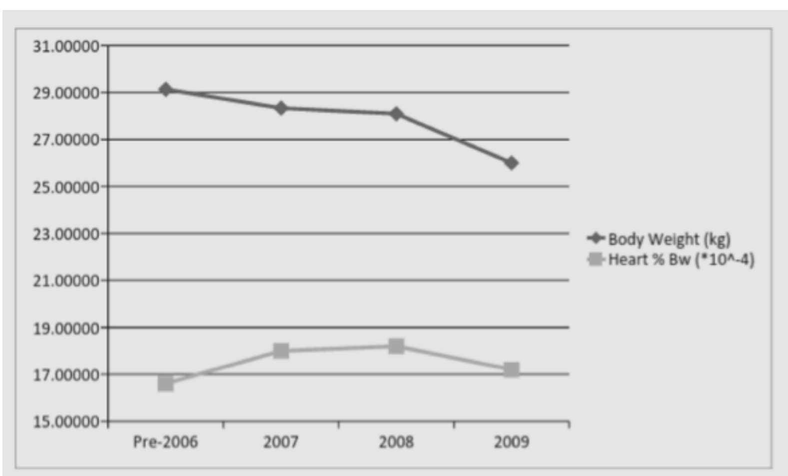

Figure 3: Body weight (kg) and average heart wt/body wt ($x10^{-4}$) of age groups

Discussion

Regarding the rather dramatic differences in average organ size/bw, it is important to take into consideration the function of each organ observed. The steatotheca and gallbladder act as storage organs; therefore, the content (and thus size) is expected to normally fluctuate quite widely based *on changes in the nutritional and digestive status of the animal. Likewise, the spleen, as a center of hematopoiesis and reservoir of erythrocytes and select leukocytes, can also be expected to show a degree of variability based on the hematological parameters and immune status of an animal. The gonads, as endocrine organs, respond to changes in seasonality and age. Additionally, size seems closely correlated to animal length; due to the variability in animal length of sampled crocodiles, a normal degree of size variance is expected. The heart and kidneys, however, based on their important and consistent bodily functions do not usually show normal size fluctuations.*

Statistical significance does not necessarily imply physiological significance (and vice versa). In regard to conclusions, it is important to identify what, if any, practical value the observations described may offer. It is reasonable to assume that the heart and kidneys, unless severely diseased, should normally show very little variation in size. Considering the relative uniformity of these organs they can perhaps be utilized as a sort of 'ruler' with which to evaluate the normalcy of neighboring organs. Even the most subtle of gross changes are important pieces to a case puzzle: these 'puzzle pieces' often act as stepping stones that guide the clinician down a specific diagnostic path and treatment path. Failure to recognize one of these hints can lead the clinician or producer down the entirely wrong path. Therefore, even rather simple visual 'tools' are incredibly helpful to recognizing abnormalities, expediting the post-mortem examination, and ultimately guiding the clinician and producer to arriving at the correct solution.

The ‘lesioned group’ consists of animals subjectively perceived to have recognizable outward or inward abnormalities and does not necessarily indicate that an animal is sick. Nonetheless, enlargement in spleen size may indicate that the animal has or has had recent exposure to something that the body perceived as dangerous and possible of causing disease. With regard to increased average thyroid wt/bw, individuals with noticeably enlarged thyroids were assigned to the ‘lesioned group’; this in itself will account for the increased average thyroid wt/bw observed. Ideally, additional diagnostics (hematology, histopathology) are indicated to identify the immune status of individuals assigned to the ‘lesioned group’ as well as to more accurately identify and describe pathological changes and any possible underlying pathogens.

The results observed within the ‘slow growers’ may offer a possible hint into the pathophysiology of poor-doing animals. Decreased total cardiac weight may be linked to the decreased growth rates observed within these individuals compared to younger cohorts of similar size. The possibility exists, however, that the results observed are entirely coincidental. Still, it is important to explore the following differentials: congenital with some correlation to the genetic makeup of the contributing dam and sire; metabolic abnormality associated with the nutritional state of the dam; acquired anomaly associated within incubation conditions; underlying infectious disease.

Patterns appear to exist in variability of organ size relative to body weight across organ type, animal age, and concurrent gross lesions. The clinical relevance of such patterns remains unclear; however, potential exists that such patterns may be used to ascertain the health status/normalcy of individual animals and individual organs and perhaps warrants further investigation.

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Implementation of a Commercial Artificial Insemination Program in Saltwater Crocodile Farming and Its Implications for Endangered Crocodilian Conservation

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Abstract

Establishment of a commercially viable protocol for artificial insemination in the crocodile begins with a safe and reliable method of semen collection, analysis and storage. Previous studies in the American alligator have been limited because of the difficulty of collecting semen in sufficient volumes, but here we report an extremely successful method of semen recovery from the saltwater crocodiles using cloacal massage of the terminal portion of the ductus deferens. We also summarise our recently published data on the seminal characteristics of the ejaculate, seminal bacteriology and experiments designed to comprehend the physio-chemical tolerance of crocodile sperm to *in vitro* manipulation and cryopreservation. Female reproductive anatomy is briefly described, along with a discussion on the potential challenges that still lay ahead with respect to full commercial implementation of artificial insemination in commercial crocodile farming. We conclude by noting the significant benefits of artificial insemination to farm reproductive and genetic management and for facilitating the breeding of rare and endangered crocodilians.

Introduction

Saltwater crocodile (*Crocodylus porosus*) farming is a rapidly evolving agricultural practice and in order to keep up with industry expansion there will need to be corresponding improvements in productivity. Compared to traditional production animals, crocodile farming is a relatively new endeavour and so builds on a limited information base that has significant potential for improved efficiency. Although much of crocodile production in Australia currently relies on the wild harvesting of eggs, future genetic improvement of desirable phenotypes (Isberg et al., 2003, 2005a, 2005b, 2006a, 2006b) and the ultimate long-term environmental sustainability of the industry are likely to be best managed through “on farm” selective captive breeding and egg production; it is within this context that we propose the development and implementation of assisted breeding technology leading to the establishment of a reliable artificial insemination (AI) program in the crocodile.

Althouse (2007) has defined AI as the process of mechanically and unnaturally depositing semen into the female reproductive tract with the goal of achieving conception. Drivers that have lead to the implementation of AI in a range of animal industries include; (1) acceleration of genetic merit, (2) increased propagation, (3) amplification of genetic progress, (4) disease control, (5) delineated reproductive management, and (6) cost savings associated with labour costs (Althouse, 2007). It can be argued convincingly that all of these advantages are highly relevant and applicable to intensive crocodile farming.

Development of a successful artificial insemination (AI) program in any species requires: (1) a method of semen collection, evaluation and preservation, (2) a detailed understanding of the physiology and sexual behaviour of the female in order to determine the most appropriate timing of insemination and (3) a knowledge of female reproductive anatomy, in order to deposit the inseminate to allow for successful fertilisation of the oocyte. While we shall present data that has made a significant advance on the 1st of these components (Johnston et al. 2014a; b), there is still significant progress that will need to be made in the area of crocodile reproductive physiology before AI becomes a commercial reality.

Of the 23 species of crocodilian currently recognised by the IUCN-SSC Crocodile Specialist Group (CSG) and CITES, 6 are listed as critically endangered, 1 as endangered and 3 as vulnerable (RedList, IUCN). Consequently, there is an urgent need to address the conservation of these species. While habitat protection and species conservation *in situ* should always be paramount, there are clearly situations in which captive breeding may yet be the best and, in some worst-case scenarios, the only viable choice for species propagation and survival. Thorbjarnarson (1992) from the IUCN-SSC Crocodile Specialist Group has endorsed captive breeding as a means of propagating endangered species for wild release programs and maintaining genetic health within the population and for establishing sustainable use programs to provide incentives for conservation of wild populations and habitats. Once sufficiently developed, assisted breeding programs using techniques such as AI and temperature manipulated sex determination are likely to play major roles in the captive breeding and genetic management of endangered crocodiles.

2. SEMEN COLLECTION, EVALUATION AND PRESERVATION

Semen collection from the saltwater crocodile

Successful semen collection was described in the American alligator (*Alligator mississippiensis*) (Cardeilhac *et al*., 1982; Larsen and Cardeilhac, 1996) and Broad-nosed caiman (*Caiman latirostris*); (Larsen *et al*., 1992) by means of aspiration and stripping of semen from the penile sulcus but these techniques recovered relatively low volumes of semen and potentially caused trauma to the penis and blood cell contamination of the ejaculate (Larsen *et al*., 1992). Although Larsen and colleagues pioneered the use of AI in the American alligator resulting in 11 fertile eggs (Gainesville Sun Newspaper, Page 4B, July 24, 1981), the semen for these successful conceptions was recovered from the ductus deferens post-mortem. Larsen *et al*. (1984) also used semen dissected directly from the reproductive tract to examine semen extenders and test sperm preservation procedures in the American alligator.

The development of a reliable non-invasive method of crocodile semen collection is a fundamental requirement for assessing male fertility, and for implementing the benefits of artificial insemination for reproductive and genetic management of farmed populations and the captive breeding of endangered species. Following an initial description of male reproductive anatomy in the saltwater crocodile (*C.porosus*), we developed a highly successful, reliable method of semen collection using cloacal massage of the terminal segment of the ductus deferens (Johnston et al., 2014a). Semen was recovered (Figure 1) from 30 of 31 collection attempts from sedated males ranging in body length from 197cm to 400cm. A further 10 collections, from 10 attempts, were successfully obtained upon a follow-up visit several months later. While the actual semen recovery (cloacal massage) component of the protocol was completed within minutes, the major rate-limiting step of the procedure was the capture and adequate sedation of the crocodile prior to semen collection.

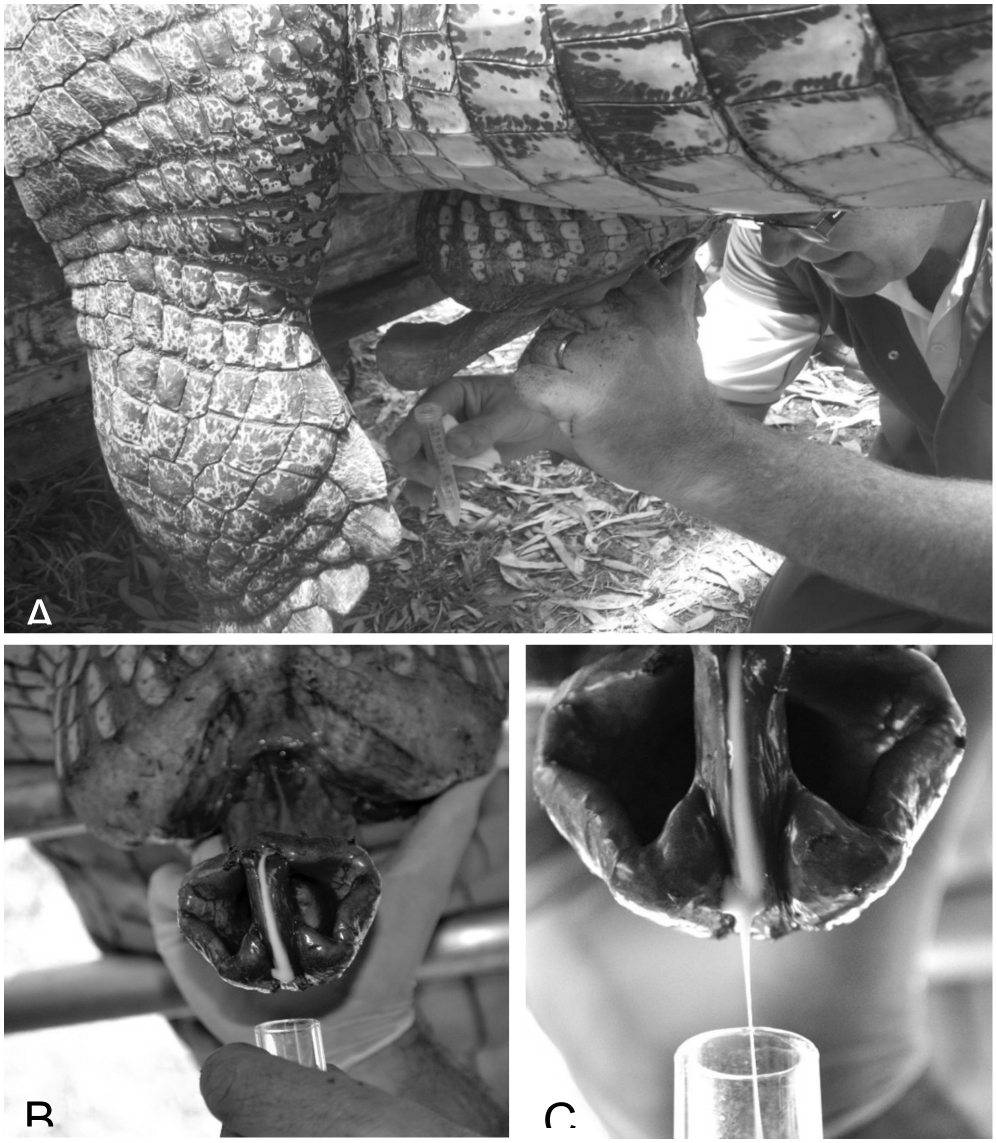

Figure 1: A. Semen collection in the saltwater crocodile by cloacal massage; B. Semen is massaged from the terminal portion of the ductus deferens down through the penile sulcus; C. The thick highly viscous ejaculate has an extremely high sperm concentration.

Characteristics of saltwater crocodile semen

The characteristics of saltwater crocodile semen collected by cloacal massage and the bacteriology (culture and sensitivity) of the semen samples have recently been documented for the first time by Johnston et al. (2014a). Mean (± SEM) seminal volume, pH, osmolality, sperm concentration, percentage of motile sperm and the percentage of sperm with an intact membrane from 30 ejaculates of 23 males measured 0.91 ± 0.16 mL, 7.3 ± 0.1, 335.5 ± 9.0 mOsm kg^{-1}, 2.29 ± 0.26 x 10^9, 50.7 ± 4.2% and 79.9 ± 3.6%, respectively. Sperm abnormalities included macro and microcephalic nuclei, teratoid spermatozoa, loose heads and a range of abnormal flagella (Figure 2).

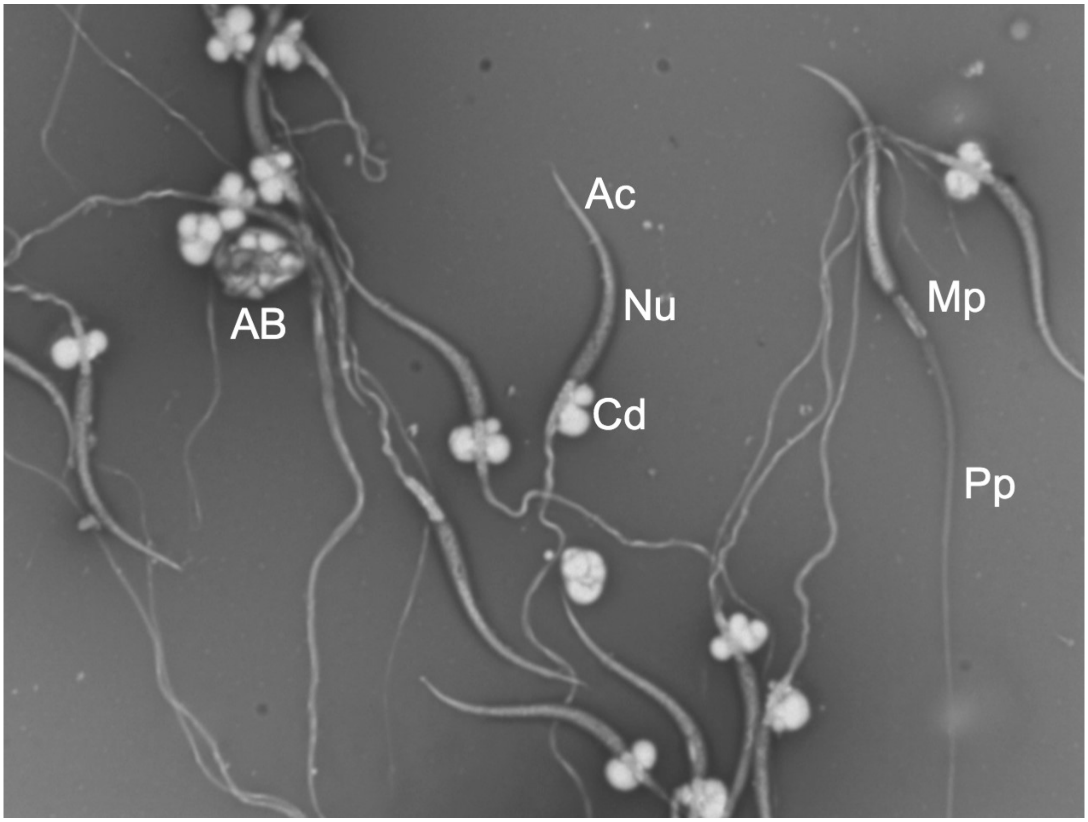

Figure 2: Saltwater crocodile spermatozoa. AB – abnormal spermatozoa; Ac – Acrosome; Cd – cytoplasmic droplet; Mp – Midpiece; Nu – Nucleus; Pp – Principal piece

This limited dataset now forms the basis of our understanding of what constitutes the normal semen sample in this species. As the seminal characteristics of this and other species are added to the database, we shall ultimately be able to develop a better understanding of how these characteristics change with parameters such as puberty, senescence, disease and a range of environmental variables (breeding season – temperature and photoperiod, water quality and nutrition); this information will have a profound effect on all aspects of male reproductive management.

Assessment of breeding soundness in the saltwater crocodile

Determining male breeding soundness in any species relies on the assessment of a range of reproductive and general health parameters including: structural reproductive anatomical confirmation, competency of the hypothalamic-pituitary-gonadal axis, an ability to engage in normal reproductive behaviour and the delivery of a sufficient number of motile normal spermatozoa for successful fertilisation and embryonic development. While there is clearly much more that needs to be learnt regarding the developmental and seasonal components of male reproduction in the crocodile, we now at least have a means of assessing the effect of these variables on semen quality. The techniques for assessing breeding soundness in the saltwater crocodile can, and should, now be attempted on other common species including the Australian freshwater crocodile and American alligator, and ultimately for the assessment of semen quality in those rare and endangered crocodilians in zoos and wildlife parks that have proven difficult to breed.

Bacteriology of saltwater crocodile semen

In an attempt to develop targeted antibiotics for use in semen diluents, microflora of the penile shaft, sulcus and semen of a subset of crocodiles was analysed for culture and sensitivity for the first time (Johnston et al. 2014a). While a diverse range of bacteria was identified, the majority were sensitive to gentamicin. While it is difficult to separate out those micro-organisms that are essentially pathogens or commensals from those which are environmental contaminates in the water, it is nevertheless the case that bacteria which might grow in the extended semen sample will need to be treated with antibiotics to allow short-term preservation and prevent pathogen transfer during AI. It will also be important to test crocodile sperm fertility following the addition of antibiotic therapy as some antimicrobial compounds are spermicidal.

***In vitro* manipulation of crocodile spermatozoa**

Semen samples from 10 saltwater crocodiles (*C.porosus*) were used to investigate sperm *in vitro* manipulation and extension (Johnston et al., 2014b). These preliminary studies have revealed that phosphate buffered saline (PBS) without Ca^{2+}, Mg^{2+} and egg yolk (EY) was a suitable extender for studies of sperm physiology. Spermatozoa diluted in PBS showed no change in survival (% motility [M], rate of sperm movement [R] and % plasma membrane integrity [PI]) when extended over a range of 1:1 to 1:16. Except for a small decline in PI, there was also no change in sperm survival when semen diluted without EY was cooled rapidly to and rewarmed from 0°C. The addition of EY (5, 10 and 20% v/v) had no beneficial effect on sperm survival when incubated in PBS for 1 h at 30°C or after 24 h storage at 4°C. Whilst crocodile spermatozoa exposed to a range of anisotonic media and then returned to solutions of 390 mOsmkg^{-1} retained their M from 220 to 390 mOsmkg^{-1}, PI remained high in hypotonic media (25-280 mOsm kg^{-1}); spermatozoa also showed an increase in the incidence of flagellar coiling (FC) with increasing hypotonic conditions (Figure 3).

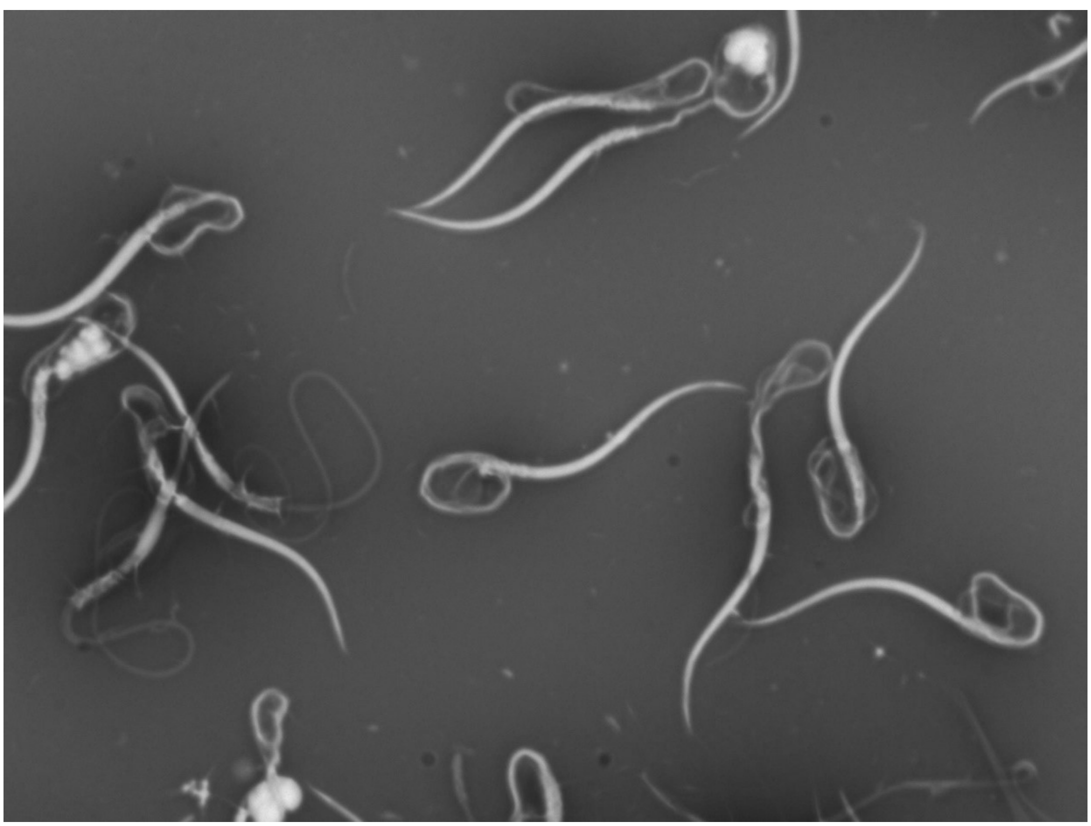

Figure 3: Saltwater crocodile spermatozoa exposed to 25 $mOsmkg^{-1}$ media – Note intact plasma membrane (live) and highly coiled flagellum of most spermatozoa.

Crocodile sperm cryopreservation

We have exposed crocodile spermatozoa to respective concentrations of 0.68 M, 1.35 M and 2.7 M glycerol, dimethylsulphoxide (DMSO), and dimethylacetamide (DMA); 2 h storage in these media at 4°C (equilibration) resulted in a reduction in M, but no change in PI (Johnston et al. 2014b). Sperm cryopreserved in the same cryoprotectant media within 0.25 mL straws at -6°C/min in a programmable freezer and thawed at 37°C for 1 min showed a major decline of M but there was still moderate protection of PI (DMA 2.7 M – 17.7 ± 4.4; DMSO 2.7 M – 22.7 ± 1.4 and glycerol 2.7 M – 25.7 ± 6.4). Spermatozoa thawed and immediately washed to remove the cryoprotectant showed an improvement in PI but not M. Future studies of crocodile sperm preservation will need to explore the apparent disjunction between low post-thaw levels of M and the high tolerance of the plasma membrane to anisotonic conditions and cryoprotectant toxicity.

3. FEMALE REPRODUCTIVE PHYSIOLOGY

Currently the single most limiting factor in the development of a successful AI program in the saltwater crocodile is a detailed understanding of the female reproductive cycle, especially as it relates to the breeding season and timing of insemination. To date, we have made no attempt to explore the reproductive physiology of the female crocodile; however, future areas of research should include (1) development of ultrasound procedures for assessing ovarian follicular activity and detecting eggs within the oviduct, (2) determining the most appropriate timing of insemination by designing experiments to examine seasonal changes in female reproductive function, such as relative changes in steroid reproductive hormones, ovarian follicular dynamics and reproductive behavior, (3) exploring the use of GnRH and eCG to induce oestrus and ovulation, and (4) studies to explore the phenomenon of sperm storage in the female reproductive tract.

4. FEMALE REPRODUCTIVE ANATOMY

Figure 4 shows the gross anatomy of the female saltwater crocodile cloacal region. A large clitoris (homologue of the penis) originates from the ventral floor of the urodeum but extends caudally into the proctodeum.

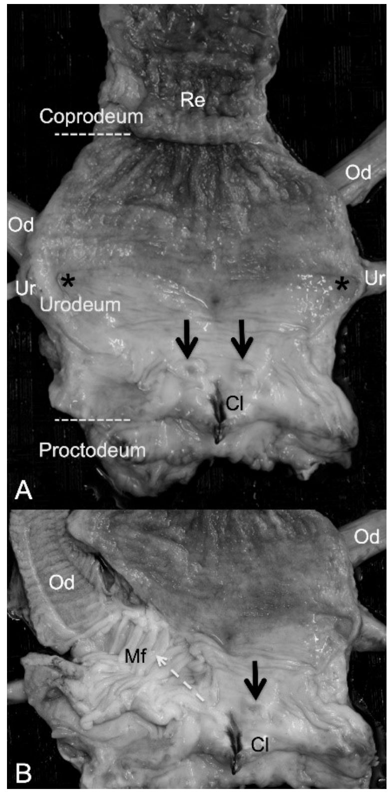

Figure 4: Female saltwater crocodile cloacal anatomy; A. Approximate relative position of the coprodeum, urodeum and proctodeum; B. Muscular folds of the distal oviduct immediately adjacent the ostia. Cl – clitoris, Mf – muscular folds, Od – oviduct, Ur – ureter, * - opening of ureter, black arrow – opening of oviductalostia, and dashed yellow arrow – pathway of artificial insemination.

Immediately cranial to the clitoris but still on the ventral floor of the urodeum are two muscular ostia (openings) of the oviducts, the caudal extremity of which contains numerous muscular folds. Gist *et al*. (2008) regard this as a vagina in the American alligator but in the saltwater crocodile it may be more similar to the muscular cervix in mammals and potentially serve as region for sperm storage. The ureters of the kidneys open cranial to the oviducts but are located on the dorsal wall of the urodeum. A clear plastic human speculum was used to bypass the proctodeum, reflex the clitoris and access the urodeum to facilitate deposition of semen adjacent but not into the oviduct (Figure 5A and B).

Females inseminated without the use of Pavulon® showed little evidence of retrograde seminal loss, as muscular tone of the cloaca remained tight. To further aid in the prevention of retrograde seminal loss the tail was also briefly tilted so that semen would pool adjacent and into the openings of the oviduct (Figure 5C).Two reproductive tracts from sexually mature females were dissected for anatomical description in an attempt to improve the AI methodology; however, even in the dissected reproductive tract, we were unable to physically pass a tomcat catheter through the muscular folds of the vagina. This suggests that manipulation of an AI catheter through the vagina of the live animal is going to be very challenging. This may not be a major issue if the muscular folds of the vaginal region are important for sperm storage and semen deposition naturally occurs in this area, as appears to be the case for the American alligator (Gist *et al.,* 2008).Interestingly, Limpus (1984) has described the use of laparoscopy to examine eggs within the oviduct of the freshwater crocodile (*Crocodylus johnstoni*) and so that this same technique could be used to inseminate semen directly into the lumen of the oviduct.

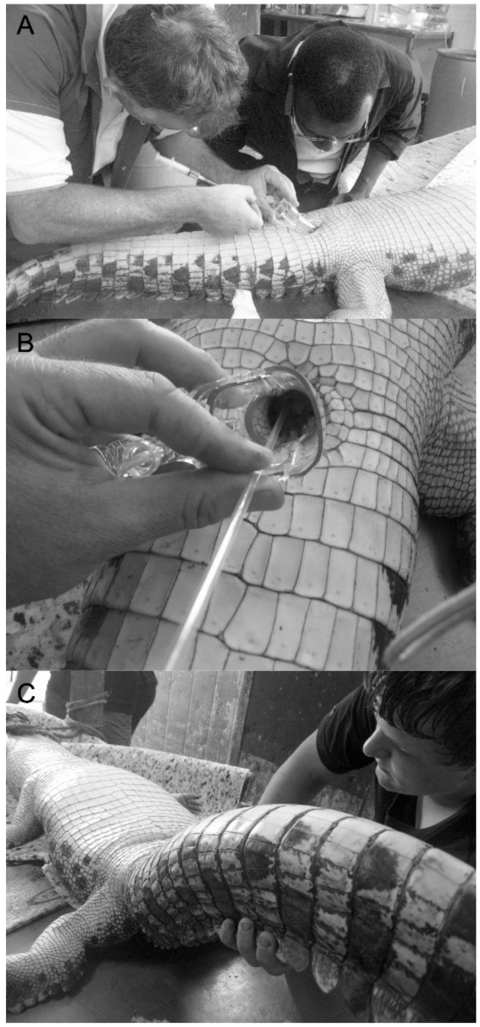

Figure 5: A and B - Artificial insemination of the saltwater crocodile using a clear plastic speculum – semen is deposited adjacent to the external ostia of the oviduct; C – The tail of the inseminated crocodile is tilted upwards to maintain pool of semen adjacent the oviductal ostia

5. PRELIMINARYARTIFICAL INSEMINATION ATTEMPTS

The greatest limitation to the successful production of offspring by AI in our studies on the saltwater crocodile has been the fact that all inseminations have been conducted without reference to timing of ovarian activity of the individual female crocodiles. While a total of 23 crocodiles were inseminated, only nine animals laid eggs, a further two produced fertile eggs and one live crocodile successfully hatched. Clearly the factors that control the timing of ovarian follicular activity and ovulation in the saltwater crocodile will need to be resolved before AI is going to be routinely successful. In our preliminary study while we naively judged the timing of insemination based on observations of natural mating of other breeding pairs at Koorana Crocodile Farm, future studies will need to map the profiles of reproductive hormones or follow ovarian activity by means of ultrasound or laparoscopy. Larsen *et al*. (1982) have also used combinations of GnRH and pregnant mare serum gonadotropin (PMSG) to stimulate follicular activity and ovulation so that perhaps this approach could be used for improving the timing of insemination. However, the precise timing of AI may still not be a major issue in the crocodile, if it is determined that sperm can be stored in the female reproductive tract for weeks at time.

Another factor that may have contributed to the failure of ovulation and fertilisation in our study is that capture and AI is likely to be a stressful event. Franklin et al. (2003) have previously shown that manual restraint of the saltwater crocodile (noosing with ropes) causes a significant increase in haematocrit, haemoglobin, glucose, lactate and corticosterone concentrations in comparison to immobilisation by electro-stunning. It is likely that the manual restraint used in our study had a significant negative effect on the hypothalamic-pituitary-gonadal axis, which may have interfered with reproductive function of the females and led to a low incidence of ovulation and poor fertility.

6. CROCODILE FARMING AND ASSISTED BREEDING TECHNOLOGY

The saltwater crocodile is the largest crocodile in the world and the only farmed species in Australia; its commercial products of high-grade quality leather and meat generate in the order of $5 million per year (Goulding et al., 2007). There are currently 13 crocodile farms in Australia, 6 in the Northern Territory, 6 in Queensland and 1 in Western Australia. These farms range in size from small (<2000 crocs) to large (30000+ crocs) and supply a market of approximately 30000 to 40000 skins per year. While many crocodile farmers anecdotally report little need for AI in their current commercial operations, the successful implementation of a reliable artificial breeding program has the potential to transform the crocodile industry through the selective breeding and rapid genetic transfer of skin quality, meat quality and disease resistance. Now that semen can be successfully collected from mature males, AI can potentially eliminate the need to keep expensive single housed males on farm, reduce the risk of mating trauma to female crocodiles and thereby also improve occupational health and safety of the farm. Artificial insemination will also greatly improve efficiency in the breeding programs as sperm quality could be rapidly assessed to determine the breeding soundness of the males. It would also facilitate genetic exchange between farms as well as allow the introduction of wild genetics to improve genetic vigour without bringing new males into captivity. Although no young have yet to be produced using frozen-thawed crocodile semen, the ability to cryobank high quality sires not only facilitates transport of these genetics in space but also in time, for decades and perhaps even for centuries.

We have also recently shown that it was possible to collect semen from males that were previously thought to be sexually immature (Johnston et al., 2014a). Whilst a 1.9m male would rarely, if ever, get the opportunity to mate with a mature female, the spermatozoa of this male’s ejaculate could still be collected and artificially inseminated, greatly reducing the generation interval and facilitating rapid genetic gain. Males currently intended for slaughter could be processed, their semen recovered and used for AI. Perhaps it may even be possible to eliminate males from the breeding program altogether, thereby cutting down on food and enclosure expenditure. A reduced reliance on males would also lead to reduced production costs and facilitate the transfer and delivery of selected genetics for improvement in production traits.

CROCODILE CONSERVATION AND ASSISTED BREEDING TECHNOLOGY

The successful development of an artificial insemination program in the saltwater crocodile could prove to be a useful reproductive model for the *ex situ* conservation of endangered and threatened crocodiles. Although species-specific differences in reproductive strategy (e.g. seasonality of breeding) may need to be investigated, the fundamentals of reproductive anatomy and physiology should be conserved across species such that the technology developed in the saltwater crocodile could be transferred. Artificial insemination combined with the use of frozen semen would greatly facilitate the genetic and reproductive management of captive crocodiles, potentially be used to overcome physical or behavioural mating incompatibilities, and reduce the need to transport whole animals between zoological institutions. Cryopreservation of spermatozoa would also allow the storage of multiple genetically valuable sires through time, effectively increasing their respective generation intervals.

As an example of how assisted breeding technology might be used to solve a conservation problem, we might consider the Cuban crocodile (*Crocodylus rhombifer*). It has been reported by Targarona *et al.* (2010) that wild American crocodiles (*Crocodylus acutus*) are beginning to interbreed with wild *C. rhombifer*. As *C. rhombifer* is currently listed as critically endangered, this activity could pose a significant threat to the integrity of this species. It is possible that semen samples could be collected from wild or captive *C. rhombifer* and artificially inseminated into their captive females thus effectively eliminating the chance of cross breeding with *C.acutus*. The resulting fertilised eggs could be managed to produce a balanced sex ratio of juveniles, which could then be released back into the wild.

8. CONCLUSION

The use of AI in the crocodile industry has been taunted for over 30 years but the rate-limiting step has always been the reliable and safe collection of semen. This paper has shown that it is now possible to collect semen from the saltwater crocodile in quantities presumably sufficient for AI, which represents an important first step towards the implementation of assisted breeding technology in the crocodile industry. Reliable semen collection will also allow for the establishment of a database for the assessment of breeding soundness in male crocodiles that can be used in a similar way as that conducted in domestic animals, in order to identify male infertility or the selection of males with higher levels of reproductive potential. We have also provided brief highlights of crocodile semen preservation technologies which, when used in combination with AI, will ultimately be powerful tools for future genetic and reproductive management in captive crocodile populations. Although the work presented here has primarily focused on the application of assisted breeding technology for improvements in commercial production (skin and meat), the techniques also have major implications for the conservation of endangered crocodilians worldwide. Using the saltwater crocodile as a model species, we propose that the techniques we have developed for semen collection can equally be applied to captive or wild crocodilians to assess male reproductive status, and ultimately in AI programs. We see a future role for semen collection from selected wild males specifically caught for their phenotypic qualities or for genetic enhancement of captive animals, especially for problem animals that require relocation because of threats to human populations.

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Do Crocodiles Contribute to Local Fishery Production in The Philippines?

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Abstract

We present preliminary results of our assessment on the aquatic primary productivity (APP) and local fisheries (secondary production) in areas inhabited by the two crocodilian species in the Philippines, namely the Philippine Crocodile (*Crocodylus mindorensis*), which was introduced in Paghongawan Marsh (Palustrine) in Siargao Island Protected Landscape & Seascape (SIPLAS), Jaboy, Pilar, Surigao Del Norte last March 22, 2013 and the indigenous population of the Indo-Pacific Crocodile (*Crocodylus porosus*) in Rio Tuba River (Estuarine), Bataraza, southern Palawan. Aquatic Primary Productivity (APP) was determined using light and dark bottles reaction method. Catch-per-Unit Effort (CPUE) of gillnets in these sites (with crocodiles) were compared with their corresponding control sites (without crocodiles) as well as with APP values. CPUEs were found higher in areas inhabited by crocodiles but appeared not directly influenced by APP. The increased fish catches in areas inhabited by crocodiles could be attributed to several factors such as reduced fishing pressure (direct effect) because the presence of crocodiles discouraged the locals to fish intensively. In addition, the completion of this comprehensive assessment is expected to provide results on the role of crocodiles in altering the nutrient regime (indirect effect) thereby enhancing the aquatic primary productivity of the aquatic ecosystems being studied. The significance of these findings from the two cases presented here that sustain local fishery in support for the conservation of crocodiles in the Philippines is discussed.

Introduction

Crocodiles have long been considered as keystone species in aquatic ecosystems by some authors, including Fittkau (1970) who first observed that in the Amazon (South America), a dramatic decline in the population of caimans in the mid-20th century caused disappearance of many fish populations. He hypothesized that caimans played a significant role in enriching the nutrient-poor water entering the mouth-lakes of the Amazon. If Fittkau's hypothesis is correct, fishery production is expectedly higher in aquatic bodies where crocodiles are thriving compared to the areas where they are absent. This can be determined by investigating the primary productivity and secondary production (fish catch composition, biomass, etc) of selected aquatic ecosystems.

In the Philippines, there are two species of crocodiles (Figure 1), the widespread Indo-Pacific Crocodile (*Crocodylus porosus*) or Estuarine Crocodile and the endemic Philippine Crocodile *Crocodylus mindorensis* (Ross 2008). The former is apparently common and widespread in its range from Australia, Bangladesh, Brunei Darussalam, Cambodia, India, Indonesia, Malaysia, Myanmar, Palau, Papua New Guinea, Philippines, Solomon Islands, Sri Lanka, Vanuatu, and Vietnam (IUCN 2012). It is well-adapted to saline or estuarine environments because of its morphological adaptations such as in having salt glands (Taplin et al. 1981). The Philippine Crocodile is one of the world's endangered crocodilian species with a small population distributed in a few freshwater habitats in Isabela, northern Luzon and Ligawasan Marsh in Mindanao (Ross 2008; IUCN 2009). Apparently, it is locally extinct on Negros Island since 1999 while it is no longer sighted in the islands such as Mindoro, Samar, Masbate, Busuanga, and Jolo (IUCN 2009). Their presence is recently recorded in high altitude areas of Abra in Luzon, Bukidnon and south Cotabato in Mindanao (Manalo 2008; Manalo et al. 2013). Based on several years of experience and field observations, C.A. Ross (2008) hypothesized that the habitat for *C. mindorensis* is restricted to small isolated ponds and streams and not necessarily major wetlands. For this reason, smaller freshwater habitats such as Paghongawan Marsh are potential release sites for *C. mindorensis*.

Figure 1. The indigenous Indo-Pacific Crocodile *Crocodylus porosus* in Rio Tuba Estuary, Bataraza, Palawan (left) and the introduced Philippine Crocodile *Crocodylus mindorensis* from Paghongawan Marsh, Siargao Island. In situ photo by CPPI/R. Manalo.

Given the dearth of information on the ecological impact of the two crocodilian species in the Philippines, this study will be of significant contribution to fill this gap of knowledge. This will be the first attempt to determine whether or not crocodiles contribute to the overall productivity of aquatic ecosystems, which in effect results to high yield of local fishery. Although the indigenous group of people living in the Agusan Marsh have claimed that the abundance of their fish catch in areas inhabited by crocodiles is due to their presence (Manalo et al. 2013), documentation of catch composition and catch-per-unit effort (CPUE) and other fishery parameters are still lacking.

In general, this study aims to determine whether or not crocodiles contribute to the overall productivity of aquatic ecosystems and specifically to: 1) measure the physico-chemical properties of selected aquatic ecosystems; 2) quantify fish catch (catch-per-unit effort and catch composition); and 3) determine whether or not fish catches and primary productivity are higher in areas inhabited by crocodiles. In this paper, we present preliminary findings from the palustrine and estuarine habitats.

Methods

The study sites (Table 1) were classified based on the presence or absence of crocodile populations and on the system classification on wetlands as described by Richardson (1995). These systems are as follows: 1) palustrine-relatively shallow water bodies where plants (including trees) occupy most of the area; 2) estuarine-river mouths and mangrove areas where there is mixing of fresh water and sea water; 3) riverine-lotic or moving freshwater rivers and streams; 4) lacustrine-lakes and reservoir where vegetation occupies less than 30% of the area.

Table 1. Classification and location of the study sites.

System Classification*	with crocodile population (experimental sites)	without crocodiles (control sites)
Palustrine (forested marshes)	Paghongawan Marsh, Pilar, Siargao Is.	Sangay-Lilaw Marsh, San Mateo, Burgos, Siargao Is.
Estuarine (mangroves and river mouths)	Rio Tuba, Palawan	Iwahig River, Palawan
Riverine (lotic/flowing freshwater rivers)	Moleta River, Bukidnon, Mindanao	Maramag River, Bukidnon, Mindanao
Lacustrine (lakes)	Seven Lakes, Sebu, South Cotabato	Lakes in South Cotabato (to be identified)

* Based on Richardson, C.J. (1995)

Thus far, the Paghongawan Marsh and Sangay-Lilaw Marsh, both Palustrine habitat in Siargao Island and Rio Tuba and Iwahig river estuaries in Palawan were surveyed.

Description of Study Sites

Site 1 – *Palustrine habitat (forested marsh)* Siargao Island Protected Landscape & Seascape, Surigao Del Norte. (18-30mASL). The two sampling sites is the Paghongawan Marsh in Barangay Jaboy (09.89155° N, 126.07717° E), Municipality of Pilar and the . Sangay-Lilaw Marsh (09.98977° N, 126.07105° E) located 10.8 km north of Paghongawan Marsh in Barangay San Mateo, Municipality of Burgos. In both sites, the common vegetation is primarily of swamp-associated species such as the cheesewood tree *Nauclea orientalis* (locally known as *bangkal*) and some herbaceous species like *Hypolytrum nemorum* (CPPI report, 2012). Inland freshwater areas in Siargao Island are not known to inhabit Philippine Crocodile population, but the Paghongawan marsh was considered due to presence of conservation introduced *C. mindorensis*. The above sites were visited from June 8-12, 2013.

Site 2 - *Estuarine-river mouths and mangrove areas*. Palawan Mangrove Swamp Forest Reserve, Southern Palawan. (15-32mASL). Indigenous population of Indo-pacific crocodile are present in Rio Tuba Estuary (08.52584° N, 117.41927° E) located in Barangay Rio Tuba, Municipality of Bataraza, Palawan. The river mouth extends to at least 600m then gradually narrows to 400m until it reached a narrow stream (non-navigable by boat) at about 6.29 km southwest from the mouth. Crocodiles are not recorded in Iwahig Estuary (09.73548° N, 118.68454° E), Barangay Iwahig, Puerto Princesa City, Palawan. The mouth of

Iwahig River is about 80-390m wide which is narrower than that of Rio Tuba. The river is relatively deep near the mouth at about 3-5m then becomes shallower (0.5m) at about 10 km away from the river mouth. In both sites, the river banks are flanked with extensive mangroves (mainly *Rhizophora*) although in Rio Tuba, timber poaching for domestic consumption was observed. These sites were surveyed from November 16-27, 2013.

Figure 2. Study area for Palustine and Estuarine site.

Primary Productivity

Physico-chemical parameters. Prior to sampling of aquatic organisms (fishes, macroinvertebrates, and plankton), collection of water samples as well as determination of the following *in situ* physico-chemical parameters were done in each site. Sub-surface temperatures using field thermometers; pH using a pH meter; Salinity using a hand-held refractometer (Westover RHS-10ATC); Conductivity and total dissolved solids using CyberScan Con 200 conductivity meter.

Three sets of sub-surface samples were collected for the following: 1) dissolved oxygen (DO) and biochemical oxygen demand (BOD) in BOD bottles; 2) gross primary productivity (GPP) and net primary productivity (NPP) in paired clear and wrapped with black plastic sheet BOD bottles; and 3) 1-L water samples for total suspended solids (TSS), total hardness, methyl orange (MO) alkalinity, ammonia, nitrate and phosphate.

For the dissolved oxygen and BOD, two sets of BOD bottles were dipped into the water and covered when full while still immersed in the water. At Day 0 (initial DO determination), oxygen was fixed by treating the samples with $MnSO_4$ and alkaline KI right away and covered with dark plastic bags. Winkler titration was done on-field working station. The second bottle was incubated for 5 days and the dissolved oxygen was then determined. BOD was then calculated as $DO_0 – DO_5$.

Gross primary productivity (GPP) and net primary productivity (NPP) were determined by the light and dark reactions (Lewis 1970). Initial dissolved oxygen was determined as in DO determination. Paired BOD bottles, one transparent and the other wrapped in a black plastic bag were suspended at about a foot from the surface of the water, each containing raw water collected from the depths at which bottles were suspended. The samples were allowed to incubate at this depth for 5 days. Quantification of chlorophyll *a* was done in the laboratory following the procedures described by Wood (1985).

Turbidity of the water samples was determined using a Merck Turbiquant 1500T. Total Hardness was determined using EDTA compleximetric titration. Fifty (50) mL samples were titrated with standard EDTA. For the MO Alkalinity, 50mL samples were titrated with standard HCl solution. For the total suspended solids (TSS), a 1-L water sample was collected using polyvinyl containers and filtered through GF/C. The filtrate was collected and transported to the Silliman University Chemistry Laboratory for the analysis of ammonia, nitrate and phosphate.

To determine whether or not crocodiles enhance the nutrients of the water in a controlled setting, the nitrate (NO3-N) and phosphate (PO4-P) levels of the crocodile pond (with water content of about 30 m^3) at AC Alcala Marine & Environmental Science Laboratories (formerly the Marine Laboratory) at Silliman University, Dumaguete City were measured. An annual accumulated nutrient of the pond occupied by a single adult *C. mindorensis* was directly measured. Pond water was replaced annually with drinking or tap water having a nitrate level of about 1.0 mg/L (0.01µmol/L).

<u>Secondary Productivity</u>

Fishery Assessment. Three gillnets, each measuring 15m x 1.5m with mesh size of 1.5cm were adopted as it is the commonly used gear by the local fishers in both palustrine (and estuarine sites. Catch-per-unit-effort (CPUE) expressed as kg/net/hour was determined. Fish catch were examined and identified to species level using available references such as FishBase (Froese & Pauly, 2012), the FAO Fish Identification Series by Carpenter & Niem (1999) and Allen (1991).

Results

In Paghongawan Marsh, the mean nitrate level of 8.36±2.55 µmol/L (ranged from 3.95-20.85) was found lower than that of the Sangay-Lilaw Marsh, with mean values of 9.85±3.21 µmol/L (ranged from 5.23-25.04). Phosphate level, however, was found higher in Paghongawan Marsh with mean value of 0.72±0.04 µmol/L (ranged from 0.55-0.84,) than that of Sangay-Lilaw Marsh with mean values of 0.605±0.009 µmol/L (ranged 0.57-0.64).

In the estuarine sites, Iwahig River Estuary has higher values of both nitrate (8.04±0.75 µmol/L) and phosphate (2.18±0.69 µmol/L) compared to that in Rio Tuba River Estuary with corresponding nitrate and phosphate levels of 5.48±0.67 µmol/L and 0.67±0.013 µmol/L, respectively.

Table 2. Physico-chemical parameters of the palustrine and estuarine sites.

Parameter	PALUSTRINE						ESTUARINE					
	Paghongawan Marsh			Sangay-Lilaw Marsh			Iwahig River Estuary			Rio Tuba River Estuary		
	Mean		SE	Mean		SE	Mean		SE	Mean		SE
pH	8.47	±	0.05	7.43	±	0.06	7.93	±	0.03	7.47	±	0.07
Salinity, ppt	0.00	±	0.00	0.00	±	0.00	14.00	±	0.00	27.00	±	1.15
Conductivity, mS	259.83	±	50.57	184.53	±	4.28	25.50	±	0.50	44.33	±	1.36
Turbidity, NTU	148.03	±	27.84	8.80	±	2.27	6.26	±	0.55	3.43	±	1.39
TSS, mg/L	135.98	±	23.06	4.88	±	0.95	12.70	±	0.35	14.80	±	0.21
TDS, mg/L	150.95	±	29.46	107.02	±	2.54	14.80	±	0.25	25.67	±	0.78
Total Hardness, mg $CaCO_3$/L	23.78	±	0.61	36.53	±	8.09	3034.72	±	53.96	6111.11	±	262.66
MO Alkalinity, mg $CaCO_3$/L	92.42	±	2.10	133.80	±	30.07	153.82	±	1.51	176.17	±	4.60
DO, mg O_2/L	6.81	±	0.52	6.84	±	0.98	3.90	±	0.05	2.09	±	0.08
BOD, mg O_2/L	6.17	±	0.55	1.96	±	0.13	0.46	±	0.11	0.25	±	0.23
GPP, mg C/m^3/hr	12.73	±	1.85	3.82	±	0.85	2.73	±	0.39	1.61	±	0.75
NPP, mg C/m^3/hr	-10.24	±	2.89	-22.06	±	6.68	0.95	±	0.36	-0.12	±	0.19
NH_3-N, mmol/L				4.07	±	0.56	3.32	±	0.46			
NO_3-N, mmol/L	8.36	±	2.55	9.85	±	3.21	8.04	±	0.75	5.48	±	0.67
PO_4-P, mmol/L	0.72	±	0.04	0.61	±	0.01	2.18	±	0.69	0.67	±	0.01

Such differences in both nitrate and phosphate levels might be influenced by other sources such as from nearby farms and households (less than 1km), surrounding vegetations, erosion, among others, and may not be directly linked to the presence or absence of crocodiles.

Aquatic Primary Productivity. The results of the Gross Primary Productivity (GPP) values showed that mean GPP values were higher in Paghongawan Marsh, 9.91±2.97 mgC/m^3/hour and 15.55±0.64 mgC/m^3/hour, in the first and second ponds, respectively, compared to that in San Mateo with only 3.18±0.99 mgC/m^3/hour (Sangay) and 4.46±1.49 mgC/m^3/hour (Lilaw). In the estuarine sites, both GPP and NPP were observed higher in Iwahig Estuary (2.73±0.39 mgC/m^3/hour and 0.95±0.36 mgC/m^3/hour) compared to Rio Tuba with only 1.61±0.75 mgC/m^3/hour and -0.12±0.19 mgC/m^3/hour, respectively.

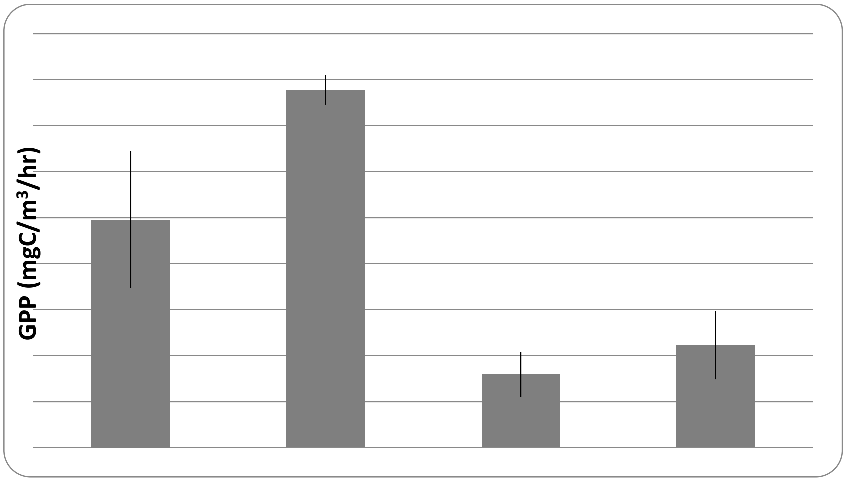

Figure 3. Gross aquatic productivity (mg C/m 3 /hour) values in Paghongawan Marsh compared with Sangay-Lilaw Marsh (June 2013).

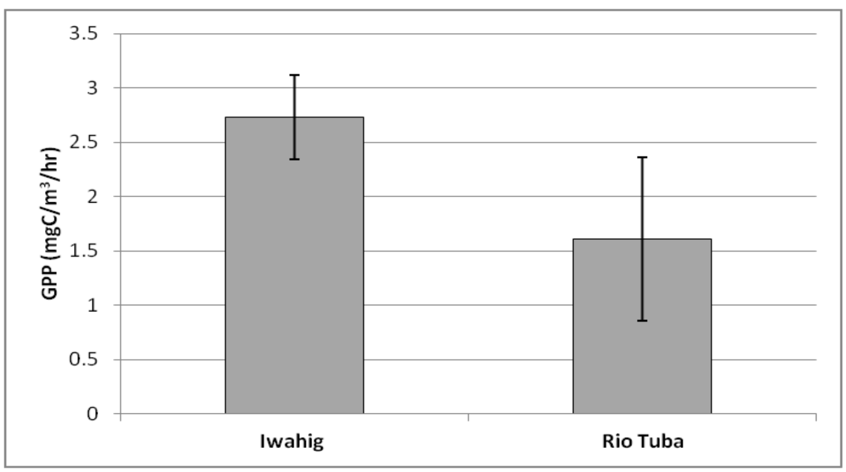

Figure 4. GPP values determined from two estuarine sites in Palawan

Fishery Assessment. The highest total catch (in one hour of fishing) was recorded in the release site in Paghongawan with 28.34 kgs of fish with mean catch-per-unit effort (CPUE) of 9.44±7.62 kg/net/hour while in the adjacent pond, only 4.58 kg were recorded (mean=1.53±0.77 kg/net/hour). In Lilaw-Sangay-Marsh in San Mateo, only a mean CPUE of 2.29±1.46 kg/net/hour and 0.36±0.23 kg/net/hour were recorded (Figure 8). The relatively increased CPUE in the release site in Paghongawan might be attributed to reduced fishing pressure in the area as the local fishers tend to concentrate their fishing activities in the second pond. It is probably too early to attribute fish abundance to aquatic productivity.

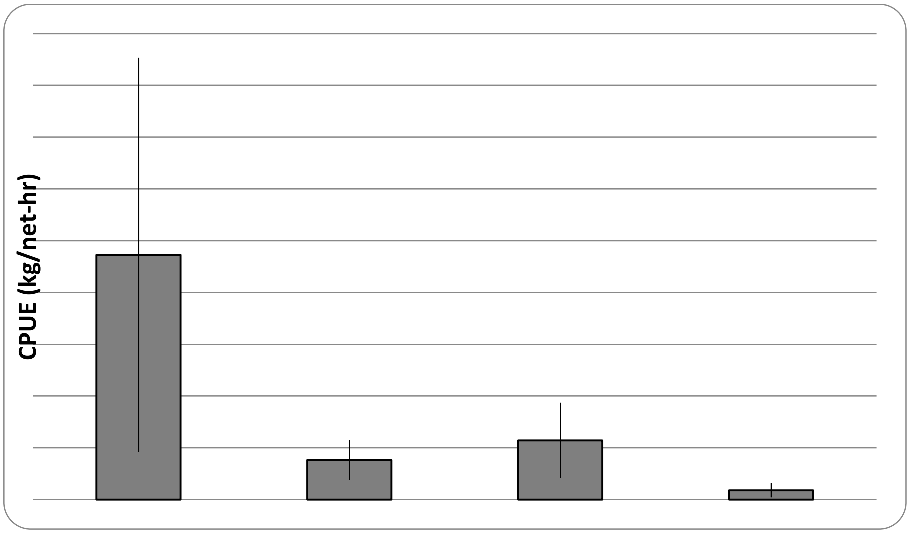

Figure 5. Catch-per-unit effort (CPUE) of gill net in Paghongawan compared with Lilaw-Sangay Marsh.

Because of the relatively low abundance of other potential prey items of Philippine Crocodiles in Paghongawan Marsh such as wading birds, reptiles, and frogs, fishes might be the main food source of the growing crocodiles in the near future. It is therefore necessary that the local fishery be managed properly.

A total of 245 fishes (belonging to six species) were sampled in Panghongawan marsh which comprised the following species: Nile Tilapia *Oreochromis niloticus* (199), Common Carp *Cyprinus carpio* (19), Catfish *Clarias macrocephalus* (15), Climbing Perch *Anabas testudineus* (8), Snakehead *Channa striata* (3), and Giant-Mottled Eel *Anguilla cf marmorata* (1). As compared in San Mateo, only 98 individuals were sampled which consisted of four species:: *Oreochromis mossambicus* (40), *Oreochromis niloticus* (39), *Channa striata* (17), and *Anabas testudineus* (2).

The mean CPUE in Iwahig was determined at 0.23±0.16 (SE) kg/net/hr while 2.6±0.85 kg/net/hr in Rio Tuba. Most of the fishes caught in Rio Tuba Estuary were target or food fishes such as rabbitfishes (Siganidae), jacks (Carangidae), and emperors (Lethrinidae) while in ponyfishes (Leiognathidae) predominate in Iwahig River Estuary. The increased fish catch in Rio Tuba might be attributed to several factors such as low fishing pressure as the presence of the Indo-pacific Crocodile (*Crocodylus porosus*) in the river discouraged the locals to fish intensively.

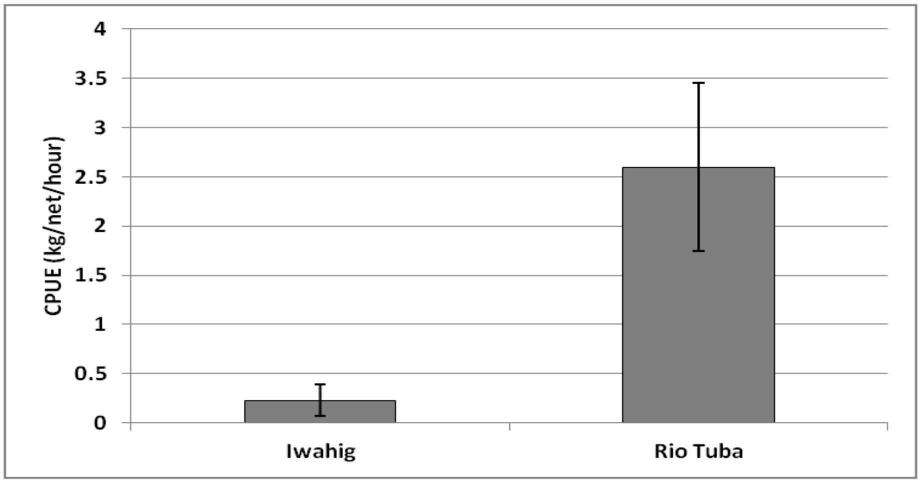

Figure 6. Gillnet CPUE values from the two estuarine sites in Palawan.

Discussion

While there seems a strong consensus among ecologists that crocodiles serve as keystone species, van der Ploeg et al. (2011) pointed out there is little empirical evidence for the claim that crocodiles improve fish catches. This study appears to be the first major attempt to quantify fish catches in areas both inhabited by crocodiles. At this stage, however, these data can be used only to compare between sites (spatial) while temporal comparisons can be derived later as fish catch data accumulates over time.

Although it is possible to demonstrate that crocodiles' metabolism may enhance the nutrient level of the water to several orders of magnitude, it appears that this complex mechanism is difficult to demonstrate in the field. In addition, it is almost impossible to find an aquatic ecosystem in developing countries like the Philippines without any human influence, including organic pollution (Tamayo-Zafaralla et al. 2002; Islam & Tanaka, 2004).

Because it was only three months since the crocodiles were released, the increased aquatic primary productivity detected during the sampling in Paghongawan Marsh might be attributed to other factors such higher nutrient input from the adjacent forest such as decomposition of plant materials (Webster & Benfield, 1986) and possibly from upstream sources such as runoff from agriculture (Briones 2005). Although we assume that at this stage, the excreta of the small, recently introduced Philippine Crocodiles may have contributed only a small amount of nutrients in the water, it is possible that they can help enhance the nutrient level in the water column as they scour the substratum (including attached algae or periphyton) when they forage.

In Rio Tuba Estuary where the crocodile population is indigenous, CPUE was notably higher compared to Iwahig Estuary but lower in terms of nutrient and aquatic primary productivity (GPP and APP). It is possible that other factors may have affected the low CPUE values obtained from Iwahig such as intensive fishing pressure, which has to be described in details. Based on actual observations and interviews with the locals in Rio Tuba, only 3 fishers are regularly fishing in the area at night time only in contrast to that in Iwahig where fishers of at least 10 intensify their effort (day and night). It is of interest to note that in spite of some cases of crocodile attack in Rio Tuba, the local fishers were not offensive against the crocodiles unlike those in the southern Islands of Palawan, Isabela in Luzon, and Bunawan, Agusan Marsh in Mindanao where most local fishers believed that crocodiles are destructive to their fishing nets and dwindling fish catch (Manalo 2003; van der Ploeg et al. 2011; and Manalo et. al. 2012). Traditionally, cultural beliefs and practices by the indigenous local fishers included strong taboos against killing and eating crocodiles

(Pomares et. al. 2008 and van der Ploeg, 2011). Fishing practices of the Agusanon Manobos are attached to the abundance of fish catch in areas inhabit by the crocodiles (Gonzales et. al. 2013).

The local fishers' cautious fishing attitude due to the presence of crocodiles in an aquatic ecosystem has some positive implications. Reduced fishing pressure would then lead to the recovery of fish stocks, similar to the effect of any fishery intervention such as temporal (closed season, see Adams et al. 2000) and spatial (no-take marine reserves, fishery refugia, sanctuaries) fishing closures (Alcala, 2001; Alcala & Russ, 1990). This is probably a direct effect derived from the presence of crocodiles while the possibility of enhancing the nutrient level of the water may be considered an indirect effect.

Conclusion & recommendations

As far as can be ascertained, gillnet CPUE values in areas inhabited by crocodiles (palustrine and estuarine sites) were found significantly higher than those in areas where they are absent. Aquatic primary productivity (gross and net productivity), however, do not conform to the observed trend, which might be also influenced by other factors such as availability of other sources of nutrients such as detritus from the mangroves. It is recommended that the study be extended into a long-term monitoring of both nutrient level of the water and fish catch.

Acknowledgement

This project was made possible through a collaborative agreement between Crocodylus Porosus Philippines, Incorporated and Silliman University. The untiring support from the DENR- Biodiversity Management Bureau, LGU of Pilar thru Hon. Mayor Lucio T. Gonzales and Brgy. Chairman Narda Trigo of Jaboy is greatly acknowledged. Our field partners CENRO-Dapa Protected Areas and Wildlife Division, Siargao Island Tourism Office and technical assistants from barangays of Jaboy and San Mateo are also thanked.

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The ecological status of the *C. Porosus* and *C. novaeguineae* wild populations trends in Papua New Guinea, 1981-2014.

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Abstract

Wild aerial nest counting result using regression analysis on the sample subsets; The *C. novaeguineae* showed (N = 21 primary sites, *1981 to 2013*, $r^2 = 0.562$, p = 0.014), and (N = 49, *1989 to 2013*, $r^2 = 0.430$, p = 0.016). Both sets are different in terms of the survey period in which they were added and the relationship mirrors both sets from 1989 and is not significant. For *C. porosus* (N = 12) primary sites (1982-2014), excluding 1998 and 2010, relationship between nest counts and year r2= 0.75, p= 0.0004, with a mean of 63.0 at a rate of 1% per annum and a SD = 15.7, range 30 to 93.

Trade figures indicated 27553 wild *C. novaeguineae*, 6284 wild *C. porosus*, and farmed 13,336 *C. porosus* skins exported in the last 24 months (2012 and 2013) from January to December. This included ranched skins and wild skins of both species exported by various exporters. Annual exports of both species from farm and wild averagely around 25000 per annum.

Wild egg harvest is conducted annually by Mainland Holdings (MHL) in the Sepik River of PNG. Last year MHL harvested 15060 eggs and this year 13966 eggs field graded. The hatchability for 2013 harvests is 82.7% whilst the 2014 harvests already has 79.4% hatchability with some nests remaining in the incubator.

Introduction

This paper discusses in general terms the wild population trends of *Crocodylus novaeguineae* and *C.porosus* (nestings, skins, eggs, and juveniles) in Papua New Guinea (PNG). The current status appears to be that crocodiles remain, in abundant numbers, widely distributed among small, large and isolated habitat patches, of lagoon and scroll systems. However, numbers continue to fluctuate due to continued habitat loss, wild hunting for skins and illegal harvest for meat. A small team of interested local community based organisation (CBOs) remains but expanding interest in crocodile conservation to a wider advocacy base needs funding and logistics for their work. The situation appears dire with a real potential for wild population decline in traditionally abundant areas in the foreseeable future if current habitats degradation continue and no effective interventions are made.

Currently there are no protected areas or management programs for in-situ conservation of crocodiles and habitats. This is due to the current results of wild populations monitoring which inferred that the wild populations are increasing but stable in numbers. This can be correlated with statistics and evidence from communities in many of the crocodile harvesting areas throughout the country which supplier's raw skins for the export market.

Crocodile population surveys and assessments have been conducted throughout PNG in the past, however due to capacity changes and restructuring within the Management Authority, only the populations of the Sepik River wetlands have been surveyed biannually using helicopters. The Mainland Holdings wild harvesting program has had no negative effects on the wild populations. The harvests need to be refined so that it is cost effective and that suppliers receive value for their continued support towards the program. At the same time the egg collection program must be monitored through the use of land owner agreements signed between landowners, the CBO and the company. Importantly, the annual egg collection as a useful method used to monitor the wild crocodile breeding populations and identify trend and problem areas.

Scope of this report
This report continues to maintain that consistency as a country and its obligation to report its updated monitoring results and other relevant management information to the biannual CSG working meeting. The report will also in brief cover; a) Number of crocodiles (eggs, young or adults) taken annually from the wild, b) Production sales and exports of the species concerned and c) other relevant conservation and management program or scientific studies undertaken in relation to the ranching operation or the wild population concerned

Apart from that, this report also ensures that PNG meets its international obligation of regular reporting because wild harvesting is continuing and that no quota restrictions are imposed by CITES.

1. Crocodile Monitoring
    1.1. Crocodylus novaeguineae

A general statement is given here indicating that there is decreasing suitable habitats for *C. novaeguineae*, and presents a high risk to the future monitoring program. Even with the habitat decline the trends is stable and increasing from the primary sites and is not statistically significant (*1981 to 2013*) N = 21. $r^2 = 0.562$ p = 0.014) with a mean of 91.1 nests/year (SD = 17.1, range of 71 to 135) over the nesting period.

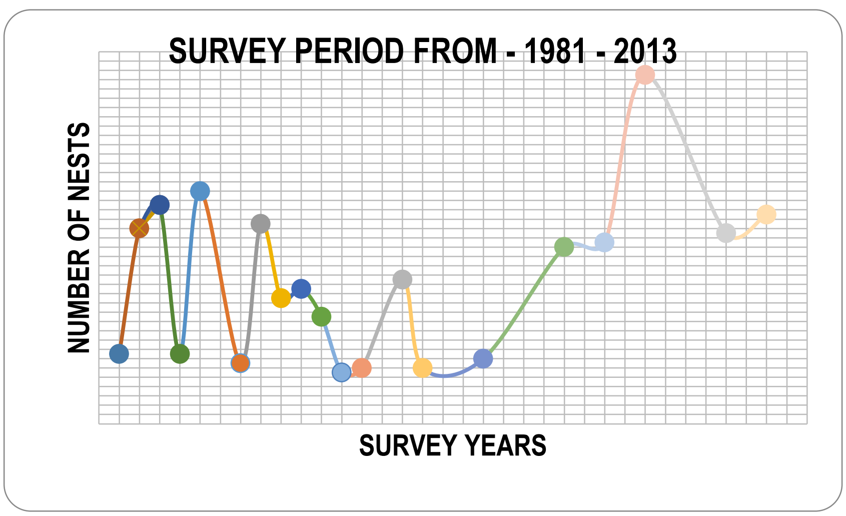


Figure 1. A general fluctuation trend for the *C. novaeguineae* species since 1981 for N = 21 primary sites.

1. The subset N = 21 (**Figure. 1**) reflected three marked observations. Between 1981 and 1988, there were years that have low nests counts in one year, often have higher nests counts the subsequent year. This effect may suggest that the nesting effort is determined in part by the nesting (reproductive effort) the previous year.

2. In 1988 and 1992 nests counts, there was a significant decrease in nesting effort from 103 nests in 1988 to 72 nests in 1992.

3. In 1993 to 1999 the nesting numbers again increased slightly but with a more significant increase in 1999.

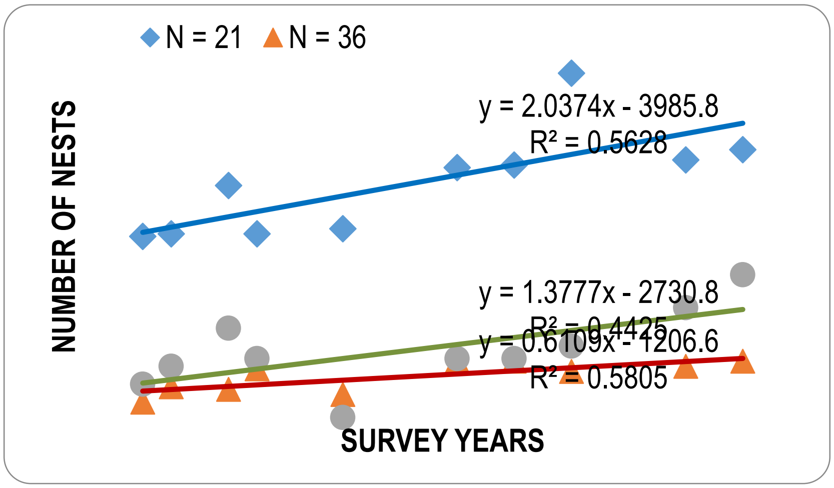
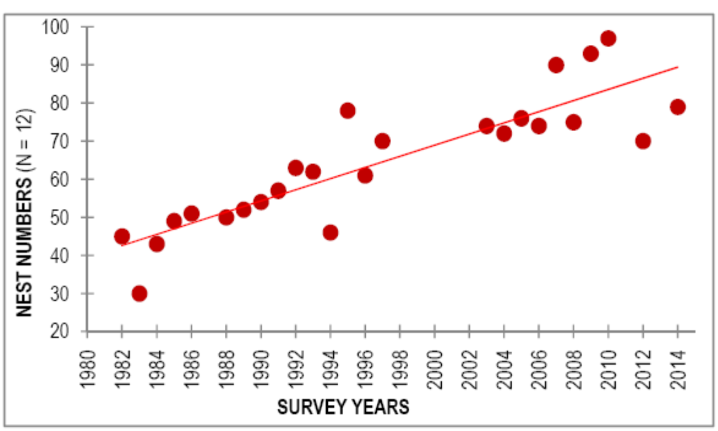


Figure 2. *C.novaeguineae* nests counts surveyed for three sites analyzed from 1992 to 2013.

In **Figure 2**, we again examined three (3) subsets for the *C. novaeguineae* species from years *1992 to 2013*, (N = 21, N = 36 and N = 49 sites). The regression results indicates an increasing trend which is not significant ($r^2 = 0.562$, $p = 0.014$; $r^2 = 0.58$, $p = 0.011$; and $r^2 = 0.44$, $p = 0.040$ respectively.

1.2. Crocodylus porosus.

The nesting effort for the primary data sets e.g. for *C. porosus* N = 12 (**Figure 3**), was regressed without nesting numbers for 1998 (reflect atypical climatic conditions), whilst the period from 1982 to 2014 with the 2010 data included (nests counts particularly high). The results indicated an increase over time N = 12 ($Y = 1.480x - 2892$, $r^2 = 0.747$, $p = 0.0005$, with a mean of 64.4 at a mean rate of 2.4% per annum, SD = 16.8 and a range of 30 – 97.



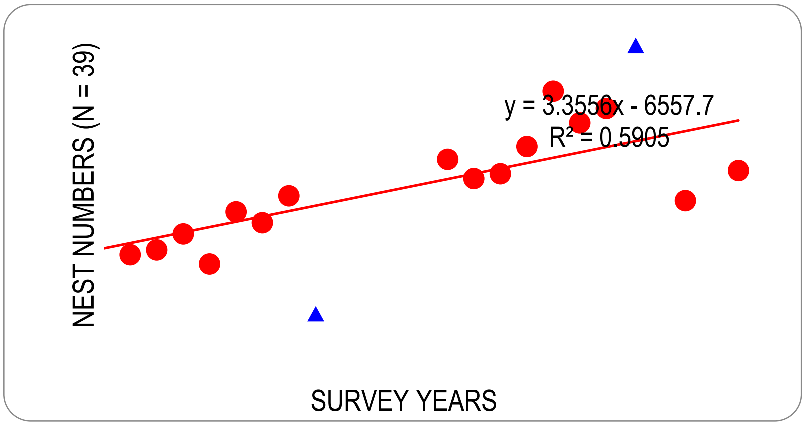


Figure 3. Linear regression relationship for *C.porosus* (N = 12), without the 1998 data but with the inclusion of 2010 data. The regression is considered significant.

Figure 4. Regression for N = 39 sites, without the 1998 and 2010 data (blue markers). This represents all *C.porosus* survey sites in the Sepik replicate area results for that period

The analysis did not include the N = 27 data which were surveyed in 1988. This subsets were considered secondary set for observations in the future analysis or to answer other relevant questions that may arise. However, a regression was conducted for the whole set of *C. porosus* that were included in 1991. It was considered useful for us to assess these set rather than the secondary sets in between years.

In which case the regression for N = 39 sites (**Figure 4**), (Without 1998 and 2010 data (cone markers) Y = 3.3556x - 6557, $r^2 = 0.590$, $p = 0.0005$, with a mean of 158, at a rate of 8.8% per annum. SD = 33 and a range of 110 – 219. The data indicated a 59% variation since 1991 and a significant relationship between years and nesting effort.

Two secondary sites were dropped (Japandai and Biimba) from the sets and their data is not included in the regression of N = 39 as these sites did not yield any nests for the last 10 survey years.

2. PNG Skins Exports

The skins exported from Papua New Guinea to various exporters are reflected in (**Figure 5 & 6** and **Tables 1 & 2**), and their origination e.g. wild or farm/ and freshwater or saltwater. The figures and tables exhibited the total skins regardless of grades and sizes. The wild hunted exports for *C. porosus* skins averagely around 4000 skins annually, whilst the ranched *C. porosus* export figures average around 8300 skins annually. There was a large export figure of ranched *C. porosus* in 2010, at 13, 139 skins. This was attributed to the thinning out process to limit overcrowding that was implemented on the farm.

In Table 1, skin exports by origin indicated that the wild skins composition for *C. novaeguineae* and *C. porosus* makes up averagely 70% whilst the remaining 30% is ranched skins. The number of skins exported largely depends on the purchase price, the hunting methods and the seasonal variation (high and dry) periods and the duration. However, the total country skins exports over the nine (9) year period since 2005 still fluctuates at an average of 30,856 000± /year .

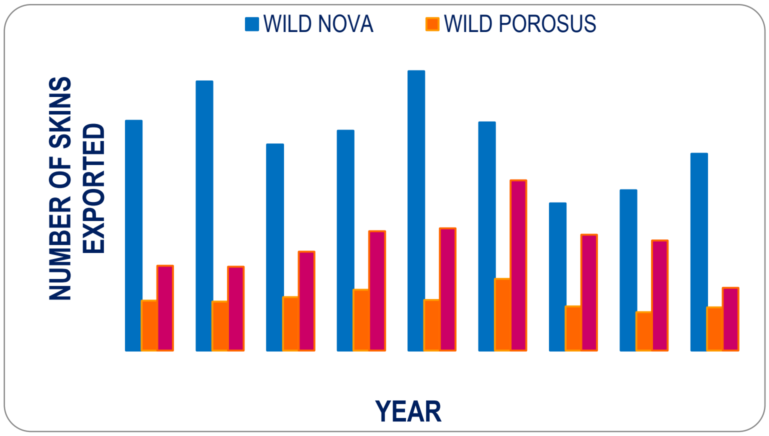


Figure 5. A representation of exports by species and origin.

Table 1. Skins exports by origin

YEARS	WILD NOVA	WILD POR	FARM POR
2005	17726	3852	6549
2006	20773	3762	6453
2007	15904	4128	7629
2008	16955	4683	9211
2009	21548	3893	9434
2010	17605	5526	13139
2011	11365	3399	8921
2012	12364	2949	8500
2013	15189	3335	4836

Table 2. PNG total exports

YEAR	NO OF SKINS
2005	30132
2006	32994
2007	29668
2008	32857
2009	36884
2010	38280
2011	25696
2012	25825
2013	25373

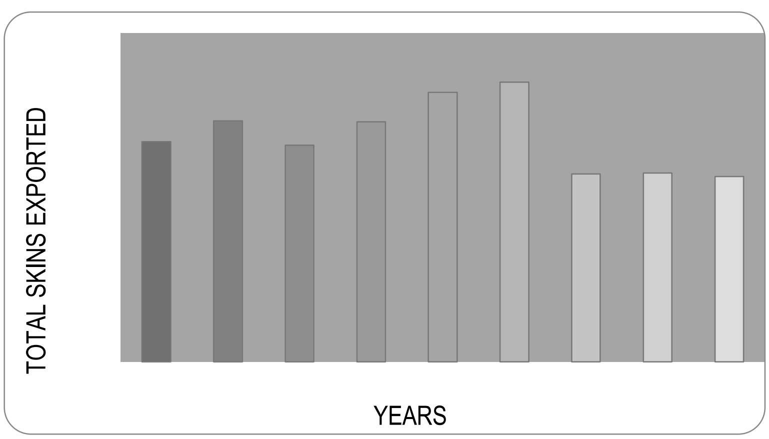


Figure 6. An indication of total skins exported from PNG

3. **Sepik wild eggs harvests.**

The conduct of the Sepik wild egg harvest to add value to the local people's economy has been operated annually since 2002 (Table 3), unlike in the past using helicopters from 1985. With the use of the canoe harvests it has been cheaper to collect more eggs and at the same time maintain the price of a single viable egg at landing costs to the company for some time.

Table 3. The number of wild eggs annually collected from the Sepik (2002 to 2014)

HARVEST YEAR	NESTS HARVESTED	% OF NESTS SURVEYED	TOTAL No OF EGGS	VIABLE EGGS	EGG PAYMENTS TO FARMERS	INFERTIILE / DEAD EGGS	% VIABLE EGGS	AVG CLUTCH SIZE	HATCHLINGS	HATCHABILITY
2002	78		4381	3465		916	79.09%	56.17	3098	89.4%
2003	159	76.20	9508	7817	#########	1691	82.21%	59.80	5832	74.6%
2004	215	46.50	12756	10261	#########	2495	80.44%	59.33	8901	86.7%
2005	205		12327	9787	#########	2540	79.39%	60.13	7926	81.0%
2006	291		17006	13491	#########	3515	79.33%	58.44	9157	67.9%
2007	215	59.07	13390	10946	#########	2444	81.75%	62.28	9019	82.4%
2008	268		12733	11790	#######	943	92.59%	47.51	9672	82.0%
2009	195	22.00	11297	8977	#########	2320	79.46%	57.93	5370	59.8%
2010	185	27.50	10411	8270	#########	2141	79.44%	56.28	6504	78.6%
2011	181	32.00	10193	7980	#########	2213	78.29%	56.31	5871	73.6%
2012	228	36.00	12798	10972	#########	1826	85.73%	56.13	8693	79.2%
2013	304	48.00	18026	15060	#########	2966	83.55%	59.30	12459	82.7%
2014	288		16491	13966	#########	2525	84.69%	57.26	9682	69.3%

The updated figures for the two (2) year period 2013 and 2014 exhibited an increase in the number of eggs collected. The MHL base figure was set at 10 000 eggs annually, however due to the necessities of the local communities the company has been for the two year period not too keen on getting more eggs than the set target. This is due to the transport relocation by air and the need to maintain control on targets so that the right approach with support is taken by landowners towards the program itself.

The 2014 hatchability at MHL is 79.4% and is anticipated that the target is to achieve about 82% for the year. Overall, community crocodile egg collection program has helped to turn the human crocodile conflict problem into a sustainable socio-ecological and economic opportunity, which supports conservation of the resource. Every year wild egg collection reports from the Sepik are filed with the DEC the Management Authority at the close of the collection period which is usually (2) two months after the payments of the farmers eggs.

Summary

Since the surveys commenced in 1981 and 1982 respectively for both species, DEC continues to maintain responsibility and conduct of these aerial surveys. Although expensive in a way there is no other option for PNG to manage it resource e.g. alternatively do ground monitoring as most of these data are not consistently conducted and the environmental variations at each locality has been difficult to successfully implement these ground surveys across the country. The aerial surveys continue to be the only significant option available by DEC as it goes into its next stages for restructuring and privatisation into an Authority. However, let alone the capacity with the heart and right training and experiences to progress this program.

The results of both species of the wild populations e.g. (aerial nesting surveys, skins export figures, wild egg harvests figures) presented over the years up to 2014 seem to indicate that the population is in a safer position. Any over exploitation of the population could be detected by one or two of the following methods:

(1). The aerial surveys would show a decline in all the data sets being regressed at each sub-set of data from both species.

(2). Wild egg harvesting would allow the determination of the nesting age of females, which will reflect lower or insufficient recruitment to the breeding population.

(3) Skin statistics from hunted populations e.g. Sepik monitoring sites would indicate lower recruitment of animals approaching breeding age.

If there is evidence of certain areas in the country e.g. the Sepik through the invasive fish species, the population could still be managed with the right support, funding and introductions of a set quota under the management plan. In conclusion it can be assumed that the PNG wild population is still healthy although with some difficulties to maintain and operate the many facets of the crocodile program.

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Human-Crocodile Interaction in the Great Tempisque Wetland, Costa Rica

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Abstract

Due to development and urban expansion the interaction between man and wildlife has increased. Those interactions may have benefits for both parties, but also there are those that lead to conflict. Great Tempisque Wetland, habitat of the American crocodile (*Crocodylus acutus*), has been subjected to human pressure, which has dramatically reduced the habitat available for this species. However, the population of *C. acutus* has increased over the last 15 years, and the probability of encounters between crocodiles and people also increases. We evaluated the interaction between human and crocodile from a qualitative approach of social research to determine human-crocodile interaction in the communities surrounding the area. The interaction between humans and crocodiles are leading to a conflict in 22 communities. This interaction results in fatal and non-fatal attacks by *C. acutus*.

Introduction

The interactions between human being and the wildlife are increasing because of the development and urban expansion; as a result there is more human presence in wildlife habitat (Wieczorek Hudenko and Decker 2008). Although interactions may have benefits for fauna and humans, there are also negative interactions that can lead in to conflict, that must now be resolved by wildlife managers (Wieczorek Hudenko and Decker 2008).

The negative interactions can result in a conflict, and they cause negative impacts on humans in the social, cultural and economic aspect or on the conservation of populations of wildlife or the environment (WWF 2005). The conflicts between human groups and wildlife have existed over the course of time (Peña 2011), and they have become more frequent and severe in the last few decades as a result of human population growth, the extension of transport routes and the expansion of agricultural and industrial activities which together, have led to the increase of the human invasion in natural areas (Lamarque *et al.* 2009).

On the other hand, in places where nature protection has been successful, threatened wildlife may recover, and sometimes cause damage to property or human casualties in households at some distance from the wild areas or the areas that it inhabits (Treves 2007). To live near wildlife imposes a variety of significant costs to the local human population, including the depredation of domestic animals, attacks on human beings and the opportunity costs. In addition, people are deprived of economic goods (eg fish) or recreational activities (eg river rides and swimming) due to the impositions caused by the presence of wild animals or conservation areas (Dickman 2010).

Because of the pressure that crocodile populations suffered in the past by hunting and skin trading in several tropical countries, protective measures were taken by different governments. This protection has been effective in some cases and several populations of different species have recovered, increased and re-occupied parts of its historic range, leading to increased interaction between humans and crocodiles which inevitably has led to conflict in many cases.

The habitat of *Crocodylus acutus* in the Great Tempisque Wetland has been under human pressure because of human population growth, and also agricultural and urban growth (Monge-Nájera and Gomez 2007), and this has considerably reduced the habitat available for the species. This reduction has forced the crocodiles to move to areas not inhabited before, looking for prey and territory. Despite this, it has been observed that contrary to what would be expected, the population of crocodiles in GTW has grown to the point quadrupled in the last 16 years (Bolaños 2012).

The increase has experienced the crocodile population and their migration to areas where they were not present before, plus the human population growth, have increased the probability of encounter between crocodiles and people, and therefore the risk of attacks on humans. Today this situation has generated a conflict with some communities that are not satisfied with the abundance of the crocodiles.

We evaluated the interaction between humans and crocodile from a qualitative approach of social research and used semi-structured interviews to determine human-crocodile interaction in the communities surrounding the area.

Methods

Bolaños (2012) described the Great Tempisque Wetland (GTW). GTW is formed mostly by the Tempisque River basin, which is located in the Guanacaste Province in northwestern Costa Rica. It has an area of 5460 km^2 (54% of the province), equivalent to 10% of the country, making it the country's largest water system (Mora *et al.* 2001).

GTW has a diversity of tropical ecosystems: tropical rain forest and mountain forest; in the mouth of the Tempisque River are mangroves; and, several important wetlands such as Bolson, Riberino Zapandi and Palo Verde (Aguilar *et al*. 1998; Monge-Nájera and Gomez 2007). In areas with lower water levels are mixed forests, including tropical dry and riparian forest, while submerged areas are comprised of swamp vegetation (Monge-Nájera and Gomez 2007).

The main river channel has a length of 194 km (Sánchez 2001). It is navigable on the last 36 km and it is the third most important river in the country in terms of its flow (Monge-Nájera and Gomez 2007). The main factors of conversion of the natural ecosystems in GTW are draining the wetland for use in agriculture, water pollution poisons in agrochemical use, changes in natural flow of the rivers, and forest fires for agricultural use and hunting (Monge-Nájera and Gomez 2007).

We worked there between September 2012 and February 2013 in 22 communities surrounding GTW (Fig. 1). We used social approach through interviews. People interviewed was chosen under these criteria: people who interact with crocodiles due to their daily activities, people living near to the rivers, people affected by crocodiles in the past. We asked people interviewed about three topics: personal information (including age, sex, level of formal education, and the time living in the community), activities and places related to crocodiles (in order to determine interaction, basically where do they work and go for recreation), and tolerance (how many crocodiles people wants to see), this is: which scenario people prefer: 1- no crocodiles in the wetland, 2- less crocodiles than there are now, and 3- crocodiles actually living in the wetland.

Figure 1. Communities visited en Great Tempisque Wetland, Costa Rica, 2012.

Results and Discussion

We did 207 interviews, mostly with adults, with low level of formal education and living in the community all their lives (Fig. 2). People interviewed were mostly men (n= 147) and 60 women. The principal economic activities by men were related to agriculture (43.5%), cattle raising (20.4%) and fishing (13.6%). Women were dedicated mostly to domestic works (81.67%).

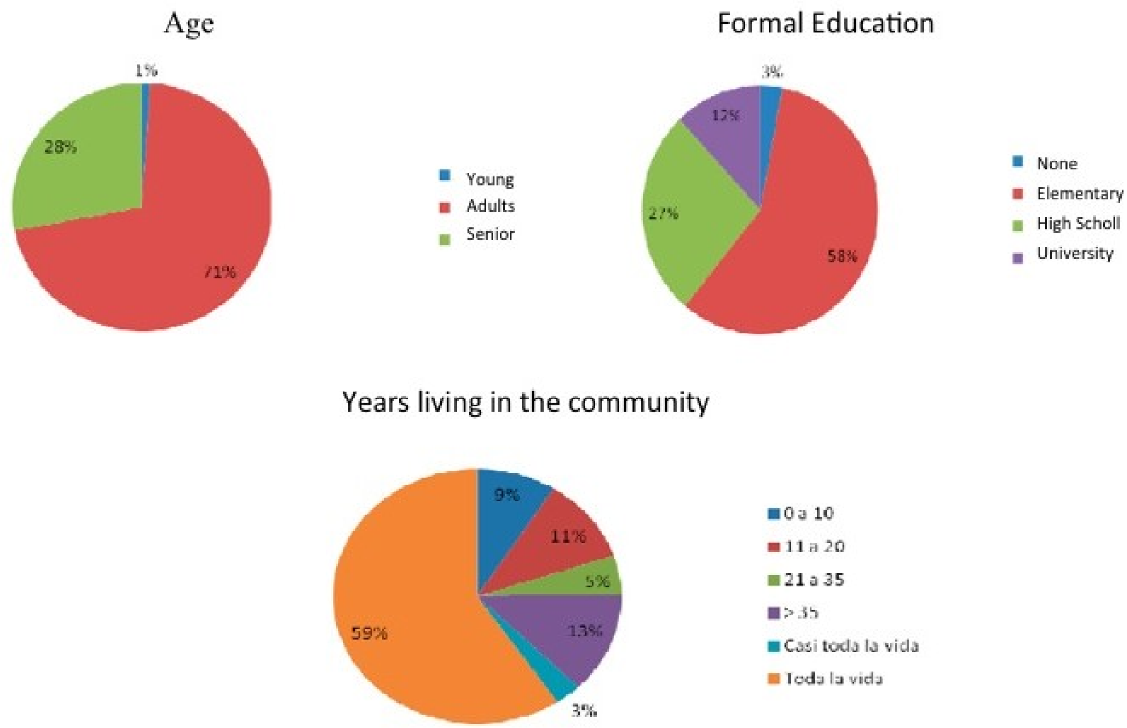

Figure 2. Percentages from the 207 interviews. Age, formal education level, and years livingn in the community. We consider Young < 19 years old, Adults 19 to 60, and Senior >60.

We found that human-crocodile interactions were produced by human economics and recreational activities related directly and indirectly to the rivers and wetlands. We considered activities with direct relationship those that people do inside or in the shore of rivers and wetlands as: a) extraction of river products (fish, clams, sand), b) touristic trips by the rivers, c) swim, d) movement of cattle through wetlands. Likewise, the activities with indirect relationship are those which are not made in the rivers, but near to them, as: a) working in agricultural fields, b) trips to rivers or wetlands, and c) daily activities made by the riverside.

People interview reported that human-crocodile interactions had resulted in 18 non-fatal attacks, of which 10 were on people fishing in the water, 5 on people swimming, 2 on people sitting by the riverside, and one on a person crossing the wetland on horseback. Also people recognized 4 fatal attacks, three of them on people swimming and one on a woman (the only woman attacked) who was walking by the riverside (Fig.

3).

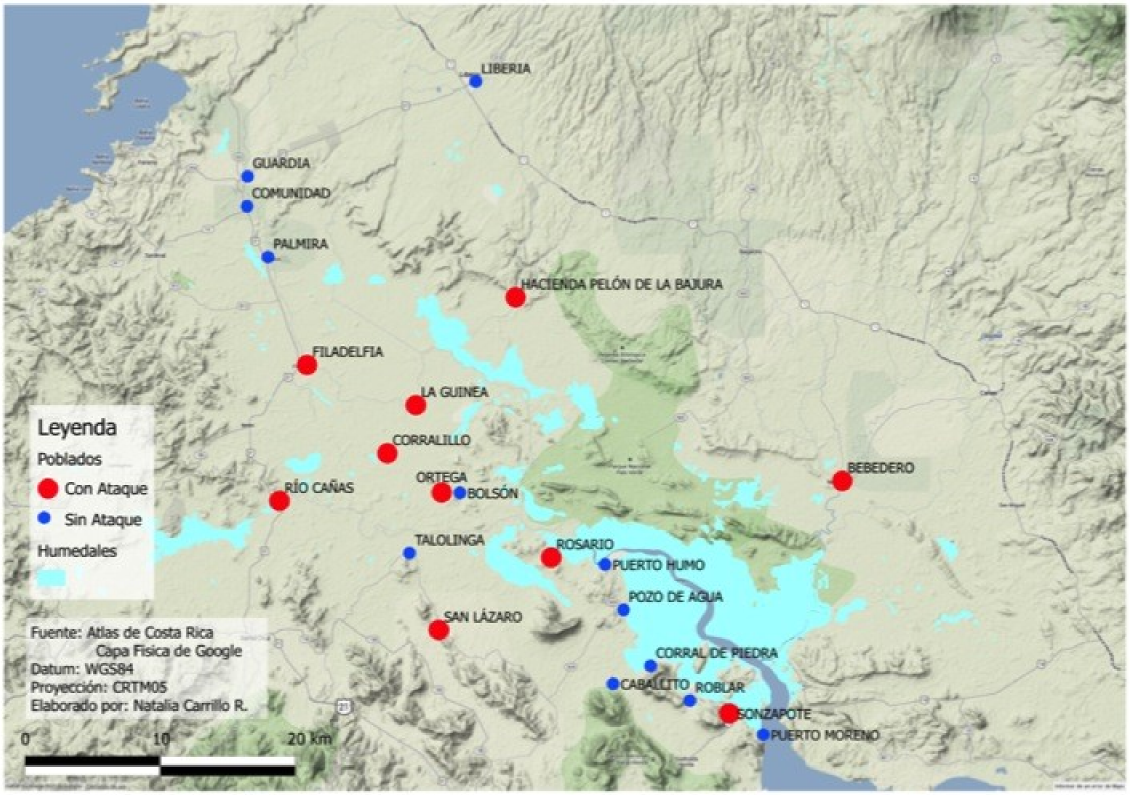

Figure 3. Communities where attacks to humans had been reported.

The reaction after a crocodile attack, was that people sometimes killed one or more crocodiles while looking for “the guilty” one. 101 of the interviewed people said that they know about some cases where crocodiles are killed because of their attacks on people or domestic animals and cattle. In general, people think that crocodiles are dangerous, and represent a risk for humans. But curiously, when we asked people about why crocodiles attack, most of the people mentioned the human imprudence as the main cause (Table 1).

The ideal scenario for people interviewed was one with presence of crocodiles, (69.1% if we add people who wants less crocodiles than actually are and those who want the current scenario). People who want a scenario without crocodiles were mostly those who had no interaction with them, especially housewives (Table 1).

Table 1. What people tell us about how many crocodiles they prefer and why crocodiles attack.

Item	Answer	No. Interviewed	% Interviewed
Scenario	No crocodiles	64	30.9
	Less crocodiles than now	79	38.2
	Current situation	64	30.9
Why crocodiles attack	Imprudence	45	60
	They are aggressive	6	8
	There is no food	9	12
	Defence of hatchlings	8	10.7
	Defence of territory	4	5.3
	Reproductive season	3	4

Not all the human population living in GTW had contact with crocodiles, and either interacts with them. It is clear that interaction between humans and crocodiles are enhanced by activates carried out by people in the river and wetlands. In GTW it is possible to find people who works at home or in places out of the wetland and then their visits to the rivers are null, as well their interaction with crocodiles.

Most of people interviewed said that attacks to people are the principal affectation they're suffered from crocodiles, and also attacks on domestic animals. This is the worst manifestation of interaction and it is the cause of the conflict. This occurs besides most of the people did not experience an attack, they just known someone attacked or listen about the attacks. However it is a real problem for them.

Barrantes (2010) indicated that between 1990 and 2009 there were 40 attacks on people in Costa Rica, 29 of which were non-fatal and 11 which were fatal. Most of those attacks were on the Pacific coast of the country (77.5%) and the crocodiles involved were larger than 3 m (3.4 m 57%, 4.5 m 30%, 5-6 m 13%). Barrantes (2010) said that frequency of crocodile attacks is increasing in Costa Rica. That is the same that is happening in GTW, where crocodile population is also increasing over the last 20 years (Bolaños 2012).

Lamarque *et al*. (2009) list several reasons why crocodile attacks are common: 1) the number of crocodiles is high and its distribution range is wide (which happens with protected populations when are recovering, 2) crocodiles can live near to people and are cryptic, this give them the possibility of attack without be seen. The crocodile population of GTW is protected and data suggest that it has recovered quickly in the last 20 years (Bolaños 2012). To the reasons listed by Lamarque *et al*. (2009), we add the imprudence of people and the feeling of familiarity that people have towards crocodiles and their habitat, because this creates a scenario for more attacks.

Some of the people interviewed mentioned that crocodile population in GTW need to be managed in order to improve the relationship between humans and crocodiles. They proposed: take out all of the big crocodiles and just keep the sizes that do not represent a risk for humans, and relocation of problematic crocodiles.

Recommendations

We need to create a management committee, made up of officials from conservation areas, representatives of affected communities and researchers, in order to manage the conflict as a whole and not in parts.

Establish an Attack Assistance Protocol, or similar, involving both SINAC and the Costa Rican Social Security Service (CCSS). Enabling the SINAC take actions such as moving the animal involved to a wildlife refuge or even kill the crocodile. In addition to the CCSS do accompaniment from professionals in the field of psychology to treat PTSD and prevent future sequels to those affected and the community in the GTW.

Develop a Crocodile module in the environmental education programs of the conservation areas located into GTW to promote more positive attitudes towards crocodiles. The content should highlight the benefits and importance of the presence of crocodiles in the environment, information on the species related to their biology, and behavior. Also, include a high content of the damages and the danger it brings the presence of crocodiles in the area, providing information that what should be done in case of attack and how to avoid it.

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An Analysis of Recent Crocodile Attacks in the Republic of Indonesia - a Case Study on the Utility of the CrocBITE Database

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Abstract

As the country with the highest number of recent attack reports and very little crocodile population data, Indonesia is a perfect example of how CrocBITE can be used as a tool to help inform crocodilian conservation and management. Indonesia is a large, heavily populated nation composed of 34 provinces over an archipelago of 17,508 islands. There are currently four recognized crocodilian species in Indonesia - Saltwater crocodile (*Crocodylus porosus*), Siamese crocodile (*C. siamensis*), New Guinea freshwater crocodile (*C. novaeguineae*) and Tomistoma (*Tomistoma schlegelii*). Between 1 January 2007 and 6 June 2014 we recorded 279 crocodilian attacks resulting in 139 deaths in 27 of the 34 provinces. Attack reports were acquired almost entirely from online news reports, the vast majority of which were reported solely in the Indonesian language. The majority of attacks and deaths were attributed to *C. porosus* (268 attacks resulting in 135 deaths), while *T. schlegelii* was responsible for a small number of attacks and deaths (10 attacks resulting in 4 deaths); a single non-fatal attack was attributed to *C. siamensis*. The information derived from these attacks provides us with important information regarding human-crocodile conflict within Indonesia and which problem areas likely require greater attention.

Introduction

Indonesia is a very large, heavily populated tropical archipelago nation covering over 1.9 million square kilometres and consisting of 17,508 islands over 34 provinces. The current human population of Indonesia is over 253 million people and covers a large number of ethnic groups speaking over 700 different languages (The World Factbook). There are currently four recognized crocodilian species present within the country - Saltwater crocodile (*Crocodylus porosus*), Siamese crocodile (*C. siamensis*), New Guinea freshwater crocodile (*C. novaeguineae*) and Tomistoma (*Tomistoma schlegelii*). The worldwide crocodilian attack database (CrocBITE/www.crocodile-attack.info) has allowed us to examine current and historical crocodilian attack reports. Historical attack reports suggest a much wider distribution for crocodilians in Indonesia during historic times than today. Our more recent attack data, combined with relevant publications regarding population status, suggest that crocodilians are still present throughout the lowlands of Sumatra, Kalimantan (Borneo), Sulawesi, Papua, and many of the smaller islands. On Java the only recent records of attacks on humans have come from western Banten province near Ujung Kulon National Park. The large size and number of islands present within Indonesia, combined with the numerous different ethnic groups present and widely varying infrastructure throughout parts of the archipelago, makes the obtaining of crocodilian attack records quite difficult. In addition, nearly all attacks that are reported by the media never go beyond the local Indonesian language news services.

Methods

Nearly all of the attack records we have obtained from Indonesia came from online news articles that were mostly reported locally and exclusively in the Indonesian language. We used online search engines to find attack reports; important search terms for finding attacks included “buaya diterkam” (“crocodile pounced”), “buaya dimangsa” (“eaten by crocodile”), etc. Online translation tools were then used to translate the articles into the English language. Most of these Indonesian attack articles provided detailed location specifics, including river ("sungai"), village ("desa"), sub-district ("kecamatan") and regency ("kabupaten"). Attack location was usually limited to waterbody and precise location was rarely known, thus the coordinates used for the attack location specify the general area in which the attack may have occurred. Some articles even provided information on which species may have been responsible, which was particularly useful in areas where the determination of the responsible species was difficult (eg non-fatal attacks in far inland areas); "buaya muara" (which translates to "estuary crocodile") referred to *C. porosus*, while "buaya supit" (which translates to "chopstick crocodile") referred to *T. schlegelii*. In most cases however, *C. porosus* was the obvious culprit given habitat type or location; in addition, in most areas *C. porosus* is the only species known to be present. The details of the attack were then entered into an Excel database before being transferred to the online CrocBITE database and publically displayed. Historical attack data (19th Century through to the mid-20th Century) came from news archives of the Dutch East Indies in the Dutch language. The historical data is significantly more limited and less accurate than the modern data, but has nonetheless provided interesting information. There is a noticeable blind-spot in our data from 1960 through 2000, likely due to Indonesian language news archives from this period not being available.

Results

Historical attack data for Indonesia is very limited and sporadic, but so far we have been able to find 131 attacks resulting in 76 deaths dating from 1854 to 1957. New historical reports are consistently found and put into the CrocBITE database. While the historical data is too sparse to providing any useful analysis of historic attack trends, it does provide us with details on the historical distribution of crocodiles (primarily *C. porosus*) within Indonesia and attack frequency in highly-populated areas from which crocodiles have been extirpated in modern times. Historically, attacks were frequently reported from Java, including within the major cities of Jakarta, Semerang and Surabaya. Attacks were also frequently reported from North Sumatra (particularly around Tanjung Balai, where a ban on bathing was reportedly considered during the mid-1930s) and from within the city of Banjarmasin, South Kalimantan. Inland records also suggest a much wider historic distribution of crocodiles in portions of Indonesia than in the present day- attacks were reported from North Sumatra in the Batang Gadis Marsh, an inland valley south of Padang Sidempuan, and from near Pematang Siantar, approximately 33 km east of Lake Toba.

Modern attack reports are, however, much more numerous and useful. For 1 January 2007 to 6 June 2014 we recorded 279 crocodilian attacks resulting in 139 deaths (49.8% fatality rate); the more numerous reports are from the years 2010 through 2014 and this is likely due to the disappearance of media reports from the internet (we didn't start collecting data until October of 2010), rather than an actual increase in the numbers of attacks. Unsurprisingly, the majority of attacks (96.1%) and deaths (97.1%) were attributed to *C. porosus*, while a small number were also attributed to *T. schlegelii* (10 attacks resulting in 4 deaths) and a single non-fatal attack was attributed to *C. siamensis*. Attacks were only attributed to *T. schlegelii* under specific circumstances, including if (in a fatal attack) the victim's remains were recovered from the Tomistoma, if (in a non-fatal attack) the species was positively identified by the victim or if crocodile specialists with knowledge of the attack location or circumstances suggested that the attack was more indicative of *T. schlegelii* than *C. porosus*. The single non-fatal *C. siamensis* incident may have been a case of unintentional provocation by the victim (Agata Staniewicz, pers. comm.). No attacks were attributed to *C. novaeguineae*, although it is possible that attacks did occur, as no attack information for any species is available from the mainland portions of Papua and West Papua where *C. novaeguineae* is present. Skins larger than 3.5 m in length for this species are apparently "regularly reported" from the Sepik River region in neighboring Papua New Guinea (Cox 2010), thus the species certainly grows large enough to represent a potential danger to humans.

Specific provinces and regencies have been the site of high levels of attack frequency. The province with the highest number of reports was East Kalimantan with 40 attacks resulting in 25 deaths, the majority of these reports came from Kutai Kartanegara regency (eg Mahakam River Delta, Santan River) and East Kutai regency (eg Bengalon River, Sangatta River). It is worth mentioning that the number of attacks reported from East Kalimantan has dropped during the past 2 years. The province of South Sumatra had reports of 27 attacks resulting in 20 deaths; the majority of these attacks (85.2%) and deaths (90%) were reported from the Banyuasin regency. The eastern Lesser Sunda Islands province of East Nusa Tenggara had reports of 28 attacks resulting in 14 deaths; the majority of these attacks were reported from Kupang regency (West Timor) and Lembata regency (Lembata Island). Other provinces with high attack report frequency were Riau (25 attacks resulting in 12 deaths), Bangka-Belitung (33 attacks resulting in 11 deaths), Lampung (19 attacks resulting in 9 deaths), Central Kalimantan, and West Kalimantan (each reporting 12 attacks resulting in 7 deaths).

In addition to providing important information on human-crocodile conflict, the Indonesian portion of the CrocBITE database has also revealed some very interesting recent species distribution records through the reporting of attacks. The current distribution of *C. porosus* within Indonesia is poorly known, thus such distribution reports provide useful information. It is unclear if attacks in an area signify a resident crocodile population or itinerant animals and all reports presumably involve *C. porosus*. The small island of Lembata lies approximately 40 km to the east of Flores Island and approximately 100 km northwest of Timor in East Nusa Tenggara Province. From December 2011 through June 2014 8 crocodile attacks resulting in 4 deaths were reported from Lembata's coastal estuaries and beaches. The attack reports suggested that the locals were familiar with crocodiles and viewed them with reverence in much the same way as the Timorese. A single fatal attack was also reported from Flores Island itself, specifically at Lembor in West Manggarai regency in western Flores. Only one non-fatal attack was reported from the western Lesser Sunda Islands province of West Nusa Tenggara. This report came from Woja in Dompu regency on Sumbawa Island. The Riau Islands province had non-fatal attack reports from Great Karimun Island and Bintan Island (both near Singapore), as well as from Lingga Island to the south. Interesting inland attack reports came from Tugumulyo and Purwodadi in the Musi Rawas regency of South Sumatra (approximately 500 km upriver) and the Kuantan Singingi regency of Riau (approximately 375 km upriver); later news reports warning of the crocodile danger in Musi Rawas stated that the crocodile involved was "buaya muara" (*C. porosus*).

Of the 249 attacks in which the sex of the victim was provided, males comprised the majority of victims (77.3%) and deaths (79.1%) within Indonesia. The most common activities associated with attacks were fishing (36.8%), bathing (17.6%) and swimming (14.7%). Fishing activities were defined as any activity where the victim was intentionally attracting or catching fish in the attack area (eg placing/retrieving fishing/shrimp nets, collecting clams or crabs, etc.) since such activities may have caused the crocodile to be attracted to the area. Bathing activities included ritual washings (ablutions), washing faces/feet, etc. and swimming activities included diving for shells, snorkeling, etc. The highest number of attack victims were in the 11-20 year old, 31-40 year old and 41-50 year old age groups, while the highest fatality rates came from the 1-10 year old and 11-20 year old (children and teenagers) age groups.

In some portions of Indonesia the killing of crocodiles in retaliation to attacks appears to be a problem. In recent years there have been numerous reports from Bangka Island of *C. porosus* of all size classes being killed following attacks on humans. On Bangka Island many of these attacks occurred in tin mines and on tin mine workers. In some attack reports from various parts of Indonesia local residents suggested that crocodile attacks did not occur or were rare prior to the destruction of crocodile habitat within the region (in many cases reportedly to make way for oil palm plantations, timber or mining).

Discussion

In the future we hope to find better regional contacts within portions of Indonesia; the country is so large and diverse (ethnically, geographically, etc.) that contacts for particular regions within the country would be very helpful. Of particular importance would be the provinces of Papua and West Papua, from which we have no attack data, and from the Maluku Islands, from which we have limited attack data. We also plan on seeking funding for localized human-crocodile conflict surveys in hot-spot regions; these surveys would include interviews/questionnaires with local people, visiting attack sites, determining the level to which attacks may go unreported, localized surveys for crocodile presence, etc. Similar surveys have been conducted by the Madras Crocodile Trust in the Maharashtra state of India (Whitaker 2007) and Little Andaman Island of the Andaman & Nicobar Islands (Whitaker 2008).

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Attitudes, Perceptions and Knowledge of the Local People Regarding Crocodiles and their Conservation in Charotar Region, Gujarat, India

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Abstract

Wetlands in Charotar region in Gujarat State harbour good population of Mugger crocodiles (*Crocodylus palustris*) which share these wetlands for various ecosystem services (water, fish and space) with humans. Humans and Muggers have been steadily increasing over the past few years around these wetlands, which has resulted in different types of human-crocodile interactions in this region, varying from peaceful coexistence to conflict. Conserving Muggers in these human dominated landscapes require a firm understanding of people's relationship with this species. This research paper examines the attitudes, knowledge and perception towards muggers in agricultural dominated landscapes of Charotar region. A total of 360 interviews, which included 136 female and 224 male respondents from 43 villages, were carried out through key informant interviews to collect data. We analyzed and tested for differences among 4 variables: gender, age, education and occupation. We found an overall positive attitude toward the presence of Muggers in the area. However, local residents indicated a low level of knowledge concerning Muggers and their management. Most (44.75%) respondent reported that the Mugger population has increased over the last 10 years, 11.61% reported that it had remained stable, and only 3.6% reported a decrease in Mugger numbers over these years. Only 48.38% of respondents knew that Muggers are protected species under the *Indian Wildlife Protection Act (1972).* Recommendations developed from this study included: increasing the awareness of Muggers through targeted education, facilitating of stakeholder involvement and exploring different cost-effective conflict mitigation strategies.

Introduction

The Marsh Crocodile or Mugger (*Crocodylus palustris*) is one of the common, widespread and most adaptable crocodilian species in India (Da Silva and Lenin 2010). Muggers are known to inhabit many of the large fresh water bodies in Gujarat (Vijaykumar *et al*. 1999; Vyas 2010, 2013). In the early 1970s the Mugger population in Gujarat was also reported to decline, along with the overall decline in Mugger populations in India (FAO 1974; Vyas 2013). But certain population survived in the state, which was reported as significant compared to other parts of the country (Vyas 2013). The Mugger population in the state was estimated as around 1650 based on the last state-wide survey in 1995-96 (Vijaykumar *et al*. 1997; Vyas 2010). Since then no state-wide survey was carried out, and so the current status of Mugger in Gujarat remains obscure. Most of the Mugger population and its habitat in Gujarat are considered secure and safe, with few exceptions like the Vishwamitri and Narmada Rivers where human-crocodile conflicts have been reported to increase, a phenomenon that is possibly the result of human encroachment into Mugger habitat (Vyas 2010). Some Mugger population in the state is saturated and has dispersed; resulting in increased human-crocodile interactions, especially in and around Vadodara City (Vyas 2005, 2010, 2012, 2013).

Earlier studies (Vijaykumar *et al*. 1999) show few wetlands of Anand and Kheda districts to contain a small number of Muggers. However, recent surveys by Vyas (2013) and Upadhyay and Sahu (2013) have revealed that significant Mugger population exists in Anand and Kheda Districts (together they are known as Charotar) of Gujarat State, who shares these wetlands for various ecosystem services (water, fish and space) with humans. This Mugger population is one of oldest populations in the state, which survived in the state, in the pre-independence period and before the *Indian Wildlife Preservation Act (1972)* was declared (Vyas 2013). The Muggers of Charotar region survive in man-made communal water bodies within the rural agricultural dominated region, establishing an ideal example of man-animal co-existence (Vyas 2013; Upadhyay and Sahu 2013). However populations of both humans and Muggers have been steadily increasing in recent years around these wetlands, which has resulted in different types of human-crocodile interactions in this region, varying from peaceful coexistence to conflict. Only a few cases of Mugger attack have been reported in last few years from our study area, which, based on available evidence, seems to be the result of misidentification and provocation by humans (Upadhyay and Sahu 2013). However, the potential for Mugger-human conflicts are likely to escalate with increasing populations of both humans and Muggers in this rural landscape.

Muggers in this landscape will need to coexist with humans. Managing and conserving Muggers in these human dominated landscapes will require interdisciplinary approaches based on firm understanding of mugger ecology; human dimension; and the complex relationships among people, muggers, and their shared environment. Hence, study of public opinion and knowledge becomes an important element of mugger conservation. Attitudes of people towards the crocodile and their conservation status are poorly understood in India. Likewise no research on public attitudes towards muggers has been published yet from this region. Hence, the purpose of this study was to determine the attitudes, perceptions and knowledge regarding Muggers in the agricultural dominated regions of Charotar region, Gujarat, India, and contribute to the conservation and management of the species.

Methods

From August 2013 to March 2014, as part of a monitoring and conservation project on the Mugger and during the surveys, we carried out the systematic interview-based survey (Annex 1) of adult villagers (18 to 80-year-olds) and young children (11 to 17-year-olds) to understand villagers' perceptions of, and attitudes towards, Muggers and to evaluate the status of Mugger. Our interviews of adults were always aimed at people who either lived in or frequently visited the wetlands in the study areas. A semi-structured survey was prepared in the form of an interview-based questionnaire (Annex 2). Respondents were asked questions relating to dependence on water body, knowledge regarding Mugger, attitude and perception towards Muggers and human-crocodile conflict. Interviews were informally carried out by 1-2 researchers. We interviewed 360 randomly selected adults (136 women and 224 men) belonging to different families from 43 villages (Fig. 1). The area covered by these surveys falls within two districts of Gujarat State, (Anand and Kheda). Results were majorly expressed as a percentage of the responses or as number of respondents.

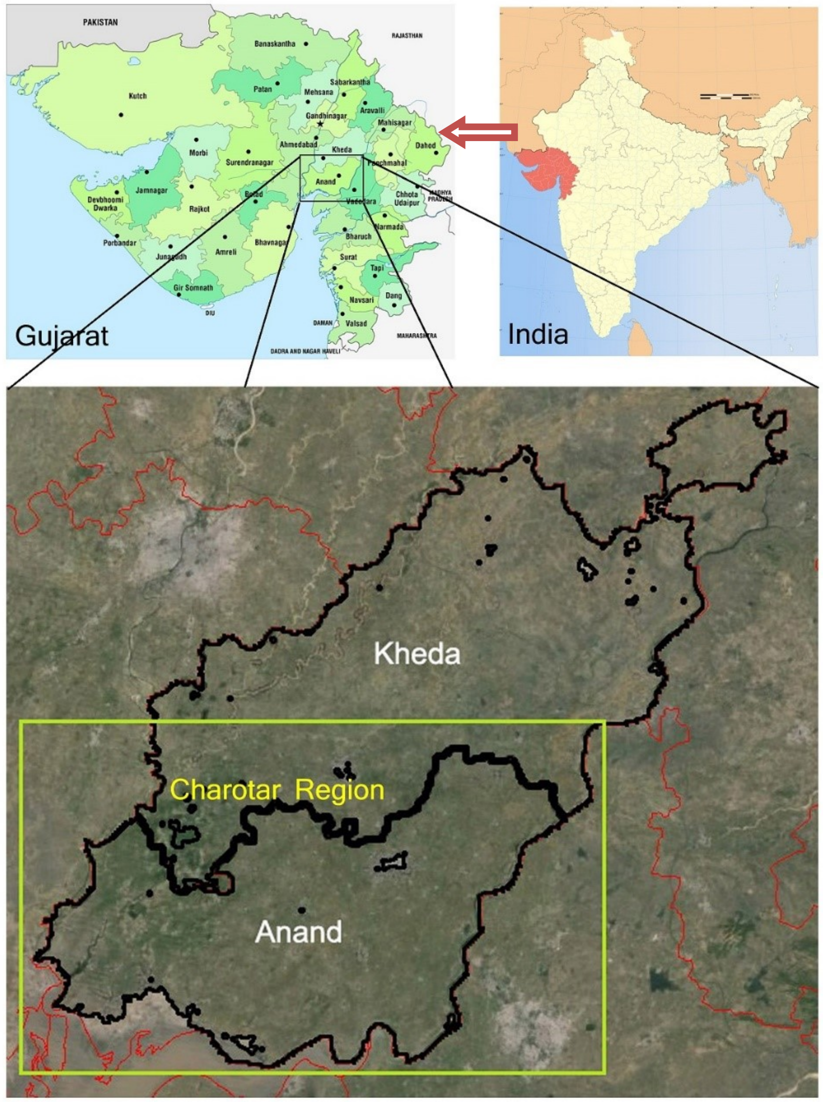

Figure 1. Map of study area - Charotar region, Gujarat, India

Study Area

The study was conducted in the Charotar Region of Gujarat (Fig. 1). Charotar consists of two districts, namely Anand and Kheda. It is located (22°44'N, 72°21'E and 22°15'N, 73°4'E) between the Sabarmati and Mahi Rivers in central Gujarat, and is well known for its crops such as tobacco, pulses, rice and wheat (Mukherjee *et al*. 2000). Large areas in this region are irrigated by the Mahi Irrigation Project (Vyas 2013), and therefore most of the water bodies are interlinked/connected by an extensive irrigation canal network. In Gujarati, the word "Charutar" means a pot full of gold. This was supposedly coined because of the agricultural fertility of the area. Because of the unique mixture of landscape feature, this region also harbours one of the highest densities of Sarus crane (*Grus antigone*) in the state (Mukherjee *et al.* 2002). Although Anand and Kheda Districts do not have significant forested areas, they have high density of trees in the state, and are considered the green bowl of Gujarat (Singh 2013).

Results

Information on respondents

A total of 360 interviews were conducted, which included 136 females and 224 male respondents from 43 villages in the study area, through key informant interviews to collect the data. The respondent belonged to different age groups and had different literacy levels. The research team surveyed 282 adults (above 18 years) and 25 young (up to 18 years) respondents. Twelve respondents did not want to tell us of their age, and so, were excluded from the analysis relating to age. The majority (65.27%) of respondents had either primary (41.94%) or secondary education (23.33%), and only 12.5% of respondents were illiterate. Twelve respondents also had university education. The respondents belonged to various classes of occupation. As expected agriculture (35.56%) was the prominent way of livelihood in the study area, followed by labor work (13.61%). Only seven respondent (1.94%) practiced fishing. Most of the respondent's family (62.78%) had been living in this region for more than 20 years; 27.50% (n= 99) of respondents had moved to this region within the last 20 years.

Dependence on the water bodies

All the Mugger-occupied wetlands were mainly used for activities like bathing, washing and drinking. Only 7 respondents answered that the wetlands are used for fishing too. However, when we asked the question "do you go fishing", 23% of respondents answered that they do occasional fishing. Many (71.66%) respondents also reported that fishing in these wetlands is carried out by fishermen coming from outside the village. The majority of the wetlands are given on lease by the Panchayat (village authority) for fishing. Only 10 respondents said that the wetlands are also used for farming. The peak hours of water use by humans were 0500-1000 h in the water bodies of the study area, which was followed by 1000-1300 h. Livestock mostly used the wetlands in the morning up to 1000 h and in the evening around 1600 h. People also use some of this wetland to grow Indian water chestnut (*Trapa bispinosa*) and Lotus (*Nelumbo nucifera)*.

Figure 2. Women washing clothes watch a crocodile near Deva village**.**


Figure 3. Mugger basking group at Deva Village.

Local people's knowledge regarding Mugger

Mugger were reportedly seen in the nearby wetlands by 86.94% of respondent. Only 22 respondents replied that they didn't see any Mugger in the wild. Surprisingly, among the 8 females who replied "no" to "seeing a crocodile in the nearby area", two and one females belonged to Vaso and Heranj village respectively, which have significant Mugger populations in the village ponds. 63.33% of respondents said that the sole food of these Muggers in this region is fish only. 16.11% (n= 58) of respondent also included other prey species such as birds, pigs, dogs and insects. Bird species reported included peafowl, ducks, crane and water hens. Only 8 respondents reported that Muggers also prey on livestock in addition to fishes. Interestingly some of the respondent (n= 25) also reported that the Muggers in this region also eat cow dung, and the muggers are referred as "Chhaniya mugger" means Dung crocodiles. 44.75% of respondents reported that the Mugger population has increased over the last 10 years, 11.61% reported that it has remained stable, and only 3.6% reported a decrease. 48.38% of respondents knew that Muggers are protected species under the *Indian Wildlife Protection Act (1972).* Awareness that the Mugger is a protected species was more prevalent among males (54.91%) than females (30.16%). Information on nesting and breeding was also collected through interviews. The people's answers were in accordance with the data collected by our research team (see Annex 2).

Attitude and perception regarding Muggers

81% (n= 210) of respondents said that they like Mugger, of which 67.61% were males and 32.39% were females. Among those who said they didn't like Mugger, the majority were males (68.57%). Male respondents who liked Mugger majorly belonged to 31-40 (23.94%) and 41-50 (26.06%) age groups. A similar trend was observed with females. Unexpectedly, "beautiful animal" (41.87%) followed by "religious reasons" (33%) emerged as the major reason for liking the Muggers. "Beautiful animal" (47.90%) was the major reason why most males liked the Mugger, on the contrary females liked the species because of its religious sentiments (37.50). 6.90% said that they liked the species because it is an endangered species and need protection. 13.30% liked Mugger because of its ecological importance in the ecosystem.

81.82% of respondents who replied to the question “Should these Muggers be conserved?”, agreed that the Mugger should be conserved. Only 4.90% respondents replied that the Muggers should not be conserved. Among the positive respondent 69.70% were males and 30.30% were females. Among those who were in favor of Mugger conservation belonged to the younger 18-30 age group (30.81%), followed by 41-50 age group (23.74%). Mugger should be conserved was represented majorly among all the age groups and literacy level. Irrespective of age groups and literacy levels, majority of the respondent (67.52%) who wanted to conserve Muggers replied that the they should be conserved where they are presently occurring. 15.81% also suggested that the Mugger should be conserved in the protected areas and not there near the villages.

To test the intensity of the positive attitudes of the people we asked the question “ will you support Mugger conservation, even if any of your family member is attacked?” And we received mixed results. 28.71% of respondents still agreed to conserve the Mugger, whereas 27.75% replied they will not conserve Mugger, in case their family member is attacked. 37.32% of respondents remained neutral to the query. Of the respondents who didn’t like Mugger, 33.33% attributed the reason to the scary look of the Mugger, while 31.58% said it was because it is a threat to livestock. 24.56% of respondents also said that since Muggers are a threat to humans, they don’t like them. Interestingly, the scary appearance of Mugger was the major reason (50%) why females don’t like them, followed by threat to humans (27.78%). Contrary to women, threat to livestock emerged as the major reason male respondent do not like them.

Human-Crocodile Conflict in Charotar

At present, Muggers in Charotar do not in itself appear to be a problem, but the wild populations are increasing in the region (Vyas 2013; Upadhyay and Sahu 2013) and there are cases of Mugger attacking human and their livestock. A total of 10 cases of crocodile attacks were reported during the survey. Among these, 3 attacks were reported on humans and 6 attacks on livestock (2 on goats, 4 on buffalo and one on dog). Of the 3 attacks on humans only one was fatal. Details of two crocodile attacks on humans have been already provided by Upadhyay and Sahu (2013) and Vyas (2013). The third case of attack came in light during the interview survey, where a woman in Deva was attacked while washing clothes in the lake. Her hand was caught by the Mugger, but was released with seconds, leaving her with minor injuries. Apart of aforementioned incidents, no other incidents of attacks were recorded in the study area. There could be few more instances of crocodile's attacks on animals (livestock/pets) in this region that remain unrecorded.

Discussion

Our samples were not equal, with male respondents almost double the number than females across age group, but our response rate was high. Females in rural India do not interact much with males other than her family members. We tried to conduct more interviews with females, but they were reluctant to talk to us, even to our female team members. We also had less student respondents. So our results must be analyzed with caution because of potential biases. The overall conclusion from implementing sampling procedures is the importance of personal contact with authorities. In villages contacting the village head prior to contacting individual respondents were incredibly important and certainly an important reason behind the high response rates.

The respondents’ views of Muggers were surprisingly favorable in our study area, considering that Muggers were feared for threatening human lives and livestock. This can have important implications for the conservation of Muggers in this region, as these populations are surviving outside the protected area and need immediate conservation and management measures. Our study allows identification of certain target groups important for conservation and management of Muggers. We found that the acceptance of Muggers in Charotar depended largely on the literacy level and to certain extent age of respondents. We hypothesized that women would express more concerns about Muggers than men would. In fact, overall men and women had similar concerns. We found some support for our hypothesis, however, in that more women than men were concerned about the danger posed by mugger to human life. By contrast, women and men showed almost equal tolerance toward Mugger. Age differences were also limited and mostly concerned contrasts between those in the young and old age groups. We hypothesized that older people would express more concerns about Mugger than younger people. Consistent with this hypothesis, less tolerance of Mugger was shown by older than by younger people. Younger people also consider Mugger a “beautiful species” more than older people. By contrast, older people saw Mugger as more of a danger to domestic animals and had more knowledge about Mugger than younger people did. Older persons’ concerns may have been leavened with more knowledge of the animals than younger people had. Although the main variable accounting for negative attitudes towards Muggers was concern for safety, many other complex variables are also involved.

Certain key findings emerge from this study, these being relevant to both the social understanding of mugger perception, and knowledge of human-Mugger relations in Charotar region. Age, education and gender were relevant to attitude and perception of Mugger, but their influence varied according to the topic discussed. Our results indicated an education-biased attitude regarding the Mugger. Mugger, although to lesser extent, were also seen negatively, based more on their intrusion into human spaces, livestock depredation and fear of attacks on humans than their natural behavior in “natural” areas. Despite pronounced urbanization and reduction of habitats, Muggers played an important role in people’s consciousness. Despite some mugger attacks, tolerance for these animals persists, though more among the younger generation and literate than among older people and illiterate.

Mugger conservation in Charotar

Currently the Mugger populations in Charotar region seems to be doing fine, however certain threats were identified during earlier surveys (Upadhyay and Sahu 2013; Vyas 2013). Muggers in Charotar live in very close proximity to the humans. This close proximity might result in conflict and can be particularly controversial when there is a question of human life or of the resources that have economic value such as livestock depredation, and the predators involved have a high conservation profile. With increasing mugger populations in the region, it is difficult to ascertain that they would not pose a problem to local people, who regularly share these wetlands with the Muggers. Although religious beliefs might be one of the factor for the low level of conflict (Vyas 2003), but is clearly not the major one. Their existences have been positively accepted majorly because of the fact that there have been very few attacks in this region. In other words the acceptance of Mugger by local people in this area depends on the degree of their contacts with Muggers. So incident of few attacks could possibly lead to the rise in negative attitudes.

Upadhyay and Sahu (2013) reported one incident, wherein one girl was attacked and killed by a Mugger in Traj Village in the study region. Agitated people demanded removal of Muggers from that village and as a result 7-8 Muggers were captured and removed somewhere else. As suggested (Upadhyay and Sahu 2013,) the cases of Mugger attacks on humans seem to be the result of mistaken identity and/or human negligence. Upadhyay and Sahu (2013) rightly pointed out that another reason for the minimal conflict in this region is that people do not offer anything to these Muggers, due to which the Muggers do not come out from their territories in to the human settlements. However during our surveys we found that in Deva village, which has the one of the highest numbers of Mugger in Charotar (Upadhyay and Sahu 2013; Vyas 2013), animal skinners of the village leave dead skinned livestock near the lake for the Muggers. Such behaviour could encourage Muggers to lose their fear of humans and to come out from the water in search of easy food, leading to a close encounters with humans.

Moreover the media seems to play a major role in influencing the attitudes of the people. Most wetlands of Charotar are interconnected by canals, so during monsoon when the water rises in wetlands and the interconnecting canals, Muggers move from one village to another, sometimes reaching places where the people may not have seen any Muggers. Such incidents are negatively highlighted by the media. We can't ignore the fact that, the people do fear of the crocodile attacks, and that such negative publicity may, while increasing the negative attitude, will hinder the conservation of Muggers in Charotar and adjoining areas.

The other aspects of conservation and threats to Mugger have been discussed by Vyas (2013) and Upadhyay and Sahu (2013) in detail. The local people are not majorly involved in fishing, and pose no threat to the Muggers or to the wetlands. The real problem is the commercial fishing carried out in this wetlands. Most of the wetlands have been leased out by the village Panchayat (village authority) to fishing contractors. During their fishing season they put large fishing nets in the wetlands, wherein sometime the muggers get caught in the fishing net. If not removed at the appropriate time, the animal might suffocate to death. Also these fishermen, who mostly come outside Gujarat, intentionally capture the mugger, tie them up and keep outside the water till they finish fishing, so as to protect their nets from breaking by Muggers. Such fishing practice may injure the animal while capturing and keeping them tied up. It was during such fishing event at Traj Village that a Mugger was captured in nets, which was then tied up and kept at the bank. One of the kids playing nearby went to close to the animal and was attacked by the Mugger (Upadhyay and Sahu 2013). The boy was rescued but was injured badly.

Another threat which was identified is that the increased road network. One incident of Mugger death on road was recorded during the survey. One crocodile (1.64 m; 5.38') was killed near Deva Village while crossing the road. During the monsoon, Muggers in this region engage in local migration moving from one wetland to another. During such movements they have to sometime cross roads and railway tracks. It was during such movement that the animal was run over by some vehicle. Encroachment in to the Mugger habitat was also found to be a serious threat to their survival. In April 2014, many Mugger burrows were destroyed while reconstruction the side of the canal at Deva Village, which harbours significant Mugger populations in the area (Upadhyay and Sahu 2013; Vyas 2013).

Figure 3. Mugger run over and killed by a vehicle on road near Deva Village, Gujarat, India.

Figure 4. Injury marks on a cow's leg, caught by Mugger at Traj Village, Gujarat.

Recommendations

Although frequency of interactions between humans and Muggers have been increasing throughout Gujarat (Vyas 2010), public awareness of this ubiquitous species has generally been overshadowed by other species. Long-term conservation of the Muggers in this region will depend on the ability of wildlife professionals to develop effective education strategies and increase the awareness of locals to maintain and improve human attitudes toward these species. The effectiveness of education strategies will depend on the implementation of educational program strategies by multi-disciplinary groups. It is also crucial to develop strategies to reduce problems between Muggers and human, otherwise increasing the attitude would be an almost impossible goal. A better appreciation by local people of the role of this prehistoric animal as "manager of the wetlands" should be emphasized in educational programs. Acceptance of predators not only depends on animal characteristics, but also on people's demographic and personal variables, which implies that sociologists, educators, and other professional involved in rural development should be involved in conservation actions. A better overall protection to the wetlands and crocodiles, will assure a safer home for this species on a long-term basis. Regular, planned and systematic surveys of all wetlands and other potential habitats are necessary which will help in keeping a tract of the changes in Mugger populations in Charotar region. There is also an urgent need for the Forest Department to establish a ground staff for protection, law enforcement and monitoring of the Muggers in the region.

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Appendix 1. Following questionnaire was used during the survey.

A. Basic information
1) Age and sex
2) Education:
3) Occupation:
4) How long you have lived in this place?

B. Dependence on water body
5) How do you depend on the near water body? (Drinking, bathing & washing clothes, washing of household materials etc.)
6) Time of utilization of water body by humans
7) Time of utilization of water body by livestock
8) Do you go fishing? (yes/no, if yes, specify mode of fishing)
9) Do the people from outside village come for fishing? (if yes, specify the place & time of the year)
10) Any other products that you collect from nearby water bodies?

C. Local people's knowledge on mugger
11) Have you seen crocodiles in the wild/near you? Yes/No, (if yes, where and how many?)
12) How often do you see them?
13) What do they eat?
14) Do they nest here?
15) Did you see the mugger eggs/hatchlings? Yes/No (If yes, how much and when?)
16) Has number of crocodiles on nearby wetland/water body/property increased in the last 10 years?
17) Do you know that crocodiles are protected? Yes/No

D. Attitude and tolerance to Muggers
18) Do you like Muggers? (Yes/ No)
19) If yes, why do you like them? (If no, skip to question No. 24)
    (a) Beautiful Animal (b) endangered species (c) maintains ecosystem (d) religious
20) Do you like mugger near you? (Yes/No)
21) Should these muggers be conserved? (Yes/No)
22) Where these muggers should be conserved?
23) Will you support mugger conservation even if a family member is attacked and injured?
    (a) Agree (b) Neutral (c) Disagree
24) Why don't you like muggers?

E. Crocodile conflict
25) Any incidence of crocodile attack on livestock/poultry/pets? (If yes, then when and where?) (If no , skip to question no.27)
26) Do you guard your livestock near water bodies? Yes/No
27) Any incidence of crocodile attack on humans? Yes/No (if yes provide details/If no, don't ask further question)
28) Why do you think they attack?
29) Have people ever tried to control/kill these problematic muggers? Y/N
30) If Yes, then how?
31) What steps the forest department takes to solve this problem?
32) Are you satisfied with current problem-mugger management by forest department? (Yes/No)
33) If no, what should be the problem mugger management strategy?

Appendix 2. Information regarding fishing activities and Mugger status at the wetlands surveyed. The numbers displayed in the table represents the number of respondents.

Sr. No	Village	Mugger Status	Do you go fishing?		Do people from outside village come for fishing?		Do muggers make den here?		Did you see the mugger eggs/ hatchlings?	
			Yes	No	Yes	No	Yes	No	Yes	No
1.	Asmali	A		1		1				
2.	Balinta	A		2	1	1		1	1	
3.	Baroda	A		1		1		1		
4.	Bhaat-Talavdi	P					1		1	
5.	Bhadkat	P	1	1	2			1		2
6.	Bhaloda	P		1		1	1			1
7.	Buddhej	A		1		1				
8.	Changa	P	4	4	8			5	2	6
9.	Dabhou	P	7	6	11	2	10	2	4	8
10.	Dali	p		2	1	1	2			2
11.	Dethali	P		2	2		1	1		2
12.	Deva	P	13	26	44	1	46	1	36	12
13.	Devataj	P		1		1				
14.	Gada	A		1				1		
15.	Gangapur	P	1	2	3		2			
16.	Gorad	A	1	1	2			2		2
17.	Heranj	P	2	35	34	4	35	1	20	18
18.	Kasok	A	1	1						
19.	Kathoda	P	1	12	11	2	3	5	7	3
20.	Khandhali	P	5	12	15	2	11	3	8	8
21.	Kunjra	A		1		1				
22.	Laval	P	2	2	5		9		7	1
23.	Machhiel	P	3	18	20	2	21	2	8	14
24.	Magrol	P	3	1	4					
25.	Mahelaj	A		2				2		1
26.	Malataj	P	4	21	23	1	21	3	13	12
27.	Marala	P	5	5	5		2	2	2	6
28.	Moraj	A		1	1			1		
29.	Nagra	P	12	16	18	7	18	7	9	18
30.	Nandoli	P		2	1		1	1		2
31.	New Pallla	A		1		1				
32.	Palo	A		2	1	1		2		2
33.	Pariyej	A		1	1			1		1
34.	Rampur	A		1						
35.	Pij	P	1		1			1		1
36.	Shekhpur	A		1		1				
37.	Sojitra	P	2	7	9		3	6	2	4
38.	Traj	P	4	20	19	2	23	1	15	9
39.	Tranja	P	2	3	3		5	1	3	2
40.	Utai	P	2	1	3	1		3	3	
41.	Valli Kenaval	A	2					2		2
42.	Vaso	P	7	3	8	1	13		4	5
43.	Virol	P	1	1	2		1	1		1

A - Absent, P – Present

River, Mountains, Deserts: The Fractured Neotropics – How Many Caimans Are There?

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Abstract

The Caimaninae of the Neotropics represent a large proportion of the known crocodilian species, and they are common in most lowland streams, rivers and lakes within their distribution. The two most numerous species, *Caiman crocodilus* and *Caiman yacare*, are subjects of ongoing debates over taxonomy and distribution. Molecular data was used to demonstrate the relationships of caiman from the described ranges of *C. c. fuscus*, *C. c. chaipasius*, *C. c. crocodilus* and *C. yacare*. Haplotypes for mitochondrial (mtDNA) cytochrome *b* from Mexico (2), Central America (21), Caribbean South America (1) and the Orinoco (5), Amazon (51) Mamoré (16) and Paraná (9) river basins were used for phylogeographic analyses.

The resulting clades support the existing taxonomy but also give evidence for additional Evolutionary Significant Units (ESUs) and challenge some described range assumptions and boundaries. Tree alignments show closer phylogenetic association of Mesoamerican caiman and *C. yacare* than with *C. c. crocodilus* from either the Orinoco or Amazon Basins. This break occurred approximately 7-8 million years before present (ma). A review of paleogeologic events leading up to the current geography that shapes the existing distributions is presented. A complex combination of tectonic, environmental, interspecific and anthropogenic forces present barriers that reproductively isolate caiman populations, resulting in genetic differentiation.

Introduction

The extant crocodylian species are the result of over 200 million years of evolution. During that long and rich history, there was a significant radiation of species into a wide variety of habitats and niches. They developed complex behaviors and intelligence that have helped them survive on evolving landscapes. Though often referred to as 'Living Dinosaurs', crocodilian species continue to evolve and are very different from their Archosaurian ancestors. The general body plan was attained early in the evolutionary history and retained remarkably intact, leading to the common notion that somehow they remained unchanged.

The Caimaninae are an interesting group of Alligatorids inhabiting much of the lowland Neotropics. The caiman species have evolved on a very dynamic landscape shaped by the forces of plate tectonics, Andean uplift, major river basin evolution and climate change. There is an ongoing debate about the taxonomy and distribution of *Caiman*. In this analysis, I have compared haplotypes of the mitochondrial gene cytochrome *b* in samples of the *Caiman crocodilus*/*yacare* complex from the northern limits of Mexico and Honduras, through Central America and including the major river basins of South America: Orinoco, Amazon and Paraguay-Paraná to northern Argentina. For simplicity in this manuscript, I refer to *Caiman* as all evolutionary significant units (ESUs) known as *crocodilus*, *fuscus, chiapasius* and *yacare* but not including the closest relative, *Caiman latirostris*.

The resulting cladograms display interesting genetic relationships between groups, and often sort into taxonomically unrecognized ESUs. When assessed, these trees are highly correlated to geography but also pose some puzzling associations. A review of recent literature regarding the closure of the Isthmus of Panama, orogenesis of the Andes with the resulting climatic effects, the paleogeology of the South American Plate and evolution of its great river basins, and potential interspecific competition with

Crocodylus spp., extinct crocodyliforms, and now *Homo* – contribute to reconstructing the present wide distribution of the caiman group.

Taxonomy Primer

Extensive reviews of caiman taxonomy have been undertaken with references to all minor changes, synonyms, etc. (eg King and Burke, 1989, Vliet, (This volume), and only the highlights important to this discussion are mentioned. Linnaeus (1758) was the origin of the first caiman name, *Lacerta crocodilus*, and first to cause confusion. He examined and named thousands of botanical and zoological specimens using his new system of nomenclature. Many came from unseen continents, as he never left Europe. The preserved types (most) are distinctly hatchling and juvenile *Caiman crocodilus*, but they are neither crocodiles nor the specimens of his written description. No collector or locality data were recorded. Medem (1981) stated that Linnaeus had described a *Caiman latirostris* from Brazil, but any corresponding voucher specimen has been lost.

Schneider (1801) described *Crocodilus sclerops*, from which the synonym *Caiman sclerops* arose, with no type locality. Despite Dr. Medem's arguments on the Rules of Priority governing systematics, *C. sclerops* has fallen into disuse in favor of *C. crocodilus*. François Daudin (1802) first described *Crocodilus latirostris* and *C. yacare* as species distinct from *C. crocodilus*. Some authors currently refer to *Caiman c. yacare* due to similarity but no formal diagnosis has been put forward as a subspecies. Johann von Spix, a German biologist, made extensive travels in Brazil. He described the genus *Caiman* (1825), and *C. niger*, the black caiman from the upper Amazon. In 1862, English taxonomist John Gray described a new genus for *Melanosuchus niger*, which has maintained usage despite arguments that it belongs to a monophyletic group and should revert to *C. niger*.

In 1868, E.D. Cope examined a caiman from the Magdalena River of Colombia's Caribbean coast. He described a specimen that Neill (1971) referred to as 'highly aberrant', giving it a new genus – *Perosuchus fuscus*, the brown caiman. It currently regarded as a subspecies, *Caiman c. fuscus*. The French zoologist Marie Firmin Bocourt wrote a brief description a caiman he discovered in the Mexican State of Chiapas, *Alligator chiapasius*, in 1876. Most authors regard this as either a C. *crocodilus* subspecies or synonym to *C. c. fuscus*. Adding to the confusion, it is often more uniformly brown than *fuscus*, the 'brown caiman'. Dr. Federico Medem collected a series of narrow-snouted caiman from the upper río Apaporis and in 1955 described *C. c. apaporiensis*. Donnoso-Barros wrote a controversial description (1974) of new subspecies *Caiman yacare medemi* in the Amazon drainage and *C. y. yacare* in the río Paraguay drainage. The treatment was unconvincing and authors did not adopt usage.

Distribution

Early descriptions often lacked even basic locality information. Travelers' accounts offered only vague and often unreliable references. Over time, a better understanding of the limits of the distribution of *C. crocodilus*/*yacare* complex was determined, even if the boundaries for the species/subspecies were not. Herpetologist K.P. Schmidt reviewed the group (1928) and concluded that the caimans consisted of *Paleosuchus trigonatus*, *P. palpebrosus*, *Caiman niger*, *C. latirostris*, *C. yacare*, *C. sclerops* and *C. fuscus*. In 1953, Fred Medem examined *chiapasius* paratypes at Harvard as well as other Central American specimens and concluded that they were unique.

North

Dr. Medem's later work took him to northern Colombia's Chocó, at the base of the Panama Isthmus. He noticed the variation in caiman outside the río Magdalena area, the *fuscus* type locality. He contrasted specimens from the Pacific slope and the western Colombian coast along the Caribbean, all *chiapasius*, with those of *fuscus* and published his data (1962). The report had a detailed distribution map of the crocodilian species sighted in the Chocó, one of the first for the Neotropics. He proposed to re-introduce *chiapasius* as a valid subspecies and it is generally recognized.

The written distributions of the era listed the 'spectacled' caiman from southern Mexico to Ecuador on the Pacific, and on the Atlantic side, from Nicaragua south and east through the Orinoco and Amazon basins to Argentina. Often only countries would be listed, or small range maps would display large swaths, including uninhabitable areas of Andes or Brazilian and Guiana shields. These constructs give an impression of connectivity in populations over immense landscapes that does not exist. Isolating geographic features must be recognized to understand gene flow through the broad but convoluted distribution.

At the first meeting Crocodile Specialists Group in 1971, most attention was placed toward worldwide declining populations and trade statistics of commercially important species. Countrywide surveys had not been conducted and most distribution details were generally unknown. When Medem's two volumes (1981, 1983) appeared, they contained valuable new information on South American crocodilians. Many areas have no further updates. He placed particular importance on the precise maps that accompanied the books, and markers were placed for all reliable, identified sightings.

Caiman c. chaipasius was known from Central America and along the Pacific slope as previously described, but Medem considered the río Atrato to the Golfo de Urubá as the eastern limit in Colombia. About 150 km further eastward is his first *fuscus* record. Localities for *fuscus* continue eastward through the significant Magdalena-Cauca river complex, across the arid Guajira peninsula, on through the Lago Maracaibo basin, and along partly arid coastal plain of Falcon State, Venezuela until habitat diminishes at the Coastal Range just south of río Yaracuy. Thorbjarnarson (pers. comm.) also felt the Yaracuy limit for *fuscus* was observable in phenotypes, but no one has detailed the distribution along that coast. Most recently, Venegas-Anaya *et al.*, (2008) demonstrated a distinct *chiapasius* clade and questioned the traditional *chiapasius*/*fuscus* boundaries with compelling genetic analysis.

Venegas-Anaya *et al.* (2008) clearly demonstrated three clades of Mesoamerican *Caiman*. One clade includes the type locality for *chiapasius* and appears limited to the Pacific coast of Mexico, Guatemala, and El Salvador, the other clades from Costa Rica, Panama and Colombia refer to *fuscus*, including a sample from the type river system. These findings greatly reduce the distribution for *chiapasius*, and increases range for *fuscus*. Escobedo-Galván *et al.* (2011) reinforced the new findings with the most accurate published range map for *chiapasius* and *fuscus*.

Certainly, in past times, interspecific competition would have limited or excluded *Caiman* in many locations along the 'Caribbean Gauntlet', the narrow belt of separated habitat islands along the north coast of Venezuela. Over 800 km separate caiman populations in Lake Maracaibo Basin from those in the Orinoco delta. These include difficult coastal environments that have impeded genetic flow from Orinoco populations. For 200 km east of the Yaracuy River mouth, the mountains of the Coastal Range plunge steeply down towards the sea, leaving scant suitable habitat for most of the distance. Streams have steep gradients and afford minimal habitat near the coast. These are generally more suited for *Crocodylus acutus* and were inhabited until recent times. Seijas (1986) recorded *Caiman crocodilus* present in many of these intermediate coastal zones but did not attempt to identify subspecies. Detailed investigation may prove a clinal distribution, but this section of coast may provide a reproductive barrier to the Mesoamerican populations of *fuscus*/*chiapasius* from source populations *C. crocodilus* in the Orinoco.

Central

For the remainder of the distribution that spans the Orinoco, Amazon and Guiana coastal rivers, Medem considered them all as one, *C. c. crocodilus*, save the upper río Apaporis (not included in this study).

Although he detailed all this in his maps and second volume, he inexplicably included some confusing text regarding Colombian *Caiman* in the first volume. Medem failed to include *C. c. crocodilus* (*sclerops sclerops*) in a valid subspecies list, and thus the drawings and photographs of Amazon or Orinoco caiman are all titled without subspecies, as *Caiman sclerops* referring only to many population demes in various river systems. I spoke with him directly on this and he replied that the publication was a mess and that he had lots of corrections to make. He died before those were addressed. Gorzula and Seijas (1989) produced a summary of the following 20 years of research but with no new distribution information.

The Orinoco and Amazon river basins are geographically isolated, for all practical purposes. Much has been made over the Casiquiare river connection between the two basins, actually a distributary of the Orinoco, but is little evidence for biotic interchange from one to the other. Reproductively, the gene pools are isolated from each other. Vasconcelos *et al.* (2006) found good genetic diversity among Amazon caiman, and isolation by distance. Caiman haplotypes from the Atlantic coast formed a subclade that was significantly differentiated, but was related to the Amazon lineage. This was an expected outcome, as the most likely source material would have been derived from Amazon stock. The major coastal currents are strongly NW, sweeping the gigantic delta plume of fresh water and sediments towards Trinidad (Hu *et al*. 2004). These effects persist for hundreds of kilometers depending on the season and would help assist migration along the coast. Previous inland connections of Guayana and Fr. Guiana systems to the Amazon basin, may explain the migration there of *Melanosuchus* (de Thoisy et al. 2006). Perhaps *Caiman* also used this now closed route.

South

For the southern populations, *Caiman yacare* is used, as was described by Daudin (1802). It inhabits the río Mamoré basin, the upper part of the Madeira (Amazon) system, as well as part of the Paraguay-Paraná system. It has been alternatively referred to as *C.c. yacare*, but I believe the molecular data show that it is comprises a distinct lineage, and can be further subdivided in two haplotype groups, corresponding to the 2 river basins it inhabits (Godshalk 2008a). The Mamoré drainage is separated from the lower Madeira by a 200 km, narrow stretch of river dominated by 16 major rapids. The river has breached the Brazilian shield but is constrained by the substrate. This has proved to be a barrier for a variety of aquatic taxa, but not all (Farias *et al*. 2010). Two proposed dams along this section in Brazil will change conditions for the near future.

A recent study (Hrbek 2008) looked at *crocodilus*/*yacare* along this corridor and concluded that either hybridization, or clinal differentiation explained the results. As seen in many other crocodylians, things get messy at the edges and hybrids can present problems to analyses. The rapids might work partly as a one-way valve – restricting upstream flow but not as much downstream. In my analyses, Mamore and Paraguay *yacare* haplotypes always separated from the Vasconcelos *et al.* (2006) material with statistical support. *C. yacare* also occurs in the Paraguay drainage along its length but is limited by the arid and haline Chaco desert in western Paraguay. The distribution continues a little further south on the lower río Paraná.

Materials and Methods

The genetic relationship of caiman from a wide variety of localities has just begun to be explored. The largest possible caiman phylogenetic data base was compiled, using the most widespread localities, to refine the phylogenetic relationships. Mitochondrial cytochrome *b* haplotype sequences were collected from a variety of species and subspecies that were archived in GenBank subsequent to publications (Janke *et al*. 2001, Farias *et al.* 2004, Vasconcelos *et al.* 2006, Hrbek *et al*. 2008, Venegas-Anaya *et al.* 2008). Haplotypes previously sequenced for prior studies were also added (Godshalk 2008a,b). For all details referring to the handling of samples, primers, lab techniques, etc., please see the source references. After compiling a master database of over 100 Caiman haplotypes, subsets were subjected to various preliminary analyses - these results are far from exhaustive. Information is provided regarding the phylogenetic affinities, taxonomic validations, geographic influences, and resulting distributions.

For these analyses, sequences ranged from 1150-1250 bp, usually including all or most of the 1147 bp of the cytochrome *b* gene. The following haplotypes were used - *C. crocodilus*: 23 haplotypes from Mesoamerica, the described locality of *C. c. chiapasius*. The majority were from Venegas-Anaya *et al.* (2008) study. Included in that study, is a map (Fig 1, p 619) of the "traditionally accepted geographic ranges of the three subspecies" that mark boundaries unsupported by any literature and is in contrast to Medem's (and others) observations. This also had an effect on the published conclusions.

A Caribbean coast haplotype from South America (Venegas-Anaya 2008) was the only sample from a '*fuscus*' locality as described by Medem. Included was material from Honduras' Caribbean coast, the northern Atlantic limit of the subspecies and an area not sampled for the Venegas-Anaya *et al.* (2008) study, and 5 haplotypes from the Orinoco basin, assumed to be *C. c. crocodilus* (Godshalk 2008b). Among the data set were 45 haplotypes derived from Vasconcelos *et al.* (2006) and Venegas-Anaya (2008) from the Amazon basin and French Guiana, all assumed to be *C. c. crocodilus*. For *Caiman yacare*, 16 haplotypes from the Mamore (Amazon) drainage and 9 from the río Paraguay drainage were used (Godshalk 2008a). For some analyses, samples from Hrbek (2008) for other caiman species were employed as outgroups.

Sequences were first aligned using ClusalW (Larkin *et al.* 2007) algorithms within the MEGA6 software framework (Tamura *et al*. 2013), which were then confirmed visually for accuracy. A variety of analyses were conducted using the Mega6 software package, usually phylogenetic inferences using Maximum Likelihood (ML) and Maximum Parsimony (MP) models. Molecular clocks were employed when appropriate, usually with the inclusion of *Alligator* as the outgroup with an accepted fossil divergence of 62-72 ma

The evolutionary history was inferred by using the Maximum Likelihood method based on the Tamura-Nei model Tamura and Nei (1993) to produce Fig 1. The bootstrap consensus trees inferred from 1000 replicates) were taken to represent the evolutionary history of the taxa analyzed. Branches corresponding to partitions reproduced in less than 50% bootstrap replicates are collapsed. Initial trees for heuristic searches were obtained automatically by applying Neighbor-Join and BioNJ algorithms to a matrix of pairwise distances estimated using the Maximum Composite Likelihood (MCL) approach, and then selecting the topology with superior log likelihood value. The analyses involved up to 116 nucleotide sequences. Codon positions included were 1st+2nd+3rd+Noncoding. All positions with less than 95% site coverage were eliminated. That is, fewer than 5% alignment gaps, missing data, and ambiguous bases were allowed at any position. There were a total of 1085 positions in most final datasets.

Analyses using the Maximum Parsimony method were also conducted with bootstrap tests (1000 replicates. Major tree topologies remained with similar bootstrap support for all sites and parsimony-informative sites (in parentheses). The MP trees were obtained using the Subtree-Pruning-Regrafting (SPR) algorithm (Nei and Kumar 2000) with search level 1 in which the initial trees were obtained by the random addition of sequences (10 replicates). The analyses also up to involved 116 nucleotide sequences. All positions with less than 95% site coverage were eliminated. That is, fewer than 5% alignment gaps, missing data, and ambiguous bases were allowed at any position. There were a total of 1085 positions in most of the final datasets.

Paleogeography

The tremendous scale of landscape evolution in the Neotropics, over the last ~15 ma profoundly shaped the Caiman complex as it exists today. By the late Miocene, the central Andes had risen to heights (>2000m) that led to increasing precipitation and erosional deposition eastward. Surface water accumulated in the foreland proto-Amazon area where a large lacustrine system arose (Campbell *et al*. 2006, Hoorn *et al*. 1995, 2010, Latrubesse *et al*. 2010). Sedimentary patterns indicate generally a northward flow with an exit in the Falcon-Lake Maracaibo area. Very little flow reached the Atlantic at the site of the present Amazon delta. The Purus arch, in the current eastern Amazon, remained as a barrier to the eastern flow until it was breached about 5-6 ma, (Latrubesse *et al*. 2010) although the age is in dispute (Campbell *et al*. 2006, Figueredo *et a*l 2009)(see Fig. 1).

The northern Andes (Colombia-Venezuela) split into separate branches as uplifts progressed north. First, the Cauca-Magdalena fluvial system was partially isolated by uplift of western and central Cordilleras. The eastern Cordillera arose to further isolate the Magdalena, and split to ring the Lake Maracaibo basin on west, south and east. The Cordillera then collided with the older Coastal Range further east to complete a mountain barrier arching from Tierra del Fuego to a low point east of Caracas. Not only were major vicariant barriers erected, but also precipitation and weather were affected on continental and hemispherical scales. Concurrent with these events was a complete reordering of the fluvial networks. As the north exit was being abandoned, the El Baul arch was breached permitting eastward flow and the Orinoco delta began forming (7-8 ma). Sometime later, the Vaupes arch arose separating the Orinoco and Amazon basins, as did the Michicola arch separating the Amazon and south flowing Paraná (Lundberg *et al*.1998, Hoorn *et al*. 2010, Latrubesse 2010).

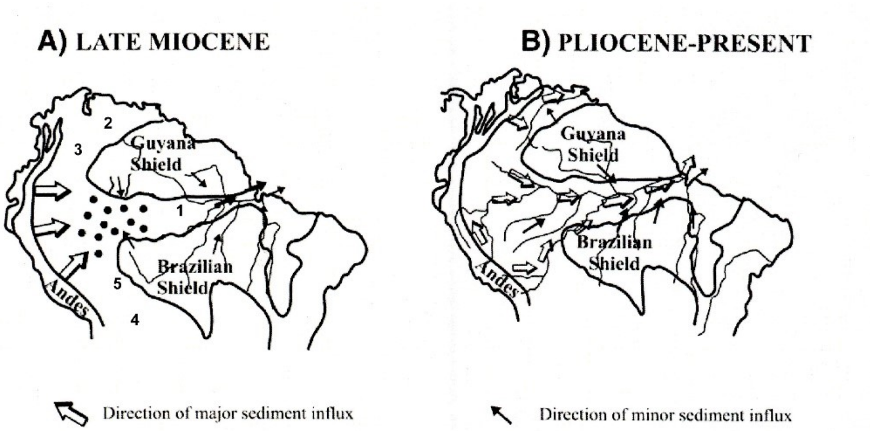

Fig. 1 - Paleogeographical reconstruction of sediment and water influx in the Amazon basin during the late Miocene and from the Pliocene to present. (A) The area was an active sedimentary subsiding basin during the Late Miocene. Western Amazonia received sediments directly from the Andes (dotted area), and drainage may have flowed north after lacustrine systems developed. Numbers refer drainage development elements: 1) Purus arch 2) El Baul arch 3) Vaupes arch 4) Michicloa arch 5) Mamoré breach. The incomplete Amazon River system drained the shield area located to the East. (B) After the reorganization of the basins, during the transition between the end of the Miocene and the early Pliocene, the rivers of Southwestern Brazilian Amazonia became lowlands rivers without contact with the Andes chain and the Peruvian basins were reorganized as today. The Amazon system became integrated as a transcontinental fluvial basin with separation of Orinoco . Modified from Latrubesse *et al*. (2010).

The southern area is less well studied. A south flowing proto-Paraná may have alternated with salt water incursions during high sea level stands. At some point the Michicola arch arose as a SW limit to the Amazon basin. Rivers draining the area just to the northwest (Mamoré basin) breached the western edge of the Serra dos Pacaás Novos, part of the Brazilian Shield. uniting with the Amazon far downstream. This had an isolating effect for some taxa.

Closure of the Panama Isthmus was a slow process, in a setting of variable ocean levels and salinities beginning ~15 ma. Many vertebrate groups including some amphibians, mammals and fish were able to cross the isthmus before a continuous land bridge. Although Venegas *et al*. (2008) found no evidence for early occupation, new fossil *Caiman* material has been identified from Chiapas that may represent colonization of pre-emergent Mesoamerica (Brochu, pers. comm). This makes sense given the habitat use by *fuscus* of brackish lagoons, tidal canals, mangrove swamps, and at times, open coast. The main obstacle for caiman to invade Central America had less to do with lack of salt glands, and more to do with the probability that habitats were occupied by other crocodyliforms. Mesoamerica is very active volcanically and tectonically, and this has led to a very heterogeneous landscape.

Results

These are preliminary observations analyzing phylogenetic relationships involving one mitochondrial gene. Looking at the cladogram for *Caiman* ESUs (Fig 2), a paraphyly exists, with all leaves converging to an ancestral lineage. The tree is rooted using Alligator at 69 ma (not shown), shown is the nearest living relative, *Caiman latirostris*, with a most recent common ancestor (MRCA) at ~20 ma. The MRCA for Clades A and B is 7-8 ma. This is a significant period for divergence as a result of reproductive separation the clades.

About 1 million years later, 6-7 ma, Clade A splits to become the most northern forms of *Caiman fuscus/chiapasius* (subclades 1-3) and the most southern form, *Caiman yacare* (subclade 4,5). A cryptic, possibly relict, ESU was found in the Peruvian Amazon by Venegas *et al.*(2008) *C.spp*. (subclade X). This lineage last shared a common ancestor with *Caiman yacare* about 4.5-5 ma (more below). Clade B, *Caiman c. crocodilus*, has a subdivision between the Orinoco river populations (subclade 6) and the rest (subclades 7,8) with the most recent common ancestor about 1.25-1.75 ma and within basin divergence following.

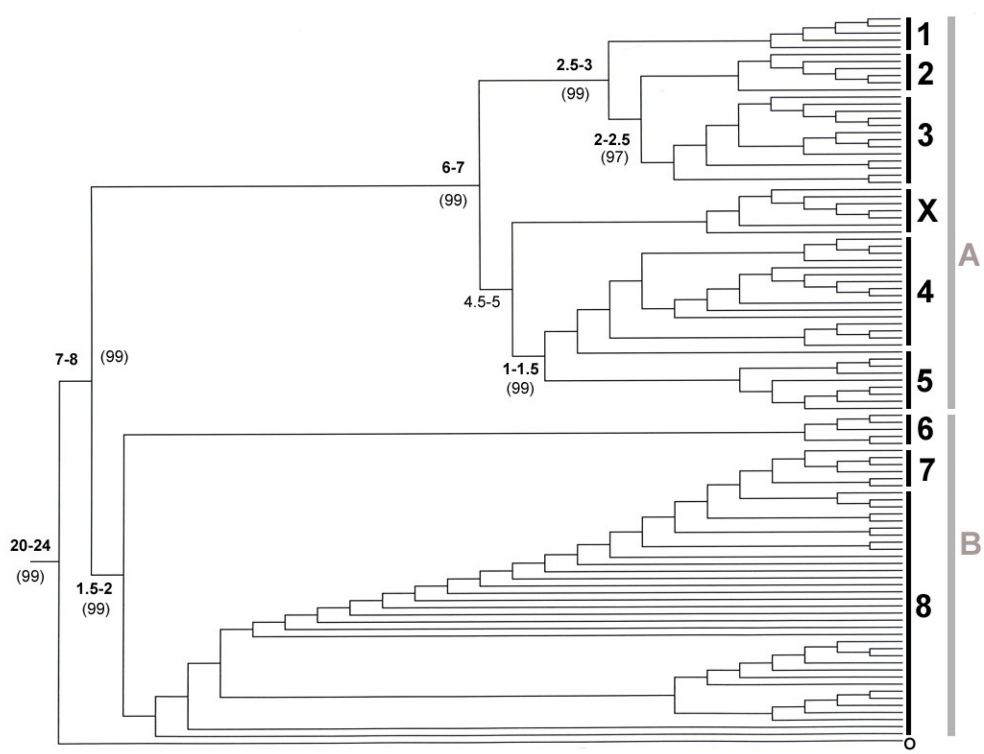

Fig. 2 - Molecular Phylogenetic analysis of *Caiman* by Maximum Likelihood (ML) method. The evolutionary history was inferred by using the ML method based on the Tamura-Nei model (Tamura and Nei, 1993). The bootstrap consensus tree of 92 cytochrome *b* haplotypes inferred from 1000 replicates is taken to represent the evolutionary history. Branches corresponding to significant partitions with more than than 95% bootstrap support are noted in parentheses. Nodes are marked in millions of years before present (ma) for most recent common ancestor (MRCA). Tree was rooted with *Alligator* using a fossil calibration of 62-72 ma (not shown), outgroup shown is *C. latirostris* (O), divergence times are estimates. Caiman forms a polyphyletic group with 2 major clades. Clade A consists of *Caiman chiapasius* (1), *C. fuscus* (2,3), *C. yacare* (4,5) and a cryptic lineage from the Peruvian Amazon as noted by Venegas-Anaya in 2008 (X). Sister Clade B consists of *Caiman c. crocodilus* which is divided broadly into Orinoco (6), Atlantic coast (7) and Amazon (8) populations.

Clade A – fuscus / chiapasius

As seen from the ML phylogenetic tree in Fig 2, the Mesoamerican *Caiman* (subclade 1-3) forms a sister clade to *Caiman yacare* (4,5). If *C. yacare* is considered a species, and both have been removed from *C. c. c*. for over 6 million years, and currently with apparent reproductive isolation, then *Caiman fuscus* should retain full species designation as first described by Cope. The process of speciation is a continuum and designation can be subjective. Mesoamerican geography is complicated and habitat is very fragmented by mountains, volcanoes, deserts, fault lines and rivers. It is not surprising that 3 subclades formed over a relatively compact landscape. It would be very interesting to analyze material from the extent of its range in Mexico (16° 30' N) south along the Pacific to the Golfo de Guayaquil (3° 30' S), and from northern Honduras (16° east across the Caribbean coast of Colombia and Venezuela. A strong geographic signal will certainly be found. In any event, this ESU (or 3!) should be recognized.

The western most clade (1) includes all specimens from Mexico and El Salvador, identified by Venegas-Anaya *et al.* (2008) as *C. c. chiapasius*. Given the above taxonomy, this might then be considered *C. f. chiapasius*. The distribution appears to be restricted to the northern Pacific coast only (see Fig 3), perhaps only west of Lake Nicaragua. It is basal to the sister subclades: *fuscu*s – North (2), and *fuscus* – South (3). These two ESUs have apparent broad range overlap along the río San Juan corridor and the Caribbean coast of Costa Rica. This is an ancient division running along the southern edge of the Chortis Block, an element of the nuclear Central American Peninsula before formation of an isthmus. Material from the northern Honduras coast (Godshalk 2008b) was added to analyses and it fell within the *fuscus*-North lineage (2). Twenty animals were sampled from a variety of coastal rivers and no caiman belonging to clade 1 or 3 were detected.

C.yacare and 'X'

Caiman yacare divides into 2 separate ESUs with a MRCA of ~1-1.5 ma. This separation follows the Mamoré basin (4) and Paraguay-Paraná (5) as documented in Godshalk (2008a). These caiman separate from *C crocodilus* in all analyses. Material from potential intergrade areas was not available for these analyses. This includes the río Madera in Brazil downstream of the Mamoré, but also in some of the western rivers that flow into northern Bolivia from Peru. These include the Manuripi, Orton and Madre de dios rivers. Videz-Roca (pers. comm) stated that traveling the stretch of Madre de Dios River (~125 river km) between Pto. Maldonado (Peru) and Pto. Heath (Bolivia), caiman change phenotypically from *crocodilus* to *yacare*. The situation needs clarification. The populations further west in southern Peru are considered Amazonian *C. c. crocodilus*.

Interestingly, the cryptic ineage (X) found in Peru by Venegas-Anaya et al. (2008) most commonly aligns with *yacare*, with a MRCA of 4.5-5 ma. In reviewing Maximum Parsimony cladograms, X always iverged from *crocodilus* (6-8) and sometimes basal to, but some trees aligned X with *fuscus*. It may represent a relict lineage,a link to the past. The most recent common ancestor to the complex most likely lived in the pan-Amazonan wetlands (*sensu* Hoorn *et al*. 2010) of the now western Amazonia. Given that modern caiman have relatively high genetic diversity and display isolation by distance, it is reasonable that populations over a large distribution may have diverged previously as a natural occurrence. Clade A may represent previous populations along the western area where the drainage north has been proposed (Hoorn *et al*. 2010). Clade B may have been derived from populations along the eastern side of the pan-Amazonia.

As the geographic events outlined above progressed, the western populations may have extended north and south for a long distance. A fossil *C. yacare* has been identified north of its current distribution (Fortier et al. 2009), perhaps new material will confirm a previously wider range. At some point with the reorganization of the landscape and drainages, the population parted, eventually leading to *yacare* in the far south, and *fuscus* to far the north, beyond the mountain barrier. This is a possible explanation for the cryptic lineage X, which may have remained *in situ*. The successful clade B may have successfully invaded western areas as rivers found new courses and connections with the east improved.

Clade B – *crocodilus*

This clade consists of two ESUs with a MRCA of 1.5-2 ma. The Orinoco (6) ESU is represented by a very small sample, only 5 haplotypes, but the basin should provide proportionate diversity compared material from the Atlantic coast (7) and Amazon (8) if sampled properly. Vasconcelos *et al.* (2006) found that the Atlantic coast caiman were significantly different from the Amazon stock, but as observed in the context of the cladogram (Fig. 2), the lineage is obscured by deeper divergences within the tree.

Discussion

The extant caimans are very poorly represented in the fossil record and very little explains the species' evolution or the past distributions. In this setting, a synthesis of phylogenetic information and paleogeography can indicate possible pathways leading to the present. The value of molecular data to elucidate the past has been shown repeatedly in the last decade as tools get refined, cheaper and more available. Results show that crocodilian evolution has continued forward, often in reaction to the fracturing of landscapes (eg Hekkala *et al.* 2011, Shirley *et al.* 2014, Rodriguez *et al*. this volume).

Many forces have combined to form the current distribution of the caiman species and ESUs: mountain building, volcanism, river basin formations, desertification and interspecific competition. Looking at the complicated geography of the Neotropics, one can appreciate the immense distances involved around unyielding geographic barriers for gene flow pathways in an aquatic animal. Understanding the paleogeography is important for interpreting the phylogenetic signal and reconstructing a possible history.

My biological inclination is toward being 'lumper' as opposed to being a 'splitter'. But crocodylians have unique problems with traditional species' models. Most species resemble each other to a great degree and post-cranial scalation and skeleton have narrow margins of variation. Conservation of body form is found throughout the long fossil history, as well as in highly derived but extinct forms. Most divergence has been inferred through cranial anatomy. When deep phylogenetic divisions are demonstrated, we must look beyond the historic bias begun with Linnaeus and his worldwide crocodile-lizard, *Lacerta crocodilus*. These differences are coming to the taxonomic forefront as data sets are being compiled for many species, which now show differentiation over widespread distributions (Shirley *et al*., Smolensky *et al.*, Ross *et al*., this volume).

This is also the case for caiman. In addition, recent discoveries of fossil crocodyliforms show widespread Miocene diversification over broad landscapes in the Neotropics (eg Brochu 2011, Bona *et al.* 2013, Scheyer et al. 2013). This information is based on material from Venezuela (Urumaco), Colombia (La

Venta), Peru (Acre) and Argentina (Paraná). Many of the species described, some over 10 m, would have shared ecosystems, and competed, with the common ancestral lineage to *C. crocodilus/yacare*. This may have inhibited the rapid expansion of caiman that is seen today in habitats where the alpha predators have been removed. Expansion has occurred as competitive exclusion was diminished as a result of hide hunting in the last century. Venegas-Anaya *et al.* (2008) concluded that *Caiman crocodilus* had entered Central America from Colombia after the isthmus had formed, 3-4 ma. If this is the case, the slow expansion northward and subsequent structure into 3 clades, may best be explained with interspecific competition included in the equation. This consists of pressure from both extinct and extant lineages.

Throughout the range of *Caiman*, it competes for resources with a larger, more dominant sympatric relative. This occurs at the latitudinal limits: Pacific coast- *Crocodylus acutus*, mountains and desert at both north and south extremes. Atlantic coast - *Crocodylus acutus* and *C. moreletii* together form a significant impediment to expansion north into Belize or to Caribbean Islands. Further north is the arid Yucatan Peninsula. The previous expanded range of *C. rhombifer* could also have affected island invasion success. *C. acutus* distribution continues sympatrically south and east, along the Caribbean Gauntlet until the delta of the Orinoco. Within the Orinoco basin, *C. intermedius* held the dominant position until about 75 years ago. Within most of the Amazon basin, Guayana and Fr. Guiana, *Melanosuchus niger* holds that position where still abundant, including the northern population of *Caiman yacare* in the río Mamoré basin. *Caiman latirostris* replaces *C. crocodilus* at some point along coastal Atlantic systems southeast of the Amazon delta (~3° S) and also for the southern population of *Caiman yacare* in the south Paraguay-Paraná basin at ~32° S.

All of these larger species have suffered great population reductions or extinctions, most recently due to commercial hunting. Caiman have a very short time to maturity as well as small size at maturity. In 1974, I caught some 'sub-adult' *Caiman crocodilus* in the Venezuelan Llanos for a captive breeding project. Most animals were about 1 meter total length and were presumed at least 1 year from breeding age. I performed a necropsy on a female (96 cm TL) after an accidental death, and found a clutch of 16 fully shelled eggs ready for laying. This size is generally safe from hide hunters in most countries. From recent studies, it appears that multiple paternity is a reproductive strategy found in most, if not all, crocodylians. These factors provide a powerful reproductive potential for recovery and invasion, as seen in many areas with *C. crocodilus*.

Caiman crocodilus is a very plastic, habitat generalist, and a crocodilian that can exist in close proximity with man. Bill Magnusson has characterized caiman as a 'weed' species; Wayne King calls them the 'crocodilian cockroach'. Both capture the notion of persistence in degraded environments, and quick population recoveries, but they more resemble aquatic coyotes – their intelligence and learning capabilities enables range expansion and make them suited even for urban existence, if tolerated by people. Female *Caiman crocodilus* within urban Manaus are seen using garbage for nesting where natural materials are absent (R. Boteros-Arias, pers. comm.). With protection, caiman populations can usually recover quickly. The biggest factor currently throughout the range is habitat loss. Lowland conversion to intense agriculture such as oil palm and bananas in Mesoamerica has removed large swaths of habitat. Deforestation, mining, and agricultural development have large impacts on *Caiman* populations in every country where they occur. A clear understanding of the phylogeography of the lineages can help direct future conservation efforts.

Conclusions

These conclusions are based on the preliminary phylogenetic analyses of cytochrome *b* haplotypes from the *Caiman crocodilus*/*yacare* complex. Large intervening areas of potential intergrades and/or hybrids remain unsampled (clade and divisions as in Fig 2). These taxonomic suggestions require much more information before being introduced formally. This is just an introduction to the ESUs as inferred by these analyses.

1) The complex is most closely related to *C. latirostris*, with a MRCA at ~20-24 ma.
2) The complex is divided into 2 clades (A & B) with a MRCA of ~7-8 ma.
3) Clade A consists of 3 subgroups: Northern (*Caiman fuscus*/*chiapasius*), Southern (*Caiman yacare*), with a MRCA of ~6-7 ma. and a cryptic lineage (X) described by Venegas-Anaya et al. (2008).
4) The northern subgroup is comprised of 3 distinct ESUs (1-3) with a MRCA of 2.5-3 ma and may be considered *Caiman fuscus* by virtue of isolation.
5) The western most ESU (1) includes the type locality for *C. f. chiapasius* and may be restricted to southern Mexico, southern Guatemala, and El Salvador.
6) ESUs 2 & 3 inhabit the rest of Mesoamerica including Honduras, although the status of Pacific populations of Colombia and Ecuador, and the Caribbean populations of Venezuela remain unknown.
7) The southern group (4,5), *Caiman yacare*, is divided in 2 reproductively isolated clades, as shown in Godshalk (2008) with a MRCA of ~1-1.5 ma. Following Donoso-Barros (1974), *C. y. yacare* is proposed for the Paraguay-Paraná population and *C.y.medemi* for the Mamoré population.
8) The cryptic lineage (X) is most closely aligned with *C. yacare*, with a MRCA of 4.5-5 ma.
9) Clade B is considered taxonomically as *C.c. crocodilus* and consists of at minimum 2 ESUs: Orinoco (6) and Amazon including Atlantic coast populations (7,8),with a MRCA of 1.5-1 ma.

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Orinoco crocodile (*Crocodylus intermedius*) head development

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Abstract

Seven photographs representing seven different head development stages (neonate; 0.5; 1.5; 2.5; 3.0; 4.0 and 4.5 years old, from Orinoco crocodiles *Crocodylus intermedius* hatched at the Dallas World Aquarium were analyzed. Each image was vectorized to determine the dimensions of the following morphometric measurements: a) dorsal cranial length, b) snout length, c) cranial length, d) cranial width, e) maxillary – pre maxillary suture width, and f) Kailin 12-12. The analyzed ratios were: snout length vs dorsal cranial length; cranial length vs dorsal cranial length; cranial width vs maxillary – pre maxillary suture width; and dorsal cranial length vs cranial width. As the Orinoco crocodile grows from hatchling stage, the snout turns longer than width, the opposite ratio as when it hatched. We detected a trend with the other morphometric ratios, but our results cannot be conclusive due the angle the photographs were taken.

Introduction

The Order Crocodylia is divided in three Families: Gavialidae, Alligatoridae and Crocodylidae. There are different morphologic characteristics among these families (Seijas 2011, Ross 1989 and Medem 1981). The first studies that evaluate the cranial measurements were done by Webb & Messel (1978) with *Crocodilus porosus* and by Montague (1984) with *Crocodylus novaeguineae*. Both studies determined cranial measurements and its relation with size classes, sex, and propose equations to determinate body conditions. The most recent papers related with cranial measurements are from Pearcy (2010) and Pearcy & Wijtten (2011). In the first paper, the author proposes the use of Kailin 12-12 measurement to better indicate the skull size than cranial width and skull length. In the second paper, the authors used the Kailin 12-12 on different crocodile's skulls from European museums to determinate differences between species. Barrios et al (2012) evaluated different cranial measurements of 121 captive Morelet's crocodile (*Crocodylus moreletii*), to determinate differences between males and females. The authors report differences in cranial width; snout width and mid-snout width in relation to total length, where the skulls of males are bigger than females. Walmsley et al (2013) analyzed different crocodile skulls, and related the head length with the prey size. When crocodiles are long-snouted, they are specialized to capture fishes. In the other hand, short-snouted crocodiles will be better to capture bigger prey. Monteiro et al (1997) evaluated skulls from three Caiman species and generated an algorithm to evaluate the head growth and its relationship with the diet.

Objectives

The objective of this work is to create a group of morphometric indicators that aloud to determine the age of *Crocodylus intermedius* with photographs when its capture is not possible.

Methodology

Digital photographs were taken from Orinoco crocodiles kept in captivity at the Dallas World Aquarium, at seven different ages: hatchling; 0.5; 1.5; 2.5; 3.0; 4.0 and 4.5 years old. The images were taken from a dorsal view covering from the post-occipital osteoderms to the tip of the snout (Figure 1).

Figure 1. Orinoco crocodile head, dorsal view.

The images were vectorized through Adobe Illustrator CS5 technique described by Velasco (2012), which remarks all head characteristics. After each image was vectorized, different skull measurements were taken as dorsal cranial length; snout length; cranial length; cranial width; maxillary – pre maxillary suture width; and Kailin 12-12. Figure 2 shows the lengths and widths we measured using the program's ruler.

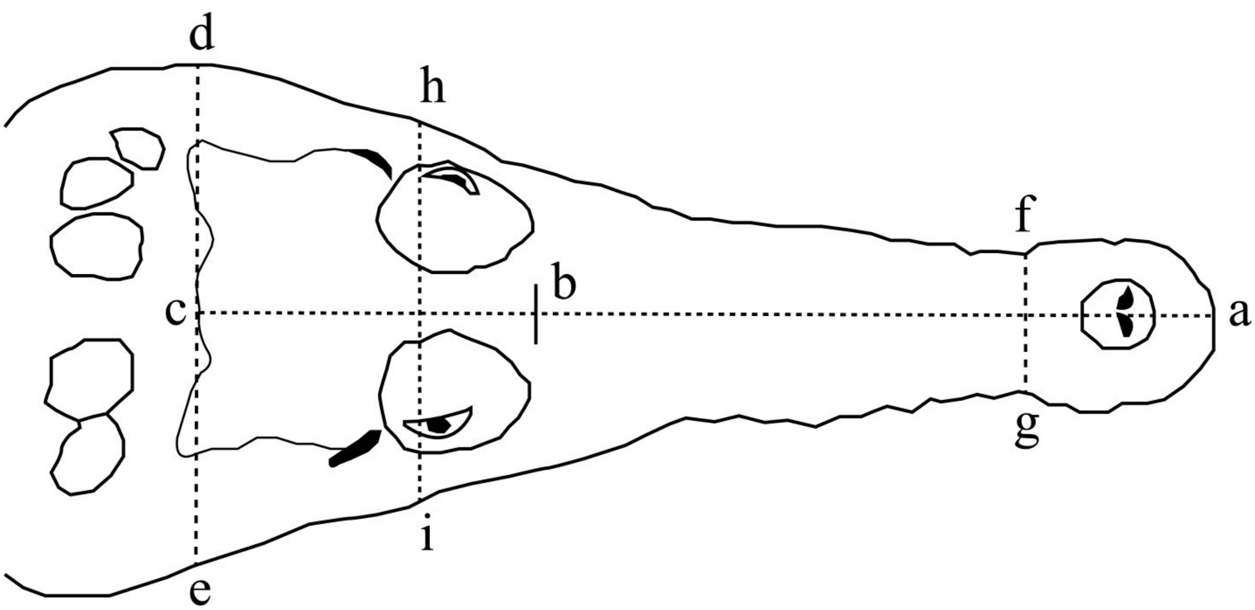

Figure 2. Measurements taken of *Crocodylus intermedius* vectorized images: a-c dorsal cranial length; a-b snout length; b-c cranial length; d-e cranial width; f-g maxillary – pre maxillary suture width; h-i Kailin 12-12.

Seven vectorized photographs were selected (figure 3) where the head development can be observed at different age stages from hatchling to 4.5 years old.

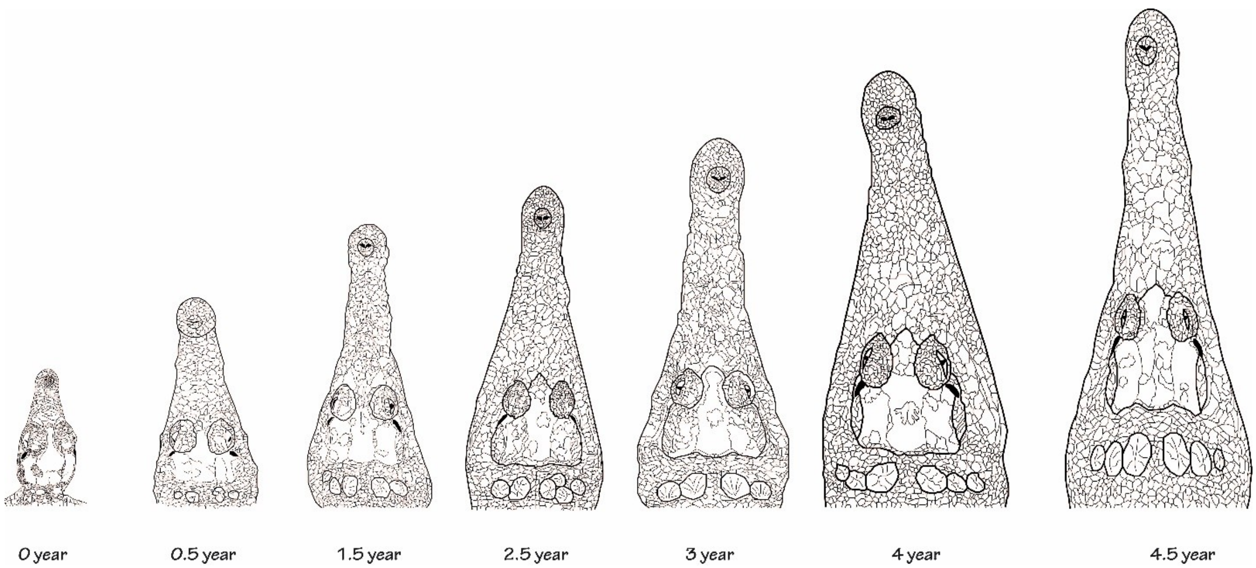

Figure 3. *Crocodylus intermedius* head vectorized at different ages.

The skull relations analyzed were: snout length vs dorsal cranial length; cranial length vs dorsal cranial length; cranial width vs maxillary – pre-maxillary suture width, and dorsal cranial length vs cranial width.

Results

The first observation over the different ages is the rostral length increase of the Orinoco crocodiles heads. In its development the rostral area (snout) will become larger and narrower. Also the badges that constitute the skull cap became ossified and defined exactly behind the eyes.

In figure 4, the relationship between rostral vs total skull length and cranial vs total skull length can be appreciated.

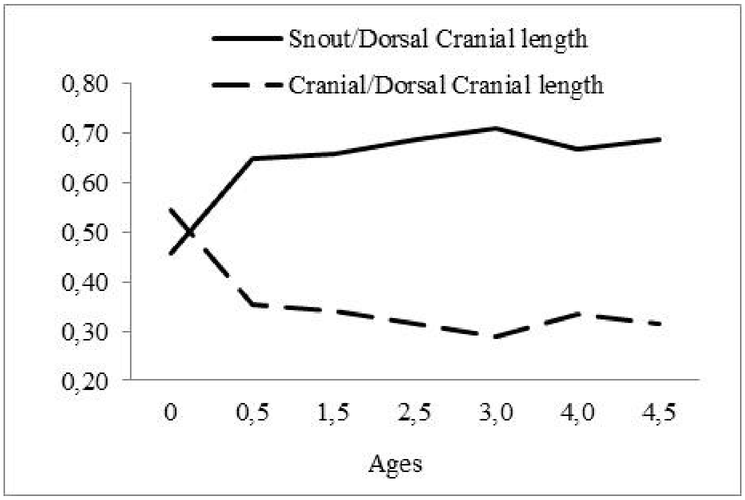

Figure 4. Relationships between snout length, cranial length, and dorsal cranial skull.

The tendency of snout length vs dorsal cranial length is increasing while cranial length vs dorsal cranial length is decreasing. Hatchling is the only stage where the cranial length is larger than the snout length. For the next ages in *C. intermedius*, the snout length represents approximately 70% of the dorsal cranial length. The relationship between cranial length and maxillary – pre-maxillary suture widths (Figure 5) increases the first years of growing until stabilized.

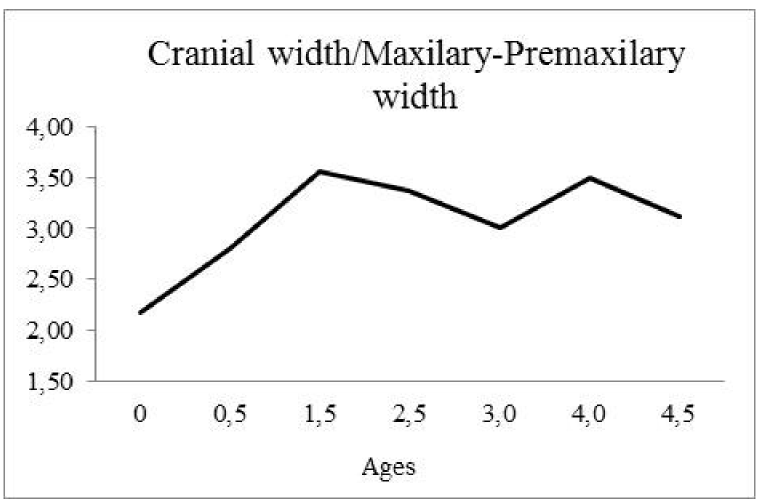

Figure 5. Relationship between cranial width / maxillary – pre-maxillary suture widths.

Figures 6 and 7 show the Kailin 12-12 measurement and the relationship between skull length/Kailin 12-12 respectively. In the figure 6, the trend is to increase and then to stabilize. This relationship does not shows any trend through the ages.

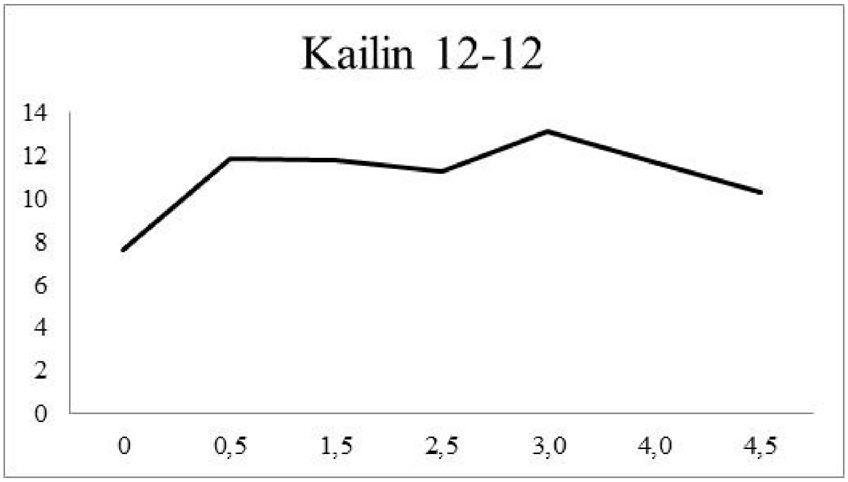

Figure 6. Kailin 12-12 on *Crocodylus intermedius*.

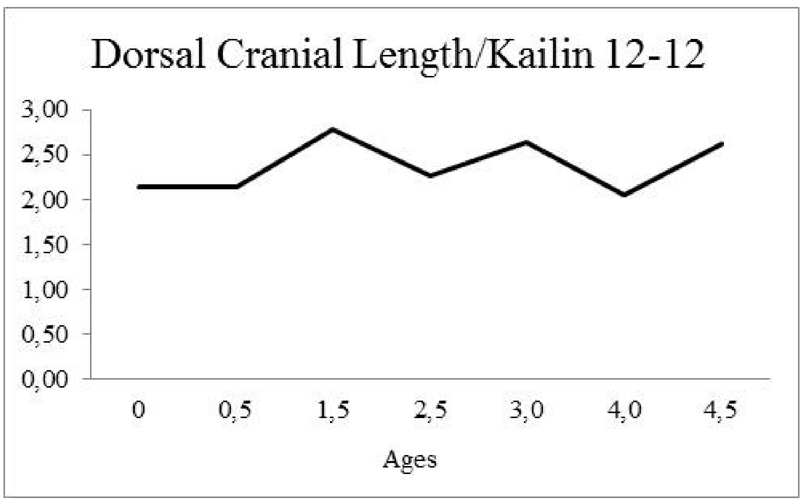

Figure 7. Relationship between Dorsal Cranial length/Kailin 12-12.

Discussion

The relationship among snout length, cranial length and dorsal skull length showed what is expected; as the crocodile grows, the head turns longer than wider. Nevertheless, with the other morphometric measurements, there is no definitive trend. An explanation to this fact could be the angle the photograph was taken over the crocodile head. These pictures should be completely perpendicular to not alter the proportions of the head.

When we analyze each crocodile head's morphometric relation, it is expected in long / narrow-snouted crocodiles, that as they grow up, the values get stabilize as they are increasing. Nevertheless, our results show some values that break the trend, becoming punctual values as a result of the base photography quality.

Three more skulls were obtained from Museums for photographs and to obtain vectorizated images. The results support the theory about the model and methodology work to estimate the age of the crocodiles. It is interesting that the results obtained with the three museum skulls, showed the morphometric relationship above the obtained curve.

The present study will be applied to other species of crocodilians raised in captivity to analyze the viability to estimate the age of the sampled species.

Dedication

The authors want to dedicate this work to the 3096 detained students in Venezuela in the last 100 days of protests, and especially to the memory those that have died in the student different actions. Our respect to all them to fight for their ideals.

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12 January 1930 - 3 March 2014
A Memorial

Fritz Huchzermeyer lived a rich 84 years, touched by a wide range of stimulating people sharing his curiosity and creativity. Fritz loved science and knowledge, but also enjoyed painting, sketching, sculpting, cooking, blowing the trumpet, writing and running. Besides his contributions to Veterinary Science, he has left many rich memories, plus an archive ranging from Comrades Marathon silver medals (long-distance running) to a poetry collection and al large number of colourful abstract paintings. The latter, he enjoyed having around him in the so-called 'gallery', his short-lived home in the German Old Age Home in Pretoria until 3 March 2014.

Fritz had an interesting and adventurous childhood on his father's small-holding near Herford in Germany. His teenage years were marked by World War II with all its threats and dark shadows. During studies in theology in Vienna, he fell in love with Hildegard, whom he had asked to type up an assignment. A change in academic direction was followed by marriage, and soon Hildegard joined him in the study of Veterinary Science at the University of Hanover. Here they were surrounded by a circle of family and of individualistic, open-minded and international friends and fellow students. As a student in post-war Germany, Fritz was a co-founder of the FIBIS (*Frei Internationaler Bund Individualistischer Studenten*). A close-knit and life-long friendship with diverse fellow students and later colleagues continues to this day. The shared ideals of this group were celebrated in later years by annual reunions, one of which was hosted by Fritz and Hildegard in 2005.

Life revolved around an ever-growing collection of books. As a young boy Fritz enjoyed learning classical languages, and as a Theology student in Vienna became proficient in Latin, Greek and Hebrew. French was learnt during an exchange year in Paris where both he and Hildegard studied at the *Ecole Veterinaire Maisons Alfort*. Later in life he learnt Spanish and Guarani, the official languages of Paraguay. The diverse languages were represented in the collection of books he read. As many guests will remember, time between supper and going to sleep was reserved for reading and he was not to be disturbed.

Open to adventure Fritz accepted a posting to the then Rhodesia (Zimbabwe) as field veterinarian for Her Majesty's Service during 1963. Fritz moved his young family, which by now included David, to Gweru in Rhodesia, with Hildegard expecting their second child, Philippa. Further moves were made to Bulawayo and then Salisbury (now Harare), where Marie was born. Fritz followed his leisure-time interests during 10 happy years on a small holding in Welston outside Salisbury, while working as a Poultry Specialist for the Veterinary Laboratory in Causeway, Rhodesia. Many new and interesting people joined the ever-growing number of close friends. Unfortunately, the untenable security situation in Rhodesia led to a reluctant move to South Africa in 1975.

In 1975 Fritz took up a senior lecturer post in Poultry Diseases at the Faculty of Veterinary Science at the University of Pretoria, South Africa. Hildegard became his colleague across the road at the Onderstepoort Veterinary Institute (OVI). Refuge from the segregated and regulated South African society was found on a beautiful thornveld small-holding in Buffelsdrift with many unconventional pets and in a growing collection of books in the various languages mastered by Fritz. From senior lecturer in Poultry Diseases at the Faculty of Veterinary Science, Fritz moved over to the OVI where he led the Poultry Section until its closure.

In 1980 the family spent a year working at the Veterinary Faculty in Asuncion as part of a technical exchange between South Africa and Paraguay. This was at the height of Fritz's marathon running. Always looking for new challenges, he transferred his extensive experience in fitness training to swimming. He crossed the Lago Ypacarai in Paraguay, a distance of several kilometres, swimming non-stop for 6 hours, accompanied by his daughter, Philippa, for most of the way. In South Africa he ran 6 Comrades Marathons (distance: >90 km) and won 5 silver medals and one bronze, as well as a host of other marathons, some with his faithful canine running companion, Steffy. Ultimately it was the Washy 100 mile race from Port Alfred to Port Elizabeth that concluded his running career at the age of 54. He finished in 17th place out of the 60 runners who completed the marathon.

A move from the Poultry Section to the Pathology Section at the OVI allowed him to follow his interest in ostrich and crocodile diseases - interests that he already developed while in Rhodesia. In this time he wrote and published the first authoritative book on the diseases of ostriches. After retiring from the OVI in 1995 he completed his PhD on malaria in game birds, a project that had occupied him for a number of years.

He continued his work on ostriches and crocodiles, and soon wrote and published the first authoritative book on crocodilian diseases. Fritz chaired the Veterinary Science Group of the IUCN-SSC Crocodile Specialist Group for many years. This was particularly dear to him and his close contact with this special group of friends continued up to the time of his death. Fritz travelled the world until recently. He remained much sought after as crocodile and ostrich specialist, writing and publishing authoritative texts and being invited by farmers and associations around the world (particularly as chair of the CSG's Veterinary Science Group).

Fritz's adventures studying crocodiles in remote regions were numerous. But his one particular interest was the Dwarf crocodile (*Osteolaemus tetraspis*). To study this species he travelled to remote regions of the Republic of Congo. One such trip in 1994 involved an 11-day crossing of the uninhabited and uncharted Likouala Swamp, on foot. At 64 he was the oldest member of that expedition. On a subsequent journey to study Dwarf crocodiles he was caught in the north-east of Congo at the outbreak of the civil war. Three weeks later he emerged in Cameroon, stranded, with no money and no air ticket. Eventually he was flown out by a logging company to Cameroon. His grandchildren, to whom he has been a huge inspiration, loved hearing the detail of this and his many other adventures.

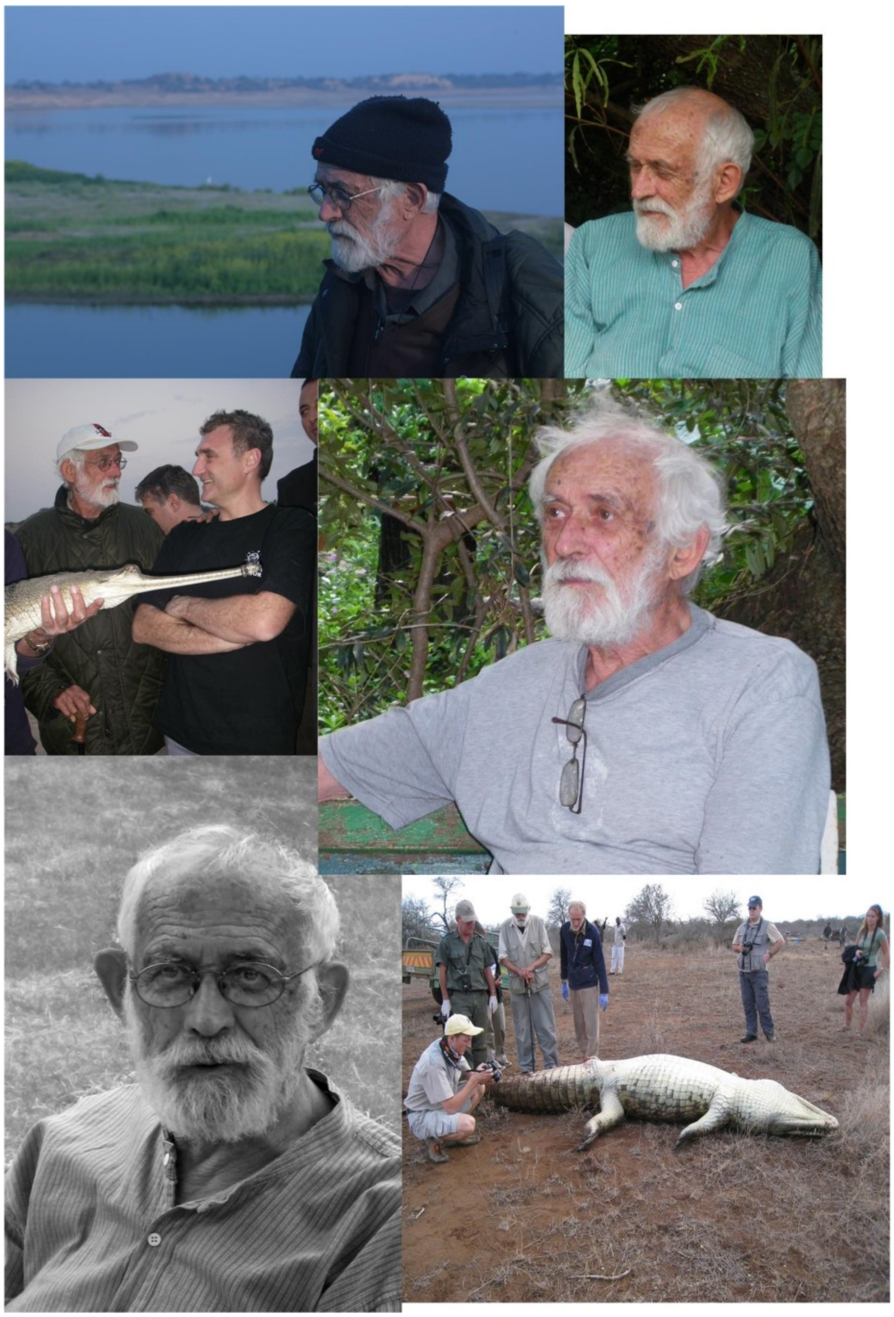
More recently Fritz was involved with several palaeontology projects that drew on his anatomical knowledge of birds and reptiles and his interest in fossils and evolution. As co-author with a team of Chinese researchers he was proud to see this work published in the prestigious journal, Nature. Fritz continued his research at the Pathology Section of the Faculty of Veterinary Science, University of Pretoria, as an extraordinary lecturer until just before his death. He shared his extensive knowledge with many colleagues interested in, especially, crocodilians. This provided the most fulfilling years of his career and he was still actively involved until two months before his death when he handed his accumulated collections over to colleagues at the Faculty of Veterinary Science, University of Pretoria, whom he had mentored.

Tortoises and other interesting animals were part of his daily life and these animals featured in his most pleasant dreams….

The following poem was written by Fritz during the CSG working meeting held in Montélimar, France, in June 2006.

To the Sacred Crocodiles of Burkina Faso
Feared and ferocious predator what is it
That you can live in harmony with man
When you are sacred and revered
And when you are accepted as an equal
That even when your lake is dry
The villagers will share their home with you?
We know already that you are a gentle parent

And yet it is so difficult to understand
Your very motions and emotions
We cannot read expressions in your face
And only barely in your voice
In our ignorance we will behave
So much more brutally than you
It is my dream that all of us
Could live in harmony with all the crocodiles
As is the case in a small part
Of Africa.



ORAL PRESENTATION ABSTRACTS

An anecdotal history of the CSG: The early years

Peter Brazaitis

Yale Peabody Museum of Natural History, New Haven, CT, USA

Following the wildlife decimations of the early 1900s, nearly all 23 species of crocodilians experienced threats to their existence, particularly crocodilians whose skin is suitable for the making of leather.

After the Second World War, people became concerned about the preservation of nature, including wildlife. As a result, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) was founded in 1945 and the International Union for the Conservation of Nature and Natural Resources (IUCN) was formed in 1948. The two entities came together in 1959, when UNESCO invited IUCN to prepare a list of nature parks and reserves. IUCN adopted a resolution in 1963 that become the basis for the 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the *Washington Convention*.

CITES would have a profound impact on all aspects of wildlife conservation and the global wildlife trade. Suddenly, the crocodilian leather industry saw themselves as "endangered species."

In March, 1971, the New York Zoological Society convened a gathering of "crocodilian specialists" from the scientific and industry communities at the Bronx Zoo's Reptile House. This marriage between industry and conservation become the IUCN Crocodile Specialist Group (CSG). This was the impetus for an explosion of crocodilian science that would explore every aspect of the species' biology, natural history and management, and provide a model for the preservation of otherwise unwanted species. This is my perspective. I happened to have been there.

The History and Development of the Louisiana Alligator Program

Ted Joanen
Wildlife Consultant

Alligator skins became somewhat fashionable in about 1855 for a short period, and then were used extensively during the Civil War (1860-1865) for shoes and saddle leather. In 1870 a large demand emerged, creating employment for hundreds. The number of alligators harvested in Louisiana was 20,000-30,000 annually, similar to present day. Alligator populations declined in the early 1950s, and the Louisiana Department of Wildlife and Fisheries (LDWF) closed the season in 1962 and began a concentrated management program which included years of research, enforcement, and the enactment of state, federal, and international laws. The research program included study the natural history, management, and captive propagation of alligators. Populations responded to the 10-year period of total protection and, in 1972, the first experimental season was conducted, which was designed to evaluate harvest quotas, methods of harvesting, tagging procedures, hunter interest, public acceptance, and shipment of new skins. Studies revealed that losses of wild alligator populations were high; 83% of the eggs and young are lost to natural causes, and only 17% reach 1.2 meters. Because of the high mortality in wild alligators, in 1986 the LDWF allowed the collection of wild alligator eggs from private lands. Environmental chambers were used to raise alligators up to three years of age. Stocking rates, feeds and feeding, and growth rates were studied. It was found that alligators maintained in controlled temperatures can reach 4-feet long in one year, and that incubation temperature influences embryonic growth, sex determination, and growth rates after hatching.

Louisiana's Alligator Management Program

Edmond C. Mouton, Jr.[1], Ruth M. Elsey[2], Lance Campbell[1], and Jeb T. Linscombe[1]

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The Louisiana Department of Wildlife and Fisheries manages the American alligator (*Alligator mississippiensis*) as a commercial, renewable natural resource. The Department's sustained use program is one of the world's most recognizable examples of a wildlife conservation success story, and has been used as a model for managing various crocodilian species throughout the world. The goals of the Department's alligator program are to manage and conserve Louisiana's alligators as part of the state's wetland ecosystem, provide benefits to the species, its habitat and the other species of fish and wildlife associated with alligators. The basic philosophy was to develop a sustained use management program which, through regulated harvest, would provide long term benefits to the survival of the species, maintain its habitats, and provide significant economic benefits to the citizens of the state. Since the inception of the Department's program in 1972, nearly 940,000 wild alligators have been harvested, over 8 million alligator eggs have been collected from the wild, and over 5 million farm raised alligators have been sold bringing in millions of dollars of revenue to landowners, trappers and farmers. Conservative estimates have valued these resources at over one billion dollars over the years providing significant, direct economic benefit to the citizens of Louisiana. This report will provide historical perspective, outline the basis and philosophy of the alligator management program; briefly review the federal government's oversight and approval role for management of the alligator, discusses wild, farm and nuisance alligator programs as well as research activities.

Florida's Alligator Management Program: An Update 2002 To 2014

Harry Dutton[1], Jason Waller[2], Dwayne Carbonneau[2], Lindsey Hord[3], Stephen Stiegler[1], Allan Woodward[4], Arnold Brunell[5], Cameron Carter[4], and J. Patrick Delaney[5]

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[2]Florida Fish and Wildlife Conservation Commission, Ocala, FL, USA
[3]Florida Fish and Wildlife Conservation Commission, Okeechobee, FL, USA
[4]Florida Fish and Wildlife Conservation Commission, Gainesville, FL, USA
[5]Florida Fish and Wildlife Conservation Commission, Eustis, FL, USA

Florida's Alligator Management Program has developed around the premise that the economic value derived from consumptive use of Florida's alligator (*Alligator mississippiensis*) resource can provide economic incentives to conserve alligators and preserve their wetland habitat. The expansion of management programs and growth of an industry dependent on the alligator resource has provided a constituency group to serve as advocates for wetland conservation. The major objectives of the program are to implement sustained alligator harvest programs while optimizing the economic, aesthetic, and ecological values of alligators as a renewable natural resource. By emphasizing these values, not only are there incentives for conservation of the alligator, but also the wetland ecosystems they inhabit. The intent of this paper is to provide the current status of this unique and comprehensive management program relative to the last update provided to Crocodile Specialist Group members in 2002 (Dutton et al. 2002).

Status of the American Alligator *(Alligator mississippiensis)* In Texas

Amos Cooper

Texas Parks & Wildlife Department

Once an endangered species throughout much of its historic and present range the American alligator (*Alligator mississippiensis*) is today protected, but is listed as CITES appendix II and is legally hunted throughout most of its range. For the past 41 years the Texas Parks and Wildlife Department has conducted alligator night count on transect lines, and for 38 years conducted Alligator nest surveys. The American alligator has been hunted in Texas since 1984. Alligator farming in Texas began in 1986, Nuisance Control Hunting began in 1985, and Alligator Egg Collection began in 1998. Although there have been some major logistical changes within the Texas Alligator Management Program in the past 2 years, it has not affected the population. Preliminary results from both nesting and night count data suggest that alligator populations in Texas are on an upward trend. Alligator hunting, nuisance control and egg collection are also on an upward trend, but alligator farming is at an all-time low in Texas, possibly due to changes in the market.

An Assessment of American Alligators (*Alligator mississippiensis*) on Red Slough Wildlife Management Area in McCurtain County, Oklahoma

Jarryd Robison and Tim Patton

Southeastern Oklahoma State University, Department of Biological Sciences

A growing population of American Alligators (*Alligator mississippiensis*) occurs in extreme southeastern Oklahoma, along the northwestern periphery of the species' range. However, aside from observational data and an annual spotlight survey, no studies have addressed factors affecting this population. In 2012 and 2013, our objectives for this study were to (1) standardize and assess spotlight survey methodology, (2) assess nesting effort, success, and overwinter survival of hatchlings, and (3) use historical observational data to identify patterns in alligator sightings. Standardization of spotlight surveys provided more robust and temporally comparable data than previous surveys, and resulted in CPUE values of 1.17 – 1.75 alligators per person-hour. In 2012, we found only two nests, with 18 and 6 hatchlings, respectively, and overwinter survival of 75%. No nests were found in 2013, likely due to drought. Review of historical sighting data revealed a large increase in sightings after 2006, and a hot-spot for sightings on Bittern Lake. Our results suggest that if spotlight surveys are to persist, they need to follow a more standardized methodological approach to be comparable across time and reveal trends. Further, we suggest that spotlight surveys be repeated more than once/year and expanded to more locations where alligators are known to exist. Our reproduction and recruitment data suggest that reproduction rates are low and overwinter survival does not occur every year. These factors are likely driven largely by climate; accordingly, this population may always be somewhat precarious.

Mississippi's Expanding Alligator Management Program, 1989 - 2014

Richard Flynt

Mississippi Department of Wildlife, Fisheries, and Parks, Jackson, Mississippi, USA

The Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) initiated its Alligator Management and Control Program in 1989. The initial objectives of the program were to develop nuisance alligator protocols, provide for nuisance agent trapper licensing, standardize population surveys, and promulgate general regulations for protection of alligators and for alligator ranching. In 2005, the MDWFP offered its first public alligator hunting opportunity to 50 lottery-based applicants on a small portion of one public waterway in central Mississippi. In 2006, the first private lands alligator hunting program was offered in three counties. By 2013, the alligator hunting program had expanded to statewide public waterway hunting opportunities and private land hunting was allowed in 28 of 52 counties. Since 2007, the MDWFP has captured and tagged over 700 alligators for the purpose of obtaining mark/recapture data. These mark/recapture data for relocated alligators document a "homing" behavior among all age classes and between sexes. Data also provide information on growth rates for inland riverine and coastal alligator populations. The MDWFP requires hunters to collect length and sex data for all harvested alligators. During the 2013 hunting season, record specimens were reported in all four record categories: longest male; longest female; heaviest male; and, heaviest female.

Status of the American Crocodile (*Crocodylus acutus*) in Florida

Michael S. Cherkiss[1], Frank J. Mazzotti[2], Kristen M. Hart[1], Jeff Beauchamp[2], Rafael Crespo[2], Seth Farris[2], Venetia Briggs-Gonzalez[2] and Laura A. Brandt[3]

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[3]U.S. Fish and Wildlife Service, Davie, Florida, USA

The American crocodile, a federally threatened species, may be affected by ecosystem restoration. Critical and quantifiable metrics believed to directly relate crocodiles to hydrologic restoration include nest distribution/nesting effort, relative density, body condition, and differential growth and survival of juvenile crocodiles. Crocodile captures from 1978-2013 were compared among areas to locate differences in these population parameters in response to restoration efforts. Data collected during systematic spotlight surveys performed for approximately 550km of the south Florida coastline between January 2004 and December 2012 were also analyzed. There has been a general increase in the number of crocodile nests per year within Everglades National Park peaking in the Flamingo/Cape Sable area in 2008 with a total of 109 nests and in NE Florida Bay in 2012 and 2013 with 36 nests. Annual captures ranged from 6 to 968 crocodiles per year, having increased immensely with the implementation of quarterly surveys in 2004 showing a remarkably stable crocodile density since 2007. Juvenile crocodiles had the lowest body condition overall and adults were captured in greater body condition in Flamingo/Cape Sable. There was a decreasing growth rate for crocodiles in NE FL Bay, while those in Flamingo/Cape Sable showed an increase, both significantly affected by habitat salinity. East Cape/Homestead Canal and NE Florida Bay produced the most hatchlings, but had lower survival, while the Flamingo/Bear Lake area produced fewer hatchlings but had greater survival. Results indicate that crocodiles demonstrate both short and long-term effects of hydrologic restoration.

Alligator Population Monitoring in Louisiana

Jeb Linscombe, Lance Campbell, and Edmond Mouton

Louisiana Department of Wildlife and Fisheries, Louisiana, USA

The Louisiana Department of Wildlife and Fisheries manages the American alligator (*Alligator mississippiensis*) as a commercial, renewable natural resource. The goals of the Department\'s alligator program are to manage and conserve Louisiana\'s alligators as part of the state\'s wetland ecosystem, providing benefits to this keystone species, thus aiding the fish and wildlife that depend upon alligators. The Department\'s sustained use program is one of the world\'s most successful conservation efforts. One of the core elements of the alligator program is its long term monitoring of the statewide alligator population through its annual aerial nest survey which began in 1970. The 9 day survey consists of over 2,800 miles of transects covering just under 140,000 acres of coastal wetland habitat. The data from the survey allows staff to estimate total density on approximately 2 million acres of coastal wetlands. Number of nests observed are classified by parish, ownership (public vs. private) and habitat (fresh, intermediate, brackish, and transitional marsh). Documenting nest densities by parish, ownership, and habitat allows for calculation of current and 5 year average nest densities for nearly 100 management units coastwide. Monitoring individual management units allows for more precise alligator egg harvest quotas and wild harvest quotas.

A detectability model for American alligators (*Alligator mississippiensis*) in freshwater marsh habitats

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The probability of observing an alligator during a night-light survey can be expressed as the product of alligator availability and the probability of detecting an available alligator. To address imperfect detection rates during alligator surveys, two detectability models were developed that examined alligator emergence dynamics and detection rates due to habitat characteristics. The alligator emergence model, modeled the proportion of time spent on the surface, or proportion available for detection, under various environmental variables. The variables included in the emergence model were; hour after sunset, season, moon phase, water depth, water temperature, air temperature, and rain fall. Three habitat detection models were also developed for common alligator habitats. Variables in the habitat models consisted of vegetation height, water depth, distance from transect, visual obstruction, and the airboat seat height. Take for example an alligator night-light survey that was conducted in spring under a quarter moon and took three hours to complete. The alligator emergence model estimated the probability of an emerged alligator at 0.34. Detection rates, under mean habitat variables for the habitats; sawgrass marsh, wet prairie, and open slough, were 0.51, 0.63, and 0.62. When combined, we are able to determine what is available (emergence model) and the probability of detecting an available alligator (habitat models). The total detection for the different habitats; sawgrass marsh, wet prairie, and open slough, were be 0.17, 0.21, and 0.21, respectively, under similar environmental conditions. This will allow managers to adjust alligator counts by the detection probability for each survey conducted.

Statewide adaptive management of public alligator harvests using structured decision making and integrated population modeling

Tara Gancos Crawford[1], Clinton T. Moore[1,2]

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[2]U.S. Geological Survey

Since its recovery following federal endangered species listing, the American alligator (*Alligator mississippiensis*) has been re-established as a game resource in the southeastern United States. In collaboration with wildlife managers in Georgia, Florida, South Carolina, and Alabama, we are establishing a structured decision making process for setting public harvest policies that respects the unique objectives, regulatory options and constraints in each state. As part of this work, we are synthesizing existing alligator population data to develop integrated population models that estimate the underlying mechanisms of harvested alligator population dynamics and account for uncertainties characteristic of population surveys and scientific research. The predictive models will enable managers to evaluate alternative regulatory options and optimize policies to achieve management goals in a biologically sustainable manner. Further, the decision framework will facilitate learning about alligator populations as the models are updated and evaluated cyclically following implementation of selected harvest polices and collection of subsequent monitoring data. Initial consultations with our partners indicate that the nature and scale of alligator harvesting and monitoring, and associated regulatory decision processes, vary across political boundaries. Moreover, the participating states have distinctive program histories and face variable pressures to change current regulations, yet all are required to make multi-objective decisions in spite of pervasive uncertainties about system status and behavior. The decision support tools and process developed by our collaboration will provide prototypes for wildlife managers to optimize regulatory polices to ensure ongoing use and conservation of wildlife resources based on observed population conditions and preexisting data.

Size, sex, and individual-level behavior drive intra-population variation in cross-ecosystem foraging by American alligators (*Alligator mississippiensis*)

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Large-bodied, top-predators are often highly mobile with the potential to provide important linkages between spatially distinct food webs. Once determined, the strength of these cross-ecosystem linkages can be used to infer the degree of connectivity between ecosystems. What factors drive variation in the strength of these linkages, however, has rarely been examined. Here, we investigated how ontogeny, sex, and individual-level behavior impacts intra-population variation in cross-ecosystem foraging (i.e., between freshwater and marine wetlands), by the top-predator *Alligator mississippiensis*. Extensive field surveys revealed *A. mississippiensis* utilizes marine ecosystems regularly and are abundant in estuarine tidal creeks (from 0.3–6.3 individuals/km of creek, n = 45). *Alligator mississippiensis* captured in marine/estuarine habitats were significantly larger than individuals captured in freshwater and intermediate habitats. Stomach content analysis showed that small juveniles consumed marine/estuarine prey less frequently (6.7% of individuals) than did large juveniles (57.8%), sub-adult (73%), and adult (78%) size classes ($P < 0.001$). Isotopic mixing model analysis (SIAR) also suggested substantial variation in use of marine/estuarine prey resources; differences were among size classes and within size classes between sexes and individuals (range of median estimates for marine/estuarine diet contribution = 0.05–0.76). These results demonstrate the importance of intra-population variation in determining the strength of predator-driven ecosystem connectivity resulting from cross-ecosystem foraging behaviors. Understanding the factors which contribute to variation in cross-ecosystem foraging behaviors will help to characterize the effects of top-predators on community structure and ecosystem function.

Effects of Feral Swine (*Sus scrofa*) on Alligator (*Alligator mississippiensis*) Nests in Louisiana: A Three Year Summary

Ruth M. Elsey

Louisiana Department of Wildlife and Fisheries

Rapid spread of the introduced *Sus scrofa* (feral hog) is a concern for landowners due to destructive rooting behavior damaging natural habitats. In response to reports by landowners of alligator nest losses due to feral swine in 2011 we sent a questionnaire addressing this to Louisiana alligator farmers licensed to collect eggs from wild nests. Over half (51.4%) reported loss of alligator nests; an estimated 598 nests were damaged/destroyed on 37 properties. Four farmers reported this was the first year they have lost nests to feral swine despite years collecting alligator eggs. Others reported seeing wild hogs while in the field or seeing sign of hogs; suggesting future losses may occur as the range and population of this non-native species is expanding in alligator nesting habitat. Nearly all farmers who lost nests to feral swine (94.7%) reported hog damage was increasing on their properties. Additional surveys sent in 2012 and 2013. In 2012 some 252 nests were estimated lost on twenty properties; five of which were new properties not previously affected. In 2013 an estimated 393 alligator nests were lost to feral pigs and sixteen new properties not previously damaged were impacted. In addition to deleterious effects on wetland habitats caused by feral swine, the financial impact of loss of the alligator egg revenue is significant. Some farmers reported that hog removal efforts limited their feral swine damage relative to past years. Factors affecting yearly variation in feral swine damage will be discussed.

Introduction to the Session and to Zoo Programs and Practices

Kent A. Vliet

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"The Impact of Zoos on Crocodilian Conservation and Biology" highlights the diverse efforts made by zoos, aquariums and other living institutions for crocodilian conservation. The CSG Zoos Thematic Group was created to strengthen ties between zoos and the CSG. This presentation introduces zoological associations, programs, and practices that zoos utilize in animal management and cooperative breeding efforts, so any references to these in later presentations will be understandable to those not in the zoo profession. Professional associations, such as the Association of Zoos & Aquariums (AZA), the European Association of Zoos and Aquaria (EAZA), Zoo Aquarium Association (ZAA) and World Association of Zoos and Aquariums (WAZA), require rigorous standards of zoos for accreditation. Taxon Advisory Groups (TAGs) consist of zoo professionals specialized in husbandry, captive management, and conservation needs of specific taxa. The AZA's Crocodilian Advisory Group (CAG), the first TAG, formed in 1987. TAGs develop Regional Collection Plans (RCPs) and maintain studbooks to manage breeding and transfer plans, conservation initiatives, and scientific research. Zoos coordinate cooperative breeding and transfer activities, principally on Endangered or Critically Endangered species, through programs like AZA's Species Survival Plans® (SSPs) and Red studbooks and EAZA's European Endangered Species Programs (EEPs) and European studbooks (ESBs). Animal record keeping systems allow access to animal identification, ownership, location, studbook information, demographics, transfers, and medical records. ISIS (International Species Information Systems) is the largest international network of animal records, using its Zoological Information Management System (ZIMS) to link data for more than 2.6 million animals of 10,000 species.

Saving the Dragon: The Pivotal Role of Captive-breeding in Chinese Alligator Conservation

Steven G. Platt[1] and Lu Shunqing[2]

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The Chinese alligator (*Alligator sinensis*) is among the most critically endangered crocodilians in the world. Historically distributed throughout the lower Yangtze River basin, the Chinese alligator was pushed to the brink of extinction by habitat loss and indiscriminate killing. Less than 150 alligators now remain in the wild and populations are highly fragmented and small (none with > 25 individuals). In 1979, 212 wild-caught alligators were used to found captive-breeding groups at state facilities in Anhui and Zhenjiang provinces, China. Initial propagation efforts were disappointing, but results improved once appropriate husbandry protocols were developed. More than 12,000 alligators are now maintained at the Anhui Breeding Center and another 1,000 are housed in Zhenjiang. The Anhui Center contains the bulk of the global Chinese alligator population, and hence its genetic diversity. Attempts to propagate Chinese alligators in the United States proved unsuccessful until 1975 when the Bronx Zoo entered into a cooperative agreement with the Louisiana Department of Wildlife and Fisheries and established a breeding group under semi-natural conditions at Rockefeller Wildlife Refuge. The Bronx and National Zoos each provided a pair of adult alligators to the program. The first successful reproduction among this group occurred in 1977, and by the mid-1990s off-spring had been distributed to 20 institutions in North America that have since become part of the species survival plan of the Association of Zoos and Aquariums. Reintroduction of captive-bred alligators into suitable unoccupied habitat will play a crucial role in establishing a larger actively managed conservation metapopulation.

The AZA Cuban Crocodile Species Survival Plan

William McMahan

Louisville Zoological Garden, Louisville, Kentucky USA

The Cuban crocodile (Croco*dylus rhombifer*) is the most endangered New World crocodilian. It has the smallest natural distribution among the earth's extant crocodilians, with a total range encompassing less than 400 square kilometers. Rampant hybridization with the widespread American crocodile (*Crocodylus acutus*), poaching, competition for resources with the introduced spectacled caiman (*Caiman crocodilus*), and rising sea levels, all endanger its existence. The Cuban Crocodile Species Survival Plan (SSP) was established in 1993, and is a program of the Association of Zoos & Aquariums (AZA), originally designed to conserve threatened species, during the current extinction crisis, for future potential repatriation. This particular program involves an ex-situ zoo-based population of some 88 (25.40.23) Cuban crocodiles, which incorporates informed demographic and genetic analyses, and resultant breeding recommendations, to enhance and preserve this captive assurance colony. In addition, the Cuban Crocodile SSP has conducted in-situ conservation efforts, in tandem with Cuban conservation authorities and biologists, to support field monitoring for the reintroduced population on Isla de la Juventud. In addition, the SSP has worked to help enhance the profile of this endemic crocodile within schools across the country, as well as in special crocodile festivals held in the communities adjacent to both wild populations.

Danau Mesangat – Crocodile Conservation Inside Out

Rob Stuebing[1], Ralf Sommerlad[2], Agata Staniewicz[3] and Natascha Behler[4]

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Tomistoma schlegelii was displayed for decades in international zoos, even while its natural history remained a puzzle. The origin of captive animals was rarely documented, so little was recorded about their original habitat. Thought to be Endangered over most of its range (Southeast Asia), the conservation status of the Tomistoma remained mostly data deficient. From the 1990s onwards, local and international researchers pieced together a better picture: populations of *Tomistoma* in Malaysia and Sumatra seemed scarce, while Kalimantan populations were widely distributed and abundant. In 2002, the new CSG Tomistoma Task Force sought to clarify the conservation status of the species. *Tomistoma* was found to be common in a site near Muara Ancalong District in East Kalimantan called Danau (Lake) Mesangat. In 2008, a British plantation company obtained rights to a property encompassing Danau Mesangat and opened it for development. Subsequently within a year, the company's conservation department and a local conservation foundation initiated formal conservation efforts at the site. Supported by the Mohamed bin Zayed Foundation, funding a group of dedicated zoos in Europe and America, WAZA and EAZA, the AZA Crocodilian Advisory Group and the CSG Tomistoma Task Force, three consecutive years of field studies were implemented. Local and international students investigated the ecology and behavior of *T. schlegelii*, and of the sympatric (and Critically Endangered), *Crocodylus siamensis*. Much more is now known about both species because of the Mesangat work, including their remarkable adaptability in sites of highly disturbed habitat.

Cooperative Efforts to Conserve Africa's Most Endangered

Crocodilian–Slender-snouted Crocodiles (*Mecistops* sp.)

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The African slender-snouted crocodiles are the least known crocodilians in the world. Available data prior to the turn of the century was insufficient to evaluate its status, but already suggested that across its range, crocodiles of the genus *Mecistops* were deteriorating. Over the last decade, population and ecological studies, combined with genetic and morphological analysis, has led to a better understanding of the conservation status and management needs for slender-snouted crocodiles. To respond to these species management needs, a collaborative partnership between the San Diego Zoo, the AZA Crocodile Advisory Group's Species Survival Plan, the Abidjan National Zoo, and Matt Shirley began in 2009 in simple support of fieldwork, but has now evolved to incorporate captive husbandry recommendations and training, facilitation of captive breeding and headstarting for wild reintroductions, and expansion of the partnership consortium to include other institutions like the Albuquerque BioPark and Busch Gardens – Tampa Bay. We present an overview of our cooperative efforts to illustrate how public – private – government – researcher partnerships can affect the real-time conservation of threatened crocodilians globally.

Developing Regional Studbooks – Genetic and Demographic Analysis of Small populations

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Since many decades zoos play a vital role in conserving ex situ-assurance populations for many animal species. The ideal long-term goal is always to keep a genetically and demographically healthy assurance population in case one day even reintroduction of extinct species into suitable habitat should become necessary. Based on our experiences as European Studbook (ESB) keepers for the African dwarf crocodile (*Osteolaemus tetraspis*) and the Philippine crocodile (*Crocodylus mindorensis*) we provide several tools how to monitor and influence the development of such populations in human hands. Captive animals are registered in SPARKS (Single Population Animal Record Keeping System) and by the use of the software PM2000 or PMx (Population Management) an exact analysis of the demography (sex distribution, age pyramid, mortality and fertility) is possible as well as of the genetics (ancestry, mean kinship, inbreeding coefficient, genetic diversity). This enables the best planning to maintain a genetically and demographically healthy population as well as high genetic diversity among the zoo populations. Precondition is of course the resolved taxonomic status of the original population, i.e. the taxon (normally species) of concern. Based on the captive population management of the afore mentioned crocodile species we highlight the importance of thorough genetical screening to ensure the purebred status of the individuals held within the conservation breeding programs. Only after such research necessary transfer recommendations and breeding recommendations can be issued based on the obtained results to exclude hybrids or falsely identified species from the breeding program.

Managing Small Captive Assurance Populations for Conservation Endeavors –

Doing a Lot with a Little

R. Andrew Odum

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In some cases, assurance populations in captivity may be the only short term option for future preservation of wild populations of crocodilians. Well managed populations create options for future repatriation and reintroduction, and buy time to secure appropriate habitat and to mitigate environmental quality issues that may be present. The resources for assurance programs are limited, both in the amount of genetic diversity secured for the founding of populations, and the captive resources to house, feed, breed, and rear crocodilians. Thus the efficient utilization of resources is essential to the success of these efforts. If the husbandry is fully understood and repeatable, there are few groups of animals that lend themselves better to small population management than crocodilians. The long reproductive life-span, large total number of offspring that can be produced in a lifetime, low mortality rates, and the ability to identify individuals all can increase the effective population size of small captive assurance populations. This presentation will review some of the basic principles of small population management and identify tools that are available to conservationist that feel it is appropriate to use small captive populations to preserve a species. A web-based tool to establish target population sizes from an available founder base will be demonstrated.

Beyond the Park Gates: Zoos Step Up with Crocodile Conservation Program $upport

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The mission of the 21st Century zoo is widely accepted to be conservation, education, recreation and research. In the past decade, concern over biodiversity loss has triggered a growing number of these institutions to contribute more funding to conservation and research that directly benefits species in the wild. Despite fierce competition from the "cute and cuddly," or, "colorful" classes of creatures, financial and in-kind support by zoos for crocodilians is gaining momentum. Information was collected via questionnaires circulated on list serves and by direct communication in an attempt to quantify the monetary support for crocodilians by zoos over the past five years. Here, we present the results of this analysis, showing that zoo support is behind most conservation programs for endangered crocodilians. We further share insights as to how zoo contributions might be increased in the future.

Zoo/Private Partnerships for Fundraising and Conservation

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[5]San Diego Zoo Global

Over the last five years there has been a marked increase in collaboration between zoos and the private sector in support of crocodile conservation. Several focused fundraising events have rapidly gained popularity, including "CrocFests", "CROCtoberfests," and "Scales and Slime." These festivals have a range of themes, but generally include fun, educational activities for people of all ages along with many different, often creative, ways to raise funds. Driven by zoological institutions or by private conservationists with a passion for crocodilians, effective partnerships have evolved through the organization and hosting of these events. These include local herpetological societies, city parks, non-profit zookeeper associations, herpetoloculture-friendly businesses and nature-loving individuals. The festivals and related outreach events have not only increased awareness of the plight of crocodilians worldwide, but have generated a significant amount of funding for field conservation and research. Here we will discuss some of these collaborative efforts, provide examples of creative fundraising, and provide an overview of the amount of funding raised as well as some of the conservation initiatives these funds have supported.

Behavioral Conditioning to Assist in Crocodilian Conservation

Flavio Morrissiey[1], Jessi Krebs[2], Andy Reeves[2,]

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Traditional methods of capture and restraint have been the standard methods used in most if not all crocodilian research and conservation projects. We highlight several examples of the effectiveness of classic and operant conditioning in crocodilians with no compromise to the welfare of the animals or safety of the staff. These methods are now widely used in captive management of crocodilians. Possible application of these methods in *in situ* crocodilian conservation projects is examined through proposed methods and case studies. Success is dependent upon the evolution of the systems implemented for conservation.

Increasing people participation in crocodile conservation: zoos as agents for change

Chris Banks

Zoos Victoria, Parkville, Australia

Thousands of species around the world are threatened with extinction. The threats are driven by people and the choices we make. The world's zoos attract more than 700 million visitors annually and many more on-line and via social media, and have huge capacity to engage people in conserving wildlife. Zoos Victoria is using social science methodologies to influence positive behaviour change for wildlife. Community conservation campaigns use a Connect-Understand-Act model that links animals in our zoos and visitor-driven threats in the wild, provides actions people can take and measures social change and wildlife outcomes. "Seal the Loop", targets marine entanglement threats to fur seals, resulting in 10km of fishing line placed in collection bins each year rather than the in sea, supported by 59 community groups. "Don't Palm Us Off" links orangutans in Melbourne Zoo with their 'palm-oil driven decline' and has influenced more than 200,000 people to ask for palm oil to be labelled on all products containing it, stimulated a bill in the Australian Parliament and caused all six major palm oil users in Australia to make time-bound public commitments to only use Certified Sustainable Palm Oil. Key factors in the success of this approach are evidence-based rigour, making people part of the solution and removing the barriers to them taking action, focused messages, and measurable targets. The process complements and enhances field-based recovery programs, and can be applied to threatened crocodilians if the campaign selection criteria are met.

Collaborative Efforts for Captive Breeding and Reintroduction of *C. siamensis* in Cambodia

Lonnie McCaskill
Zoological Manager Disney\'s Animal Kingdom

Almost twenty years ago the discovery of a single Siamese Crocodile in the Cardamom Mountains of Cambodia triggered a partnership and collaboration between local Khmer mountain people and Fauna and Flora International. Through the assistance of many partners a strong alliance has been built for the conservation of the Siamese Crocodile. I have been assisting FFI in surveys of wild populations, captive husbandry, relocation and reintroductions since 2004. This presentation will cover many great successes, challenges and learning's throughout this ongoing project. I will share during the presentation how these partnerships have resulted in a conservation collaboration that has successfully protected, breed and reintroduced --- individual animals back into the Cardamom Mountain region.

Home range of *Caiman latirostris* (Crocodylia, Alligatoridae) in the Pampas of Argentina

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Ranching programs are developed for *Caiman latirostris* in Argentina. These programs are based on eggs collection and release of a fraction of the hatchlings in the wild after one year of captive rearing. However, information about the behavior of reintroduced animals such as home range and habitat use are still missing. In this study we aimed at determining the home range of wild and reintroduced females in Santa Fe province, Argentina. Field work was carried out in a protected area with a natural stream and lagoon (30º11'26"S 61º0'27"W) between December/2010 and April/2012. We monitored eight adult females (four wild and four reintroduced) with radio transmitters (VHF, GPS and UHF). Monitoring period ranged from 19 days to 455 days. Home range was estimated by Minimum Convex Polygon (MCP) and Kernel 95% (K95) methods. Mean females home range (MCP and K95, respectively) was 98 ±91.2 ha (14-268 ha) and 39.7 ±35.3 ha (1-89 ha). There was no difference between wild and reintroduced females home range (MCP: 60-268 ha and 14-142 ha respectively; K95: 21-49 ha and 1-89 ha, respectively). However, reintroduced females predominantly used the lagoon, whereas wild females used both water bodies indistinctively. Such difference in habitat use apparently resulted in differences between MCP and K95 values for wild females. The present results suggest that reintroduced females have similar home range as wild ones, but with distinct habitat use.

Community-based Siamese Crocodile Conservation in Lao, PDR

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Populations of the Siamese crocodile (*Crocodylus siamensis*) have been decimated throughout Southeast Asia by a combination of illegal killing for skins and meat, collection to stock commercial crocodile farms, and habitat destruction. In Lao PDR (Laos), potentially viable, but fragmented populations of wild *C. siamensis* are confined to wetlands in Attapu, Salavan, and Savannakhet provinces. A long-term species recovery plan developed by Wildlife Conservation Society in collaboration with the Lao Government identified six wetlands in Savannakhet Province harbouring small crocodile populations amenable to conservation action. A crocodile conservation program was initiated in communities surrounding these wetlands in 2008. Community discussions led to the establishment of site-specific management plans to protect crocodiles and their habitat. Village Conservation Committees were organized in each community and tasked with enforcing conservation regulations, monitoring crocodile populations, and collecting crocodile eggs as part of a head-starting program. Population monitoring is conducted using a combination of spotlight counts, camera trapping, track and sign surveys, and nest counts. Head-starting is being conducted at the Lao Zoo and Tan Soun Village; eggs are collected from nests and artificially incubated, and hatchlings are reared for about 1.5 years and then released. A single clutch was collected and incubated in 2011, 2012, and 2013. The 2011 cohort was released in 2013 and the 2012 cohort is slated for release in 2014. A breeding group of 10 genetically-pure Siamese crocodiles assembled at the Lao Zoo in 2012 produced 21 hatchlings in 2013.

Heightened river dynamics from 100-year flood threaten growing crocodile population in South Africa

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A catastrophic flooding event has lowered the carrying capacity of a South African river, hindering the further expansion of a growing crocodile population. While other Nile crocodile populations along the southern range limit have decreased, this peripheral population in an unprotected, closed system has increased over the last 30 years, despite negligible immigration, no protective fencing, little law enforcement, increasing urbanization and farming, and unsustainable river use. However, occurrences of catastrophic floods, termed 100-year floods, in 2000 and 2013 have reshaped the river and amplified effects of deforestation and farming. The crocodile population is subject to these floods and the increasing dynamics of the river are reducing chances of survival. We quantified the amount and quality of riverine and bank habitats of 95km of river, from the source to a fenced protected area, and intensively surveyed 15km to estimate the carrying capacity of the river both pre and post the 2013 flood. Following the flood, we found a decrease in the quality of habitat and, in turn, carrying capacity. Sandbanks, where 44% of crocodiles were found, decreased by 25% following the flood, inclusive of regular seasonal fluctuation of around 8%. We suggest an increase in the frequency of 'one in 100-year' floods will cause the rate of reproduction and sexual maturity to be insufficient to compensate for the heightened pressures of a more dynamic river. We further discuss how lessons learned in this study can be used in conservation of small populations in nonprotected areas across Africa.

Transboundary Sanctuary for Gharial (*Gavialis gangeticus*) Conservation in Bangladesh

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Surveys conducted to assess the status and to identify suitable habitats for gharials in Bangladesh revealed that suitable habitats are still present in some secluded areas of the Padma River (=Ganges River). One such area is at Guhomabuna on the banks of the river Padma in Rajshahi district adjoining the Indian border where adult gharials and hatchlings have frequently been sighted. This particular area shares the no-mans-land between Bangladesh and India and is relatively peaceful with little or no threat. High sandy river banks mark the area that serves as the nesting habitat for the gharials. The population of gharials in Bangladesh has reduced significantly and gharials once used to nest at Char Khidirpur downstream of Guhomabuna. This area if managed jointly by Bangladesh and India can support a healthy gharial population. The area is also important for the migration of gharials between Bangladesh and India and recent sightings of gharials in the Indian Bhagirati and Hoogly rivers bears the evidence. Upstream the Farakkha dam hinders movement of the gharials and other aquatic animals like dolphins (Platanista gangetica) so alternately the gharials might have chosen the distributaries of the Padma River for their movement. Joint surveys conducted by both the Bangladeshi and Indian biologists can shed some more light into this and the area can be proposed for the creation of a gharial transboundary sanctuary to the policy makers of both the governments setting an example of transboundary cooperation.

Movements and Activity Levels of Nile Crocodiles in the Lake St Lucia Estuarine System, South Africa

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Understanding the movement ecology of a species can have important management implications for its conservation. Despite crocodilians being apex predators and important ecosystem indicators, there have been few detailed studies on movement and activity levels. We investigated movements and activity of 18 Nile Crocodiles (*Crocodylus niloticus*) at Lake St Lucia, South Africa from 2009 to 2012. We used GPS-satellite transmitters with sufficient daily positional fixes to give detailed activity and movements at spatial and temporal scales. The overall activity level was 41%, and it differed significantly throughout the day. There was a significant seasonal effect on activity and *C. niloticus* was most active during autumn (52%) and least during winter (30%). We found a positive correlation between crocodile size and daily movements with mean daily movement 1252 m. Adult males were most mobile, but not much more than adult nesting females, although considerably more than adult non-nesting females and sub-adults. Adult C. niloticus moved more at night, but sub-adults moved significantly more during the day. There was a seasonal difference in crocodile movement. Water temperature correlated with mean monthly crocodile movement, and the correlation was stronger for sub-adults than adults. Overall, the longest movements were made during autumn and the shortest in winter. Size, sex, reproductive status and habitat were all important predictors of activity levels and movement. Insights from this study will improve management and allow for comparison across populations and species for a more complete interpretation of crocodilian biology, ecology and life history.

Monitoring American crocodiles (*Crocodylus acutus*) through tourist photographs at Sumidero Canyon National Park, Chiapas, Mexico

Luis Sigler

Dallas World Aquarium

Sumidero Canyon National Park (SCNP) was decreed on 1980 after the construction of a Hydro electrical dam on the Grijalva River. Since 1993 through 2003, 165 crocodiles were captured and marked, and a head start group of 293 crocodiles were marked and released at one or two years of age. The tail's simple crest was used for the year of hatching; the left double crest represents tenths, and the right double crest units. 126 photographs obtained from Flickr and Google were selected because they showed clear marked crocodiles. 65 crocodiles were identified, 18 were wild caught from a total of 165 (10.91% survival) and 47 were released from a total of 293 (16.04% survival). Internet images of marked Sumidero Canyon's crocodiles started in 2004, with a highest peak in 2010. Crocodiles are more visible during sunny days along the rainy season because the river level is lowered for management purposes at the Hydro electrical dam. Growth estimation is 240 mm/year in crocodiles 9 years old, and 190 mm/year in crocodiles between 14 and 17 years old. Females started nesting at 9 years of age. Photographs showed marked females thriving with adult wild males at established territories year round; others revealed large densities never seen before. An official project will starts in 2014 in conjunction with the tourist boat cooperatives and the national park managers, to ask tourists to send their images to a specific webpage to continue monitoring the marked crocodiles at SCNP.

Caiman survey in Corrientes province, Argentina

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Programs using wildlife should have a monitoring system so if necessary correction action could be done in order to maintain sustainability. In Argentina ranching programs need to have a monitoring of the populations under management, in this work we present monitoring results of Corrientes populations since 2008 until 2013. Surveys were done in places were YACARE PORA harvests caiman nests, inside IBERA RESERVE, and in private land were no management occurs. We used the highest relative density (RD) of every place for a certain year in order to calculate mean RD for every one of the three management options described. We did not find any clear trend for populations, besides that RD seem to change in a regional scale producing peaks for every management option in the same years. IBERA RESERVE populations show the highest variation in RD over time, possibly related to the high surface of floating vegetation in the area. Nest harvesting and reintroduction of yearlings is not affecting population trend.

Monograph “Crocodylia of Cuba”: bringing together decades of crocodile research in Cuba.

Manuel Alonso-Tabet[1], Roberto Ramos[1], Roberto Rodríguez-Soberón[2], John B. Thorbjarnarson[3], Josabel Belliure[4] Vicente Berovides[5].

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Research on crocodile ecology and conservation in the Cuban Archipelago has been deeply improved during the last decades due to the activity of a group of specialists: Manuel Alonso Tabet, Roberto Ramos Targarona, Roberto Rodríguez Soberón, and John B. Thorbjarnarson. The Wildlife Conservation Society together with the University of Alicante (Spain) agreed to compile and edit the information issued by the group, to generate a printed material of documentary and scientific character that is introduced in this meeting: the monograph “Crocodylia of Cuba”. The book is addressed to a broad spectrum of readers: professional workers involved in crocodile research, conservation and farming, wildlifers, ecologists, lecturers, and students. It fills a sensible gap in the Cuban biological literature, offering a synthetic body of multivariate information about the crocodiles in Cuba, ranging from the outcomes by the early chroniclers of Indies, to an opportune first-hand update of the most recent achievements in crocodile phylogeny, ecology, ethology, genetics, and management; their present situation and future trends.

Everglades Restoration: Projecting benefits to the American Crocodile

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The goal of Everglades restoration is to increase the quality and quantity of freshwater flows from Lake Okeechobee into the Central Everglades. When in sufficient quantity and with strategic removal of barriers to flow, this water will ultimately empty into Everglades estuaries such as Florida Bay. Much of the remaining American crocodile (*Crocodylus acutus*) population in Florida resides in this region of the coastal Everglades and is locally endangered as a result of degraded coastal and nesting habitat, reduced freshwater inflows, and hypersaline conditions. The Central Everglades Planning Project (CEPP), a recent undertaking to scope out the next phase of Everglades Restoration, resulted in a plan with region-wide benefits that will also increase inflows through Everglades National Park into Florida Bay. Model output of the CEPP plan projected a significant decrease in salinity on average (about 3 psu) across Florida Bay and even greater improvements in northeastern Florida Bay, resulting in habitat improvements for juvenile American crocodiles. This combined with recent implementation of the C-111 Spreader project, which has shown immediate hydrologic benefits and is anticipated to increase flows by as much as 10% into eastern Florida Bay, will also have significant benefits for the crocodile. With support from Lacoste, the Everglades Foundation has begun development of an end-point plan for Everglades Restoration that will involve diverting more freshwater flow to the Everglades, removing further barriers to flow, and maximizing benefits to Florida Bay and its imperiled inhabitants such as the American crocodile.

Spatial Ecology of the American Crocodile in Everglades National Park, FL

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The American crocodile (*Crocodylus acutus*) in Florida is a large, upper trophic level predator currently listed as threatened under the U.S. Endangered Species Act. In Florida, environmental conditions within estuarine habitats of the American crocodile are expected to change due to Everglades restoration and global climate change. These changes will potentially affect growth, survival and spatial patterns of American crocodiles. Understanding different patterns of movement and habitat use of highly mobile top predators contributes to greater understanding of the interactions between top predators and the ecosystem they inhabit. Here we used satellite telemetry to determine current patterns of movement and habitat use. We estimated kernel density utilization distributions (KDEs) to depict crocodile home ranges (95% KDE) and core-use areas (50% KDE). Mean overall home ranges were 66.8 ± 33.3 (SD) km^2 and mean core-use areas were 14.2 ± 7.2 (SD) km^2. Average daily distance moved for crocodiles was > 1.0 km. Generalized Linear Mixed Effects Model showed that salinity ($p = 0.002$) and temperature ($p = 0.003$), environmental parameters most likely to change due to Everglades restoration and global climate change, significantly influenced crocodile movement patterns. As the American crocodile in Florida continues to recover and expand into its historic range and the environment undergoes potentially dramatic changes, understanding how crocodiles will spatially respond to these changes will inform us as to how crocodiles influence food web dynamics, create habitat linkages, and adjust their spatial use strategies to this changing environment.

Life's a Beach: Status and Conservation of the American Crocodile in Turneffe Atoll, Belize

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In the early 1990s, surveys of the American crocodile (*Crocodylus acutus*) in Belize were accorded high priority by the IUCN Crocodile Specialist Group. As a result, a country-wide survey of the Belize coastal zone was conducted from 1994-1997. This survey indicated that the largest *C. acutus* population and highest concentration of nesting activity in the country occurred in Turneffe Atoll, approximately 35 km offshore of the mainland. Turneffe Atoll is now thought to serve as a source population for *C. acutus* elsewhere in the coastal zone of Belize and believed to play a critical role in regional metapopulation dynamics. Reproduction of *C. acutus* in Turneffe Atoll is highly dependent on elevated beach ridges composed of coarse sand, and due to a combination of natural and human-related factors suitable nesting beaches are rare in the atoll. From 1994 to 2013, we conducted a long-term *C. acutus* monitoring program in Turneffe Atoll using a combination of spotlight surveys and counts of recently hatched nests to census the population. Crocodile encounter rates from 2008-2013 declined > 2-fold compared to those from 1994-2002. Nesting activity in the atoll declined to its lowest levels on record in 2008, but thereafter increased to the highest levels yet recorded in 2012. While *C. acutus* in Turneffe Atoll faces multiple threats, the most significant is the loss of nesting habitat. As nesting beaches are increasingly threatened by development, the conservation status of *C. acutus* in Turneffe Atoll remains tenuous.

The Danish Crocodile Zoo model for conserving crocodilians *in situ*

Rene Hedegaard, Colin Stevenson

Danish Crocodile Zoo, Eskilstrup, Denmark

"In the end, we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught." Baba Dioum, 1968, IUCN. Modern zoos strive to fulfil a conservation and research mandate that links their educational exhibits and talks with conservation impact for *in situ* projects. As a taxon-specific facility, the Danish Crocodile Zoo (DCZ) has been able to focus all of its efforts into projects for targeted crocodilian species around the world. Starting with a Chinese alligator conservation project in the 1990s, the DCZ has to date established projects for Philippine crocodiles, Orinoco crocodiles, black caimans, gharials, amongst others. It is the second zoo to house all 23 currently recognised crocodilian species, and has achieved a breeding record unique in European zoos, with 12 croc species bred at the zoo. Over the years, the conservation model we have developed has seen significant funds, personal involvement, and increased support for select species. Here, we describe this model and the impact it has had on crocodile conservation.

American crocodile, *Crocodylus acutus*, Population Distribution in Ambergris Caye, Belize

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The population of the American crocodile, *Crocodylus acutus*, in Belize is presently decreasing primarily due to continual pressure from illegal hunting, and the fragmentation and loss of habitat (Platt & Thorbjarnarson, 2000a, Thorbjarnarson et al., 2006; Rainwater & Platt, 2009). Countrywide, *C. acutus*'s non-hatchling population is estimated to be less than 1000 (Rainwater & Platt, 2009). To determine the stability of the population of *C. acutus* on Belize's largest offshore caye, Ambergris Caye, mark-recapture and eyeshine surveys conducted from January 2011 thru April 2014 document the crocodile's distribution. To date, 283 *C. acutus* are tagged for identification by Pro-ID microchips and/or scute clipping: 147 < 70cm (hatchlings/yearlings); 26 = 70-90cm (juveniles); 58 = 90-180cm (sub-adults); and 58 > 180cm (adults). During eyeshine surveys in April-May 2013, 99 American crocodiles were encountered in 138.7 km surveyed; then, in February-April 2014, 110 crocodiles were encountered within the same survey routes. Over half of the *C. acutus* population resides around the local sewage ponds. Raw data is available to The Crocodile Specialist Group for the recommendation of an attainable "American Crocodile Conservation Action Plane" for Ambergris Caye, Belize.

Crocoland Farm: The experience of seven years in the conservation, management and sustainable exploitation of *Caiman yacare* in Bolivia

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In 2006, Crocoland Farm Management Plan was approved for the conservation, management and sustainable exploitation of Caiman yacare under two systems of Ranching and Farming. The system of breeding in captivity started with a reproductive stock of 1600 females and 400 males that were harvested in the Bolivian Pantanal and the ranching program started in Communities and Private Properties of the TCO CIRPAS. Since 2007 to 2013, five exploitation cycles were completed for the Farming program, whose initial productive quantity ascended to 41,820 neonates, 30851 reached optimal productive size for exportation, registering a mortality index of 25.3%; from this program, 384 juveniles were taken and incorporated to the parental reproductive stock of the farm. For the Ranching program, four exploitation cycles were completed, its initial productive quantity ascended to 102,925 neonates and 71524 reached optimal productive size for exportation, registering a mortality index of 28.1%; from this program, 616,384 juveniles were taken and incorporated to the parental reproductive stock of the farm. And 1900 were separated for reintroductions programs. We present the captive management strategies for *Caiman yacare* including the methodologies for the harvest of eggs, artificial incubation, hatching, lift and fattening, taking into account parameters of temperature, density, nutrition, sanity and stress control. This project has being generating data for the "National Lizard Program of Bolivia" that should not be taken as simple results, but for a source of generating more information that could propose new conservation, management and sustainable management strategies.

Do crocodiles benefit local fishery productivity in the Philippines?

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We present preliminary results of our assessment on the aquatic primary productivity (APP) and local fisheries (secondary productivity) in areas inhabited by the two crocodilian species in the Philippines, namely the Philippine Crocodile (*Crocodylus mindorensis*) which was introduced in Paghongawan Marsh (Palustrine) in Siargao Island Protected Landscape & Seascape (SIPLAS), Jaboy, Pilar, Surigao Del Norte last March 22, 2013 and the indigenous population of the Indo-Pacific Crocodile (*Crocodylus porosus*) in Rio Tuba River (Estuarine), Bataraza, southern Palawan. Aquatic Primary Productivity (APP) was determined using light and dark bottles reaction method. Catch-per-Unit Effort (CPUE) of gillnets in these sites (with crocodiles) were compared with their corresponding control sites (without crocodiles) as well as with APP values. CPUEs were found higher in areas inhabited by crocodiles but appeared not directly influenced by APP. The increased fish catches in areas inhabited by crocodiles might be attributed to several factors such as reduced fishing pressure (direct effect) as the presence of crocodiles discouraged the locals to fish intensively. In addition, the completion of this comprehensive assessment is expected to provide results on the role of crocodiles in altering the nutrient regime (indirect effect) thereby enhancing the aquatic primary productivity of the aquatic ecosystems being studied. The significance of these findings from the two cases presented herein that sustains local fishery in support for the conservation of crocodiles in the Philippines is discussed.

The American crocodile Crocodylus acutus at “La Encrucijada” Biosphere Reserve, Chiapas, Mexico: Perspectives for conservation and sustainable use

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The unsustainable use of *Crocodylus acutus* skins on the coast of Chiapas occurred by the twentieth century put them on the brink of extinction. Mexico enacted a total ban for the three species of Crocodylia in 1970 and now they are protected in the Mexican Official Normativity. In 1995 La Encrucijada Biosphere Reserve in the Pacific coast was decreed; and in 1996, the first formal research on *Crocodylus acutus* and *Caiman crocodilus* populations was performed. Annual monitoring was continued until 2014. During the surveys from 1996 to 2000, *Crocodylus acutus* was represented mainly in El Hueyate estuary, although there were records of the species in other parts of La Encrucijada and other parts of the coast of Chiapas. The encounter rate (ER) estimated in 1998 was 1.43 crocodiles / km and 19 active nests were recorded in 1999. It is possible that protective measures taken since 2000 as ecological awareness and transplanting several clutches to safe places, and continue monitoring of the population have favored the recovery of the species, because the amount of nests increased to 31 in 2010, crocodile interactions to humans increased in the past three years, the ER in 2014 increased to 2.71, and American crocodiles are now abundant in other estuaries close by. A management program is proposed to maintain populations of crocodiles stable, diminishing human-crocodile conflicts and to allow their sustainable use by education campaign, eggs and hatchlings ranching, sub adults extraction, and captive display of nuisance crocodiles.

Demographic Approach of an African Dwarf Crocodile *Osteolaemus tetraspis* (Crocodylia: Crocodylidae) Population: Control Study Before a Long Term Monitoring

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The African dwarf crocodile *Osteolaemus tetraspis* is classified “vulnerable” in the IUCN red list, protected by the annex I of the Washington convention and its data about populations are listed as “extremely poor” by IUCN. I studied one of these populations in the South of Republic of Benin to determine its characteristics. The study is based on morphometric data which were measured on 40 wild *Osteolaemus tetraspis* and compared to data resulting of 17 captives dwarf crocodiles in France. Basing on the determination of maturity size (which is determined around 1 meter), it showed that there were more juveniles than reproductive crocodiles and that age classes of juveniles were logically distributed with a individual number decreasing when age increases. Both firsts’ age groups are subsampled and we have to find a selective sample technique to catch little crocodiles. The sex-ratio is relatively balanced but it is not usual in crocodilian populations. But as it depends of environmental factors and of nest place choice by females, we can’t say if the sex-ratio is abnormal in this population. This control study allowed to know better the *Osteolaemus tetraspis* population of the Sitatunga valley and should be followed by a long-term management of it.

Pilot project on sustainability, production systems and traceability of *Crocodylus moreletii* in Mexico

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Currently, five closed-cycle captive breeding operations are actively producing *Crocodylus moreletii* skins for commercial purposes in Mexico. Mexican Government has been developing a pilot project on *C. moreletii*, in collaboration with the Responsible Ecosystems Sourcing Platform (RESP), in order to tackle the challenge of increasing Mexico´s production of skins by incorporating ranching systems that complement the existing closed-cycle operations. Through best-practices and an effective traceability information system, enforcement of legal and sustainable trade will be enhanced, at the same time creating market incentives for the conservation of biodiversity. The project will build from knowledge generated through the Morelet's Crocodile Monitoring Program in Mexico and its network of experts, as well as from the preliminary analysis developed by RESP and the National Commission for Knowledge and Use of Biodiversity of Mexico (CONABIO) on the existing data collection, production systems, current tagging and marking mechanisms in place. Preliminary pilot sites will be identified throughout Morelet´s crocodile distribution in Mexico, and additional sites will be selected as the project evolves and is successfully achieved at preliminary sites. The project will be implemented through an inter-disciplinary multi-stakeholder partnership between Mexican authorities, producers, research institutes and local communities, which will form a national coordination committee that in turn will engage to international stakeholders of RESP. The project will contribute to develop and test best-practices on sustainable use of Morelet´s crocodile focused on conservation and livelihoods, and involving all stakeholders of the value chain. The project is expected to start in 2014.

Health assessment of the American alligator (*Alligator mississippiensis*) found on the Kennedy Space Center / Merritt Island National Wildlife Refuge, Florida.

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From 2006 to present a multi-disciplinary study ranging from ecotoxicology to basic life history of a estuarine population of the American alligator. The study area includes 56,655ha (140,000 acre) of Kennedy Space Center and Merritt Island NWR, east central, Florida. To date 1,264 alligators have been captured and released, which includes 239 recaptures. From each captured animal sex, morphometric data, location, blood, urine and tissue samples were collected and tagged with PIT (Passive Integrated Transponder) tag. For this presentation the results from the life history portion of the study will be discussed. Average lengths were 216cm (7.08ft) for female and 267cm (8.75ft) for males with the largest 379cm (12.43ft). Sex ratio of captures was 2:1 male. To determine nesting success, 2,202 eggs from 46 nests (all years) were collected, incubated, hatched and released. The average clutch size was 36 eggs with an overall hatch rate of 74%. Concurrently, an effort was made to quantify, sex determination temperature profile patterns in wild nests. From 2010-2013, three thermistors per nest were inserted and stratified within the egg chamber of 40 individual nests. These recordings track temperature profiles on a fine scale (5min) throughout the incubation process including the critical time period of incubation when Temperature Sexual Determination (TSD) occurs. The TSD average temperature for all nests was 31.63C.Further study is needed to determine if point source pollution or other variables (e.g, new launch vehicles) could change the existing environment that these animals live in.

Progressing Research and Conservation Efforts for the Endangered Tomistoma (*Tomistoma schlegelii*) in Kalimantan, Indonesia.

Anthony Pine

The Tomistoma Fund, Riverside, California

The Tomistoma Fund is an established 501(c)3 public charity founded in May, 2011, to further promote funding and collaboration of efforts towards the research, conservation, and management of wild Tomistoma (*Tomistoma schlegelii*). As an endangered species in the IUCN Red List, there is an immediate need to further our scientific understanding of the species current geographic distribution, ecology, reproductive biology, behaviour, and diet in order to pursue future conservation and management efforts. The objective of this organization is to help facilitate *Tomistoma* research projects and initiatives in the aforementioned, but not limited to, fields of study. Equal in importance, our organization aims to promote local and international education and awareness for the species through literature and public presentations. In 2014, The Tomistoma Fund and members of Universiti Malaysia Sarawak and Sarawak Forestry Department conducted a series of pilot research surveys and conservation efforts for the *Tomistoma* at three, high-priority sites in Sarawak, Malaysia. Although these intensive efforts were successful in creating a better understanding for areas where the *Tomistoma* have historically been known to exist, the understanding for current densities and distribution for the species in Sarawak is still lacking. In this regard, there has been a focus shift to promote and progress efforts in field research, conservation, and long-term management at locations where the species is better known to exist within the wetland habitats of East and West Kalimantan, Indonesia. Promising opportunities have developed towards such collaborative efforts in Kalimantan along with new and exciting potential for *Tomistoma* conservation.

Trends and characteristics of American alligator (*Alligator mississippiensis*) bites on humans in Florida

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We evaluated trends and characteristics of 321American alligator (Alligator mississippiensis) bites on humans in Florida during 1948-2013. The estimated frequency of bites resulting in major injury to the victim increased at an annual rate of 3% during 1971-2013 but fluctuated over time. The rate of bites per Florida resident was relatively stable for most of the 1971-2013 period, but has declined since reaching peak in 2001. Monthly frequency of bites was positively correlated with mean maximum air temperatures and not correlated with testosterone concentrations in adult male alligators, suggesting that bites are more related to temperature than territorial defense. We documented only one instance where a bite was prompted by defense of eggs or young by an adult female. Alligators were not observed prior to biting the victim in 79% of bites, suggesting that alligators usually used stealth when attacking humans. Twenty-two fatalities were attributed to alligator attacks. Alligators involved in fatal attacks were in good physical condition with few deformities or injuries. Alligator bites in Florida largely appear to be feeding attempts, although in slightly over half of cases (53%), the incident consisted of a single bite then release, suggesting that alligators were unsure about their prey or possibly biting in defense. The risk of an unprovoked alligator bites has been contained by removal of potentially problem alligators through Florida's nuisance alligator management program. We discuss reasons for the most recent decline in the rate of bites.

Human-Crocodile Conflict in the Australia-Oceania region

S. Charlie Manolis and Grahame Webb

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Although the status of Saltwater Crocodiles (*Crocodylus porosus*) within the Australia-Oceania region varies between countries, the frequency of crocodile attacks in each country is increasing over time. The status of *C. porosus* populations in Timor-Leste and the Solomon Islands needs to be quantified, and both countries have identified the need to develop crocodile management programs. In the case of Timor-Leste, a small, developing island nation, crocodiles are culturally important, and management options may be more restrictive than what has been applied by other regional neighbours (eg Papua New Guinea, Australia). In Australia, public education plays an important role in mitigating human-crocodile conflict, and problem crocodile programs have been established to enhance public safety. We examine the history of HCC in the region, and provide some guidance on crocodile management that may assist in achieving the goals of ensuring crocodile conservation and public safety within the social, political, cultural and geographical context of the countries.

A Roadmap for Crocodile Conservation in Sarawak

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In Sarawak, the mention of crocodiles spews an air of love and hate – more of hate at present. Despite the current irritability with crocodiles which are regarded as vermin, the culture of the various tribes in Sarawak has always heralded crocodiles as a protector with divine strength and power. Sarawak's football team has a crocodile as its mascot, instilling its team with an aura of invincibility. Protection by the law for over twenty years had allowed the once near-threatened population to recover, so successful was the recovery that Sarawak is now faced with an increased in Human-Crocodile conflict. Incessant public outcries propelled the State Cabinet to issue a directive to conduct statewide crocodile culling exercise. The management authority, however, has convinced the cabinet to review this directive holistically and scientifically resulting in the approval of the "Holistic Crocodile Resource Inventory for Sarawak" and other initiatives to ensure win-win coexistence between human and crocodile. This paper reports on the up-to-date status of the study and on the various efforts in developing and implementing a roadmap for a comprehensive crocodile management in Sarawak.

Human/Crocodile Conflict in South Asia and Iran

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Culture, poverty and a growing human population present unique challenges to conservation and wildlife management within the South Asian region. The three crocodilian species here are the saltwater crocodile, the mugger, and the gharial. Although each species is recovering across much of their range, the loss of habitat combined with human expansion into previously wild areas is causing increased reports of conflict. Cultural and social reliance on natural and man-made water resources has always been a source of human-crocodile conflict (HCC). Here, we look at the extent of HCC, the consequences of conflict, and how it is currently dealt with across the region. We also make recommendations for mitigating human-crocodile conflict within the South Asia/Iran region as part of some much-needed management plans.

Melanosuchus niger and people: a clashing scenario as both human and caiman populations increase in the Amazon with particular reference to tourism.

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TRAFFIC South America, Quito, Ecuador.

In August 2012, a couple of tourist were attacked and severly maimed by a large male black caiman (Melanosuchus niger)in the Ecuadorian Amazon. A close analysis of the case: why it happened and how further accidents can be prevented, has helped guide both authorities and communities to better cope with the evident reality of increasing black caimán populations -in numers and size of animals, and the threats that this coexistence brings to people and to the persistence of the species in its hábitat. An analysis of recent attacks on humans by M. niger compiled by the Croc-bite data base and other sources, helps profile what situations generate higher potential for attacks and what measures can be taken to prevent them and so increase social enemity towards the species throughout the Amazon basin as the final looser will be a species that is recovering from its massive killing in the XX Century.

Louisiana's Nuisance Alligator Program

Ryan King and Ruth M. Elsey

Louisiana Department of Wildlife and Fisheries

The Louisiana Department of Wildlife and Fisheries manages the American alligator (*Alligator mississippiensis*) as a commercial, renewable natural resource. The goals of the Department\\'s alligator program are to manage and conserve Louisiana\\'s alligators as part of the state\\'s wetland ecosystem, providing benefits to this keystone species, thus aiding the fish and wildlife that depend upon alligators. The Department\\'s sustained use program is one of the world\\'s most successful conservation efforts. This success has increased the statewide alligator population, but because of this success, the occurrence of human – alligator conflict has also increased statewide. The Department receives over 2,200 nuisance alligator complaints annually. Approximately 3,000 nuisance alligators are harvested and an additional number of smaller sized nuisance alligators are relocated annually by state licensed nuisance alligator hunters. Habitat loss and human encroachment are increasing in Louisiana, and as the human population increases, so will the occurrence of human – alligator conflict. The nuisance alligator program continues to strive to minimize alligator and human conflicts throughout the state. The analysis of the 2011–2013 nuisance alligator data will be discussed. Number and location of complaints received by parish, month, and nuisance hunter will be reviewed. The number and size of alligators harvested or relocated and the time to complete the complaint assignment will be analyzed. Management implications developed from this analysis will also be discussed.

Predicting the Probability of Crocodile and Human Close-Encounters

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Eliminating the chance of undesirable close-encounters between humans and crocodiles is a key goal for wildlife managers and policy makers. To help achieve this overarching goal, both human and crocodile behaviours have to be considered and aligned, thereby providing the opportunity to determine the probability of close-encounters. This information can then be used to develop strategies (e.g. education and increasing awareness) that promote crocodile-human co-existence. In this study we took advantage of a long-term acoustic tracking study on estuarine crocodiles (*Crocodylus porosus*) in northern Australia, to monitor the movement patterns around a site (a river-crossing) that is frequently visited by the general public. Combining this telemetric movement and residence data with population estimates for *C. porosus* in the study area we were able to estimate the probability of the presence of large crocodiles at the river-crossing. We then undertook a human-based survey of residents of, and visitors to, the nearby township of Weipa to understand their appreciation of crocodiles and their actions/behaviours in crocodile habitat and specifically at the river-crossing. The majority of those surveyed were unaware of the high probability of the presence of crocodiles at the river-crossing and revealed actions (fishing, swimming, camping) that would deem to place them at risk. We argue and advocate that the approach taken in this study is useful in assessing the risk of negative encounters between humans and crocodiles and that communicating the probability of crocodile presence is an easy to understand approach in conveying the potential risk to the general public.

Human Crocodile Conflict in South Africa and Swaziland from 1949-2014

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Imperial College Conservation Science

This paper will begin with an overview of HCC in South Africa, including some information for Swaziland (these two neighbouring countries share river systems). There is no database for the region and record keeping by the conservation authorities is very poor. Data will be presented for the period from 1949 to the present, drawing on archival sources including official reports, media including newspapers an online sources, interviews with conservation managers, and the personal records of A.C. Pooley, responsible for HCC for the Natal Parks Board from the mid-1960s until 1984. The geographic area, and precise location of most of the attacks, will be shown on an interactive map. Utilising this map, I will provide analysis of the demographics of the victims by age, gender and activity at time of attack. The focus is on unprovoked attacks in the wild, i.e. excluding injuries sustained by conservation managers, or croc handlers in zoos, snakeparks or commercial crocodile farms. Only attacks where victims were actually harmed or equipment they were using (canoes, vessels for gathering water, etc.) was damaged by a crocodile are included. Attacks are classified according to date, location, season, victim’s age, gender, and activity at time of attack, and interpretation of the accumulated data (patterns, trends) will be given. Brief notes and recommendations on attempts at mitigation will conclude the paper, alongside a demonstration of a proposed data visualization tool to encourage and enable the use of crocodile attack data by conservation managers and others in the field.

Current records of the Human-Crocodile Conflict in Mexico

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The conflicts between man and crocodiles have been around since ancient times. In Mexico there are three species of crocodilians but only *Caiman crocodilus* is the one free of unfortunate records. From 2010 to date, 46 reports have been obtained from health institutions, press and regional authorities. *Crocodylus acutus* is the species mostly involved with 34 interactions (74%) including two fatalities, while Morelet\'s crocodile had 12 interactions (26%). The situation by state is as follows: Jalisco with eight interactions, all of whom were attended personally by the first author; Michoacan with seven events; Quintana Roo and Tamaulipas had six cases each; Oaxaca four cases; Nayarit and Guerrero three cases; Chiapas, Colima and San Luis Potosí with two cases each; and finally, Tabasco, Veracruz and Campeche with one case each. There is now the National Attention Protocol for Conflicts with crocodiles in Mexico coordinated by the General Direction of Wildlife from SEMARNAT since 2013. This protocol involves federal, state and municipal authorities, researchers, and Mexican crocodile handler. In Jalisco, crocodile's dental impressions are made in cardboard to estimate the total length of the animal involved and to compare with the people wounded.

Human-Crocodile Conflict with *Crocodylus acutus*, with comments on *Crocodylus moreletii* and *Caiman crocodilus*, in Mexico

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Human-Crocodile Conflict (HCC) with *Crocodylus acutus* is reported from 10 countries. Information is presented up to 2010. A data base for HCC in this region including common Caiman and Morelet´s crocodile is under preparation from Mexico. HCC related to *C. acutus* shows trends and percentages by age and sex of persons involved, and the most common causes of conflicts. Finally, hot spots, the most "dangerous" places for people are presented. México has the greatest number of HCC reports, primarily along the Pacific coast that has the greatest concentration of the distribution of *C. acutus*. Costa Rica has the greatest number of deaths recorded, which may be related to the large size of the *C. acutus*. Polymonial regression shows increasing incidence over the years ($p>0.05$), with a similar tendency in Jalisco State, at the country level (México), and throughout the distribution of the species. This increase is associated with the recovery of the species, habitat reduction andhabitat use by humans. The highest proportion of incidents, are associated with rustic and local fisheries, at least in México. Deaths by *C. acutus* are recorded from 9 countries. In México deaths are recorded from all of the coastal states where species is distributed, except Nayarit, where one possible death case is under investigation. Deaths related with Morelet´s crocodile in Mexico are recorded from the Mexico´s gulf coast in Tamaulipas, Veracruz, Campeche and Quintana Roo. Deaths related to caiman are not recorded.

Management of Human-Crocodile Conflict in the Northern Territory, Australia: Review of Crocodile Attacks and Removal of Problem Crocodiles

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Rebuilding of depleted crocodilian populations leads to increased Human-Crocodile Conflict (HCC), and the focus of management changes from conservation to mitigation of HCC. We quantified HCC in the Northern Territory of Australia by reviewing the historical records of saltwater crocodile attacks and the removal of saltwater crocodiles. Between 1977 and 2013, a total of 5,792 problem crocodiles were caught, of which 69.04% were males. The most common size class was 150-200 cm and their mean size did not change significantly over years. Between 1971 and 2013, 18 fatal attacks and 45 non-fatal attacks occurred. About 60% of these attacks occurred around human population centers including remote communities. The number of attacks, particularly non-fatal cases increased over years. This increase was strongly related to the increase in both human and crocodile populations, and the increasing proportion of larger (>180 cm) crocodiles. The peak of problem crocodile capturing and crocodile attacks was in the beginning (Sep.-Dec.) and end (Mar.-Apr.) of the wet season. However, fatal attacks occurred almost all year around. Attacks by >400 cm crocodiles often resulted in death of the victim (73.33%). Crocodiles in 300-350 cm class were more responsible for attacks than any other sizes. Proportions of indigenous and non-indigenous victims did not differ greatly. Local and male victims were much more common than visitors and females, respectively. The most common activity of victims was swimming and wading. It is essential that the public receive messages about crocodile awareness and risks through education programs.

Analysis and Review of Man and Mugger Crocodile Conflict in Gujarat State, India

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From the earliest record of human-crocodile conflict in India dating back to the 8th century, we review the history and trends in HCC within Gujarat State, India. There has been an increasing trend of attacks by crocodiles within the state, with 64 recorded incidents over the past 50 years. The attacks broadly follow the two major river systems in Gujarat, and the crocodile species responsible is the mugger crocodile, *Crocodylus palustris*. Gujarat holds a growing mugger population, a species that adapts well to modified habitats. By analyzing HCC events, we can better determine the solutions to minimize conflict. Currently, there is no coordinated plan for managing crocodiles within the state. We therefore look at mitigation of conflict within a broader management context, and make suggestions toward the development of a crocodile management plan for Gujarat state.

Attitudes, perceptions and knowledge of the local people regarding crocodile and their conservation in Charotar region, Gujarat, India

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Wetlands in Charotar region in Gujarat state harbour good population of mugger crocodiles (*Crocodylus palustris*) who share these wetlands for various ecosystem services (water, fish and space) with humans. Humans and mugger crocodiles have been steadily increasing over the past years around these wetlands, which has resulted in different types of human-crocodile interactions in this region, varying from peaceful coexistence to conflict. Conserving muggers in these human dominated landscapes require a firm understanding of people's relationship with this species. This research paper examines the attitudes, knowledge and perception towards muggers in agricultural dominated wetlands of Charotar region. A total of 360 interviews, which included 156 females and 224 male respondents from 43 villages, were carried out through key informant interviews to collect the data. We analyzed and tested for differences among 4 variables: gender, age, education and occupation. We found an overall positive attitude toward the presence of muggers in the area. However, local residents indicated a low level of knowledge concerning muggers and their management. 44.75 % of the total respondent reported that the mugger population has increased over the last 10 years.11.61% reported that the population has remained stable, whereas only 3.6 % of the respondent reported a decrease in mugger numbers over these years. Only 48.38% of the responded knew that muggers are protected species under the Indian Wildlife Protection Act (1972). Recommendations developed from this study included: increasing the awareness of muggers through targeted education, facilitating of stakeholder involvement and exploring different cost-effective conflict mitigation strategies.

An analysis of recent crocodile attacks in the Republic of Indonesia – a case study on the utility of the CrocBITE database

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As the country with the highest number of recent attack reports and very little crocodile population data, Indonesia is a good example of how CrocBITE can be used as a tool to help inform crocodilian conservation and management. Indonesia is a large, heavily populated nation composed of 34 provinces over an archipelago of 17,508 islands. There are currently four recognized crocodilian species present within Indonesia- the saltwater crocodile, Crocodylus porosus, the false/Malayan gharial, Tomistoma schlegelii, the New Guinea crocodile, C. novaeguineae, and the Siamese crocodile, C. siamensis. We collected data from 265 crocodilian attacks from January 1st, 2007 through April 1st, 2014 that resulted in 136 fatalities (51.3 % fatal) in 26 of the 34 provinces. Attack reports were acquired almost entirely from online news reports, nearly all of which were reported solely in Indonesian. The vast majority of crocodilian attacks (95.8 % attack) and fatalities (97.1% fatal) were attributed to C. porosus (254 attacks resulting in 132 fatalities), while T. schlegelii was also responsible for a small number of attacks (3.8% attacks) and fatalities (2.9% fatal); a single non-fatal attack was attributed to C. siamensis. The provinces with the highest number of reported attacks were East Kalimantan (40 attacks, 62.5% fatal), Bangka-Belitung (31 attacks, 35.5%), East Nusa Tenggara (26 attacks, 53.8% fatal), and South Sumatra (25 attacks, 72% fatal). The information derived from these data provide us with important information regarding human-crocodile conflict within Indonesia and which problem areas likely require greater attention.

Activities that may influence the risk of crocodile (*Crocodylus acutus*) attack on people in the Tempisque River area, Guanacaste, Costa Rica

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One of the largest population of *Crocodylus acutus* in Costa Rica is in the Tempisque River. Despite being threatened by habitat loss and poaching, populations have increased, due mainly to legal protection. Landscape changes in the Tempisque include increasing agriculture, human population growth, urban pressure, improvement of road networks and emerging crops. Our research took place in Guanacaste Province, in 11 communities, covering high, medium and low crocodile habitats. We assessed popular knowledge, activities in/near the river, and perceptions of 374 residents. We found the most dangerous activities were grouped in four broad categories (recreation, swimming, artisanal fisheries, gutting fish). Residents showed a lack of knowledge about crocodile natural history and habitats. People didn't know about risks and reasons for attacks, crocodile abundance, or even numbers of attacks in the area. Residents recognize crocodiles as an abundant species, and use the river for fishing, swimming and transportation. Main reasons for attacks are: aggressive behaviour of crocodiles, high crocodile density, reproductive season, feeding, human recklessness, and proximity of the riverbank. 55% thought the species is abundant, 35% thought there were few in the river, and 70% believe the crocodile population has increased over the last 10 years. Regarding precautions taken to prevent attacks, almost 60% said not approaching the river, avoid places where crocodiles live (16%), and 11% said to be careful. Environmental education at 4 schools showed that children in four communities varied with respect to knowledge about crocodiles and their biology. In general, perception of crocodiles is unfavourable.

Human-Crocodile interaction in the Great Tempisque Wetland, Costa Rica

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Due to development and urban expansion the interaction between man and wildlife has increased. Those interactions may have benefits for both parties, but also there are those that lead to conflict. Great Tempisque Wetland, habitat of the crocodile (Crocodylus acutus), has been subjected to too much human pressure, which has dramatically reduced the space available for the species. However population of crocodiles has quadrupled in the last 15 years, and this causes that probability of encounters between crocodiles and people increase. We evaluated the interaction between human and crocodile from a qualitative approach of social research and the focused semi-structured interview technique was used to know the perceptions of different stakeholders, and also establish the level of tolerance in the communities surrounding the Tempisque River. The existence of conflict by the presence of crocodiles was identified in 22 towns near to Great Tempisque Wetland. Negative perception about crocodiles in the communities surrounding the Wetland is greater than positive and it is influenced by gender and town of residence. The negative perception is higher in women and in the villages guard, community, Palmira, Hacienda El Pelón the inshore, Philadelphia, La Guinea, Corralillo, Rosario, Puerto smoke, water well, San Lazaro, Caballito, Puerto Moreno. It was determined that if people recognized benefits or damages from the presence of crocodiles, this has an effect on the perception about this specie.

Fatal errors - learning from the past to mitigate future conflict; the CrocBITE database

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Understanding how to deal with human-crocodile conflict is a priority for crocodilian conservation. The success that we see in the recovery of wild populations risks being reversed if the lives and livelihoods of people living around them are threatened. Addressing this human-crocodile conflict requires baseline information so that the most appropriate solutions to area-specific conflict can be sought. The CrocBITE database launched in December 2013 with 1,700 records, and has added approximately 100 records a month from new attacks and historical data. Records were provided by a large number of contributors, but the majority of data were sourced from media reports and historical archives. This demanded that the quality of each record be assessed, as reports ranged from forensically detailed to little more than anecdotes. Interpreting the results of statistical analysis of such a dataset requires careful consideration of the assumptions made and the strengths and weaknesses of data for individual countries and as a whole. Loss of data has also been a factor, with preservation of historical attacks in the media becoming tangentially worse with increased time since attack. This gives CrocBITE an important role in preservation of information. We present some interesting statistics from the database, but more importantly we discuss the realistic contribution that it can make towards HCC mitigation and record-keeping.

Saltwater crocodile (*Crocodylus porosus*) nest temperatures at Melacca Swamp, Northern Territory of Australia and the implications of climate change

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Continuous nest and air temperature data were collected from seven *C. porosus* nests in Melacca Swamp, Northern Territory of Australia during the 2012-13 nesting season to determine how nest temperatures varied with respect to several parameters, such as; time of day, ambient air temperature, rainfall events, season and stage of incubation. Historical nest temperature data taken during ranching operations in Melacca Swamp since the 1981-82 nesting season were analysed to determine the usefulness of spot measurements. Weather station data were also analysed to search for evidence of changes in temperature and rainfall patterns. The potential effects of changing climatic conditions on incubation success and sex ratios of C. porosus were also discussed. Egg temperature appeared to be cooler during the day and warmer at night, as a result of evaporative cooling, thermal inertia and the insulating effects of nest material. Egg temperature was also consistently warmer than external ambient air temperature due to decomposition of nest material and metabolic heat. Rainfall events caused substantial decreases in overall egg temperature (0.7-7.3°C) and temperatures took on average 3-5 days to recover. Mean egg temperature appeared to increase approximately 1.5°C throughout the course of incubation as a result of metabolic heating. Several sources of variation (metabolic heat, rain events, time of year) made trends difficult to extract from the historical data and it was not possible to detect any changes in egg temperatures over time. Clear increases were found in maximum air temperatures, minimum air temperatures and rainfall, consistent with climate change predictions.

Designing, Developing and Constructing Crocodile Nesting Habitat in South Florida

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From the 1960s to the 1980s, the American crocodile (*Crocodylus acutus*) population in south Florida was at its lowest, with an estimated 250 ±78 non-hatchlings remaining. In 1978, Florida Power & Light (FPL) joined the recovery efforts by initiating an American Crocodile Management Program on their Turkey Point Property in Florida City, Florida. In 2006 FPL made plans to design and construct additional crocodile nesting habitat in an area south of the power plant. In the 1940s, this area (approximately 2.3 ha) along the S20 Outfall Canal was under consideration for a housing development with access to Biscayne Bay. Two canals were dredged adjacent to the property and the rock fill was used to increase elevation. The project never came to fruition and instead invasive, exotic vegetation reigned. Although used for shelter by crocodiles and other native wildlife species, there was no suitable nesting substrate. The restoration project involved removal of the invasive vegetation and much of the rock fill and replacing it with substrate suitable for crocodile nesting along with native plants. A series of ponds were designed and built to retain fresher water than Biscayne Bay. The construction was complete in December 2008 and the first successful crocodile nest hatched in July of 2009. Since then, there have been 5 successful nests and the hatchlings use the ponds regularly. The lessons learned from this project were used in designing other crocodile nesting sanctuaries in the USA and Jamaica.

Sexual Maturity in the American Alligator

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In the American alligator (*Alligator mississippiensis*) males are assumed to be sexually mature at about 1.8 m in total length, but it is not clear at what size they produce testosterone, spermatozoa and mate successfully. The minimum size for sexual maturity is thought to be around 1.8 m, but social hierarchy favors breeding by male alligators over 2.2 m. We decided to re-examine this question by studying plasma testosterone levels in blood samples from a large sample of alligators (-1,500) collected in every month of the year and ranging in size from approximately 61 cm (2 ft) to 360 cm (11.5 ft). In addition a number of testicular samples were taken for histology from alligators (close to, and equal to 1.8 m total length) during the mating season to assess degree of spermatogenesis and gonadal maturation. Testosterone values ranged from 0.05 ng/ml to 115.41 ng/ml. All size classes of alligators exhibited a seasonal cycle in testosterone levels, but the concentration were size-dependent: the larger the alligator the higher the testosterone. In all size classes, testosterone reached a peak in the breeding season (March-May). Mean testosterone in the largest size class during breeding was 75 ng/ml whereas in the smallest size class peak testosterone was less than 3 ng/ml. The smallest size class (61-89 cm) showed an additional rise in testosterone in late summer. The attainment of sexual maturity in alligators appears to be closely associated with growth and is a gradual process lasting several years.

Age-Related Fertility and Long Term Site Fidelity of Nesting American Alligators (*Alligator mississippiensis*) in Coastal South Carolina: A Progress Report

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This is a status report on the first five years of an ongoing study investigating age-related fertility and site fidelity of adult female American alligators (Alligator mississippiensis) in coastal South Carolina. Aspects of alligator population dynamics have been widely studied, particularly fecundity. However, the length of time female alligators remain in reproduction is unknown and this may have a profound influence on population growth potential. To investigate this parameter, we recaptured previously-marked female alligators at their nests in 2009-2013, and herein report on age of nesting females based on estimated age at first capture from growth curves and length of time to most recent capture. We located 107 active alligator nests during June 2009-13 on the Yawkey Wildlife Center in Coastal South Carolina. Mean clutch size was 44.0 and early incubation clutch viability was 92.2% for intact clutches (n =100). We captured 61 nesting females between June 11 and July 15 during this study. Thirty of these were recaptures from this and previous studies. Time between initial-capture and recapture for these alligators ranged from 1-31 years. The range of estimated ages of nesting females was 15 to ¡Ý55 years. Sixty-two percent of captured nesting females were estimated at <30 years, and 38% were estimated at >30 years of age. Those with estimated ages of >40 years accounted for 24.6% of captures, with five of these estimated at ages ¡Ý52 years.

Erectile mechanics in the American alligator (*Alligator mississippiensis*)

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Although the cross sectional morphology of the crocodilian phallus resembles the inflatable penises of mammals and turtles, its shaft neither inflates nor increases in stiffness prior to copulation. Dissections of the phallus from sexually mature male American alligators (*Alligator mississippiensis*) suggest the shaft of the organ is noninflatory because it contains dense collagenous tissues that do not significantly change shape when fluid is added to the central vascular space. Moreover, the wall tissue in this region lacks the organized collagen fibers that provide reinforcement during inflation in variable-volume hydraulic skeletal systems. Instead, the intrinsically stiff phallus is everted by cloacal muscles: 3D reconstruction of cloacal serial sections shows that paired muscles at the anterior end of the cloaca form a sling around the phallus at the level of the ventral tendon, immediately distal to the fusion of the crurae. Contraction of these muscles rotates the phallus out of the cloacal opening and strains paired tendons that connect the base of the phallus to the ischium. When the cloacal muscles relax, the elastic recoil of these tendons can rapidly return the phallus to its original position inside the cloaca.

Using GIS to assess nest site selection and nest abundance by American alligators (*Alligator mississippiensis*) in three central Florida lakes

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In Florida, alligator farmers commercially harvest eggs from public waters. The alligators are raised for the production of meat, hides, and other products. Historically, egg collection quotas were established by aerial surveys conducted annually prior to collections. Due to safety and budget concerns, aerial surveys were discontinued after 2005 and quotas are now established using population estimates from night-light surveys in combination with historical egg collection quotas. The objectives of this project were to develop a habitat-based model for predicting nest abundance, and examine nest site selection as a way to determine critical nesting areas for future lake and wetland management. We located 668 nests on the 3 study sites between 2010 and 2011 using aerial surveys. We visited 159 nests and collected data on nesting habitat and nest characteristics. Additionally, 61 sites were randomly selected for habitat sampling. Our results indicated that habitat differed between nest sites and random sampling plots. We found that specific plant species, organic depth, distance to water, distance to trees, and elevation were the most influential factors for nest site selection. Logistic regression that incorporated population survey data indicated the estimated number of 1.8m – 2.8m alligators was a good predictor of nest abundance (F1,33=12.85,P=0.001). Nesting distribution models were created using Maxent with environmental variables such as elevation, distance to water, distance to trees, and 13 plant community classes. The models performed well (AUC values ranging from 0.716 to 0.954), and have proven to be an effective method for determining nesting habitat use.

Video recording as a tool for the study on terrestrial reproductive activity patterns on *Caiman latirostris* on semi natural conditions. Progress report.

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Santa Fe Province is the southernmost limit on the distribution area of Argentina with a mean rainfall of 990 mm a year, and where the mean maximum temperature is of 24.8ºC. In order to record the terrestrial reproductive activity during the warm season, we utilized three digital infra-red video cameras (VideoMan digital Model VM3000 S), with a four mm wide angle and night vision up to 20 meters, connected to a Digital Video Recorder Standalone H264. The three cameras recorded the activity 24 hours a day between December 5th and up to March 31st 2014. The cameras were located on a forested area of a semi natural enclosure where *C latirostris* are reproducing year after year in conditions similar to the nature (EZE 31°35\'11.35\"S ,60°41\'39.51\"W). A total of 8,424 hours were recorded on that period and 16,828 videos of 30 minutes each were analyzed. The water and air temperature was recorded with HOBO data loggers. The information it was classified according to different categories of reproductive events as mating, territorialism, nesting, laying and nest care. It is remarkable a mating event observed on the land relatively far from the water when the air temperature was of 26.8º C at 08,07 PM. A total of ten egg laying event were observed between December 26th and January 14th.

Corticosterone Plasma levels of Embryos and Newly Hatched Broad-snouted Caiman (*Caiman latirostris*) Incubated at Different Temperatures

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The temperature-sensitive period (TSP) is the time during development at which sex determination occurs in temperature-dependent sex determination systems, such as in caimans. It is also known the interplay among temperature and steroid hormones during TSP in temperature-dependent sex determination systems in crocodiles. This experiment was aimed to determine if incubation temperature affects plasma corticosterone levels in the Broad-snouted caiman (*Caiman latirostris*). Caiman eggs, taken from wild nests just after laying, were incubated at different temperatures (31, 33 and 34°C) until hatching. Plasmatic corticosterone was determined by radioimmunoassay (RIA) in embryos, after the TSP and in hatchlings. We obtained 100% of females at 31°C and 100% of males at 33 and 34°C incubation temperatures. Significant differences among nests were observed in plasma corticosterone. However, hormone levels showed no differences between sexes in *Caiman latirostris* embryos or after hatching. Corticosterone levels in embryos incubated at 31°C ranged from 0.01 to 2.2 ng/ml, in those incubated at 33°C range was 0.01 to 4.65 ng/ml, finally embryo incubated at the highest temperature ranged from 0.01 to 6.31 ng/ml. Hatchlings presented higher levels of corticosterone, those produced from incubation at 31°C ranged from 1.11 to 16.96, at 33°C from 2.85 to 11.5 and 34°C 2.72 to 13.77 ng/ml.

Is the Sexual Determination/Differentiation Process Shared by all TSD Reptiles?

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Developmental processes underlying gonadal differentiation are quite conserved among vertebrates, but the triggers are extremely variable. In many reptile species, sex determination is strongly dependent on temperature during a critical period of embryonic development. Besides, gonadal differentiation is also sensitive to steroid hormones and on this respect, there is abundant information correlating estrogen and aromatase expression to ovarian differentiation. It has also been proven that some genes, involved in the mammalian gonadal differentiation, such as AMH, SOX9, SF1, WT1, are also present in reptiles having similar functions. However, few studies demonstrate how these genes interact with aromatase expression. In this context, the aim of the present work is to perform a brief revision of the process of gonadal differentiation in reptiles and suggests that, in some species, aromatase expression is critical step on the process of gonadal development. However, this model can explain the sex differentiation outcomes of some but not all reptiles.

Evaluation of a prospective model of the potential nesting status for *Caiman yacare* in the region of the Pantanal, San Matias, Santa Cruz, Bolivia

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On 2006 is proposed to begin the ranching of *Caiman yacare* eggs in the Bolivian Pantanal. The model that was used to establish ecological bases took into account the quantity of adult males bigger than 180 cm (GIV) in the population structure, from which infer the quantity of potential reproductive females (sex ratio of 4 females to 1 male of GIV), establish a reproductive success of the 50% of the females and calculate the potential nesting in the exploitation area. This model infers 25,520 potential nests, 14,816 in the TCO CIRPAS and 10,704 in the private properties. Since 2007 to 2012, the evaluation of the nests in the exploitation area consisted in searching, marking and taking biological data in every nest that was found. The evaluated area was delimited by marking a perimeter according to the extreme GPS nests marks (minimal convex polygon), the density was calculated dividing the total number of nests found between the evaluated surface and this result was extrapolated to the whole permanent flooding zone that cover 62.706 km^2. It was determined a mean potential of 1840.3 nests for the permanent flooding zone without including ANMI San Matias. The results show an overestimation in the potential nesting; therefore it is necessary to adjust this type of prospective model taking into account reproductive aspects that could improve the estimation of nests from abundance and structure data for exploitation purposes.

Reproductive Ecology and Hatchlings' Growth Rates in American Crocodiles in Coiba Island, Panama

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We assessed the reproductive ecology of the American crocodile on Coiba Island (Panama) from January to December 2013. At two different temporal stages of our study (January-April) and (April-December) we examined nesting sites and hatchling survivorship respectively. Ten nests were found at three nesting areas where thirty-percent of the nests were found under forest canopies, and 70% of them were exposed (distance to nearest tree 2.85 ± 1.11 m). Fifty-percent were close to the sea >15m from freshwater, and 50% were closer to freshwater about (7.0 ± 3.6 m). The nest dimensions were 17.5 ± 7.8 cm deep from clutch to surface, 42.9 ± 9.9 cm to the bottom, and 35.9 ± 3.6 cm wide. Chemical soil conditions had high concentrations of Potassium (69.3 ml/l) and low concentrations of Aluminum (0.1 Cmol/l) and Copper (0.0 ml/l), which were consistent across the nests. Volumetric Water Content was about 25.44 ± 16 at the nest-bottom and 24.66 ± 2.07 in the middle of the clutch. Hatching success was 86.1 ± 14.2 %, of which 64.4 ± 34.7 % hatched by themselves or with the mother's aid, and 21.8 % hatched with our aid. Population size was estimated at about 218.6 hatchlings for that area. The hatchling population declined at about 65.7% the first two months (April-June) and 95.9 % by the third month (July) leaving only 0.5 % by December. This is the first study to assess nesting conditions and survivability of hatchlings in a Pacific population of American crocodiles.

First successful steps towards a commercial artificial insemination program in saltwater crocodile farming and its implications for endangered crocodilian conservation

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Development of a protocol for artificial insemination in the crocodilia that is commercially viable and non-invasive begins with a safe and reliable method of semen collection, analysis and storage. Previous studies in the alligator have been limited because of the difficulty of collecting semen in sufficient volumes but here we report an extremely successful method for saltwater crocodile by means of cloacal massage of the terminal portion of the Wolffian duct. We also report the seminal characteristics of the semen samples, seminal bacteriology and a summary of the results of experiments designed to comprehend the physio-chemical tolerance of crocodile sperm to in vitro manipulation and cryopreservation. Female reproductive anatomy is briefly described, as are the potential challenges for full commercial implementation of the artificial insemination technique. We then outline the potential benefits of developing an artificial insemination protocol in terms of reproductive and genetic management as a means of improving productivity in the global crocodile farming industry and for the conservation of rare and endangered crocodilians.

Breeding and reproductive behavior of Philippine Crocodile (*Crocodylus mindorensis*) in soft-release condition in Southern Mindanao, Philippines

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Seven adult captive-bred Philippine crocodiles (*Crocodylus mindorensis* Schmidt) were released in 2006 into an enclosed semi-wild 1,600sqm natural swamp at the Pag-asa farms, Kapalong, Davao del Norte. Two of the seven were males and the rest were females. The animals were allowed to interact with each other without human intervention while two HD network cameras recorded activities near the nesting area from 2012 to 2013. Observations on the courtship, mating, nesting, and hatching behavior of the *C. mindorensis* were described from recordings of a handled video and still digital camera between January and March 2014. Under these semi-wild conditions, vibrations in the water surrounding a female and head movement of both breeders during courtship were noted. Females were also observed laying eggs during the months of April through August with 95-100 days incubation period at an average nest mound temperature of 29.2^{o}C. The annual breeding events in this semi-wild condition have yielded a total of 94 naturally hatched individuals from 2009-2013. Shared nesting was also recorded in 2012. Female adults exhibited parental care from the laying of eggs to the raising of their young.

Clinical anatomy of the cloaca and spinal venous sinus of the Nile crocodile

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Although collection techniques for blood and urine are well established, the clinical anatomy of the collection sites has not been thoroughly investigated in crocodilians. Blood samples are usually collected from the post-occipital spinal venous sinus. The anatomy of the cranial neck region was investigated macro- and microscopically, radiographically and by means of computed tomography. The spinal vein runs within the vertebral canal, dorsal to, and closely associated with the spinal cord and it changes into a venous sinus, cranially, in the post-occipital region. For blood collection the spinal venous sinus is accessed through the interarcuate space between the atlas and axis (C1 and C2) by inserting a needle angled just off the perpendicular, in the midline through the craniodorsal cervical skin, just cranial to the cranial borders of the first cervical osteoderms. The gross anatomy and histology of the spinal venous sinus of the Nile crocodile will be discussed, as well as the blood collection technique. Crocodilian urine is unfortunately not used as often as blood samples. This is most likely due to the fact that the potential of crocodilian urine, as a diagnostic sample, is underestimated. Based on the gross anatomical features of the cloaca of the Nile crocodile, it was confirmed that urine accumulates in a chamber consisting of the urodeum and coprodeum. Clean urine samples can easily be collected from the cloaca (urinary chamber) with an ordinary dog urinary catheter. The anatomy of the Nile crocodile cloaca will be discussed, and the urine collection technique briefly explained.

Disease Syndromes Associated with Herpesviruses in Farmed Saltwater Crocodiles (*Crocodylus porosus*) in the Northern Territory of Australia

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In June 2006, a disease syndrome emerged in farmed saltwater crocodile hatchlings characterised by severe ulcerative conjunctivitis and pharyngitis with marked associated lymphocyte proliferation. In older crocodiles, the syndrome occurs in a much milder form. The syndrome was initially attributed to infection with Chlamydia sp. bacteria based on the pathological character of the lesions and detection of the organism in affected tissue using polymerase chain reaction (PCR); however, subsequent research revealed a poor correlation between presence of the organism and lesions. In 2009, a second disease syndrome emerged characterised by nodular ulcerative skin lesions associated histologically with intense localised infiltration of the dermis with lymphocytes. The lesions result in rejection of skins in low numbers of harvested crocodiles. In 2010, a third new syndrome of ill-thrift and poor growth in juveniles emerged, with histological lesions of widespread lymphoid proliferation and non-suppurative vasculitis and encephalitis. Using primary saltwater crocodile cell lines, herpesviruses have been isolated from affected crocodiles in each of the three syndromes. Sequencing of PCR products has revealed that there are likely two novel herpesviruses associated with the syndromes. While there are many significant diseases associated with herpesviruses described in other species, these are the first in crocodilians.

Evaluation of Four Euthanasia Methods in American Alligators (*Alligator mississippiensis*)

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Lack of studies on euthanasia of reptiles and the need to improve welfare procedures of captive crocodilians led us to evaluate four different euthanasia methods in American alligators. Twenty-four captive hatched and reared American alligators were used in this study. The animals had an average snout to tip of the tail length of 146.29 cm. The animals were equally divided amongst the four study groups: spinal cord severance, spinal cord severance and pithing of the brain, penetrating captive bolt, and non-penetrating captive bolt. Electroencephalogram readings were obtained from each animal at three different time points (while awake, under anesthesia, and upon euthanasia) in order to record brain activity. The results of the study revealed that penetrating captive bolt, non-penetrating captive bolt and pithing cause significant depression of brain activity in American alligators below levels recorded during anesthesia. Cord severance alone did not suppress brain activity below that of anesthesia. For this reason, spinal cord severance alone should be considered inappropriate for euthanasia of alligators.

Comparison of electrical immobilization with manual capture in farmed Nile crocodiles (*Crocodylus niloticus*) by monitoring stress-related physiological parameters

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Electrical immobilization is nowadays a frequently used tool on most commercial farms in South Africa to safely handle Nile crocodiles. Although this capture method has been substantially evaluated for the Australian saltwater crocodile (*C. porosus*), its capability and restrictions have not been examined for Nile crocodiles. The aim of the project was therefore to compare electrical immobilization with manual capture in farmed Nile crocodiles (*Crocodylus niloticus*) by monitoring stress-related physiological parameters. Randomly selected study animals (n=45) were housed in communal pens on a farm in northern Kwazulu-Natal, South Africa. Crocodiles were captured by either e-stunning (n=23) or noosing (n=22) and serum lactate, glucose, corticosterone, alanine aminotransferase, alkaline phosphatase, aspartate aminotransferase and creatinine kinase concentrations determined in serum samples collected immediately after capture as well as four hours post-capture. In addition, individual capture time was recorded for all animals. Comparison of the parameters revealed significantly higher lactate concentrations in noosed animals ($P<0.001$) if compared to e-stunned crocodiles. Otherwise, there was no significant difference in the parameters monitored between the two capture methods ($P>0.05$). It took longer to restrain crocodiles with the noosing method compared to immobilizing animals via e-stunning. This could be an explanation for the higher concentrations of blood lactate. In conclusion, e-stunning is recommended as the preferred capture method for Nile crocodiles, from a physiological perspective, as well as an animal welfare and human safety viewpoint.

Characterising Poxvirus in Saltwater Crocodiles (*Crocodylus porosus*)

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Small pin-point translucent foci (commonly referred to as "pix") are the cause of many Australian saltwater crocodile (*Crocodylus porosus*) skins being downgraded but their aetiology is unknown. We hypothesised and investigated the likelihood of poxvirus being the causative agent. Fourteen crocodiles (five hatchling (<1yo), five yearlings (1-2yo) and four grow-out (>2yo) animals) were selected based on a criterion of 10 "active" and healing poxvirus lesions and tracked over 24 weeks to examine the healing process. One "active" lesion from each animal was identified and DNA extracted for PCR amplification of two genomic regions. Sequencing of ORF99 showed a high similarity (97%) with the published Nile crocodile poxvirus, whereas ORF19 was more variable (91%). One animal from each age group, showing at least three active lesions, was selected for necropsy. A full pathological examination confirmed no underlying bacterial septicaemia or herpesvirus infection. Transmission electron microscopy confirmed pox-virus infection. The previously tracked, partially-healed blemishes, as well as an additional "active" blemish, were examined using standard H&E histology to determine the depth of integumentary damage and the subsequent healing process. Before histological examination of the tracked lesions, they were examined on the light table, and there is no evidence of a relationship between "pix" and poxvirus lesions, if lesions are allowed to heal before harvest.

Determining average organ mass of select organs in finishing *C. porosus* and any relation to age, health status.

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Relatively few reference materials are available to aid the clinician/layperson in determining normalcy with regard to crocodile visceral characteristics; even less information is present when one further enquires about organ characteristics relative to individual variables. The viscera of 114 finishing *Crocodylus porosus* was grossly examined immediately following slaughter. The weight and length of selected organs from each individual were recorded and any apparent external/internal gross lesions were described and photographed. Relation of organ size to animal mass was determined; variability in organ size relative to animal mass was then compared to animal age and animal health status in attempt to identify any apparent relationships/patterns. Across sampled individuals, notable variability exists in specific organ size relative to body mass: Large variability is noted in thyroid mass, steatotheca mass, and gallbladder mass; moderate variability in spleen mass and gonad mass; and relative uniformity in heart mass and kidney mass. In individuals with lesions noted, average spleen mass and thyroid mass was larger. Individuals from older cohorts that presented for slaughter consistently correlated with smaller heart mass across 4 different age groups. Conclusion: Patterns appear to exist in variability of organ size relative to body weight across organ type, animal age, and concurrent gross lesions. The clinical relevance of such patterns remains unclear; however, potential exists that such patterns may be used to ascertain the health status/normalcy of individual animals and individual organs and perhaps warrants further investigation.

Individual feeding specialization across the range of the American alligator

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Individual niche specialization (INS) is increasingly recognized as an important component of ecological and evolutionary dynamics. However, most studies that have investigated INS have focused on the effects of niche width and inter- and intraspecific competition on INS in small-bodied species for short time periods, with less attention paid to INS in large apex predators and the effects of prey community composition on INS. We investigated the prevalence, causes, and consequences of INS in foraging behaviors across different populations of American alligators (*Alligator mississippiensis*), the dominant aquatic apex predator across the southeast US, using stomach contents and stable isotopes. Gut contents revealed that over the short-term, although alligator populations occupied wide ranges of the INS spectrum, general patterns were apparent. Alligator populations inhabiting lakes exhibited lower INS than non-lake populations, likely driven by variation in habitat type and prey community composition. Stable isotopes revealed that over longer time spans alligators exhibited remarkably stable use of variable mixtures of carbon pools. We conclude that INS can be affected by prey community composition in large apex predator populations, and that INS should be incorporated into management strategies and ecological models which typically do not consider behavioral variability. We further suggest that though crocodilians are usually thought of as dietary generalists, they may in fact exhibit context-dependent specialization in foraging behavior that is stable over many years.

The ecological status of the *C.porosus* and *C.novaeguineae* wild population trends in Papua New Guinea, 1981 -2014

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Monitoring result using regression analysis done on the large subsets for *C. novaeguineae* (N = 21, 1981 to 2013, r^2 = 0.056, p = 0.346), and (N = 49, 1989 to 2013, r^2 = 0.430, p = 0.016). Both sets are different in terms of the survey period in which they were added and the relationship mirrors both sets from 1989 and is significant. For *C. porosus* (N = 12) primary sites (1982-2014), excluding 1998 and 2010, relationship between nest counts and year r^2= 0.75, p= 0.0004, with a mean of 63.0 at a rate of 1% per annum and a SD = 15.7, range 30 to 93. Trade figures indicated 27553 wild C. *novaeguineae*, 6284 wild *C. porosus*, and farmed 13,336 *C. porosus* skins exported in the last 24 months (2012 and 2013) from January to December. This included ranched skins and wild skins of both species exported by various exporters. Annual exports of both species from farm and wild averagely around 25,000 per annum. Wild egg harvest is conducted annually by Mainland Holdings (MHL) in the Sepik River of PNG. The program has taken a significant approach to supporting local communities to value and protect their habitats towards sustainable effort to wild harvesting. Last year MHL harvested 15,060 eggs and this year 13,966 eggs field graded. The hatchability for 2013 harvests is 82.7% whilst the 2014 harvests already has 50% hatchability with some nests remaining in the incubator at the time of presenting this report.

Nest Ecology of Black Caiman, *Melanosuchus niger*, in the Mamirauá Sustainable Development Reserve, Middle Solimões River, Brazil

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Caiman Research Program in Conservation and Management. Mamirauá Institute for Sustainable Development. Tefé, Amazonas – Brazil

Current information indicates that black caiman, *Melanosuchus niger*, in the Brazilian Amazon is abundant and at low risk of extinction. However information on the biology and population ecology of this species and other Amazon caimans are few. This study aimed to gather information on nest ecology of black caiman in the Mamirauá Sustainable Development Reserve, Middle Solimões River, Brazil. Between 2011 and 2013 we visited 351 water bodies and found 1076 nests of *M. niger*, 15% of which were opened. In 39 nests we captured the females for measuring and marking. The average clutch size was 28.10 ± 8.3 eggs (1-65, n=161). Mean length of eggs was 82.03±3.9 mm (52.28-110.34, n=4121) with a diameter of 4.9±2.5mm (27.16-76.69, n=4121) and mass of 121.8±11.1g (94-210, n=4121). These variables did not differ between water bodies visited, although a trend was observed of variation in egg masses. The total length of captured females ranged from 2.33 to 2.92m (mean = 261.2 ± 13.3 m) and weigh ranged between 39 and 78.2kg (mean = 56.7±9.2kg). We found a positive correlation between the mass of females and the number of eggs per clutch (r^2=0.2146, $p < 0.001$). Predation was recorded in 362 nests (33.6%), men being the major predators (34.4%). Nine percent of nests were found in environments such as small channels and bays, which are more vulnerable to hydrological variations. These results suggest that in high density areas some individuals can be more generalists when choosing nesting sites, disagreeing with previous studies.

Results of seasons 2011-2013 of the Monitoring Program of Morelet´s crocodile (*Crocodylus moreletii*) in Mexico

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On the first three seasons of the Monitoring Program of Morelet´s crocodile (Crocodylus moreletii) in Mexico, a total of 572 surveys were conducted, covering up to 5,532 km of lakes, rivers, mangroves and estuaries. Condition of habitat at the monitoring sites was considered good or very good. Approximately 3,500 individuals were observed at an encounter rate of 3.04-3.33 ind/km, which considering the potential distribution of the species in Mexico, suggested an estimated population of more than 79,000 wild individuals, with a preliminary stable trend. Size class structure reflected a healthy population (pyramidal form with great production of young and good proportion of juveniles and reproductive adults). A total of 356 individuals were captured, measured, weighted and marked, showing a sex ratio slightly leaned to males and normal to robust body condition in 86% of individuals (relation between total length, weight and tale base perimeter). Seasons 2011-2013 results were validated in a workshop on November 2013 in Mexico City where 44 experts from Mexico, Guatemala and Belize participated, among others. Season 2014 will begin in April-May. Fieldwork in Mexico has been coordinated by representatives of the Biology Institute of the National Autonomous University of Mexico (UNAM), Juarez Autonomous University of Tabasco (UJAT) and two NGOs, CHEBAL JALALAL and Amigos de Sian Ka´an. Information is obtained following a Procedures Manual to secure comparable and homogenized data (http://www.conabio.gob.mx/institucion/cooperacion_internacional/doctos/manualf_monitoreo_cocodrilo.pdf), which are compiled and analyzed in a database held in CONABIO, from which reports are published (http://www.biodiversidad.gob.mx/planeta/cites/publicaciones.html).

How many species of crocodiles are there? Current advances in crocodilian species identity.

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How many species of crocodilians exist today? Neither I nor, I suspect, anyone else speaking in this session, intend to answer this question. Since the very early 1800s, biologists have been attempting to sort out and classify crocodilians. Early efforts at organization and classification necessary confined themselves to morphology, comparative anatomy, embryology, and fossil discoveries. Specimens accumulated in the great European museums often had either no data, or erroneous or confusing data, with them. Species collected from different regions were often given different names. From the eyes back, most crocs look quite similar. Although there is great diversity in snout morphology among both extant and extinct forms, phylogenetic analyses of ancestral forms have revealed that these features can be remarkably plastic and potentially of limited taxonomic value. Systematic analyses of characters and character states within single taxa are needed to define intraspecific variation. Many taxa now being considered or proposed as unique species have long been recognized and their taxonomic treatment has vacillated over time. The molecular revolution in biology has provided tools to objectively measure both diversity and divergence among populations and species. Molecular analyses have revealed that several long-recognized ‘species’ of crocodiles are in fact composed of two or more cryptic species. Armed with this knowledge, we are now seeking to identify morphological differences among remarkably similar cryptic species. Recognition of these new found species poses new and possibly urgent concerns about their conservation status.

Species concepts and delineation from a deep-time perspective

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Species are historical entities resulting from descent with modification rather than static assemblages of interbreeding organisms. Reproductive isolation generates species, but should not define them - biological species concepts cannot be applied to fossils and fail when independently evolving lineages are capable of interbreeding. Both of these are problematic with crocodylians – extinct species outnumber their living relatives by at least 8 to 1, and recently-diverged species complexes, such as those within Crocodylus, remain interfertile. The smallest diagnosable units we observe (operational species) approximate actual species diversity, but the approximation will always be imperfect. Fossil species simultaneously underestimate and overestimate species diversity; soft-tissue features and molecular markers are unavailable, limiting our ability to delineate operational species within a time horizon, but discontinuous sampling of a single evolving lineage over time cannot be distinguished from sampling different closely related lineages. Simultaneously, because speciation is a gradual process, it may be impossible to draw a firm boundary between lineages, even if geographic and political factors limiting sampling can be overcome. The biggest challenge we face is not scientific, but political – because a stable species-level taxonomy cannot be achieved in the long-term, laws regulating wildlife management should be formulated to incorporate uncertainty caused by the shrinking, but enduring, disconnect between operational and real species.

Conservation implications and enigmatic genetic questions raised by *Crocodylus acutus*

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Crocodylus acutus is a widespread New World crocodilian that stands apart from its sympatric congeners (*C. intermedius, C. rhombifer, and C. moreletii*) by inhabiting brackish environments. Within the last ten years, genetic studies of C. acutus populations have shown low genetic diversity, evidence of hybridization in wild and captive populations, anthropogenically mediated migration, and even evidence of ancient hybridization. Ongoing studies are revealing additional instances of hybridization and evidence of potentially cryptic species. We review these data and touch on their implications for conserving this threatened/endangered keystone predator.

Rigorous Approaches to Species Delimitation Lead to Recognition of Cryptic African Crocodiles in the Genera *Mecistops* and *Crocodylus*

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Accurate species delimitation is often confounded by highly conserved morphology and frequent introgression in groups like the Crocodylia. Misidentification and the potential for hybridization can hinder management plans for wild and captive crocodile populations. To mitigate the effects of uncertain taxonomy on threatened species management, we used rigorous molecular and morphological species delimitation methods to test the hypothesis that the slender-snouted crocodile (*Mecistops cataphractus*) is composed of multiple species corresponding to the Congolian and Guinean biogeographic zones. We found unanimous support for two Mecistops species isolated to the Upper Guinean and Congolian (including Lower Guinean) biomes that have been in isolation since the late Miocene (6.5–7.5 Mya). To further our understanding of the systematics and distribution of African Crocodylus, as well as better manage ex situ populations of both genera, we implemented a DNA barcoding protocol to identify both wild caught and captive held individuals in AZA collections. Our results support DNA barcoding as a valuable tool for identifying African crocodiles and show, interestingly, that captive collections in the USA contain mostly a single species from each genera – fortunately, the more threatened of each. Our results underscore the necessity of comprehensive phylogeographic analyses within currently recognized taxa to detect and better manage cryptic crocodile species. We hope that the body of evidence supporting a greater extant crocodilian diversity than previously believed catalyzes discussion on the conceptualization of crocodilian species, especially in light of the conservation ramifications for this economically and ecologically important group.

Continuing evidence for three cryptic species of Osteolaemus and our updated understanding of their biogeography

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The dwarf crocodiles (*Osteolaemus*) are widely distributed throughout the Guinean-Congolian forest regions of Africa. The genus has been conventionally recognized as monotypic (*O. tetraspis*), though its taxonomy was debated for over a century and two subspecies were proposed – *O. t. tetraspis* and *O. t. osborni*. Since 2004, we undertook to resolve these outstanding taxonomic debates by investigating the inter-population evolutionary relationships of dwarf crocodiles amongst forest fragments and across river basins over their geographic distribution. To do so, we implemented rigorous phylogenetic and species delimitation analyses on both genetic and morphological datasets. Our results unambiguously recognized *O. t. tetraspis* and *O. t. osborni* as species-level lineages. And we identified, surprisingly, a third, equally divergent lineage. The three *Osteolaemus* lineages appear to be allopatrically distributed among the three recognized biogeographic zones of forested western and central Africa - Upper Guinean, Lower Guinean, and Congolian. Recent evidence demonstrates, however, that dwarf crocodiles are capable of transcending river basins and mountain ranges that isolate other forest taxa, resulting in a somewhat atypical zoogeography for the genus. We estimated that species-level diversification in the genus began in the late Miocene while intraspecific diversification dates to the late Pleistocene. Both of these periods coincide with continent-wide aridification and isolation of forest blocks, suggesting that the distribution of *Osteolaemus* lineages may originate from a dependence on forest refugia during climatic cycles. These advances in our systematic and taxonomic understanding should facilitate *Osteolaemus* species conservation and management through efforts to regionalize threat mitigation.

Two species of freshwater crocodile inhabit New Guinea

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This presentation revisits the observations of Phil Hall, Jack Cox and Andy Ross on New Guinea freshwater crocodiles. *Crocodylus novaeguinea* was described by Schmidt in 1928 from specimens collected from the Sepik River in northern PNG and the species was assumed to occupy all the drainages of the island of New Guinea. Neill (1971) suggested regional variation in morphology of *C. novaeguinea* and speculated that the species might not be monotypic. During field studies in Papua New Guinea conducted between 1980 and 1982 the late Philip M. Hall examined a total of 692 specimens from the wild and 126 museum specimens, including skulls, skins, preserved specimens and embryos, and published extensive analyses of morphometric data (Hall 1989, Hall and Portier1994). Hall characterized consistent differences in nuchal scalation and palate morphology between specimens collected from north of the central cordillera of PNG and south of that geographical barrier, noting that the two forms he observed were completely isolated. Jack Cox first drew attention to the different reproductive biology of the two forms involving nesting season clutch size and egg mass. Subsequent examination of additional specimens, comparisons with freshwater crocodiles elsewhere in South East Asia, electrophoresis (Densmore 1983) and mitochondrial DNA and microsatellite data (Gratten 2003) suggest that these may be closely related but separate species. The southern form of *C. novaeguineae* remains to be named.

The Genomes of Three Crocodilians Provide Insight into Archosaur Evolution

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We describe the genomes of three crocodilians, *Alligator mississippiensis* (the American alligator), *Crocodylus porosus* (the saltwater crocodile), and *Gavialis gangeticus* (the Indian gharial), each representing one of the three extant families of the Order Crocodylia. The larger clade that includes turtles, crocodilians, and birds is noteworthy in the exceptionally slow karyotype evolution in all three groups and slow morphological evolution of turtles and crocodilians. We find that this slow rate of evolution is recapitulated at the level of nucleotide substitutions, insertions and deletions, transposable element content and movement, and chromosomal synteny. Analysis of heterozygosity within these species indicates that each of the three crocodilians has suffered a reduction in population size through the Pleistocene. Finally, using these crocodilian genomes, multiple avian genomes, and outgroup genomes, we have computationally inferred the genome of the archosauri.

Effective Gene Flow between *Crocodylus acutus* Populations in Pacific Costa Rica: Evidence from Microsatellite and Mitochondrial DNA

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Maintaining genetic diversity and effective gene flow is crucial to the survival and management of threatened and endangered species. In this study we analyzed the genetic diversity and population genetic structure of four American crocodile (*Crocodylus acutus*) populations (Las Baulas, Santa Rosa and Palo Verde National Parks and Osa Conservation Area) in Pacific Costa Rica. We genotyped 183 individuals at nine microsatellite loci to investigate genetic diversity and gene flow between and among a portion of the cyt-b gene, 3 areas of the mitochdondrial DNA, the d-loop and the cytochrome oxidase gene were sequenced. A model-based clustering analysis indicated that crocodiles were segregated into three main clusters along the coast; (1) Las Baulas National Park (2) Osa Conservation Area and (3) Santa Rosa and Palo Verde National Parks. The level of population subdivision supports the presence of metapopulations along the Pacific *Crocodylus acutus* in Pacific Costa Rica.

Rivers, mountains, deserts: The fractured Neotropics - How many caimans are there?

Robert Godshalk

The Caimaninae of the Neotropics represents a large proportion of the known crocodilian species, and they are common in most lowland streams, rivers and lakes within their distribution. The two most numerous species, *Caiman crocodilus* and *Caiman yacare*, are subjects of ongoing debates over taxonomy and distribution. Molecular data was used to demonstrate the relationships of caiman from the described ranges of *C. c. fuscus*, *C. c. chaipassius*, *C. c. crocodilus* and *C. yacare*. Haplotypes for mitochondrial (mtDNA) cytochrome b from Mexico (2), Central America (21), and the Orinoco (5), Amazon (52) Mamoré (14) and Paraná (9) river basins were collected for phylogeographic analyses. The resulting clades support the existing taxonomy but also give evidence for additional Evolutionary Significant Units (ESUs) and challenge the described range assumptions and boundaries. Tree alignments show closer phylogenetic association of Mesoamerican caiman and *C. yacare* than with *C. c. crocodilus* from either the Orinoco or Amazon Basins. This break occurred approximately 7-8 mya. A review of paleogelogic events leading up to the current geography that shapes the existing distributions is presented. A complex combination of tectonic, environmental, interspecific and anthropogenic forces present barriers that reproductively isolate caiman populations, resulting in genetic differentiation.

Are "pygmy" Australian freshwater crocodiles a new species, or simply an example of phenotypic plasticity?

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Compared to downstream areas, populations of freshwater crocodiles (*Crocodylus johnstoni*) in escarpment habitats grow more slowly, show reduced size at maturity, have reduced maximum size, and are geographically isolated from downstream populations by natural barriers. Given this isolation and distinctly different phenotype, we investigated whether these stunted "pygmy" crocodiles are taxonomically distinct, or whether this is simply an example of intra-species phenotypic plasticity. We compared mtDNA haplotypes from 35 pygmy crocodiles with 32 standard-sized crocodiles. We discovered shared haplotypes between dwarf and standard-sized populations, and an uncorrected pairwise divergence consistent with intra-species variation, hence no support for taxonomic distinctiveness. Despite this, certain haplotypes were restricted to widely-separated pygmy populations. We discuss how this may have occurred, because it gives these "ecological species" conservation value due to their unique phenotype and genetic characteristics. The impact of invasive cane toads on these populations has already been significant, and may have serious implications for their survival.

Conserved DNA elements as tools for understanding crocodilian biology

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DNA assays can be used for a large variety of purposes, ranging from phylogenetics to species identification and comparative genomics to captive breeding evaluations. We have developed a new class of DNA markers that make use of ultraconserved elements (UCEs) that we are using for all of these purposes. Overall, this technique makes use of new massively parallel DNA sequencers that are used for sequencing human genomes and a DNA enrichment technique similar to what we have used to develop microsatellite DNA loci for more than 20 years. We will demonstrate the utility of this approach for crocodilian research, highlighting three studies: 1) to determine the phylogenetic relationships of all crocodilians and yield new markers for species identification, 2) to understand the rate of molecular evolution of crocodilians compared to other tetrapods, and 3) to conduct evaluations of captive breeding stocks of saltwater crocodiles.

Crocodylian Bite Mark Diversity in Modern and Fossil Assemblages

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Experimental and naturalistic studies of bite marks often focus on diagnostic criteria for identifying predator feeding traces in both modern and fossil assemblages. However, emphasis is sometimes placed on cataloging only the most diagnostic features, without necessarily reporting details of the total diversity of mark types created by different clades. Here we present recent research with Crocodylus niloticus and Alligator mississippiensis aimed at uncovering not only diagnostic feeding traces for Crocodylia, but also a diversity of non-diagnostic traces that may overlap morphologically with other types of bone surface modifications. Similarities between marks created by these species (e.g. the high density of marks on bones, the presence and rate of diagnostic bisected marks, the presence of hook scores) provide key features by which taphonomists can differentiate crocodylian bite marks from traces left by members of other major clades. Differences between the two species (i.e. rates of fracturing and element consumption, the presence or absence of furrows, the frequency of hook scoring) demonstrate that even within Crocodylia, variation in feeding strategy and behavior can be reflected and preserved in the ensuing physical traces. We also present a diversity of previously unreported bite mark types created by members of both species. Though non-diagnostic, these marks represent a more complete survey of possible crocodylian feeding traces. Because some of the scoring marks can mimic other bone modifying processes, such as stone tool marks from early human archaeological sites, these feeding traces suggests that equifinality should be more stringently considered when drawing taphonomic conclusions.

Evolutionary and Ecological Determinants of Neotropical Crocodile Diversity

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There is widespread agreement that species represent individual evolutionary lineages but the criteria used to distinguish evolutionary lineages generally depend on the intrinsic properties of the species such as genetic, morphological, ethological or ecological characteristics, associated with different evolutionary processes operating in various geographic and temporal contexts. Applying lineage-based framework to species delimitation, we examined a “multiple criteria” approach with independent data sets to review the systematics of Neotropical crocodiles. “Genetic interchangeability” was assessed by testing the null hypothesis that the organisms sampled were derived from a single evolutionary lineage using gene tree genealogies, estimating the maximum clade credibility tree, time of divergence, genetic diversity, and population structure with mitochondrial and nuclear data. “Ecological interchangeability” was evaluated by testing the null hypothesis that the identified independent lineages are ecologically interchangeable by establishing the geographic spatial distribution of genetic diversity and the ecological niche model for each lineage. We also performed a Species delimitation test using General Mixed Yule Coalescent Model (bGMYC) to identify statistically supported for at least two new species of Neotropical crocodiles.

Swamp Smarts: Discovering Cryptic Intelligence in Crocodilians

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In recent years, our appreciation of the complexity of crocodilian behavior has changed dramatically as a result of numerous discoveries in the emerging field of crocodilian behavioral ecology. I will present a brief overview of these discoveries, focusing on those I have contributed to: \"alligator dances\", multimodal signaling systems optimized to habitat, and complex hunting behaviors such as collaborative and coordinated hunting and use of lures.

To catch a fish - unique hunting methods and cooperation in saltwater and mugger crocodiles

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Crocodiles employ a range of different hunting strategies to secure a meal. Here we describe variations on fishing techniques used by saltwater and mugger crocodiles, both non-collaborative and cooperative hunting. Saltwater and mugger crocodiles use a variation of the \"cross posture\" previously described in caimans, holding the arms perpendicular to the body to act as a sensory net to detect fish within striking range, to which the high concentration of ISOs on their arms and front feet are ideally suited. Mugger crocodiles further modify this behaviour by sweeping their arms through the water in an arc towards the head (a "forelimb sweep"), triggering a leaping escape response in any fish that they touch, which are then seized in mid-flight by the crocodile. This behaviour, which has not been described previously in any species, appears to be a response to feeding conditions where high densities of fish are present in drying pools. We also describe communal feeding scenarios that appear to be cooperative in both species, a "circular drive" by mugger crocodiles to corral fish into higher densities, and a "phalanx formation" by saltwater crocodiles to form a barrier that fish must negotiate. Both scenarios increase prey capture success for all participants, and we discuss the circumstances resulting in such behaviour, and indeed whether this apparent cooperation is the result of coordination, or simply a convenient by-product of selfish individuals.

Observations on the Defensive Mechanisms of Crocodilians in the Genera *Paleosuchus* and *Osteolaemus*

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The members of the crocodilian genera *Paleosuchus* and *Osteolaemus*, although separated by tens of millions of years of evolution, have many divergent morphological and behavioral features. Both exhibit relatively small body sizes, are heavily armored, and live terrestrial lifestyles, relative to other crocodilians. Members of these genera also exhibit unusual defense mechanisms. When seized by the neck, wild *Osteolaemus tetraspis* remain completely motionless in an apparent attempt to rely on camouflage to conceal their presence. *Paleosuchus trigonatus* and *Paleosuchus palpebrosus* throw their heads back to pinch the hand between the nuchal scutes, presumably a method of defense that has developed to interlock their bony scutes and protect the spine from bites of jaguars, their main predators. We speculate that, because of their terrestrial nature and small body sizes, these distantly-related crocodilians have evolved unusual defense strategies that function in protection from terrestrial predators to which other crocodilians are typically not exposed.

Orinoco crocodile (*Crocodylus intermedius)* head development

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Seven photographs representing seven different head development stages (neonate; 0.5; 1.5; 2.5; 3.0; 4.0 and 4.5 years old, from Orinoco crocodiles *Crocodylus intermedius* hatched at the Dallas World Aquarium were analyzed. Each image was vectorized to determine the dimensions of the following morphometric measurements: a) dorsal cranial length, b) snout length, c) cranial length, d) cranial width, e) maxillary – pre maxillary suture width, and f) Kailin 12-12. The analyzed ratios were: snout length vs dorsal cranial length; cranial length vs dorsal cranial length; cranial width vs maxillary – pre maxillary suture width; and dorsal cranial length vs cranial width. As the Orinoco crocodile grows from hatchling stage, the snout turns longer than width, the opposite ratio as when it hatched. We detected a trend with the other morphometric ratios, but our results cannot be conclusive due the angle the photographs were taken.

Stress-immune interactions in farmed saltwater crocodile (*Crocodylus porosus*) hatchlings

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Stress has been shown to affect numerous features of organismal phenotype, including immune function. In agricultural production environments, immune function is of principal concern as lowered immunity and subsequent disease may prevent resource allocation for other favorable production traits such as growth. Hatchling crocodiles were repeatedly measured and blood sampled during their first year. Plasma corticosterone (CORT), which was used to measure stress, was found to be lower than previously described in saltwater crocodile (*Crocodylus porosus*) hatchlings. To explore immune-stress relationships, two immune tests were utilized: phytohaemagglutinin (PHA) injection and the bacterial killing assay (BKA) using two bacterial species. Bactericidal capacity of plasma was significantly increased over consecutive sampling periods for both species. Although the initial bactericidal capabilities between the two species were different at the first sampling, capabilities were similar at the third sampling. PHA-induced swelling was only significantly different between the first and third sampling, suggesting that it may not be an effectual assessment for enumerating immune function. CORT was not significantly associated with growth (head length) or any of the immune parameters with the exception of one bacterial species, whereby increased CORT provoked an augmented bactericidal capacity. Whilst future investigations are required to further clarify crocodilian immunity and stress-immune relationships, our results suggest satisfactory management regimes being utilized on the farm of study.

Long Submergences by Crocodylians and their Physiological Support: a Working Hypothesis

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We present a working hypothesis about the significance of long submergences by crocodylians and their physiological support. Some authors have assumed that long voluntary dives are supported anaerobically, an assumption probably influenced by the prevailing (but questionable) belief that crocs rely heavily on anaerobic metabolism for most of their activity. Long dives by mammals and birds too were thought to be supported anaerobically, but during the 1980s it became accepted that almost all their dives are aerobic; surfacing with high plasma lactate is unusual. Might the same model apply to crocodylians? There is little information about the diving behavior of free ranging crocodylians and it is difficult to make reliable generalisations about the behavioural circumstances in which dives of different lengths are made. However, recent data from Crocodylus johnstoni suggest that dives made actively, as in foraging, are short, whereas the longest dives are associated with resting. In laboratory studies on C. porosus, neither short nor long voluntary dives showed an accumulation of plasma lactate. Calculated maximum aerobic dive times accommodate the longest voluntary field submergences recorded so far, assuming a down regulation in metabolic rate. We propose that, as in other diving vertebrates, most voluntary submergences by crocodylians are aerobic, a hypothesis consistent with their use of water for rest and refuge. More behavioural data from the wild are desirable, combined with end-dive plasma lactate (challenging!) whenever possible.

Biomonitoring Heavy Metal Pollution Using An Aquatic Apex Predator, the American Alligator, and its Parasites

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The surveillance of heavy metal bioaccumulation within various organismal tissues has become a useful tool to determine current or chronic exposure to environmental pollutants. In this study, we analyzed the bioaccumulation of As, Al, Cd, Cr, Cu, Fe, Pb, Mg, Ni, Se, and Zn in the American alligator, *Alligator mississippiensis*, and its parasites from Louisiana and Florida. We then used this data to examine the role of alligators and their parasites as pollutant biomonitors in comparison to water and sediment data. Overall, parasites accumulated higher levels of As, Cu, Se, and Zn in comparison to their alligator hosts, and water and sediment samples, whereas Fe, Cd, and Pb levels were higher in alligators. Further analyses showed alligator intestinal trematodes concentrated As, Cu, Cr, Fe, Se, and Zn at significantly higher levels relative to intestinal nematodes and parasites from other organs. Stomach and intestinal nematodes were found to be the poorest
bioaccumulators of metals. Our study also found that parasitic abundance decreased as levels of As increased among alligator hosts. Conclusively, we suggest that parasites, particularly intestinal trematodes, are superior biomagnifiers of As, Cu, Cr, Se, and Zn, whereas alligators themselves may be good bioindicator candidates of Fe, Cd, and Pb.

Telemetric recordings of central cardiovascular flows and pressures in free-ranging crocodiles

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The anatomy of the central cardiovascular system of crocodilians has intrigued and fascinated biologists since it was described by Panizza (1833). Similar to birds, the crocodilian heart is four-chambered, however unlike birds there are two aortic arches, a right aorta emanating from the left ventricle and a left aorta from the right ventricle. Adding to the anatomical complexity, is an actively controlled valve (cogwheel) found in the subpulmonary conus of the right ventricle and the Foramen of Panizza, an opening between the left and right aortas. Together this complex arrangement of structures and vessels, that is unique to crocodilians, has generated considerable discussion about the functional significance of the heart. What is clear is that it allows for a range of flow and pressure configurations, including the ability to shunt blood away from the lungs (pulmonary to systemic shunting). To date, studies of the haemodynamics of crocodilians have been lab-based and as a consequence questions after been asked about the relevance of the findings due to issues associated with confinement, artificial conditions and the tethering of animals. In this study, a new telemetric -implantable device, capable of recording blood pressures and flows, was surgically inserted into Nile crocodiles, allowing for the first time the recording of cardiovascular dynamics in free-ranging animals, living in their natural environment. Recordings were made from five animals over 4 weeks providing the opportunity to better understand the functional significance of the cardiovascular system of crocodiles during rest, swimming, basking and diving

Evaluation of Methods for Efficiently Assessing Mercury Concentrations in American Alligator (*Alligator mississippiensis*) Muscle Tissue

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Because of its position in the food chain as an apex predator, the American alligator (*Alligator mississippiensis*) is susceptible to accumulating high concentrations of mercury. Tests of alligator meat from Florida lakes in the early 1980s revealed a range of average concentrations among areas. Concerns about the human health implications of mercury in alligator meat were elevated in 1988 with the initiation of the statewide alligator harvest, which greatly increased the amount of wild harvested alligator meat available for consumption. Because of logistics and costs, a monitoring program has never been established to determine the extent of mercury concentrations in alligator meat from hunted areas on a consistent basis. Previous sampling events have been conducted sporadically and without a methodical approach, compromising our ability to determine if changes are occurring in mercury levels for individual areas. Our study was designed to assess methods that would be feasible to implement in a statewide monitoring program, and to attempt to learn more about the dynamics of mercury as it relates to alligator biology. We found that muscle tissue samples obtained by punch biopsies and analyzed by combustion atomic absorption spectroscopy gave comparable results to tissue samples obtained by fillet extraction and cold vapor atomic absorption spectroscopy. We also determined a relationship between alligator length and mercury concentrations that can be applied to different areas. Mercury concentrations were greater in the fall than spring, indicating that mercury is accumulated during the warmer months and/or depurated during the colder months.

Crocodilian Nuclear Factor Kappa B1 Protein: Functional Domain Analysis and Homology with Other Vertebrates

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We have deduced the amino acid sequence of the Nuclear Factor KappaB1 (NF-κB1) protein from genomic data for the American alligator (*Alligator missisisppiensis*), the estuarine crocodile (*Crocodylus porosus*), and the Indian gharial (*Gavialis gangeticus*). A 105 kDa protein, NF-κB1 exhibits complex post-translational processing multiple mechanisms of activation, and acts as precursor for a p50, a Rel homology transcription factor, which influences the transcription of key genes for developmental processes, apoptosis, and immune function. The amino acid sequences of the crocodilian proteins share very high sequence identity with each other (97.2 ± 0.7%), birds (81.0 ± 1.1%, n=6), mammals (75.3 ± 1.6%, n=4), reptiles (80.3 ± 5.1%, n=2), and less identity with fish (55.5 ± 5.5%, n=4) and one amphibian (66.1 ± 0.8%). The crocodilian protein has a well-conserved Rel homology domain, a nuclear localization signal, and a glycine-rich region which facilitates proteasome-mediated generation of p50. The Rel homology domain facilitates dimerization, DNA-binding, and nuclear translocation activities. In addition, seven ankyrin repeats were located on the C-terminal half of the protein, which putatively allow for inhibition of transcriptional regulation by mediating interaction with Inhibitor kappa B. Other features include a death domain, and conserved serine residues, near the C-terminal end, which act as potential phosphorylation sites for activation of the proteolytic generation of p50.

POSTER PRESENTATION ABSTRACTS

Minimum number of breeding adults in American croc (*Crocodylus acutus*) populations in Santa Rosa, Las Baulas, and Palo Verde National Parks, Costa Rica

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The American crocodile (*Crocodylus acutus*) is widely distributed in the American neotropics. It is endangered throughout most of its range and is listed as vulnerable by the International Union for the Conservation of Natural Fauna and Flora (IUCN) and on Appendix I of the Convention for the International Trade in Endangered Species of Wild Flora and Fauna (CITES). Despite this listing, there are few published reports on the reproductive biology throughout the species range. Previous work has indicated that multiple paternity exists in C. acutus but this phenomenon has been studied in few wild populations. Genetics samples were collected from hatchlings in Santa Rosa, Las Baulas, and Palo Verde National Parks, Costa Rica. The mother crocodile could not be identified. Crocodile encounter rates range from1.3 crocodiles/km (Santa Rosa) to 4.1 crocodiles/km (Palo Verde). Preliminary results indicate that hatchlings from the smaller populations were more related suggesting fewer breeding adults in these areas. We used a genetic analysis to estimate the minimum number of breeding adults (males and females) in Santa Rosa, Las Baulas, and Palo Verde National Parks. This study will provide important information on reproductive biology in naturally fragmented populations and could enhance management practices of crocodiles worldwide.

Genome Analysis and Signature Discovery for Diving and Sensory Properties of the Endangered Chinese Alligator

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Crocodilians are diving reptiles that can hold their breath under water for long periods of time and are crepuscular animals with excellent sensory abilities. They comprise a sister lineage of birds and have no sex chromosome. Here we report the genome sequence of the endangered Chinese alligator (*Alligator sinensis*) and describe its unique features. The next-generation sequencing generated 314 Gb of raw sequence yielding a genome size of 2.3 Gb. A total of 22,200 genes were predicted in *Alligator sinensis* using a de novo homology- and RNA-based combined model. The genetic basis of long-diving behavior includes duplication of the bicarbonate-binding hemoglobin gene co-functioning of routine phosphate-binding and special bicarbonate-binding oxygen transport and positively selected energy metabolism ammonium bicarbonate excretion and cardiac muscle contraction. Further we elucidated the robust *Alligator sinensis* sensory system including a significantly expanded olfactory receptor repertoire rapidly evolving nerve-related cellular components and visual perception and positive selection of the night vision-related opsin and sound detection-associated otopetrin. We also discovered a well-developed immune system with a considerable number of lineage-specific antigen-presentation genes for adaptive immunity as well as expansion of the tripartite motifcontaining C-type lectin and butyrophilin genes for innate immunity and expression of antibacterial peptides. Multifluorescence *in situ* hybridization showed that alligator chromosome 3 which encodes DMRT1 exhibits significant synteny with chicken chromosome Z. Finally population history analysis indicated population admixture 0.60-1.05 million years ago when the Qinghai-Tibetan Plateau was uplifted.

Parasitism in the American crocodile, Morelet's crocodile, and Spectacled caiman in Mexico, Belize, and Guatemala

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Unlike many other reptiles, crocodilians are capable of a rapid innate immune response as a result of a robust complement system eradicating various viruses and bacteria. However, increased stress due to natural disturbances and toxins in coastal wetlands and inland habitats are threatening the physiology and immunocompetence of crocodilians internationally. As urbanization continues to encroach and transform crocodilian habitats, examining changes in host-parasite relationships to anthropogenic and/or environmental impacts could assist in preventing mortality or morbidity in a population. Research conducted on these crocodilians will not only help within their own conservation, but as the apex predators within their habitats, will provide an umbrella effect regarding their entire ecosystems. The goals of this study are to 1) identify helminth communities of *Crocodylus acutus*, *C. moreletii*, and *Caiman crocodilus chiapsius*, 2) evaluate anthropogenic impact on parasitic prevalence, abundance, intensity, and species richness between size, sex and urban vs. non-urban localities, and 3) propose ecological alterations effect on host parasitism.

Treatment of corneal ulcer in Caiman (Caiman yacare - Daudin, 1802)

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Given the growing conditions, there are recurrent the cornea in Caiman yacare, incurring ulcer can lead to eye loss. For treatment, chloramphenicol was adopted by possessing a broad spectrum of antimicrobial action. In clinical evaluation, the alligator was found with circular single, median erosion, with delimited visually lips, intense edemaciação eyeball, presence of congestive vessels in the dorsal portion of the sclera, partial loss of the reflection of the 3rd eyelid (nictitating membrane), change in Normal corneal staining with the presence of irregularities in the delimitation of the borders between the cornea and sclera, was diagnosed as a process tending to chronicity, with the prognosis a reserved table. With 05 days of treatment was observed slight decrease of dark staining of the cornea (ventral), with the presence of several points misting volume of the eyeball near normality, smoothing the irregularities of the cornea and sclera, nictitating membrane movement of the reflecting. The case will be evaluated to achieve the best solution for the pathological picture. These observations are intended to enhance veterinary clinic in these animals.

Behavioural conditioning as a tool for reducing human-crocodile conflict

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Human-crocodile conflict has negative implications for wildlife conservation and rural development. Current conflict mitigation strategies are suboptimal due to a variety of intrinsic issues. We explore the potential of a novel, low-cost method of reducing crocodile attacks based on the modification of wild crocodile hunting behaviour by means of a combination of classical and operant conditioning. The method involves the establishment of an association between a previously neutral stimulus (bell ringing) and an unpleasant experience (electric shock) so that the conditioned stimulus (bell ringing) elicits a fear response. Positive punishment (electric shock) subsequently reinforces the negative association between feeding behaviour and ringing bells, and encourages crocodiles to retreat from the sound of ringing bells. The concept was tested on wild and captive Nile crocodiles in Namibia and Botswana respectively. Preliminary findings suggest that crocodiles may be discouraged from hunting in close proximity to humans and livestock through the use of predefined associations and simple cues.

The Sex Ratio of Wild Chinese alligators Alligator sinensis

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The Chinese alligator (*Alligator sinensis*) is one of the most endangered crocodilian species and typically exhibits temperature-dependent sex determination. It is extremely important to clarify the sex structure of Chinese alligators to implement recovery projects the sex ratio of wild Chinese alligators remains unknown. In this study we collected 28 years of sex ratio data from Chinese alligators residing in the natural and artificial habitats of Changxing Nature Reserve, China, and examined the differences in the sex ratio dynamics between these two populations. We observed that the sex ratio of wild Chinese alligators is 1 male to 4.507 females, which was significantly lower compared to that of the captive population (1 to 2.040; $P = 0.000$), and is significantly different to previously documented sex ratios for this species (all $P < 0.01$). Furthermore, we documented an annually stable ($P = 1.000$) female-biased sex ratio for wild alligators at hatching [1 male to 4.747 females; 0.174 (0.167Â¨C0.182)] in contrast to a dramatically fluctuating sex ratio ($P = 0.000$) in captivity [1 male to 1.674 females; 0.374 (0.246Â¨C0.593)]. Finally, we found that the hatchling sex ratios were similar to that of the population sex ratio ($P = 0.748$) with little correlation to air temperature values in the 60-70 day incubation period during the breeding season (July and August; both $P > 0.05$). Overall this study indicates that the stabilized female-biased sex ratio of Changxing Chinese alligators might result from selection pressure caused by local mate competition and major inbreeding.

Video Documentation of the Hatching Process of a Wild American Alligator (*Alligator mississippiensis*) in Central Mississippi

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The nest hatching process of the American alligator (*Alligator mississippiensis*) in the wild is not well documented, therefore much information about the hatching process is assumed from interrupted series of observations by wildlife biologists (pers. comm. A. Woodward). A wild American alligator nest was remotely monitored and digitally video recorded during the complete nest excavation process in central Mississippi, USA on August 17, 2013. A color/infrared motion-detecting surveillance camera and DVR were used to document continuous hatching activity which lasted 11 hours 48 minutes. There were fifty-eight trips by the adult female from the nest to the water during the hatching process. On average, the adult female spent 2 minutes 45 seconds to retrieve each hatchling/egg prior to returning to the water and 9 minutes 34 seconds at the water before returning to retrieve another hatchling/egg. Video documentation includes the adult female precisely locating eggs in the nest via apparent vocalizations, complete excavation of the nest by using front feet and the mouth, and transporting live hatchlings and eggs from the nest to the water. In one instance, a hatchling that was lying on the back of the adult as she returns to the nest, falls off her back as the adult is excavating an egg and the adult interrupts the excavation to carry the fallen hatchling back to the water 3.25 m (128 in.) away. The adult female's length was estimated by image referenced features at approximately 2.59 m (8.5 feet).

Alligator as a Counterintuitive Exception to the "Law of Specialization"

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Alligator mississippiensisis is often treated as a "typical" crocodylian representing the primitive condition of Crocodylia. However, when fossils and phylogeny are taken into account, it becomes apparent that this species and a few of its closest relatives are actually highly unusual alligatorines which secondarily evolved several morphological traits homoplasious with modern crocodylids. We reconstructed ancestral states on trees of Eusuchia and created regression plots of relative snout length vs. size. The plesiomorphic state for Alligatorinae–indeed, all of Globidonta–is to be small and brevirostrine with globidont dentition. This plesiomorphic condition is specialized for durophagy of small, shelly prey such as turtles, molluscs, and crustaceans. Coincident with the local Middle Eocene extinction of large, generalist crocodylids North American alligatorines had coexisted with, the lineage leading to Alligator was able to expand into the large generalist niche by increasing in size, losing the specialized globidont dentition, and increasing relative snout length through predisplacement and hypermorphosis. This is a rarely-documented and counterintuitive exception to the "Law of the Specialized", wherein specialists are assumed to go extinct while generalists speciate into both generalist and specialized niches.

Characterisation of Viperin from the Saltwater Crocodile (*Crocodylus porosus*)

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The Australian saltwater crocodile (*Crocodylus porosus*) represents a prehistoric species of reptile and little is known about its ability to control pathogens. Viperin is an evolutionarily conserved host protein displaying broad antiviral activity. This study investigates the early innate immune response of crocodiles including the characterisation of crocodile viperin. The cDNA sequence of viperin was isolated from a crocodile liver-derived cell line (LV-1) and was found to encode a 338 amino acid peptide. This protein showed a high homology to viperin from both mammal and fish species (>70%) with the majority of sequence variation occurring in the N-terminus. Crocodile viperin maintained the conserved ‘radical SAM domain’ and the C-terminal domain, which has been shown to be important in its ability to limit numerous viral strains. Immunofluorescent studies demonstrated that crocodile viperin localised mainly to the endoplasmic reticulum as previously seen with other viperin proteins. Dengue virus-2 infection of LV-1 cells at 24 and 48 hours significantly upregulated several interferon stimulated genes (ISGs), including viperin, demonstrating for the first time that crocodile cells activate early innate immune signalling pathways in response to viral infection. This is the first study to examine crocodile viperin, and has the potential to provide an insight into the evolutionary profile of one of the most wide-acting antiviral proteins shown to date. Further elucidation of crocodile innate responses has the potential to improve outcomes within the crocodile industry, and possibly decrease both skin and systemic pathogen-related problems.

Chicken probiotics raise the length and weight of Caiman yacare

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With the intention of improving the culture conditions was tested probiotic chicken as a food supplement in Cayman yacare. Probiotics chicken were added to the diet consisted of C. yacare 4 groups: control = T01 (0,00%), T02 = 0,25%, T03 = 0,50 % and T04 = 1,00%. The feed was traditionally performed 3 times a week and the animals were weighed and measured every 14 days. Among the principal outstanding results: Due to the random distribution of animals in tanks, none of the treatments showed a significant difference at the beginning of the experiments. After 168 days, T02 was the only treatment difference with higher values than control values: body weight, snout vent length and total length when subjected to analysis of variance one-way Tukey HSD. In this sense, one can say that probiotics represent an industrialized chicken for creators of alligators alternative. This project will continue and samples will be subjected to laboratory tests in order to explain how these probiotics influenced the growth and fattening of animals, and that animals treated with high concentrations of probiotics showed no proportional gain weight.

Yield Cuts and Carcass caiman (Caiman yacare Daudin, 1802) Created Cultivation System

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For industrial purposes has been reported yield carcass cut Caiman yacare in the fridge COOCRIJAPAN, Cáceres-MT. The performance evaluation used 206 alligators weighing on average 3.869 kg. The total physical composition in percentage was 54.97% carcass, 6.18% of heads, 1.97% blood, skin 16.03%, 2.06% of legs, 13.44% of viscera, 4.57% and 0.83% of zest toiletries. Among the weight of the evaluated sections was obtained 30% tail filet, 2% tip of tail, 18% of thigh, drumstick of 9%, 13% of beef sirloin, filet mignon 2%, 13% fillet of dorsum 10% of chips and 3% of baits. The scientific literature is limited in the area, specifically regarding yacare Caiman species, there is a need for further studies on commercial cuts. Carcass yield was similar to the literature found for other species of alligators to the same total weight.

Multiphoton Microscopy Imaging of American Alligator Collagen

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Collagen is the main structural protein of animal connective tissues and extracellular collagen fibers play a crucial anatomical role in producing strength and stiffness. These material qualities are crucial for effective phallus intromission during copulation. The American alligator phallus is a complex appendage with multiple structural uses of collagen. The proximal shaft is continually rigid due to densely packed collagen bundles while the distal glans and tip show evidence of collagen-regulated inflation during copulation. To better visualize these collagen fiber architectures, we have employed multiphoton microscopy - a laser-scanning, non-linear imaging technique that can probe hundreds of microns into thick tissue slices. This method capitalizes on the capacity of collagen fibers to autofluoresce when excited by specifically tuned laser light. This fluorescence capability is endogenous and does not require staining or immunostaining. Using this microscopy technique, we have begun to investigate fiber thicknesses and three-dimensional orientation characteristics that affect the tensile qualities of phallic tissues. Paired with DAPI nuclear and phalloidin cytoskeleton staining we present our initial imaging results and discuss the exciting possibilities of utilizing this technique in investigating the collagenous functional anatomy of non-model and wildlife species.

Genome Analysis and Signature Discovery for Diving and Sensory Properties of the Endangered Chinese Alligator

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Crocodilians are diving reptiles that can hold their breath under water for long periods of time and are crepuscular animals with excellent sensory abilities. They comprise a sister lineage of birds and have no sex chromosome. Here we report the genome sequence of the endangered Chinese alligator (*Alligator sinensis*) and describe its unique features. The next-generation sequencing generated 314 Gb of raw sequence yielding a genome size of 2.3 Gb. A total of 22,200 genes were predicted in *Alligator sinensis* using a de novo homology- and RNA-based combined model. The genetic basis of long-diving behavior includes duplication of the bicarbonate-binding hemoglobin gene co-functioning of routine phosphate-binding and special bicarbonate-binding oxygen transport and positively selected energy metabolism ammonium bicarbonate excretion and cardiac muscle contraction. Further we elucidated the robust *Alligator sinensis* sensory system including a significantly expanded olfactory receptor repertoire rapidly evolving nerve-related cellular components and visual perception and positive selection of the night vision-related opsin and sound detection-associated otopetrin. We also discovered a well-developed immune system with a considerable number of lineage-specific antigen-presentation genes for adaptive immunity as well as expansion of the tripartite motifcontaining C-type lectin and butyrophilin genes for innate immunity and expression of antibacterial peptides. Multifluorescence *in situ* hybridization showed that alligator chromosome 3 which encodes DMRT1 exhibits significant synteny with chicken chromosome Z. Finally population history analysis indicated population admixture 0.60-1.05 million years ago when the Qinghai-Tibetan Plateau was uplifted.

Evaluation of Factors Associated with Nest Predation of Broad-snouted Caiman (*Caiman latirostris*)

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Predation is a major cause of crocodilian egg loss. It is reported that predators have the ability to detect prey from visual and olfactory signs. This study aimed to determine the natural predation rate on *C. latirostris* nests on a normal year (no presence of extreme climatic events), to assess whether olfactory or visual evidences attract predators to caiman nests, and to evaluate the percentage of nests care by females. We searched nests during December/2010 in the northern of Santa Fe province (Argentina) and we assigned the following treatments: control (nests were observed from a distance to avoid disturbances), visual attraction (yellow flagging tapes were tied to vegetation around nests), olfactory attraction (nests were opened, one egg of the clutch was broken, and then the nests were covered again) and olfactory attraction from human disturbance (material was manipulated by researchers without causing any damage to the eggs). We found that the natural predation on broad-snouted caiman nests was approximately 20% in a nesting season. We also observed that olfactory and vision sensory cues were associated with increased predation rates, Human disturbance had a strong association with increased nest predation in terrestrial sites. Female attendance at nests did not decrease the likelihood of predation. To reduce nest predation of broad-snouted caimans, we propose, increasing early search efforts of nests in terrestrial environments relative to those in aquatic environments, avoiding identifying nest sites with highly visual marking, and collecting eggs immediately after they are found.

Changes on lipid profile by addition of flaxseed in caiman diet

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Crocodilians have limited capacity to desaturate fatty acids. These reptiles are unable to synthesize fatty acids such as alpha-linolenic acid (n-3) and linoleic (n-6) so they must be supplied in the diet. Flaxseed is recognized as a source of alpha-linolenic acid, which could be used to enrich the diet of crocodilians. The objective of this study is to evaluate if addition of flaxseed in the diet of *Caiman latirostris*, modify lipid profile in organs such as liver, kidney and fat body. We maintained 27 individuals of *C. latirostris* in captivity, randomly assigned to three feeding treatments: control diet (normal diet: dry balanced food and ground chicken head); whole seed diet (normal diet with the addition of whole flax seeds) and ground seed diet (normal diet with the addition of ground flaxseed). After a month, organs were extracted, with the objective to evaluate total lipids. In the kidney, there was no differences in the fatty acid profiles among treatments; while in liver, whole seeds (but not ground seed) added in the diet resulted in an increase in the concentration of n-7 fatty acid over the control. The diet with linseed (whole and ground seed) increased the proportion of fatty acids (n-3 and alpha-linolenic acid) in the body fat; but did not change the proportion of n-6, therefore decreased of ratio n6/n3. In the present work it was possible to modify the lipid profile in a different way in organs of *C. latirostris*, incorporating flaxseed to the diet during one month only.

Impact of Na Alginate on Nutrient Digestibility of Extrudate Feed for Farmed C. porosus

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Na alginate is used in feed for aquatic animals to improve its stability in water and produce more durable pellets, however, some studies reported reduced digestibility when it was used. Our objective was to measure digestibility of feed with and without added Na alginate in juvenile salt water crocodiles. Ten crocodiles (2.2-2.4 years old, 1.2-1.9 kg BW) were selected from farm-raised stocks and kept at 31-32.4°C with 98-99% relative humidity. Animals were gavage-fed (2% BW) for 12 d with an extrudate diet (non-heat treated feed forced through a die at low pressure) comprised of approx. 33% minced chicken carcasses, 14% chicken blood, 5% poultry offal meal, 5% pulped eggs, 18% wheat millrun, and 23% supplement, as-fed) with and without 1.4% Na alginate and 1.9% CaCO3. Faeces were collected over the last 5 d, after which animals were slaughtered and digesta sampled from the ileum. Faecal and ileal apparent digestibilities were measured for dry matter, organic matter, energy, nitrogen and amino acids using acid insoluble ash as an internal marker. There were no differences in any amino acid, nitrogen (65.0 vs 55.8%, SE = 12.2%), and organic matter (46.8 vs 39.6%, SE = 12.8%) digestibility at the ileum between diets with and without alginate, respectively. Faecal digestibilities of organic matter (69.8 vs 39.2% SE = 9.1%) and energy (72.2 vs 44.4%, SE = 8.3%) were greater in alginate containing diets ($P < 0.05$). Our results show that addition of Na alginate does not deleteriously affect digestibility of nutrients in *C. porosus*.

Ranching programs: does resources exploitation change between wild and reintroduced crocodilians?

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Wild animals minimize intraspecific competition through maximizing the exploitation of available resources. Crocodilians show a dramatic increase in body mass from hatchling to adult, which results in changes in the exploitation of food resources. Stable isotopes analyses are useful to verify intraspecific variations in feeding habitats because the chemical composition of animals tends to reflect the food consumed. This study aimed to verify the existence of sexual and ontogenetic feeding habitats variation for the broad-snouted caiman (*Caiman latirostris*) in a stream surrounded by a flooded area in northern Argentina using carbon and nitrogen stable isotopes. Isotopes compositions were determined from claw samples of 34 individuals (14 juveniles: 9♂ and 5♀; and 20 adults: 10♂ and 10♀) collected during field work between October/2010 and January/2012. We found no difference between juveniles and adults for $\delta^{13}C$ (J: -20.4 ± 1.1‰; A: -21.0 ± 1.3‰) and $\delta^{15}N$ (J: 7.2 ± 0.9‰; A: 6.7 ± 0.5‰). We also found no difference between sex inside size class for $\delta^{13}C$ (A♀: -20.7 ± 0.8‰; A♂: -20.2 ± 1.4‰; J♀: -20.5 ± 1.7‰; J♂: -21.4 ± 0.9‰) and for $\delta^{15}N$ (A♀: 7.6 ± 0.8‰; A♂: 6.8 ± 0.9‰; J♀: 6.9 ± 0.4‰; J♂: 6.7 ± 0.7‰). Similar values of isotopic compositions could indicate an intraespecific overlap on exploitation of food resources. This could be due to the wide availability of food resources on the study area being capable to support higher population densities.

Improving Water Stability of Extrudate Feed for Farmed *C. porosus*

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Extrudate feed (non-heat treated feed forced through a die at low pressure) made with chicken-by products is fed to C. porosus farmed by Mainland Holdings Crocodile Farm (MHCF), PNG. However, it disintegrates on contact with water, which leads to loss of nutrients, inefficient feed utilisation, and water contamination. Na alginate is used in feed for aquatic animals to improve pellet durability in water, but its use in diets for crocodiles has not been reported. A diet similar to one fed to farmed crocodiles at MHCF was formulated containing approximately 40% minced chicken carcasses, 17% chicken blood, 5.6% poultry offal meal, 5.6% pulped eggs, and 28% supplement, as-fed. Three commercially available Na alginates were included at 1.7 or 3.3% (as-fed); $CaCO_3$ or $CaCl_2$ at 2.1% was added to aid cross-linking. The feed was extrudated through a 19mm die using a table-top sausage press. Resulting feed was submersed in water (29-34ºC) for 24 hours. Feed remaining intact was captured on a 0.5 mm screen and dried to determine dry matter retention (DMR). Reaction with CaCO3 resulted in greater DMR compared with $CaCl_2$ (80.68 vs 16.08% DMR; $P < 0.05$). Regardless of which product was used, Na alginate inclusion with CaCO3 resulted in a greater than 10-fold increase in DMR compared to when it was not used (80.68 vs. 6.2% DMR). Our results show that addition of Na alginate improved feed stability in water, and potentially could enhance feed efficiency and economic returns whilst decreasing effluent discharge and environmental pollution.

Persistence of large American alligators (*Alligator mississippiensis*) in populations that have been hunted

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One of the concerns with harvest programs is their effect on populations where the largest individuals or individuals with certain features (e.g., large antlers) are desired by hunters. In the case of Florida's annual statewide alligator harvest program, both wildlife professionals and the general public have expressed concerns regarding the effects of harvest on the existence of large American alligators (Alligator mississippiensis). Large alligators are commonly targeted by hunters, and as a result, many larger alligators are removed from the population. We used harvest data and night-light survey data to determine if there has been a decline in the number of bull (≥ 2.7 m total length) alligators taken in the statewide alligator harvest. Both, the average length of harvested alligators and the percent of harvest that consisted of bull alligators each year between 1988 and 2011 have been relatively stable. Another indicator for the presence of large alligators on hunted areas is the largest alligator taken for a given year. At least 1 bull alligator greater than 4 m in total length has been harvested from the original group of hunted areas every year since 1988. An assessment of annual survey data indicates that there has been no significant trend in the number of bull alligators on hunted areas since the statewide recreational alligator harvest program began. Although bull alligators are targeted by hunters, available survey and harvest data suggest that large alligators continue to occupy hunted areas throughout Florida.

New microsatellite markers specific for *Caiman latirostris* applicable to genetic-population and mating system studies

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Nowadays, microsatellites are considered as a molecular tool of choice for the development of population-genetic studies and mating systems. Due to difficulties encountered in the setting and application of specific molecular markers for *Caiman latirostris* previously developed, we looked for the mission of developing new microsatellite markers for this species. This work was carried out requesting to the Institute of Agro-biotechnology of Rosario, Argentina (INDEAR-CONICET) the service of partial sequencing of *C. latirostris* genome using a ROCHE 454® sequencer. From the sequences obtained, 16 microsatellite markers for *C. latirostris* were detected using the software FullSSR specially designed to perform together the discovery of microsatellites and design of the respective primers. The obtained results were corroborated using MISA® (Microsatellite Identification Tool) and Primer3®, both traditional programs for microsatellite discovery and design of primers respectively. Nine pairs of primers were designed for *C. latirostris*, 8 of them amplified successfully DNA samples of that species. All of them proved to be polymorphic and it have a size product ranging between 74 bp and 520 bp. Besides, these markers have also been used successfully to amplify samples of *Caiman yacare*. Employing these new markers we believe that we can expand the pool of available microsatellites specific to the Caiman genus to broaden and complete genetic-population studies and mating system analyses.

Population Structure of American Crocodiles in Coiba National Park and Gulf of Chiriquí, Panamá

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We characterized the patterns of genetic and morphological variation between the American crocodile (*Crocodylus acutus*) populations from Coiba Island and continental mainland from where this island separated at the end of the last glacial period during the Late Pleistocene. We collected nine diagnostic morphological measurements from 134 individuals as well as genotyped140 individuals at 17 polymorphic microsatellite loci developed for Crocodylus. The results from multivariate statistics suggested no any significant morphological differentiation among the insular and mainland populations of American crocodiles. In contrast, the model-based clustering analysis (STRUCTURE) and the estimates of genetic differentiation (pairwise FST) performed on microsatellite data revealed that there are three populations of American crocodiles present in our study area. The estimates of bidirectional short- and long-term gene flow detected between pair of populations suggest that American crocodiles disperse by the sea using currents as pathways. Interestingly, our results also demonstrate that these despite varying levels of gene flow detected among these populations, they are still able to maintain their “genetic integrity”. Based on our findings, we consider these three populations as a part of one dynamic system that maintains the overall integrity of American crocodiles in the region. We recommend that any management strategies such as translocation of individuals, setting up harvest quotas, commercial farming, and/or sustainable use programs should be designed individually for each of these populations taking into account the integrity of the entire system.

Cuban Crocodile, *Crocodylus rhombifer*, reproductive behavior and nesting phenology at the Smithsonian's National Zoological Park

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The National Zoo has two enclosures exhibiting *Crocodylus rhombifer*, one housing a pair (M1 and F1) and an adjacent exhibit, separated by metal bars, holding a trio of one male and two females (M2, F2, and F3). In 2012 and 2013 all females built nests and laid eggs, including one older female (F3) who was assumed to be reproductively dormant. Fertility rates were determined initially by the formation of opaque bands on the eggs and later confirmed by opening the eggs to verify fertility. In 2012, F1 laid 21 eggs in a mound nest, F2 laid 31 eggs in a mound nest and F3 laid 26 eggs in a hole nest. Out of F2's 24 eggs not destroyed during oviposition, 87.5% banded and 83.3% showed signs of fertility when opened. Of F3's 26 eggs, 38.5% banded and 34.6% showed signs of fertility when opened. Fertility rates for F1 in 2012 were not assessed. In 2013, 86.7% of F1's 19 viable eggs were banded and 73.3% showed signs of fertility when opened —34.3% of F3's 35 eggs showed partial or full banding and 25.7% were fertile. None of F2's 30 eggs banded or showed signs of fertility in 2013. In addition to tracking fertility, staff witnessed several interesting nesting and agonistic behaviors in 2013 that may be linked to changes in fertility and group social dynamics. Ongoing observations aim to further contribute to our understanding of captive *C. rhombifer* reproductive behavior.

Intraspecific feeding habitats variation in broad-snouted caiman (*Caiman latirostris*) in Argentina

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Wild animals minimize intraspecific competition through maximizing the exploitation of available resources. Crocodilians show a dramatic increase in body mass from hatchling to adult, which results in changes in the exploitation of food resources. Stable isotopes analyses are useful to verify intraspecific variations in feeding habitats because the chemical composition of animals tends to reflect the food consumed. This study aimed to verify the existence of sexual and ontogenetic feeding habitats variation for the broad-snouted caiman (Caiman latirostris) in a stream surrounded by a flooded area in northern Argentina using carbon and nitrogen stable isotopes. Isotopes compositions were determined from claw samples of 34 individuals (14 juveniles: 9♂ and 5♀; and 20 adults: 10♂ and 10&#9792 collected during field work between October/2010 and January/2012. We found no difference between juveniles and adults for δ13C (J: -20.4 ± 1.1‰; A: -21.0±1.3‰) and δ15N (J: 7.2 ± 0.9‰; A: 6.7 ± 0.5‰). We also found no difference between sex inside size class for δ13C (A♀: -20.7 ± 0.8‰; A♂: -20.2 ± 1.4‰; J♀: -20.5 ± 1.7‰; J♂: -21.4 ± 0.9‰) and for δ15N (A♀: 7.6 ± 0.8‰; A♂: 6.8 ± 0.9‰; J♀: 6.9 ± 0.4‰; J♂: 6.7 ± 0.7‰). Similar values of isotopic compositions could indicate an intraespecific overlap on exploitation of food resources. This could be due to the wide availability of food resources on the study area being capable to support higher population densities.

Trophic Ecology of *Osteolaemus* Species

Nicole Smolensky
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Crocodilians are mobile top predators in their environments and can serve as energy and nutrient couplers of terrestrial and aquatic habitats. They undergo ontogenetic niche shifts in habitat and trophic ecology occupying both prey and predatory roles as they grow. Few studies have integrated their ontogenetic niche shifts with their functional roles as nutrient vectors across terrestrial and aquatic systems. I investigated this aspect in dwarfed species of crocodile, *Osteolaemus tetraspis* and *O. osborni*, that occur in Cameroon Africa. I used stable isotope analyses of carbon and nitrogen to compare the trophic position of these species in a large river vs. small tributaries. I collected samples from plants, detritus, dominant primary and secondary consumers and constructed δ13C- δ15N bi-plots and Bayesian mixing models to explore the trophic positions and terrestrial vs. aquatic basal sources supporting these crocodiles. In large rivers and small tributaries there was little variation in the nitrogen isotope ratios between yearling, sub-adult and adult crocodiles with their trophic positions similar to predatory fish but not above them. There was significant positive correlation in the carbon isotope ratios with size such that larger crocodiles had higher δ13C isotope ratios which were found in terrestrial prey while smaller crocodiles had lower δ13C isotope ratios found in aquatic prey. These results suggest that *Osteolaemus* species occupy similar trophic positions in large and small tributaries and that larger individuals are more likely to transfer nutrients between terrestrial and aquatic systems than smaller individuals.

You stole our body type: An older, semiaquatic crocodyliform

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Crocodyliforms are part of a larger clade, crocodylomorpha which include all taxa closer to extant crocodilians than to other pseudosuchians. Crocodlyomorphs first appeared in the Late Triassic. The modern species are characterized by a uniform body shape and semi-aquatic lifestyle. Goniopholididae was established as a family by Cope in 1875 for Mesozoic crocodyliforms. The group includes neosuchian crocodyliforms known from the Jurassic and Cretaceous of Laurasia that are superficially similar to living crocodylians in body shape. Unfortunately, the group has been used as a wastebasket for Jurassic and Cretaceous crocodyliforms lacking specializations that would link them with other groups. Wastebasket groups are typically the result of inadequate systematic research and analysis of diagnostic characters and are assigned with plesiomorphies or homoplasies. In phylogenetics goniopholidids have been recovered as the sister group to Eusuchia, which includes the crown group, and it has been recovered as part of a larger clade including Pholidosauridae. The semi-aquatic lifestyle and streamlined body is not unique to Crocodylia, but has appeared in multiple lineages. The closest lineage to share that body plan with Crocodylia is potentially Goniopholididae. This could provide useful outgroup information and help in trying to establish polarity for the crown group.

The effects of dietary exposure to coal fly ash contaminated prey on the immune system of the American alligator (*Alligator mississippiensis*)

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The combustion of fossil fuels for energy production has been an area of concern, not only due to the release of CO2 emissions, but also the subsequent release of associated contaminant waste into the environment. Coal burning power plants produce approximately 34% of the electricity in the U.S. and create waste products containing 20 different trace element contaminants that are often disposed of in settling basins. These anthropogenically-derived contaminants have the ability to act as environmental stressors in resident wildlife through several potential exposure routes. In this study, 24 juvenile alligators were fed coal fly ash contaminated prey items (mosquito fish and crawfish) in living stream mesocosms for a two-year period to measure the effects of contaminants on the immune health of a high trophic carnivore. Alligators were separated into 4 experimental groups receiving contaminated prey items either 0, 1, 2, or 3 times a week for the duration of the study. To assess animal health and immune function, we used phytohaemagglutinin injection and bacteria killing assays in conjunction with measures of weight and contaminant burdens in the liver and kidneys. Information gained from such studies can help identify and evaluate the potentially deleterious effects of anthropogenic stressors, such as contaminants, on the immune system of long-lived top trophic carnivores.

Transition metal concentrations in caudal scutes of American crocodiles (*Crocodylus acutus*) on Ambergris Cay, Belize

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Due to their high trophic status, broad diet, long life span, and occurrence in a variety of aquatic habitats, crocodilians are susceptible to exposure and accumulation of numerous persistent environmental contaminants, including metals. Such exposure may result in potential health hazards and have a more pronounced effect on populations already subject to other stressors (e.g., habitat loss, deliberate killing). Previous studies have documented transition metals in caudal (tail) scutes of crocodiles from remote areas of mainland Belize; however, no such data are available for crocodiles living on the country's offshore islands (cays). In this study, we examined transition metal concentrations in caudal scutes from American crocodiles (*Crocodylus acutus*) sampled from various localities on Ambergris Cay, Belize. In addition, a smaller number of *C. acutus* scutes from Costa Rica was also examined for comparative purposes. Sixteen metals were detected in scutes: Pb, As, Cu, Ag, Be, Cd, Al, Cr, Ni, Co, Mo, Sb, Se, Tl, Sn, and Zn, with Al, Zn, Cu, and Sn exhibiting the highest concentrations. Metal concentrations differed by sex, body size, site, and proximity to putative contaminant sources. Surprisingly, juvenile crocodiles generally contained the highest metal concentrations, and for many metals concentrations decreased with increasing body size. Unusually high concentrations of Al were noted and are as yet unexplained. Future work will examine mercury concentrations in these same scutes as well as the relationship between metal concentrations and site-specific environmental matrices.

Embryotoxicity Evaluation of Different Pesticides (Glyphosate, Cypermethrin and Endosulfan) on *Caiman latirostris*: Hatching Success, Development and DNA Damage. Preliminary Report.

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Massive use of pesticides causes several damages on wild species like *Caiman latirostris* in different developmental stages, being the early stage the most sensitive. Biomarkers like morphometric parameters and DNA damage are important tools for analyzing toxicity. The aim of this study was to evaluate the effects of in ovo exposure to pesticides (Glyphosate, Cypermethrin and Endosulfan) on hatching success, development and DNA damage. Eggs (N = 204) of C. latirostris coming from different nest were distributed into 17 experimental groups of 12 eggs each. Experimental groups were: a negative control (NC), ethanol as vehicle control, a positive control treated with 700 µg/egg of Cyclophosphamide, 4 treatments exposed to Endosulfan (1, 10, 100 and 1000 µg/egg), 4 treatments exposed to Cypermethrin (1, 10, 100 and 1000 µg/egg), and 6 treatments exposed to two Glyphosate formulations, three with Roundup® and three with PanzerGold® (500, 750 and 1000 µg/egg). After hatching, animals were weighed and measured in total length and snout-vent length. Hatching success was registered per group and blood samples obtained from all neonates to apply the Comet Assay on peripheral blood erythrocytes, as previously adapted for this species. No significant differences were found in hatching success and size of the neonates between the exposed groups and the NC for any of the pesticides and concentrations tested. DNA damage index is being analyzed now so we cannot arrive to any conclusion yet, but previous studies indicate genotoxic effects of pesticides on *C. latirostris*.

Total and differential white blood cells count in *Caiman latirostris* after in ovo and in vivo exposure to (two) insecticides

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Agricultural activities associated mainly to soybean cultures affect natural environment, including wildlife, by habitat destruction and the extensive use of agrochemicals. The aim of this study was to evaluate the immunotoxic effect of Cypermethrin and Endosulfan insecticides in *C. latirostris*, analyzing total (TWBC) and differential white blood cell count (DWBC) after in ovo and in vivo exposure. Eggs (in ovo) and hatchlings (in vivo) from nests harvested in natural habitats were artificially incubated and reared under controlled conditions in the Proyecto Yacaré (Gob. Santa Fe / MUPCN) facilities. Exposure of embryos were performed by topicacion on the eggshell during the first stage of development. The treatments were: negative control (NC), vehicle control (VC), positive control (PC), 4 groups treated with different concentrations of cypermethrin (CIP) and 4 with endosulfan (END). The in vivo exposure was performed by immersion, and the treatments were: a NC, a VC, 2 groups exposed to CIP and 2 to END. After embryonic exposure to insecticides, no differences were found in TWBC or DWBC between exposed and controls hatchlings.The same was observed for TWBC in yearlings after a subchronic exposure during two months, but DWBC showed differences between NC and CIP1 for heterophils, lymphocytes and monocytes; and between CN and END1 for lymphocytes and monocytes. The results indicate that excessive use of these insecticides may alter some aspects of the immune response of *C. latirostris*, especially in neonates and juveniles, increasing their susceptibility to certain infections and compromising their ability to respond to challenging factors.

Preliminary results: estimation of SVL and growth of *Caiman latirostris* and *Caiman yacare* through phalange diameter

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Caiman latirostris (C.l.) and *Caiman yacare* (C.y.) are the only crocodilian species present in Argentina, and both of them are being managed through ranching. Ranching programs need information about population dynamics in order to evaluate the situation of reintroduced individuals. In this study our goal was to identify if phalange diameter of caimans is related to individual size. We captured and measured 51 C.l. and 30 C.y. of different sizes and the last phalange of the third finger (being the inner most finger the first) of the right foot was surgically removed. Once in the laboratory, the bone was cleaned and diameter was measured. We found a linear relationship between phalange diameter and animal SVL, for both species (C.l.: P<0.0001; R2=0.83; C.y.: P<0.0001; R2=0.94). This relationship now needs to be explored (and calibrated) as a tool to measure growth using the growing rings in the phalanges, so only one capture would be needed to estimate previous SVL.

Influence of increasing and decreasing fluctuations of photoperiod on growth of juvenile captive *Caiman latirostris*

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Under natural conditions, during the winter, the activity of crocodilians is scarce, limited to a few movements (sun exposure or dive). In spring, with increasing temperature, begin feeding until the peak of activity in the reproductive season. However, in captivity under controlled constant temperature (31±1°C), similar to those for warm weather, it could be noted that *Caiman latirostris* still reduces partially its activities during cold seasons despite the invariable temperatures. It is believed that this behavior goes beyond the search for heat. Therefore, it should exists another factors that influence it, such as the natural photoperiod, which varies in different seasons. For this research, were used 72 hatchlings of *Caiman latirostris* from three different nests harvested in nature, artificially hatched and reared under controlled conditions of temperature and humidity. The three treatments (A, B, C) were made by varying the number of hours of light in each: A) growing way up to 16 hours light; B) downward until 8 hours; C) and the control treatment with 12 hours light/12 hours dark, constantly. The evaluation was realized in a period of 109 days. Growth was evaluated using two parameters: Weight (W) and Snout-Vent Length (SVL). The results evidenced a significant increase in the variable W using the A treatment, in comparison with B and C. Based on these results, it could be assured that -in addition to temperature- photoperiod is another factor of importance with influence in the growth of *Caiman latirostris*.

Development of follicles and eggs and hormone levels in *Caiman latirostris* (Crocodylia, Alligatoridae) in Argentina

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Despite that there is much information available about Caiman latirostris reproduction, the percentage of adult females actively reproductive over a year is lacking, and this information can help in estimating some population parameters such as population size based on nest counting. In this study we monitored and determined the development of follicles and eggs, and correlated these results with plasma steroid hormone levels in 32 adult females captured in Santa Fe, Argentina. Field work was carried out during two reproductive seasons (October-January) between 2010 and 2012. Using an ultrasound device to take images of the reproductive structures of adult females, we found: vitellogenic follicles (n=5), eggs (n=4), atretic follicles (n=11) and no reproductive structures (n=12). High levels for estradiol were found during ovulation (November). During nesting (December and January) no difference was found in estradiol between reproductive and non-reproductive females. During end of nesting (January) no differences in estradiol were found between reproductive, non-reproductive and females with atretic follicles. There was no difference between progesterone levels for reproductive females during the studied period (October-January), but they showed higher levels during nesting (December) than non-reproductive females. We found no differences in progesterone levels between reproductive females and females with atretic follicles during end of nesting (January). Ultrasound evidenced to be an efficient non-invasive technique to study reproductive structures at the beginning of reproductive cycle of the broad-snouted caiman.

Discrete character coding and allometric and geometric morphometric analyses delineate two apparently cryptic African slender-snouted crocodile species

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Cryptic species exhibit slight morphological differences, usually unnoticed until genetic or ecological evidence prompts in-depth investigation. Their presence confounds efforts to measure biodiversity and effectively conserve imperiled species. A recent molecular phylogenetic analysis of the African slender-snouted crocodile (*Mecistops cataphractus*) revealed two divergent, cryptic lineages allopatrically distributed in West and Central Africa. We used a multipronged analytical approach to test a null hypothesis of no morphological divergence between these lineages. We implemented a double-blind discrete character coding protocol for 105 cranial specimens, computed 231 allometric ratios based on 22 skull measurements, and conducted geometric morphometric analyses of 31 cranial landmarks. Blind character coding identified 14 discrete characters distinguishing the lineages, and non-metric multidimensional scaling and cluster analysis resulted in two distinct clusters supporting the molecular results. Welch 2-sample t-tests revealed over 55 significantly different cranial allometric ratios between West and Central African specimens. At least 15 ratios of interest did not overlap in interquartile ranges, indicating potential use for species identification. Principal component analysis of the landmark data identified 16 PCs that explained >95% of inter-clade variance, and latent Dirichlet allocation assigned specimens to clusters with an 88.1% accuracy rate with no a priori species assignment. We reject the null hypothesis of no morphological divergence and support the molecular phylogenetic hypothesis that Mecistops cataphractus is comprised of two species. Our results suggest that rigorous morphological analyses such as these can accurately delineate cryptic crocodile species.

Oxidative stress and DNA damage in neonates and adults broad snouted caiman (*Caiman latirostris*) environmentally exposed to pesticides

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Many pesticides can produce toxicity to organisms by the production of reactive oxygen species (ROS). In excess, ROS can overwhelm the normal antioxidant buffering capacity of the cell, leading to significant damage to cellular components, including proteins, lipids and DNA. Cell damage caused by this excess of ROS is defined as oxidative stress (OE). Genotoxicity and OE are considered biologically relevant and highly informative as early warnings of the impacts of pollutants on natural populations. The aim of this work was to evaluate the environmental situation of wild populations of *Caiman latirostris* living in an area highly exposed to pesticides in the central-east region of Argentina. Blood samples were taken from hatchlings and adults coming from exposed and control areas and the following techniques were applied as previously adapted for this species by our group: 1) biomarkers of genotoxicity: Comet assay (CA) and Micronucleus (MN) test, 2) OE damage to DNA: CA modified with bacterial enzymes FPG and ENDO III, 3) lipid peroxidation by TBARS, and 4) antioxidant defense capacity through enzymatic (Catalase and Superoxide dismutase) and non-enzymatic (reduced-oxidized glutathione relationship) systems. Animals exposed to pesticides showed oxidative damage evidenced by lipid peroxidation and oxidation to DNA, as well as alteration in antioxidant defense enzymes and genotoxicity in comparison with controls ($p<0.001$). The final fate of the alterations observed is uncertain, but they could affect the normal function of physiological processes in this species, with serious consequences at cellular, individual and population level, especially under conditions of continuous environmental exposure.

Quick learning and long term memory in crocodilians

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Training of crocodilians is an effective management tool. It is used to enrich environments, to modify behaviors, and/or to aid in husbandry. I investigated long term memory retention of previously learned tasks in an experimental study conducted at the Madras Crocodile Bank, Chennai. A female *Alligator mississippiensis* accurately retained a total of 10 commands after a period of 39 months. I also investigated how quickly crocodilians learn new instructions through training. I randomly selected 6 individuals of various species (5 not previous trained: *Caiman crocodilus, Melanosuchus niger, Crocodylus palustris, Crocodylus moreletii,* and *Osteolaemus tetraspis*; and one previously trained: *A. mississippiensis*). I set up target goal behavour for all and measured time and the number of reinforcements used to achieve target behaviour. Animal's participation, attitude and learning were scored per session. Target goals were achieved in maximum 3 sessions (15 minutes max/session; total=45 minutes) demonstrating rapid learning in all species. Related studies also indicate age and sex differences in learning tasks, as well as observational learning. Video clips will illustrate representative features of training and learning as described above in various species. (Additional video documentation online: https://www.youtube.com/user/sOhAmsnakefreak).

Influence of temperature variations on the sexual proportion in *Caiman latirostris*

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Caiman latirostris is an ectotherm animal that inhabits temperate zones, showing a marked seasonality on its activity. This species exhibits temperature sex determination, in which only males are produced at constant temperatures of 33°C , only females are produced at 29 and 31°C; and 34.5°C produces both sexes. Most studies of sex determination in crocodilians have been conducted under constant temperature conditions. Furthermore, the thermal influence on the sex ratio is poorly documented on wild. We study the sexual proportion produced in eggs of *C. latirostris* incubated at 32°C and exposed to constant thermal cycles approximately 32±1°C and 32±2°C during development. The design also allowed us to evaluate the effect of the variations of temperature on incubation period, hatching success and hatchling size. We located and collected five nests in study area of PROYECTO YACARÉ (Santa Fe province), which were incubated at different thermal treatments. Our results indicated that the variation in incubation temperature affects the sexual proportion of *C. latirostris*, however each nest responded differently to heat treatment. The temperature variation treatments affected negatively the hatching success and size and weight of hatchlings, compared to the constant treatments, but incubation period was not affected.

Assessment of microsatellites in estimating inter- and intraspecific variation among Neotropical Crocodylus species

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We tested microsatellites that were developed for the saltwater crocodile (*Crocodylus porosus*) for cross-species amplification and to provide an estimate of inter- and intraspecific variation among four species of Neotropical crocodiles (*C. rhombifer, C. intermedius, C. acutus, and C. moreletii*). Our results indicated that with the exception of 2 loci in *C. intermedius*, all 10 microsatellite loci were successfully amplified in the 4 species, producing a set of variably sized alleles that ranged in number between 2 and 14 alleles per locus. Similarly, private alleles (i.e., unique alleles) also were reported in all 4 species for at least 3 loci. The mean observed and expected heterozygosity (averaged across species for all 10 loci combined) ranged from 0.39 to 0.77 and from 0.44 to 0.78, respectively. In addition to this, we evaluated these microsatellites in 2 populations of *C. acutus* and *C. moreletii* to assess their utility in estimating intraspecific levels of polymorphisms. These microsatellites also showed considerable allelic variation in population level analysis. The set of 10 microsatellite loci in our study have the potential to be used as a tool in population and conservation genetic studies of Neotropical crocodiles.

Are Stress-related Hormones Involved in the Process of Temperature Sex Determination (TSD) in Reptiles?

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The gonadal outcome in some reptiles is regulated by temperature during a critical period of the embryonic development; and steroidal hormones are seen as effectors of the gonadal differentiation process. Recently, cortisol has also been implicated in the temperature-dependent sex determination (TSD) process of fish. Corticosterone, the glucocorticoid stress-related hormone in reptiles, has been considered as a potential modulator of the gonadal differentiation process. In fact in some reptiles a feminizing effect of corticosterone was described. This hormone plays a significant role in the intermediate metabolism, osmoregulation, growth, and reproduction; and its plasmatic levels rise under stressful situations. In this context, we aim at assessing whether stress-related hormones can affect the sex differentiation process of *Caiman latirostris*, a species with strong TSD, using a glucocorticoid agonist, dexamethasone. As a first step, we incubated embryos at masculinizing temperatures (33°C; 100% males). Different doses of dexamethasone were topically applied to the eggshell at stage 22, previously to the first morphological signs of gonadal differentiation. Embryonic mortality was not affected by dexamethasone manipulation. No effects of dexamethasone on sex differentiation were found, and all histologically analyzed individuals evidenced testis. However, hatchlings from dexamethasone treated eggs had a shorter incubation time and were also heavier and larger than control ones. Our results do not account for a dexamethasone involvement in ovarian differentiation, at least at temperature that produces 100% males. Nevertheless, they suggest that dexamethasone might improve embryo development by enhancing intermediate metabolism, or by direct stimulation of growth hormone secretion.

Presence of Natural Antibodies in Broad-Snouted Caiman (*Caiman latirostris*) serum

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Crocodilians suffer serious injuries caused by different reasons but usually they do not show signs of diseases. Based on that, they have been objects of many studies, mainly related to innate immunity. This immunity, more ancestral than the acquired, provides the first-line of protection against pathogenic microbes where appear two interrelated humoral components: natural antibodies (NAbs) and complement system (CS). The CS has been characterized in many crocodilian species highlighting its remarkable ability to recognize and eliminate antigens. Additionally, NAbs are encoded directly by the germ-line genome and do not require somatic hypermutation and recombination during ontogenesis like occurs with the adaptive antibody repertoire. Natural antibodies have not been studied yet in any crocodilian or reptiles species. In the current study, we detected the presence of NAbs in Broad-snouted Caiman serum from different ages and nest, and characterized them under different laboratory conditions. Rabbit red blood cells were used in the hemagglutination assays and the titres of NAbs were measured. Results showed that neonates have 4 and 5 titres lower than one or two year old animals, and in both cases, temperature dependence was found. Although NAbs are the only immunoglobulins that do not require a previous contact with specific antigens, they always need a first exposure to antigens to put on work its mechanism of production, and this happen after hatching. This can explain the difference found in Nabs between neonate and juvenile caimans. These results allow us to propose NAbs as unspecific marker of the humoral immunocompetence.

Saltwater crocodile management in the Northern Territory of Australia, 2009-2013

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The wild populations of saltwater crocodiles (*Crocodylus porosus*) in the Northern Territory of Australia are mainly managed by the Northern Territory Department of Land Resource Management (DLRM). This paper reports on the crocodile management with particular focus on population monitoring, problem crocodiles, and harvest from the wild. DLRM conducted spotlight surveys in 8 monitoring rivers in 2009-2013. The results showed that the population of non-hatchling *C. porosus* in most rivers continued to increase or remain stable. Survey results also indicated that the size of individual animals has been increasing in most rivers, reflecting the continued maturity of the population still recovering from the unregulated hunting in the period 1945 to 1971. A total of 1,135 problem crocodiles were removed between July 2009 and June 2013 by Parks and Wildlife Commission (PWC) staff for public safety and to protect stock in pastoral areas, of which 78% were males and 67% were caught in the Darwin Harbour. PWC continues to promote community awareness for safety and participation through CROCWISE campaign programs using a variety of media. Under the increasing ceilings, 245,744 eggs were allocated to harvest, but only 192,772 live eggs were collected between July 2009 and June 2013. During the same period 151 hatchlings, 91 juveniles and 272 adults were harvested. The adults harvested were mostly biased to males and the average body size of the harvested animals was about 2.2 metres for females and 2.7 metres males.

Microucleus Test and Nuclear Abnormalities in *Caiman latirostris* (Broad-snouted caiman) Exposed in vivo to Commercial Formulations of Insecticides: Edosulfan and Cypermethrin.

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The agricultural frontier expansion in Argentina led to a high transformation of many environments occupied by natural populations of *Caiman latirostris*. The aim of this study was to evaluate genotoxicity induced by insecticides Endosulfan (END) and Cypermethrin (CYP) on *C. latirostris* hatchlings, using the Micronuclei (MN) and other nuclear abnormalities (NA) as biomarkers. *C. latirostris* hatchlings, 20 days old, were exposed to two concentrations of END (END1 and END2), and two of CYP (CYP1 and CYP2), including those recommended for their application in crops, using ethanol as a vehicle and a control without treatment (NC). Animals were maintained in plastics pens, during two months and concentration of insecticides progressively decreased through time in order to simulate their degradation in water in natural conditions. After exposure, blood samples were taken to all animals for determination of the Frequency of MN (FMN) and NA (FNA; vacuolated nuclei, notched nuclei, buds, binuclei, eccentric nuclei) in erythrocytes as markers of genotoxicity. The NC and vehicle control showed no difference in the FMN indicating that ethanol caused no genotoxic damage ($p>0.05$). Statistical significant differences were found in the FMN between exposed groups: CYP2 ($p=0{,}023$) and END1 ($p<0{,}001$) compared to the NC. No significant differences were observed in any of the NA analyzed in the exposed groups, respect to the NC. These results showed that the MN test is more sensible than other NA as a biomarker of genotoxicity, demonstrating negative effect of different pesticides in various studies made in broad snouted caiman.

Effect of egg rotation on embryo survival

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In crocodilians ranching programs, eggs harvest is one of the most critical steps to ensure maximum survival of embryos. It is broadly known that one extremely important factor to be taken into account in eggs collection is the maintenance of the same position in which they are found in the nest during all the incubation, and avoiding denting of the eggshell to ensure the maximum chance of hatching success. \r\nIn general, eggs collection involves different steps that include handling by local people who identifies the nests, an eventual intermediary stage into carry containers, and the final transfer to the incubation container. Besides, most of the time, nesting habitat are far from program facilities, implying long ways transportation of the eggs on foot or by horse, and then driving through unpaved roads, etc. All these are potential causes of embryo mortality. If we considering that the eggs sometimes arrive to the program facilities in a wrong or altered the upright position, and the decision to rotate them to the right position must be taken at the moment. The aim of this study was to evaluate the effect of rotation at different periods of the incubation in the survival and size of embryos in order to define the maximum moment or tolerance up to which is possible to modify egg position.

cDNA Sequence Coding of the Third Complement Component (C3) of Broad-Snouted Caiman (*Caiman latirostris*)

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From several years ago, we have been talking and reporting some important characteristics of crocodilian immune system (IS) and its ability to avoid spreading infection. Likewise, many components of this IS were reported but few studies have been go into molecular details. If we can detect the origin of these abilities, we could think the idea to replicate it and apply therapeutically. The complement system (CS) is one of the major effector mechanisms of the IS and it was reported in crocodilians. It is a set of 30 different plasma proteins that act sequentially and whose function consists in recruiting effectors of pro-inflammatory cells, opsonization and lysis of pathogens. The CS is activated by three different pathways and the initiation of any of the 3-way is performed by activation of C3, the main protein. In order to identify the cDNA coding *C. latirostris* C3, a set of random primers of the gene were designed from the C. latirostris partial genome sequence and the alignment of sequences from phylogenetically related species obtained from NCBI. Nowadays, 90 % of Caiman C3 was identified and by using rapid amplification of the cDNA ends (RACE), it is yielding the full open reading frame. This characterization is the initial step to perform a first evaluation of the future application of products derived from this species in non-specific antimicrobial therapy in animals of zootechnical interest. These findings generate an enhancement of the resource that is being subject to sustainable management programs with a major social impact.

Corticosterone response in Broad-snouted caiman (*Caiman latirostris*) after restraint conditions

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Corticosterone (CORT), the main stress hormone in reptiles, helps these organisms to recover homeostasis state after acute or chronic stressors. We investigated plasma CORT profiles in juvenile Broad-snouted caimans in response to acute stress. Ten juvenile caimans raised under controlled conditions were held in restraint situations inducing stress. Half of animals were maintained at indoor temperature (IT) (20±1.2°C) and the rest at outdoor temperature (OT) (12.7±1.5°C) during 12 hours. Animals were bled at different time periods: 15 min, 30 min, and 1, 2, 4, 8 and 12 hours. Corticosterone levels were measured by radioimmunoassay (RIA). At the beginning of the study, CORT concentrations (time 0) ranged between 0.06 and 6.85 ng/mL. Maximum values were detected in the IT group ranged from 11.01 to 56.5 ng/mL, and OT group from 9.78 to 38.8 ng/mL. Under IT, CORT levels increased progressively reaching maximum values between 4 to 8 hours and after that CORT decreased until 6 ng/mL, approximately. Some animals of the group OT presented a plateau with maximum values from 2 to 12 hours, and other increased progressively until 12 hours, possibly because of ambient temperature dropped by the end of the experiment causing an additive stress effect. Only some individuals presented an increase of CORT after the first bleeding, while other presented low values until 2 hours. In order to avoid the interference generated for the action of CORT on target mechanisms, it is convenient to collect samples as soon as possible or within 30 min after capture.

Effect of ultraviolet radiation on the immune response of Broad-snouted caiman (*Caiman latirostris*) injected with LPS from *Escherichia coli*.

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Ultraviolet radiation (frequencies A and B) is necessary in many vital processes and all organisms have a dependence on it, directly or indirectly. In natural conditions, quantity and quality of UV radiation received by organisms depends on numerous factors. Under artificial conditions, it is possible to provide and regulate UV exposure, but an overexposure might induce adverse effects such as immune suppression. This may debilitate the recognition of some antigens even few days after the irradiation, with serious consequences on both animals and human health. Lipopolysaccharide (LPS) is a major component of the outer membrane of Gram negative bacteria and contains a toxic substance (Lipid A) that is recognized by the immune systems of higher eukaryotes, causing an inflammatory reaction. In this case, LPS was used to challenge an immune response in *C. latirostris*. Caimans of 3 months were maintained under different treatments of UVR intensities during ninety-five days and then injected with LPS or saline solution. Animal growth (weight, total and snout vent length), as well as immune response was evaluated. The results showed that immune parameters, as complement system, was only affected by the high intensities of UV exposure ($p < 0,01$) while growth of the animals was not affected by UVR exposure ($p>0,05$).

Evaluation of the spatial ecology of the American Crocodile *Crocodylus acutus* (Crocodylidae - Crocodilia; Cuvier, 1807) in the Coiba National Park, Panama

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The American Crocodile is a keystone species in the maintenance and function of seaside ecosystems in the long term, however, is listed as threatened or endangered by the IUCN. On the other hand, the lack of knowledge about the biology of the species in many places, for example the Coiba National Park in Panama, is a limiting factor when making plans for effective conservation management of this species. In order to determine the spatial ecology of *Crocodylus acutus*, during the period from August to December2013, using the method of the UHF radio telemetry and home range estimators. Sixty nine monitoring along 4 circuits, were made to 16 individuals, obtaining 309 geo- referenced locations, averaging 12.8±10.1 location points per individual. An area of 7.2km2 of general scope of home with the minimum convex polygon method was obtained. Analysis of Kernel Density estimation showed a central area of 0.18km2, which is equivalent to 26.7% of the home range calculated. In terms of habitat selection, with 73.6% of registers within the mangrove habitat was determined as the habitat preferred by individuals. However, habitat selection depends on the age of the individuals, as the Sub - Adults occasionally explore areas towards to the sea, while juveniles were in shallow areas; habitat selection also depends on the climate. The presence of this species along the study gives evidence that system is in a high level of conservation influenced by low human pressure on this island, being considered as indicators of ecosystem health of PNC.

Recovery strategy of the "Runt Syndrome" in *Caiman yacare* hatchlings by the use of one suppressor and three supplies in Crocoland farm, Santa Cruz, Bolivia

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In 2008, at the end of the first five months of captive breeding, the 24% of the hatchlings were affected by the Runt Syndrome and in the next two months, they manifested physiological and morphological insufficiencies. Laboratory and clinical analysis recommended, as a mitigation measures, the use of one suppressor and three supplies: anabolics, injectable B complex and oral B complex with amino acids. This study proposes two design factors: a) six treatments using Albendazol, Estigor, Rubralan 5000 and Hipramin B and b) Four temperature conditions. By this experimental design we evaluated the individual effect of both factors and its interaction over three variables of responses: survival and weight gain and height. We selected 720 hatchlings with a weight under 41.6 gr. and a size under 25cm. Every month each treatment was applied to a group of 30 hatchlings (24 groups), obtaining averages of weight gain, height gain and survival in five months per group. The results conclude that the time and effort invested in the treatments are not compensated for the survival levels obtained that are lower than the 50%. The actual recovery just happened in 11 hatchlings with a weight gain of 65 gr. (0.4 gr/day) and growth of 7.8 cm. (0.05 mm/day). Therefore, according to this experimental design, it was not possible to achieve and effective recovery strategy for the Runt Syndrome at an efficient productive level.

The report of the first reproductive event of the F2 Generation of *Caiman yacare* under captive breeding conditions in Crocoland Farm, Santa Cruz, Bolivia

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The National Program of Conservation and sustainable exploitation of *Caiman yacare* use an strategy to assign quotes of harvest dependent of selective size categories. However, little is known about variation of minimum reproductive age and size at which this specie reach reproductive maturity and its biological characteristics. One of the objectives for the captive breeding is to answer this kind of questions. In 2007, we began the harvest program in the artificial pools of the farm. On 2009, when the specimens reached an optimal size for exportation, 1000 individuals were incorporated to the parental reproductive stock and five years after the farm registered the first reproductive event of the F2 Generation. We present the biological and reproductive data of a female of 7 years old, 153 cm. long and a weight of 18.5 kg. The dimensions of the nests are 94x72x32 and registered 37 eggs, 33 were fertile, 3 were broken and 1 was infertile. The eggs shown and average of 6.598 ± 0.415 cm. length, 4.073 ± 0.061 cm. wide and a weight of 64.4 ± 1.8 gr. The index of viability was 27.27% with 9 effective hatchings. Even though we are incorporating valuable information for the reproductive biology of this specie, it is necessary to make more researching on minimum age and size reproductive characteristics for separate males and females under captive breeding conditions.

Comparison of the reproductive ecology of *Caiman yacare* between wild and captivity

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We present the data and a comparative analysis of the reproductive ecology of *Caiman yacare* in wild and captivity that was done since 2007 to 2012. The evaluation was done in the Bolivian Pantanal, region of San Matias, including communities of TCO CIRPAS and private Properties, while captive evaluations were done in the artificial pools of Crocoland farm, which reproductive stock was harvested in the year 2006 from the same areas where the wild evaluations were done. In wild, the average was of 27.05 ± 2.16 eggs/nest, 25.33±1.47 fertile eggs/nest, 1.66±1.37 infertile eggs/nest and 0.06±0.05 broken eggs/nest. In captivity, it was registered and average of 27.01±2.27 eggs/nest, 22.87±2.95 fertile eggs/nest, 3.36±1.81 infertile eggs/nest and 0.78±0.5 broken eggs/nest. According to the total harvested nests in wild (5711) and captivity (3298), it was determined a fertility index of 94.07% and 85.82% respectively. The comparative analysis was done during artificial incubation of the whole fertile eggs annually harvested for both Ranching and Farming systems. Because wild eggs shown a viability index of 93.22% and 78.07% was registered for the eggs harvested in captivity, it is necessary to evaluate all the possible factors that are affecting the viability of the reproductive biology in captivity that annually is decreasing and reduce the productivity of the managements and exploitations models under captivity conditions.

Optimizing Survey Designs for Complex Habitat: Evaluating Seasonal Variation of AlligatorAbundance Estimates Derived from Nightlight Surveys in South Carolina

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Nightlight surveys are a commonly used, cost-effective monitoring method to acquire crocodilian abundance, occupancy, and size class distribution data. Monitoring data can be directly applied to infer population trends and inform management decisions. However, reliability of nightlight survey-derived abundance estimates are heavily influenced by survey design components, including season, number of replicate surveys, and replicate time interval. In the United States, five states in the American alligator's (*Alligator mississippiensis*) eastern distribution have established nightlight-survey based monitoring programs in the last decade. However, new programs are frequently modeled after existing programs in other regions with different alligator habitat, with little to no empirical evaluation to determine if the proposed survey designs are appropriate for areas beyond their original use or if an alternative design may increase demographic estimation precision. A "one-size-fits-all" approach to monitoring program design is risky, as it can produce imprecise or deficient data and ultimately, wasted time and resources. Here, we describe an on-going study in South Carolina aimed at identifying the optimal nightlight survey design that maximizes precision of size-class specific abundance and detection probability estimates, in order to minimize uncertainty associated with harvest decisions. From 2014-2016 we will conduct two replicate nightlight surveys within the breeding, nesting, and post-nesting periods (6 surveys/route/year; N = 6 routes), in several major habitat types. Our main objective is to quantify levels of demographic uncertainty associated with varying combinations of survey design components and identify a design that is tailored to South Carolina's habitat, management needs, and resources.

The Role of the American Alligator (*Alligator mississippiensis*) and American Crocodile (*Crocodylus acutus*) as Indicators of Ecological Change in Everglades Ecosystems

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The system-wide Monitoring and Assessment Plan (MAP) for the Comprehensive Everglades Restoration Plan (CERP) identified indicators and targets for monitoring ecosystem responses and track progress toward meeting restoration goals. Responses of alligators and crocodiles are directly related to suitability of environmental conditions, including changes in depth and period of inundation and salinities. Therefore, these species have been selected as indicators for the Greater Everglades module in the MAP. Here we present analyses on data collected from 2003-2012 throughout South Florida for both alligators and crocodiles. We examined encounter rates of both alligators and crocodiles and nesting for crocodiles. We found that alligator abundance (measured as relative density) significantly declined in 5 areas, and did not change in 3. The declines occurred in areas with drier conditions. The areas with no change in abundance since 2003 had the longest hydroperiods and experienced less frequent and less intense dry-downs. Our findings suggest that alligator abundance remains stable in areas with hydroperiods > 11 months/year, dry-downs no longer than about 40 days (1 ¼ months), and at least 2 years between dry-downs. Across all years there was a decrease in mean encounter rate of crocodiles. However, the number of crocodile nests annually has increased over the past 25 years. Initiation of crocodile nesting along East Cape and Buttonwood canals coincided with the plugging of those canals in the 1980s. This has led to faster increase in nesting effort in Buttonwood and East Cape Canals over that in northeastern Florida Bay.

Abundance, Demographic Structure and Habitat of the American Crocodile (Cuvier 1807) in the Parque Nacional Coiba, Panama.

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Abstract: The wild population of *Crocodylus acutus* was characterized in their natural habitat present in Coiba National Park located in Panama during the months of January to June of 2013, with the aim of estimating the size and population structure, assess their interactions with habitat and the distribution of the species. There were a total of 156 sightings along 8.1 km of sampling area. To know the values of abundance was estimated abundance index which was 69.56 individuals approximately. The visible fraction determined by size classes was 24.20% for class I, 28.31% class II, 44.70% class III, 39,68% class IV and finally to the class V a 25.74% value. Followed by this we calculated the population size of 70.10 ± 48.94 individuals. For the demographic structure the dominance of class I in the histogram was evidenced due to the hatching season of the species, followed by class III. On the other hand, the variables that affected the presence of *Crocodylus acutus* was the variable environments followed by tide-oscillation and very close to this value, lunar phase. Finally, the behavior observed for the distribution of the species in Coiba National Park was grouped.

Multiple Genes Code for Two Distinct Crocodilian Complement C3 Proteins

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Serum complement component C3 is the most abundant serum complement protein, and exhibits the most complex immunoregulation. We searched the crocodilian genomes of the American alligator (*Alligator mississippiensis*), estuarine crocodile (*Crocodylus porosus*), and the Indian gharial (*Gangetius gavialis*), and found two distinct C3 genes. The deduced crocodilian C3 protein sequences of each isoform shared high amino acid sequence identities (96.2 ± 0.7%) with each other. However, the C3-1 protein (1655 aa) only exhibited 69.0 ± 0.4% identity with the C3-2 isoform (1652 aa). The C3-1 protein showed moderate amino acid sequence identities with mammalian (n=5), avian (n=5), reptilian (n=4), and amphibian (n=1) C3 proteins. However, the C3-2 protein exhibited much lower amino acid homologies with C3 proteins from the same vertebrate taxa. Since these two genes are adjacent to one another in the genomic DNA, then it is likely that C3-2 was the product of a gene duplication event (based on the lower homology of C3-2 with those of other vertebrate taxa). The results from this study reveal that crocodilians have two complement C3 genes, which may be responsible for the previously-observed, broad-acting innate immunity.

Multiphoton Microscopy Imaging of American Alligator Collagen

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Collagen is the main structural protein of animal connective tissues and extracellular collagen fibers play a crucial anatomical role in producing strength and stiffness. These material qualities are crucial for effective phallus intromission during copulation. The American alligator phallus is a complex appendage with multiple structural uses of collagen. The proximal shaft is continually rigid due to densely packed collagen bundles while the distal glans and tip show evidence of collagen-regulated inflation during copulation. To better visualize these collagen fiber architectures, we have employed multiphoton microscopy - a laser-scanning, non-linear imaging technique that can probe hundreds of microns into thick tissue slices. This method capitalizes on the capacity of collagen fibers to autofluoresce when excited by specifically tuned laser light. This fluorescence capability is endogenous and does not require staining or immunostaining. Using this microscopy technique, we have begun to investigate fiber thicknesses and three-dimensional orientation characteristics that affect the tensile qualities of phallic tissues. Paired with DAPI nuclear and phalloidin cytoskeleton staining we present our initial imaging results and discuss the exciting possibilities of utilizing this technique in investigating the collagenous functional anatomy of non-model and wildlife species.

Animal-borne imaging reveals novel insights into the foraging behaviors and diet activity of a large-bodied apex predator, the American alligator (*Alligator mississippiensis*)

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Apex predators can exert strong top-down effects within ecological communities through their interactions with prey; however, little is known regarding their feeding behaviors and activity patterns, information that is essential to understanding their role in food web dynamics and ecological processes. We used animal-borne imaging systems (Crittercam) to study the foraging behavior and activity patterns of a cryptic, large-bodied predator, the American alligator (*Alligator mississippiensis*) in two estuaries of coastal Florida. We found the frequency of prey-attacks (mean = 0.49 prey attacks/hour) as well as the probability of prey-capture success (mean = 0.52 per attack) were significantly affected by time of day. Alligators attempted to capture prey most frequently during the night. Probability of prey-capture success per attack was highest during morning hours and sequentially lower during day, night, and sunset, respectively. Position in the water column also significantly affected prey-capture success, individuals' experienced two-fold greater success when attacking prey while submerged. These estimates are the first for wild adult American alligators and one of the few examples for any crocodilian species. Our results reveal that our understandings of crocodilian foraging behaviors are biased due to previous studies containing limited observations of cryptic and nocturnal foraging. Our results can be used to inform greater understanding regarding the interactions of American alligators in estuarine food webs. Additionally, our results highlight the power of using animal-borne imaging when studying the behavior of elusive large-bodied, apex predators, as it provides critical insights into their trophic and behavioral interactions.

Caimans hunting for bait use in the Piracatinga (Calophysus macropterus) Fishery in the Mamirauá Sustainable Development Reserve, Middle Solimões River, Brazil

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The Amazon caimans: *Melanosuchus niger* and *Caiman crocodilus* were intensively hunted in the past for illegal trade of their products. In early 2000, poaching of these species restarted, with the difference that nowadays main use is as bait for piracatinga (*Calophysus macropterus*) fishery. This study aimed to gather information on illegal commercial hunting of caimans in the Mamirauá Sustainable Development Reserve. We visited 55 riverine communities, in order to interview hunters and attend caiman hunting events. We used snow ball methodology to select hunters that we would interview. Of the communities visited, 22 are involved in caiman hunting. Hunting for meat consumption was recorded in only three communities and occurs occasionally. Obtaining and supplying bait for piracatinga fishery is the main reason for hunting caimans in 21 communities. Trade occurs in 18.2% of the communities and set price lists occur in 50% of these. Prices vary from US$4.00 to US$ 80.00 and are associated to total length and hydrological cycle, being more expensive during the flood season. Providing caimans commercially as bait is recent, having started around 2006. The number of caimans killed for fishing piracatinga per year for the surveyed sectors can get close to 2300 animals and 18.5% of these are traded as bait. Over the years, activity of Amazonian caiman hunters for bait use is acquiring industrial characteristics with well-defined market relations, as well as labor divisions and assigned prices, which can cause an increase in the number of animals illegally slaughtered.

Nest Predation in Black caiman, *Melanosuchus niger*, and Spectacled caiman, *Caiman crocodilus*, in the Mamirauá and Amanã Sustainable Development Reserves, Middle Solimões River, Brazil

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Predation is an important energy source in food chains and should be considered as a natural relation of ecological dynamic in Amazon varzea. The objective of this study was to identify the occurrence of predation on black caiman (*Melanosuchus niger*) and spectacled caiman (*Caiman crocodilus*) nests in varzea environments, in the Mamirauá and Amanã Sustainable Development Reserves, Middle Solimões river. We recorded nest predation and identified predators by checking holes on nests and footprints found next to them. In 2012 and 2013 we monitored 967 nests of *Melanosuchus niger* (89.14%) and Caiman crocodilus (10.86%) and 33.09% of them were predated. The predators were: humans (*Homo sapiens*) with 34.38%, tegu lizards (*Tubinambis teguixin*) with 25.31%, jaguars (*Panthera onca*) with 13.13%, and capuchin monkeys (Sapajus apella) with 6.25%. In 20.94% of nests we were not able to identify the predators. Human predation was registered in this study only for self-consumption. We concluded that caiman eggs are part of the diet of several species and a food source during the dry season. Therefore, nest monitoring should be continued, as an important tool to increase knowledge of ecological interactions and dynamic of varzea environments.

Preliminary study of the fatty acid profile of fertile and infertile eggs of wild Caiman latirostris

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The lipids are the major nutritive components of the eggs of reptiles and, the fatty acids derived from the yolk lipids are the main energy source for embryonic development. Among fatty acids, the essential polyunsaturated fatty acids are vital for the embryo development and, consequently, the lack of some of these components compromises the hatching success. We compared the total fatty acid profile in fertile and infertile eggs of wild C. latirostris. We analyses the fatty acids composition in yolk of eggs collected (9 infertile and 11 fertile eggs) using the technique of methyl esters and, then analyzing them by GCMS. The results showed that fertile eggs had a higher percentage of oleic (C18:1) and total monounsaturated fatty acids and a lower percentage of palmitic (C16:0), heptadecenoic acid (C17:1), linoleic (C18:2), and total saturated fatty acids, respect to infertile eggs. The oleic fatty acids (C18:1) belong to one of the three families of unsaturated fatty acids which have greater biological importance for embryonic development in oviparous species, because they are precursors of polyunsaturated fatty acids of long chain. Thus it is probably that differences in the fatty acid composition of the yolk could be associated with fertility and hatching success of eggs. In this context, it would be interesting to evaluate in future studies whether changes in the chemical composition of fertile eggs may be associated with an increased hatching success of eggs and/or survival of offspring.

The CSG's Student Research Assistance Scheme

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Since its inception in 2009, the CSG's Student Research Assistance Scheme has approved 70 projects (average of 13 per year), carried out in 24 countries. The SRAS grant was developed with the specific goal of encouraging and assisting undergraduate and post-graduate students to undertake formal research on crocodilians, particularly field research. Crocodilian research often involves a greater commitment of resources and time by students, relative to many other subjects. It is important to encourage research that gives students the skills needed to assist crocodilian conservation and management initiatives, and to allow them to become active CSG members in the future.

IUCN/Species Survival Commission

The Species Survival Commission (SSC) is one of six volunteer commissions of IUCN - The International Union for Conservation of Nature, a union of sovereign states, government agencies and non-government organizations. IUCN has three basic conservation objectives: to secure the conservation of nature, and especially of biological diversity, as an essential foundation for the future; to ensure that where the earth's natural resources are used this is done in a wise, equitable and sustainable way; and to guide the development of human communities towards ways of life that are both of good quality and in enduring harmony with other components of the biosphere.

The SSC's mission is to conserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats. A volunteer network comprised of nearly 7,000 scientists, field researchers, government officials and conservation leaders from 188 countries, the SSC membership is an unmatched source of information about biological diversity and its conservation. As such, SSC members provide technical and scientific counsel for conservation projects throughout the world and serve as resources to governments, international conventions and conservation organizations.

IUCN/SSC also publishes an Action Plan series that assesses the conservation status of species and their habitats, and specifies conservation priorities. The series is one of the world's most authoritative sources of species conservation information available to nature resource managers, conservationists and government officials around the world.

IUCN
The World Conservation Union

SSC
Species Survival Commission