CROCODILE SPECIALIST GROUP NEWSLETTER

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CROCODILE

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NEWSLETTER

VOLUME 32 Number 4
OCTOBER 2013 - DECEMBER 2013

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COVER PHOTOGRAPH: Saltwater crocodile (*Crocodylus porosus*) at the Mary River, NT, Australia. Some of the largest Australian *C. porosus* have come from the Mary River, which also has the highest population density for the species. Photograph: Grahame Webb.

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The CSG Newsletter provides information on the conservation, status, news and current events concerning crocodilians, and on the activities of the CSG. The Newsletter is distributed to CSG members and to other interested individuals and organizations. All Newsletter recipients are asked to contribute news and other materials.

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The Ebey family, New Mexico, USA.
Nao Thouk, Phnom Penh, Cambodia.
Marco Schultz, Germany.

Editorial

It was very sad indeed to learn that two well-respected CSG members have passed on. Thierry Bordat (France) was the director of Civaux Crocodile Park "La planète des crocodiles" located in west of France, and was a passionate, knowledgeable and respected member of the herpetological community. Robert (Bob) Chabreck (Louisiana, USA) was a true pioneer in the CSG. He attended the first CSG meeting in New York (1971), and the early meetings in Maningrida (1976) and Madras (1979). His early research on alligators remains as important today as it was 40+ years ago.

Long-time friend and CSG life member, Phil Wilkinson, turned 80 last November, and I join with his many CSG friends in thanking Phil for his extensive service to crocodilian conservation, management and research and wish him all the best for the years to come.

I was awarded an Honorary Doctor of Science from Charles Darwin University in October 2013 - all very humbling. It specifically recognises my contribution to the biology, conservation and management of crocodilians. However, not to be outdone, wife Giovanna was awarded the "Australian Rural Woman of the Year", at a ceremony in Parliament House, Canberra, Australia. And then son Freddy was part of the winning basketball team in under-14 and under-16 years. A crazy year!

The proposed meeting of the CSG's Siamese Crocodile Task Force scheduled for December 2013 has been deferred to April 2014. Details of the dates, venue and agenda will be provided to members as they become available.

Marisa Tellez's "A Checklist of Host-Parasite Interactions of the Order Crocodylia" is now published and available through the University of California Press. Congratulations to Marisa for this great publication. (www.ucpress.edu/book.php?isbn=9780520098893). Marisa has summarised species interactions in an easy-to-use excel data sheet, which is now available on the CSG website (www.iucncsg.org/pages/Resources-provided-by-the-CSG-Veterinary-Group.html)..

Also now available is "VIII. Biology and Conservation of the Crocodylia of Colombia", edited by Monica A. Morales-Betancourt, Carlos A. Lasso, Jaime de la Ossa and Alirio Fajardo-Patino. Numerous crocodilian specialists contributed chapters to this volume, which is published by the Humboldt Institute (2013).

The 23rd Working Meeting of the Crocodile Specialist Group will be held on the McNeese State University campus at Lake Charles, Louisiana, USA, from 26-30 May 2014, (www.CSG2014louisiana.com). I would encourage CSG members and other possible participants to register and book their accommodation as soon as possible.

A special scientific session will be held during the meeting, on crocodilian reproduction. Presentations on this topic, both poster and oral, will be eligible for publication in a special issue of the peer-reviewed South American Journal of Herpetology (SAJH) dedicated to crocodilian reproduction. Details can be found at the meeting website or through Mark Merchant (CSG2014@mcneese.com) or Carlos Piña (cidcarlos@infoaire.com.ar).

The 51st annual meeting of the Association for Tropical Biology and Conservation (ATBC), being held in Cairns, Australia, 20-24 July 2014, will host a crocodile symposium 'Bridging science and practice in crocodilian conservation' during the conference (www.atbc2014.org). The key contact person is Ruchira Somaweera (ruchira.somaweera@gmail.com), and he is chasing 6-12 talks.

After repeated efforts, Val Lance has finally managed to push through a symposium on the "Integrative Biology of Crocodilia" at the annual meeting of the Society for Integrative and Comparative Biology (SICB; formerly the American Society of Zoologists). The symposium will be held on 5 January 2015 at West Palm Beach, Florida, USA. Further information will be provided as it becomes available.

The CrocBITE worldwide crocodilian attack database (www.crocodile-attack.info), developed by the Research Institute for the Environment and Livelihoods (RIEL) at Charles Darwin University, in cooperation with Adam Britton's company, Big Gecko, was recently launched (https://theconversation.com/croc-attacks-a-new-website-with-bite-20671). CSG members are encouraged to submit attack records, from any species and any country.

Proceedings of 23rd CSG working meeting, held in Negombo, Sri Lanka, have now been completed and sent out to participants. Another fine job by Anslem de Silva and his enthusiastic team, who really did a great job with the meeting. A limited number of copies of the proceedings are available for sale - contact Anslem at <kalds@sltnet.lk>.

Professor Grahame Webb, *CSG Chairman*.

23rd CSG Working Meeting

Lake Charles, Louisiana, USA; 26-30 May 2014

The 23rd Working Meeting of the Crocodile Specialist Group will be held on the McNeese State University campus in Lake Charles, Louisiana, USA, on 26-30 May 2014. The working meeting will be preceded by a meeting of the CSG Steering Committee on 25 May.

Information on the working meeting is available on the meeting website (www.CSG2014louisiana.com). Mark Merchant and his team have expended considerable effort into organising this meeting, and it is shaping up to be one of the biggest meetings ever held by the CSG. We encourage all CSG members to consider attending the meeting.

Obituaries

On 5 December 2013, Thierry Bordat, CSG member and Director of Civaux Crocodile Park "La planète des crocodiles" located in west France, tragically passed away due to a cardiac incident. He was only 40 years old, and was married with three youg children (9-11 years). His love and respect for human, crocodiles and any form of life was outstanding, and his passing is a huge loss for the CSG and the French herpetological community.

Dr. Robert Henry Chabreck died on 30 December 2013 at the age of 80. Robert was born in Lacombe, Louisiana and graduated from Slidell High School and Louisiana State University. His personal life focused on family, hunting, and all things LSU sports. He was a loyal and dedicated family man. Robert was a retired Professor of Forestry and Wildlife in the School of Renewable Natural Resources at Louisiana State University. He was regarded as an expert on wetlands and marsh management with special emphasis in the area of plant and animal management in the coastal zone. He authored the book "Coastal Marshes - Ecology and Wildlife Management", the chapter on Gulf Coast Wetlands in the book "Creation and Restoration of Wetlands - State of the Art", and over 130 scientific and popular articles dealing with wildlife and wetlands. Robert possessed a vast deal of experience in marsh management and pioneered many of the research techniques currently used today. He was well respected in the international community serving as a US advisor to programs in Cuba, India and Poland.

Bob was one of the first members of the CSG, and attended some of the group's first meetings (eg New York 1971, Maningrida 1976, Madras 1978). He was considered an expert on alligators, and was a past recipient of the Louisiana Governor's Award - Conservationist of the Year and the Governor's Award for the Louisiana Conservation Educator of the Year. Robert is survived by his wife of 59 years, Merle Tabary, sons, David and wife Michele, James and wife Leigh, Thomas and wife Ruth, and daughter Brenda and husband Richard, 10 grandchildren, 4 great grandchildren, sister, Suzanne and sister-in-law Claire, and numerous nieces and nephews.

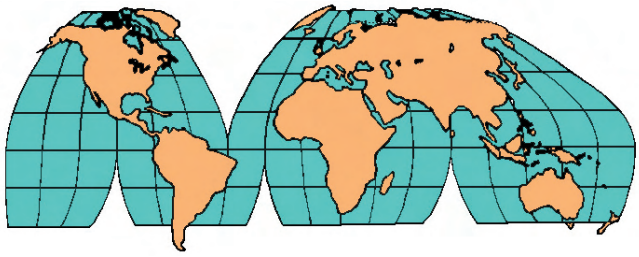
CSG Student Research Assistance Scheme Update

The CSG Student Research Assistance Scheme (SRAS; http://www.iucncsg.org/pages/General-Information.html) provided funding to one student in the October-December 2013 quarter (see below). A total of 11 SRAS projects were supported in 2013.

1. Adrian Gurra (Australia): Saltwater crocodile nest temperatures at Melacca Swamp, Northern Territory of Australia, and the implications of climate change.

Tom Dacey, *CSG Executive Officer, <csg@wmi.com.au>*.

Regional Reports



South Asia and Iran

India

Udayan Rao Pawar (14 y) has won Young Wildlife Photographer of the Year 2013, for his photograph of hatchling Gharials (*Gavialis gangeticus*) riding on an adult's head. Pawar camped near a Gharial colony on the banks of the Chambal River, in Madhya Pradesh, and got up before dawn to get a fabulous image. His photos, as well as the other winning photos, will be on display at the Wildlife Photographer of the Year exhibition at London's Natural History Museum, from 18 October 2013 until 23 March 2014.

Source: *Rowan Hooper, Ghost elephants win Wildlife Photographer of the Year prize; New Scientist, 15 October 2013; http://www.newscientist.com/article/dn24407#.Ul9m2yRU2X1.*

EFFECT OF WEATHER ON HATCHING SUCCESS OF GHARIAL IN CHITWAN NATIONAL PARK. In Nepal the Gharial (*Gavialis gangeticus*) is a protected under the National Parks and Wildlife Conservation Act of 1973, and is facing a variety of anthropogenic-related threats, including low prey (fish) abundance due of overfishing and gill netting, river pollution, sand mining, stone quarrying and river dams which do not allow upstream movement (Maskey 1989; Ballouard and Cadi 2005; Thapalia *et al*. 2008). With an estimated wild Gharial population of around 57 in 1980 (CNP 1998), the Gharial Conservation Breeding Center (GCBC) was established at Kasara, in Chitwan National Park (CNP), in 1978. The aim was to collect wild eggs, incubate them under semi-natural conditions, rear the hatchlings to >1.5 m total length, and release them back into the wild in order to reinforce and maintain a viable wild population. Presently, GCBC houses 660 Gharials (302 hatchlings, 325 juveniles, 18 sub-adults, 15 adults). Since 1981, a total of 891 Gharials have been released into different river systems in Nepal, but a survey in 2013 revealed 124 Gharials in the Rapti, Narayani, Babai and Karnali Rivers (DNPWC and WWF Nepal 2013; Khadka 2011-2013).

Gharial courtship begins during winter (December-January), copulation occurs in February, nesting occurs in the last week of March and the first week of April (dry season; Khadka 2011), and hatching occurs in the second and third weeks of June. The rainy season typically begins in early June and continues to the end of September. Here we present data on the effects of heavy rainfall and drought conditions during the egg incubation period (April-June) in 2011-2013, on wild (*in situ* and relocated to natural and artificial sand banks) and captive-laid Gharial eggs.

Experienced nest watchers were hired from local fishing communities to follow wild breeding Gharials and record location of nesting sites and laying dates. Egg-laying occurred at night, and eggs were located the following morning based on fresh tracks on the nesting banks. Once nests were located, nest watchers informed GCBC, which sent two staff to each of the nest site. Detailed information was recorded on a standard datasheet (Nest ID, lay date, clutch size, egg viability, weight, distance from river, sand bank height, sand type, depth of nest, nest circumference, presence of human disturbances, etc.).

After all the measurements were taken, nests from the Narayani River were transferred in plastic pots by boat to the Gharial Monitoring Centre (GMC) at Amaltari. Similarly, nests from the Rapti River were transported to GCBC. Nests from each area were re-buried in a natural sand bank near GMC (Narayani River) or re-buried in an artificial sand bank at GCBC. Badly cracked eggs were not incubated eggs, and in the case of dented eggs plastic tape was placed on dents to prevent fluid leaking from eggs. At GMC, near the time of hatching, keepers would hit the sand and listen for hatchling calls from within the nests and open the nest and remove hatchlings and relocate them to the GCBC nursery.

In 2013, 5 wild nests were left *in situ* (one each at Dumaria and Dudhaura, Rapti River; one each at Batkholi, Velauji and Bhagadi, Narayani River), rather than being relocated elsewhere. The eggs of four nests were processed, before being buried in the same nest cavity. One nest could not be checked because of the presence of the guarding female, and the disappearance of tracks prevented it being located again later. An additional nest (Dumaria, Rapti River) was found to have all eggs cracked/crushed due to fighting between females over nest sites - it was excluded from all analyses.

Nests laid in captivity at GCBC were left *in situ* until hatching, at which time remaining eggs and hatchlings were examined.

For most nests it was difficult to distinguish infertile eggs from fertile eggs that had died early in incubation. All eggs in four wild nests (3 in 2011, 129 eggs; 1 in 2012, 37 eggs) had no opaque banding, and were considered to have been completely infertile - these nests were not included in analyses (see Table 1). Thus, hatching success, calculated as the proportion of total eggs that produced live hatchlings, was the only index that could be used to compare incubation treatments (Table 1).

Captive eggs, incubated *in situ*: There are no historical data on hatching success for captive eggs at GCBC, so it is not possible to compare the 2011-2013 years with previous years. The lowest success (4.7%) was recorded in 2013, but it was relatively low for both 2011 and 2012 (Table 1). Mean incubation period was longer during the "wet" years.

Wild eggs, left *in situ*: Of the 5 wild nests left *in situ*, 4 nests were completely washed away by floodwaters caused by heavy rainfall near the time of hatching. One hatchling was produced from one nest (Table 1), and the remaining eggs in that nest contained hatchlings that had pipped but which were all dead. The incubation period of 95 days is considered to have been the result of rainfall cooling the nest environment and/or restricting oxygen exchange through the eggshell membrane to the embryo.

Wild eggs, relocated to natural sand bank at GMC: Hatching success was low in all years, with the lowest during the "dry" year of 2012 (Table 1).

Wild eggs, relocated to GCBC: Hatching success was better than other treatments in 2011 and 2012, and was similar for wild eggs related to natural habitat in 2013 (Table 1).

The impact of flooding on wild nests in 2013 may be related to rainfall in that particular area, or the impact of the rain was more severe due to the physical attributes of the nesting banks. But clearly the relocation of eggs in that year probably resulted in a higher number of hatchlings, albeit relocated nests were also impacted by the prevailing weather conditions.

As the wet season typically begins around the time of hatching for Gharial eggs in Nepal, nests can experience periods of rainfall in the final stages of incubation. In our experience, light rain is not considered detrimental to hatching success, and indeed may be essential to preventing dessication and/or overheating of eggs where dry conditions prevail at the beginning of the wet season. However, high rainfall at this time can reduce hatching success considerably, as evidenced by the almost complete loss of all wild nests left *in situ* in 2013 (<1% hatch success; Table 1).

Dry or very wet conditions during the latter stages of incubation tend to result in a higher proportion of smaller, thinner hatchlings with abundant yolk ("balloon shape"), which mostly die within 6 weeks of hatching. Webb *et al*. (1987) reported on the effect of incubation temperature on the amount of yolk in hatchling *C. porosus*, and so our observations are consistent with "hotter" nest temperatures during drought conditions. Dehydration of eggs may also affect the ability of hatchlings to get out of the egg (Manolis and Webb 1991). Flooding late in incubation is likely to result in reduced oxygen exchange through the eggshell, and in such cases embryos may enclose the yolk sooner than they would normally, and essentially hatch prematurely (C. Manolis, pers. comm.). Again, our observations are consistent with complete or partial flooding reducing hatching success and resulting in sub-optimal hatchlings. However, there may be other effects of flooding and overheating on the fitness of hatchlings that could impact on post-hatching growth and survivorship (Webb and Cooper-Preston 1989; Joanen and McNease 1987).

Gharials are already facing a variety of anthropogenic-related threats, and natural weather events during the nesting period can drastically reduce hatching success. The observed weather patterns in 2011-2013 appear to be recent changes, and it is unclear whether they will remain in the long-term. If so, the relocation of eggs is a management practice that should continue, but with more careful attention to characteristics of the sites to which eggs are relocated and re-buried is warranted. That is, sites with a lower probability of flooding, or perhaps where protective structures can be erected, may need to be selected. However, the impact of these weather patterns on incubation and hatching success of captive-laid eggs suggests that consideration also needs to be given to the development and construction of an incubator at GCBC to obtain high hatching rates and contribute to higher hatchling fitness.

Table 1. Hatching success (HS) of Gharial eggs subjected to four "incubation" regimes during periods of excessive rain in April-June (2011, 2013) and drought conditions in April-June (2012). Captive= laid in captivity, left *in situ*; Wild-RW= wild eggs, relocated to natural sand bank near GMC; Wild-RC= wild eggs relocated to artificial sand bank at GCBC; Wild= wild eggs, reburied on nesting bank; * = Mean clutch size based on 4 nests.

Year	Treatment	Nests	Eggs	Mean Clutch Size	Infertile and Early Death	Late/Full Term Dead	Mean Inc'n Period (d)	Normal Hatchlings	Abnormal Hatchlings	HS (%)
2011	Captive	10	328	32.8	169	18	86.1	135	6	43.0
2012	Captive	9	337	36.3	172	38	78.7	127	0	37.7
2013	Captive	5	193	38.6	163	21	91.0	0	9	4.7
2011	Wild-RW	3	99	33.0	40	7	82.7	52	0	52.5
2012	Wild-RW	5	158	31.6	51	76	73.6	31	0	19.6
2013	Wild-RW	3	64	21.3	28	8	85.0	28	0	43.8
2011	Wild-RC	3	78	26.0	12	3	80.7	63	0	80.8
2012	Wild-RC	5	156	31.2	40	12	78.2	99	5	66.7
2013	Wild-RC	3	77	25.7	7	34	88.0	36	0	46.8
2013	Wild	5	>120	25.8*	?	?	95	1	0	<1.0

Acknowledgements

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Europe

Czech Republic

MORE GHARIALS FOR EUROPEAN COLLECTIONS. Dvur Kralove Zoo (Czech Republic) imported 5 adult female Gharials (*Gavialis gangeticus*) from Hyderabat Zoo (India) at the end of September 2013. The importation was carried out on the basis of more than two-year-old agreement between these zoos. However, by the time the transfer, Dvur Kralove Zoo was more focused on African fauna, so the Gharials were placed at other zoos.

Two females were moved to Crocodile Zoo Protivin (Czech Republic), the only European zoo with an adult male Gharial, and three females were transferred to Berlin Zoo (Germany). Berlin Zoo made large display area at its Aquaria building available to them. We assume that they will be able to acquire a young male Gharial from other European collections in the future.

Pavel Moucha, *ZOO Dvur Kralove a.s., Stefanikova 1029, 544 01 Dvur Kralove, Czech Republic.*

PROTIVIN CROCODILE ZOO. Protivin Crocodile Zoo (PCZ) holds Europe's largest crocodilian collection. The successful breeding of three critically endangered crocodilian species in one year highlights the zoos efforts with *ex-situ* conservation breeding. In addition, PCZ continues to support *in-situ* conservation of *Tomistoma schlegelii* and *Crocodylus siamensis* by Rob Stuebing, Agata Staniewicz, Natascha Behler and others in East Kalimantan.

PCZ succeeded in breeding *C. rhombifer*, but did not incubate this years clutch as Director Miroslav Prochazka did not want to provide them to the private sector. It is the zoos policy to transfer its captive-bred offspring to the managed conservation-breeding programs established by the EAZA or to other accredited zoos overseas which are involved in

Cuban Crocodile conservation and management projects. The 2013 clutch was provided to Czech scientists for research purposes.

For the second time, PCZ was successful in breeding *C. siamensis*, with 9 Siamese Crocodiles hatchings (unsexed) in July 2013. We sre still hoping for a captive management program to be established by the EAZA for this critically endangered species.

Just a few days after Cologne Zoo breeding success with *C. mindorensis* in Europe, PCZ was proud to announce 8 Philippine crocodile hatchings being produced in Protivin. The parents were obtained by Avilon Zoo based on a breeding loan agreement between DENR-PAWB, Avilon Zoo and PCZ as part of the Philippine Crocodile Conservation Program. To include *C. mindorensis* in the EAZA studbook, which is kept by Dr. Thomas Ziegler at Cologne Zoo, PCZ provided blood samples of its adults for genetic testing at Braunschweig University. Preliminary testing has by the University of South Bohemia suggested that they were pure. PCZ is still waiting for the test results from Braunschweig University to continue with its breeding project. A detailed paper on the successful breeding of Philippine Crocodiles at PCZ is in preparation.

In October, PCZ received 3 adult female *Gavialis gangeticus*, which had been imported by Dvur Kralove Zoo from Hyderabad Zoo, India , to become part of one conservation breeding project as PCZ has the only adult male Gharial in Europe. An albino female American Alligator (*Alligator mississipiensis*) arrived from St. Augustine Alligator Farm and Zoo and will join PCZ's adult male.

All in all, 2013 has been a memorable year for PCZ. For the future, the zoo will strengthen its efforts with managed *ex-situ* conservation programs and *in-situ* conservation projects for critically endangered crocodilians. We are grateful for the support provided by several CSG colleagues and friends to our successes.

Miroslav Prochazka, *Director, Protivin Crocodile Zoo, Czech Republic, <porosus@atlas.cz>*.

Denmark

23 CROCODILIAN SPECIES FOR DANISH CROCODILE ZOO. With the arrival of 6 female Orinoco crocodiles (*Crocodylus intermedius*) in August 2013, the Danish Crocodile Zoo (DCZ) joins Florida's St. Augustine Alligator Farm in displaying 23 species of crocodilian.

The Orinoco crocodiles came after arrangements with Dallas World Aquarium (DWA), where the crocodiles were bred 6-7 years ago. The DCZ had supported DWA's conservation program, and will continue to do so into the future. The crocodiles are already the basis of the DCZ's new education programs for visitors to the zoo. To our knowledge, these are the only Orinoco crocodiles in European collections, and the first ones imported into Europe.

In 2014, the DCZ will receive 3 unrelated male Orinoco crocodiles from Venezuela. Together, these crocodiles will form the core of a future European breeding group for the species, along the same lines as the DCZ did for the Philippine crocodile (*C. mindorensis*). Several of the Orinoco crocodiles will be placed in other European zoos in exchange for which an annual amount will be donated to Venezuelan conservation projects for the species.

Crocodylus intermedius is a species that, for a specialist zoo such as DCZ, offers visitors the sight of a crocodile rarely seen in European collections, and also provides an opportunity to draw attention to its Critically Endangered status - and by extension, to crocodilian conservation in general. The DCZ has a long association with Orinoco crocodile conservation in Venezuela, so acquisition of the species was an exciting step forward.

The DCZ opened to the public in 2000, with the aim of not only acquiring the 23 currently recognised crocodilian species, but also with the desire to support crocodilian conservation and target certain species where it was felt that DCZ support would be especially useful.

This year (2013) marked a few significant results for the DCZ. Not only does it now have 23 crocodilian species, but it succeeded in breeding the Black caiman (*Melanosuchus niger*) for the first time outside of South America. We hold one of the largest captive groups of Black caiman in the world, obtained from a ranch in Ecuador. The 3 males and 8 females are now attaining maturity, and two clutches of eggs (26 and 32 eggs respectively) were produced from two

separate pairs. Only one clutch hatched successfully, with 23 hatchlings produced from 26 eggs (see photograph below).

The DCZ's success with Chinese alligators (*Alligator sinensis*) continues - it was was the first zoo to breed them in Europe. In 2010 a single alligator was produced, and 20 were hatched in 2013 (see photograph below).

When we arranged for the importation of *C. mindorensis* into Europe, it was to establish a breeding program for this Critically Endangered species within European zoos. Since then, Cologne Zoo has successfully bred from the pair sent to them. The DCZ pair has produced eggs, but no hatchlings yet. This latter pair is the youngest of the crocodiles imported, so we are hopeful that within the next few years viable eggs will be produced. Significant funds from this program have already been sent to the Mabuwaya Foundation for Philippine crocodile conservation. We hope our project for Orinoco crocodiles will be just as successful.

With 23 crocodilian species, and renewed breeding successes, the DCZ is looking forward to new developments in the next few years. We invite all CSG members to come and visit us if you are travelling near Denmark.

Rene Hedegaard, *Danish Crocodile Zoo, <croczoo@mail.dk>*.

Latin America and the Caribbean

Venezuela

NEW PAIR IS INTRODUCED TO THE CAPTIVE BREEDING, INTRODUCTION AND REINTRODUCTION PROGRAM OF THE ORINOCO CROCODILE IN VENEZUELA AT MASAGUARAL CATTLE RANCH. "Omar" and "Carolina" are Orinoco crocodiles (*Crocodylus intermedius*) that were kept at a cotton factory (Algodonera Orinoco C.A.) located in Cabrutas, a small town located at Guarico State, by the majestic Orinoco River. The crocodiles were kept at these facilities since they were very little, apparently coming from different places or taken at different years (although precise information on origin is lacking).

The crocodiles were incorporated into the Captive Breeding Introduction Reintrodution Program for the species, and the importance of these two animals lies in avoiding problems of incompatibility of proposed breeding pairs. Both specimens were in good conditions, without any lacerations, and were 2.58 m and 3.32 m total length, for the female and male respectively.

They were captured and transported to Masaguaral Cattle Ranch, located between Calabozo City and Corozopando town in Guarico State. The whole operation started early on 10 July 2013, and was completed by midnight the same day. The crocodiles were released into their new captive enclosures the next morning, and at the time of writing of this report, they had begun eating, and we are hoping that they will produce offspring next year.

I would like to acknowledge Mr. Dani Marazzato for his assistance on the vehicle used to transport the crocodiles, Mr. Frank Vera who was responsible for transportation, Mr. Ruben Velazquez of the Algodonera Orinoco C.A and his personnel who collaborated with the capture and shipment, the personnel of Masaguaral Cattle Ranch, particularly Mr. Jose Gregorio Acosta, Omar Hernandez, representative of the Foundation for the Development of Sciences Physics, Mathematics and Naturals (FUDECI) and Alvaro Velasco, Chairman of the Crocodile Specialist Group of Venezuela (GECV).

Roldan De Sola R., *Ministry of the Popular Power to the Environment, <rdesola@gmail.com>*.

FIRST SYMPOSIUM ON ECOLOGY AND CONSERVATION OF CROCODILES IN VENEZUELA. The First Symposium on Ecology and Conservation of Crocodiles in Venezuela was held on 19 November 2013, in Merida City. Organized by the Crocodile Specialist Group of Venezuela (GECV), within the X Venezuelan Congress of Ecology, it was attended by more of 50 biologist, researchers, professors and students.

The agenda included 12 presentations on diverse items of crocodilian conservation, such as: abundance, population status and nesting of *Paleosuchus trigonatus* in the Ka'kada River, Bolivar State; artificial incubation of *Crocodylus acutus* by a Bari indigenous community in Zulia State; cultural perception about crocodilians in Venezuela and its implications for conservation; common habitat use by *C. intermedius* and *Caiman crocodilus* and nesting biology of *C. intermedius* at Capanaparo River, Santos Luzardo National Park, Apure State; aspects that affect growth of C. intermedius in Masaguaral Rearing Facility, Guárico State; synchronization of *C. intermedius* nesting dates in relation to lunar phase; evaluation of commercial fish food complement for captive *C. intermedius*; analysis of open and closed cycle rearing facilities for *C. intermedius* and its implications on growth an body condition index; and, the historical balance of *C. intermedius* reintroduction program over 25 years of captive rearing effort and the current status of crocodilian conservation in Venezuela.

The symposium ended with two round tables and open discussions among the participants. The first dealt with the evaluation of the GECV database, which contains all the information on the *C. intermedius* reintroduction program, and the second assessed the historical balance and future perspectives of crocodilian conservation in Venezuela. In the first case the recommendation was to review the database to identify transcription errors, duplicated data and the best way to present the information for public access. The second discussion dealt with the *C. intermedius* conservation program and the status of existing rearing facilities. The main problems identified were the lack of effective protection of wild crocodilian populations in their habitats and the diminishing economic funding and support for activities related to research and captive rearing of endangered crocodilians.

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Brazil

AMAZONIAN ENCOUNTERS WITH FOUR CROCODILIAN SPECIES IN ONE SINGLE NIGHT! In all tropical and subtropical habitats worldwide where crocodilian species occur it is common to find examples of two species living in sympatry: *Gavialis gangeticus* and *Crocodylus palustris* (Rao and Choudhury 1992), *C. porosus* and *C. johnstoni* (Webb *et al.* 1983), *C. niloticus* and *Mecistops cataphractus* (Ross 1998; Eaton 2010; Shirley 2010), *M. cataphractus* and *Osteolaemus tetraspis* (Eaton 2010; Shirley 2010), *Alligator mississippiensis* and *C. acutus* (Ross 1998), *C. acutus* and *C. rhombifer* (Milián-García *et al.* 2011), *C. acutus* and *Caiman crocodilus* (Seijas 1996), *C. intermedius* and *C. crocodilus* (Espinosa-Blanco and Seijas 2010), *C. latirostris* and *C. crocodilus yacare* (Godshalk 2006; Piña *et al.* 2010), *C. latirostris* and *Paleosuchus palpebrosus* (Fábio Maffei, pers. comm. 2013). Occurrence of two crocodilian species in sympatry is a relative common phenomenon. Ross (2001) stated "Most crocodile habitats support only a single species, or, occasionally, a sympatric pair of species, but I know of no wild location where one could sit and expect to see three species in a day".

The Amazon Basin comprises around 7 million km^2, approximately 30% of which is composed by habitats annually flooded by white, black or clear water rivers (Junk *et al.* 2011). If we also consider the extensive networks of small forest streams throughout the rainforest, such a diversity and extension of aquatic environments provide some clues to figure why the Amazon represents a clear exception to Ross' statement. The complex characteristics of the Amazon watershed have led to the evolution of a mega biodiversity, including potential prey for crocodilians and supports great biomass production.

This complex biome is the only one known to support four crocodilian species in sympatry: *C. crocodilus*, *Melanosuchus niger, P. palpebrosus* and *P. trigonatus* (Medem 1983; Magnusson 1985), and represents the highest crocodilian diversity in the world, with 17% of all extant forms (Ross and Magnusson 1989). Although sympatric over large areas, Amazonian caimans are rarely syntopic (Magnusson 1989), showing spatial segregation and differences in habitat or resource use (Aguilera 2008; Magnusson 1985; Herron 1994; Da Silveira *et al.* 1997; Marioni *et al.* 2008; Villamarín *et al.* 2011).

The floodplains of central Amazonia hold the largest populations of *M. niger* and *C. crocodilus* (Da Silveira 2002), which inhabit large rivers, oxbow lakes, creeks and canals (Thorbjarnarson 2010; Velasco and Ayarzagüena 2010). *Paleosuchus palpebrosus* occurs in several aquatic habitats, varying from flooded forests near major water rivers and lakes to roadside borrow pits (Magnusson 1985; Botero-Arias 2007; Magnusson and Campos 2010a). *Paleosuchus trigonatus* is more restricted to small shaded forest streams, called igarapé in Brazil, occurring in non-flooded forests (Magnusson 1985; Magnusson and Campos 2010b). This species is also common in the highly impacted urban hydrological system of Manaus,

the capital of Amazonas State (Villamarín *et al*. 2010).

Multiple-species studies on caiman have been undertaken in some Brazilian localities. Furthermore, in the southwestern region of the Amazon Basin, *C.c. yacare* was reported to occur in sympatry with the other Amazonian species (Brazaitis *et al*. 1998; Godshalk 2006; Vasconcellos *et al*. 2006; Aguilera *et al*. 2008; Hrbek *et al*. 2008). Three caiman species sharing the same habitat have been reported in some localities of Central Amazonia (Magnusson 1985; Da Silveira *et al*. 1997; Rebelo and Lugli 2001; Da Silveira 2003; Da Silveira *et al*. 2008). However, to our knowledge, there are no studies focusing on the ecology of four crocodilian species in the same locations at the same time.

This unusual research is now being carried out during the monitoring activities of the Caiman Conservation Program in the Piagaçu-Purus Sustainable Development Reserve (PP-SDR), located in the lower Purus River, about 350 km southwest of Manaus. This protected area of 834,245 ha (Deus *et al*. 2003) comprises both terra firme (uplands, covered by non-flooded Amazonian rainforest) and várzea habitats, which are forests seasonally flooded by sediment-rich rivers of Andean origin (Prance 1979; Junk *et al*. 2011).

In the surrounding northeastern portion of the Reserve occur a variety of black-water lakes, perpendicularly oriented to the Purus River, which originate from streams with their headwaters inside terra firme forests. These lakes discharge water into the Purus River and during high water season there can be mixing of black and white waters typical of this region. These lakes represent a transition between terra firme streams and várzea floodplains. This hydrological connectivity facilitates the co-existence of species from each type of environment, including caimans and their prey.

The main objective of our research is to identify the occurrence of the four caiman species occupying the same water bodies, their spatial distribution in the hydrological system and their relative abundance. We also focus on the development of protocols to better understand inter-specific interactions and relations among species and their habitats.

Between March and August 2013 (high water season), we visit three distinct hydrological systems located just outside of the borders of the PP-SDR and thus, not legally protected. During daylight hours we opened 15 aquatic transects (5 to 15 km long), entering the upstream flooded forest along the canals of 13 different igarapé. Two other transects were in várzea environment (Fig. 1). During spotlight surveys carried out along igarapé shores, most of the caimans observed (80.0%) were identified to the species level, had their size estimated and were geo-referenced with a GPS. Individuals were captured, measured, weighed, sexed, marked and immediately released at the same capture location.

We carried out 39 night-surveys in 15 localities, totalliing 238 km. We observed 624 caimans, of which 499 being identified (5.5% *M. niger*, 60% *C. crocodilus*, 20% *P. palpebrosus* and 14.5% *P. trigonatus*). Observed densities varied between 0.3 and 15.5 ind/km (mean= 3.5, SD= 3.4). We observed three species in 20 transects and at least two in other 13. On six occasions it was possible to capture the four species along one transect in the same night (Fig. 2). We only found 30 hatchlings (SVL<20 cm): 11 of *C. crocodilus* and 19 *P. palpebrosus*. We captured 156 caimans, 8 *M. niger* (100% males), 39 *C. crocodilus* (61.5% males), 74 *P. palpebrosus* (68.9% males) and 34 *P. trigonatus* (94.1% males).

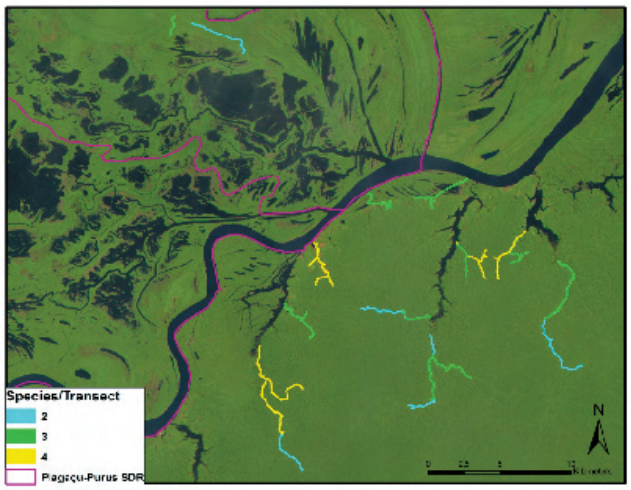

Figure 1. Location of aquatic survey transects (March-August 2013). Coloured rivers represent the number of species registered in each transect. Purple line represents the limits of Piagaçu-Purus Reserve.

Figure 2. The four Amazonian caiman species, from top to bottom: Spectacled caiman (*Caiman crocodilus*), Schneider's Smooth-fronted caiman (*Paleosuchus trigonatus*), Black caiman (*Melanosuchus niger*) and Dwarf caiman (*Paleosuchus palpebrosus*). Only the *P. palpebrosus* shown is an adult (110 cm total length).

As a humble tribute we titled the night when all four species were encountered and captured as "JT Night", in honor of our mentor and friend John Thorbjarnarson, who would had been enthusiastic about undertaking such surveys. Information gathered during this initial phase of the project is still being processed. Further research undertaken in this region is specifically aimed at locating nesting areas and shedding light on the ecological relations of the reproductive biology in these multi-species environments. A better understanding of inter-specific interactions of space-occupancy patterns and trophic relations along environmental gradients like the ecotone between terra firme and várzea forests represents a huge challenge for crocodilian ecological studies.

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Mexico

COURSE ON CROCODILE MANAGEMENT IN NAYARIT, MEXICO. The 1st Course on Theory and Practical Aspects of Crocodile Management was successfully undertaken in San Blas, Nayarit, Mexico, from 18-21 September 2013.

The first part of the course focused on theoretical aspects of biology and handling, and was covered at the National School of Fisheries Engineering and UMA Cocodrilario Kiekari. It was attended by 48 students from the National School of Fisheries Engineering of the Autonomous University of Nayarit, Coast University Center of the University of Guadalajara.

The second part of the course covered practical aspects of handling and monitoring of crocodile populations. Thirty participants from NSFE (10), and from the Mexican states of Sonora, Sinaloa, Zacatecas, Nayarit, Jalisco, Chiapas, Mexico and Mexico City, and other countries (Bolivia, Colombia) participated in this part of the course.

The course was delivered by crocodilian specialists Dr. Helios Hernandez Hurtado, Biól. Jerónimo Domínguez Laso, Dr. Pablo Hernandez Hurtado Simitis, DVM José de Jesús Romero Villaruel, DVM José Miguel Centeno Román, Tech. José Guadalupe Ruiz Vidal, Tech. Macedo Daniel Robles Rosales and Eng. Salvador Rosales Jiménez.

Estuaries and lagoons of the San Blas region were visited to cover practical aspects of monitoring of wild crocodiles. The American crocodile (*Crocodylus acutus*) occurs in the area, and spotlight counts of 59 and 16 crocodiles were recorded at La Mataiza, San Cristóbal (9 km; 17 x 27-60 cm, 9 x 61-120 cm, 12 x 121-180 cm, 9 x 181-240 cm, 12 x >240 cm), and Las Garcitas Lagoon (1.35 km; 11 x 27-60 cm, 1 x 121-180 cm, 2 x 181-240 cm, 2 x >240 cm), respectively.

On the basis of this single monitoring exercise one can infer that there is relatively low recruitment of hatchlings and juveniles. We also captured 12 adult individuals, which appeared in good health and acceptable body condition - morphometric data were recorded before they were released at their capture site. There have been reports of crocodiles being taken in the area, and as well as nests and hatchlings, and it is clear that further research and conservation actions are required on the crocodile population in the San Blas region.

Practical training on safe handling and measurement of adult crocodiles was undertaken at UMA Kiekari, and involved 13 of 19 large (2.70-3.78 cm total length; 90-294 kg bodyweight) resident crocodiles. The measurements recorded, including bodyweight, will be used to monitor and evaluate growth (and health) of crocodiles at UMA Kiekari.

The course/workshop was registered at the Ministry of Teaching at the Autonomous University of Nayarit, and participants received a diploma with curricular value of 40 hours.

Figure 1. Some of the instructors and participants of the course.

Figure 2. Capture of a 2.9 m adult female *C. acutus* by 3 female participants.

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NEW RECORD OF A NON-FATAL ATTACK BY AN AMERICAN CROCODILE AND GEOGRAPHIC ANALYSIS OF HISTORICAL ATTACKS IN OAXACA STATE, MEXICO. Human-crocodile conflict (HCC) has increased in recent years in Oaxaca State, however, some

of the events have not been documented in detail and only reported at a local level (García-Grajales 2013). Thus, the causes of the attacks are unknown and a partial view of the event is generated. While in part the causes of HCC relate to weather (excessive rains) causing displacement of individuals to new habitats and subsequent encounters with humans (Anonymous 1999; García-Grajales *et al*. 2013), other avenues of attack probably result from a combination of factors, including increasing human and crocodile populations, human encroachment into/near crocodile habitats, deliberate feeding of crocodiles in areas populated by humans (Garel *et al*. 2005), and overconfidence of people living in or near the habitats of crocodiles (García-Grajales 2013).

Moreover, the events that have occurred to date have been treated in isolation geographically. Historical knowledge about the geographic locations of crocodile attacks in Oaxaca State can help us understand whether there is a related effect with human pressure on the crocodiles, or, whether increasing densities of crocodilians resulting in movement of individuals to other sites has increased the likelihood of attacks. Here, we report on a non-fatal attack by an American crocodile (*Crocodylus acutus*) in Oaxaca State and we complement it with a geographical analysis of historical attacks. The hypothesis is that human proximity and knowledge about the presence of crocodile populations are negative factors in HCC and the probability of conflict decreases in human settlements away from waterbodies.

On 13 November 2013, at around 1930 h, a non-fatal attack by *C. acutus* occurred in the town of Chacahuita, in the Municipality of Santa Maria Tonameca. The incident took place on the banks of the Tonameca River, approximately 20 m from a residence in the same village. Mr. Jesús Marcial Arbea was walking back to his farm on a sidewalk near the shore of a body of water when he stumbled upon a crocodile of about 2.20 m length. The crocodile bite covered his right leg and part of his right hand. Mr. Arbea was immediately taken to the Regional Hospital of San Pedro Pochutla, where he underwent surgery.

The first author (JGG) was notified of the incident the next day via Facebook, and immediately coordinated with staff of the Centro de Investigación de Vida Silvestre (CIVS Chacahua) de la Dirección General de Vida Silvestre, thereby activating the S.O.S. Crocodile Program to immediate move to the scene. Due to site conditions, it was not possible to attempt capture of the crocodile immediately, but staff of the Cooperative La Ventanilla did catch a crocodile two days after the attack, and moved it to CIVS Chacahua. The animal was of similar size as described by Mr. Arbea.

This attack occurred 47 days after a fatal attack in the region of National Pinotepa (see García-Grajales *et al*. 2013).

Attacks by crocodilians on humans can be the result of nest defense by females, territorial defence, feeding or self-defense (Pooley et al. 1989). However, based on the events narrated by Mr. Arbea, we conclude that the attack was more in line with the crocodile reacting instinctively to the presence of "something" at the water's edge at night, and would classify

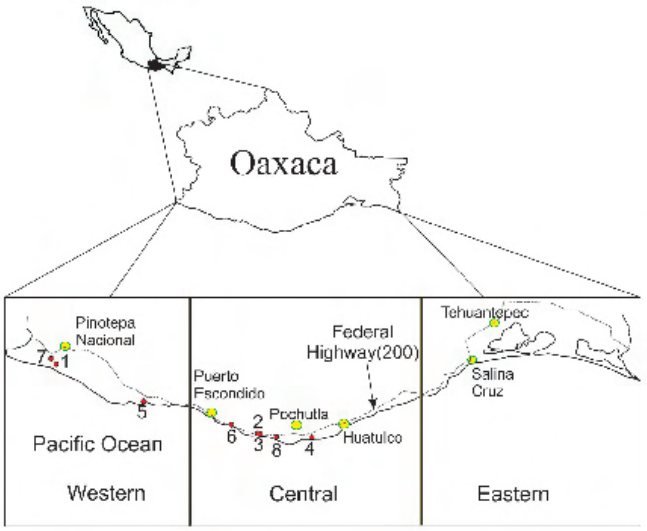

Figure 1. Locations of historical crocodile attacks in Oaxaca State. A= western region, B= central region.

Table 1. Records of American crocodile (*Crocodylus acutus*) attacks in Oaxaca State, Mexico. F= Fatal, NF= Non-fatal, Live.= livestock, PNLC= Parque Nacional Lagunas de Chacahua.

	Region	Year	Site	F/NF?	Details	Reference
1.	western	Oct 2004	Corralero, Pinotepa Nacional	NF	Male (25 y); loss of right arm	Local news
2.	central	Apr 2008	Vainilla, Santa María Tonameca	F	Male (47 y)	García-Grajales *et al*. (2008)
3.	central	Jun 2008	Vainilla, Santa María Tonameca	Live.	-	Local news
4.	central	Aug 2010	Zapotengo, Pochutla	F	Child (2 y)	Local news
5.	western	Nov 2011	Zapotalito, Chacahua	NF	Male (25 y); injuries/marks on head	Record blod on PNLC
6.	central	2011	El Tomatal, Santa María Colotepec	NF	Female (16 y); injuries to left foot	Local news
7.	western	Sep 2013	Arroyo Motillas, Pinotepa Nacional	F	Child (10 y)	García-Grajales *et al*. (2013)
8.	central	Nov 2013	Chacahuita, Santa María Tonameca	NF	Male (35 y)	This work

this event as a defensive bite (Dirección General de Vida Silvestre 2013). Moreover, there are warning signs near the attack site, and citizens are advised to take precautions.

Historical knowledge of the locations where crocodile attacks on humans have occurred over time is critical to the design of a strategy to reduce HCC. In this case, with the help of Google Earth (Google Inc.), we divided the coast of Oaxaca State into three regions: 1) eastern region, 2) central region and 3) western region. Later, we marked and listed the places where attacks/incidents have occurred and compiled the information (Table 1).

Significantly, the central region (Santiago-Puerto Escondido Astata) has the largest number (N= 5) of crocodile attacks in the state, while the eastern region (Santiago Astata Isthmus of Tehuantepec) has no records of attacks, however, it is also the region with no information on the status of the crocodile population in this area.

By the end of 2013, the DGVS developed the "Protocolo nacional de atención a conflictos con cocodrilianos en México". This document will help to understand the actions that must be taken to prevent and address crocodile attacks. In addition, its dissemination to the various federal, state and local government entities and civil society organizations, researchers and academics, will be critical to achieving coordinated actions dictated by the established protocol. A number of reviews of this national document were recently published by García-Grajales (2013) in order to improve the document in the future. Finally, a good way to achieve this disclosure will be by creating regional fora in which the various groups involved are linked, explaining step by step actions to take and the right people to be involved, and to create a directory with all involved in the region. We thank our institution (Universidad del Mar) for its support of actions on HCC.

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NEW RECORD OF FATAL AMERICAN CROCODILE ATTACK IN OAXACA STATE, MEXICO. Human-crocodile conflict (HCC) refers to the negative interactions between crocodilians and humans, in which latter (or pets and livestock) are threatened, attacked or injured. HCC generates mixed opinions within society, economic losses on livestock and fisheries production, and negative opinions towards the crocodilian species (Caldicott *et al*. 2005; Aust *et al*. 2009; Lamarque *et al*. 2009; Sidelau and Britton 2012).

HCC may be related to the rainy season, when water levels increase and different water bodies may become joined, and thus facilitating the movement of crocodiles that are confined to shallow pools during the dry season (Anonymous 1999). Weather events such as hurricanes on the Mexican Pacific coast are common. Coupled with this, the territorial behavior of crocodiles causes displacement of individuals to new habitats, and increasing the risk of HCC during travel, as happened recently in Tampico, Tamaulipas, Villahermosa, Tabasco and Chetumal en Quintana Roo.

In the case of Oaxaca State, most cases of HCC have been reported through local newspaper articles, which tend to be alarmist and exaggerated, and contributing every little to the knowledge of the problem. Attacks are probably the result of a combination of factors, including increased human and crocodile populations and residential development near crocodile habitats (Garel *et al*. 2005). In Mexico, there are few records of fatal American crocodile (*Crocodylus acutus*) attacks (Cupul-Magaña 2010). In 2008 there was a fatal attack on an adult human in the region of Vanilla, Municipalitiy of Santa María Tonameca (García-Grajales *et al*. 2008), and in 2010 a 2-year-old child was attacked and killed by a crocodile in the same region. Here, we report a new record of a fatal American crocodile attack in the Pinotepa Nacional region.

The attack occurred at around 1230 h on 27 September 2013 in Motillas Creek, in Pinotepa Nacional Municipality, approximately 18.6 km in a straight line from Pinotepa Nacional (Fig. 1). The incident took place in a sandy section with herbaceous vegetation. Motillas Creek has typically low flow, and an average depth of 1 m (Fig. 2). This area has a small hamlet called Rancho El Conejo, with 6 low-income dwellings whose main economic activity is cattle milking.

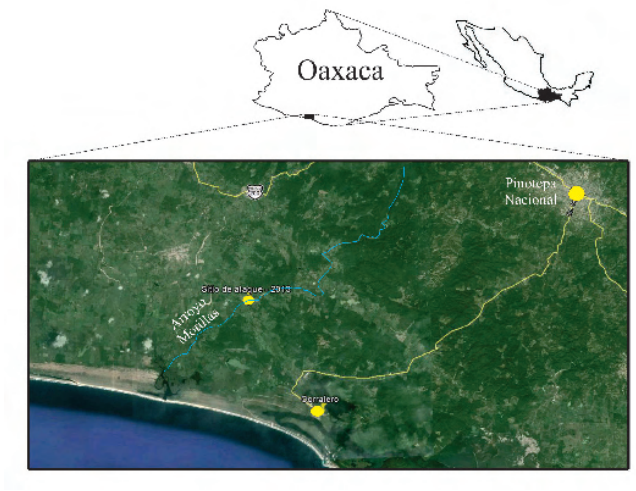

Figure 1. Location of fatal American crocodile attack.

Figure 2. Site of American crocodile attack, Motillas Creek.

Evaristo Leovigildo (10 y, 130 cm in height and approximately 40 kg in weight) was with his older brother (13 y), swimming and playing in the stream. Both children were alone, without any pets. The boys had jumped onto a boat moored approximately 1.5 m from the water's edge, when Evaristo was grabbed on the right side of his body (between thorax and abdomen) by the crocodile and pulled hard into the stream. The boy's mother was immediately alerted by the other boy, and they sought help from people in a nearby papaya cultivation. After 45 minutes, and several trips along the stream, the crocodile was sighted with the body in its mouth, resting on a bank, and Miguel Santiago managed to get a hold of the child' feet and retrieve the body.

The first author (JGG) was notified via Facebook about the case by Protección Civil personnel for the Municipality of Santiago Pinotepa Nacional. Staff of the University of the Sea, the Centro de Investigación de Vida Silvestre (CIVS Chacahua) of the Dirección General de Vida Silvestre, and the Parque Nacional Lagunas de Chacahua, coordinated subsequent activities. We recommended that the Department of Civil Protection find out the causes of the attack, and try to calm residents in the area.

The alert S.O.S. crocodile is a national strategy to respond to HCC situations. On 28 September 201 (1100 h), we arrived at the site and were notified that the villagers had shot at the crocodile the night before, and claimed to have hit it twice. We conducted an inspection during daylight hours on a section of the stream, but did not see anything. Due to intense heat (35°C), the decision was made to perform activities at dusk.

Using a flat-bottomed aluminum boat, nets and poles, we captured a crocodile, just a few metres from the attack site. The animal had wounds in the left eye and lower jaw caused by the gunshots. The crocodile measured 3.47 m in length and weighed about 280 kg (Fig. 3). As there were no other crocodiles in the area, we considered it to be responsible for the attack, and relocated it to CIVS Chacahua. We concluded that the crocodile considered the child to be prey, and was "feeding".

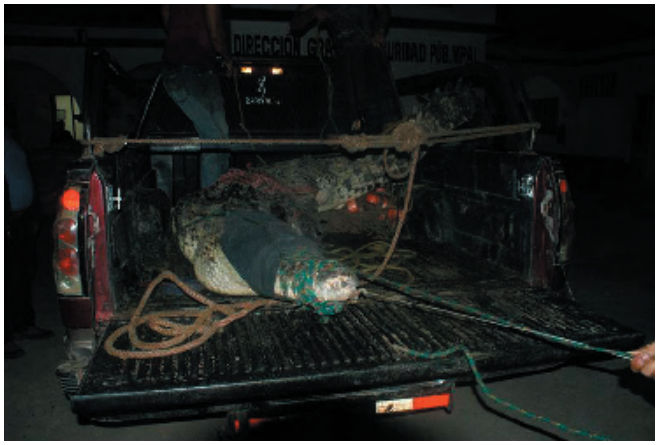

Figure 3. Crocodile suspected to have attacked the child.

Unfortunately these facts make us reflect on the lack of a National Protocol to help mitigate HCC in Mexico. Without a doubt, cooperation in coordination between different institutions in the coast of Oaxaca (Universidad del Mar, CIVS Chacahua, Comisión Nacional de Áreas Naturales Protegidas, Protección Civil) served to better address the situation, however, the need for a regional forum to disseminate and coordinate state actions forevents like this could serve as a model to mitigate HCC in Mexico.

We thank our institutions (Universidad del Mar, CIVS Chacahua, Comisión Nacional de Áreas Naturales Protegidas) for their support of or activities relating to HCC in Oaxaca.

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East and Southeast Asia

Singapore

SALTWATER CROCODILES REAPPEAR IN SINGAPORE. For a few years now there have been consistent sightings of Saltwater crocodile (*Crocodylus porosus*) in Singapore, a species considered to be extirpated there (Webb *et al*. 2010). Up to 10 crocodiles are reported to be present in Sungei Buloh Wetlands Reserve and in nearby Kranji Reservoir, and a number of good quality photographs that clearly identify the species have appeared in local media and online blogs. The crocodiles are sufficiently comfortable with the presence of people such that they have begun to attract a number of tourists and local visitors keen to catch a glimpse of them (The Annotated Budak 2011; The Straits Times 2013). Based on the various photographs and reports available the crocodiles appear to be within the 1.5 to 3 m size range.

It is unknown whether this population has become sufficiently established to be considered resident, or even whether future breeding in the area is a possibility, but it seems likely that these were originally itinerants that moved along the Straits of Johor on the north coast, an area where they reportedly began to appear several years ago. The source of these itinerants would seem to be nearby recovering populations, but little else is confirmed. There has also been some suggestion that development activities along the northern coastline may have forced some individuals to move into Sungei Buloh, and are reclaiming former habitat they were known to occupy over three decades earlier.

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Cambodia

GETTING RID OF THE CROCODILE PEST IN CAMBODIA. Two species of crocodile make Cambodia their home: the Siamese crocodile (*Crocodylus siamensis*) and the Saltwater crocodile (*C. porosus*). Today, the Siamese crocodile is critically endangered, and, while the Saltwater crocodile is considered as "least concern" globally, it has probably disappeared from Cambodian waters, or nearly so (Webb *et al*. 2010). One of the few remaining areas in Cambodia where Siamese crocodiles are known to live and breed is the Cardamom Mountains, although some rivers here are currently under threat by hydro-dam projects (Simpson and Bezuijen 2010). The disappearance of the crocodile from Cambodian waters has been a relatively fast process that started ~150 years ago, when Europeans arrived in the region and the French started to rule Indochina. The following accounts probably relate to the Siamese crocodile, because

areas mentioned are located many hundreds of kilometres inland.

Crocodiles appear in the bas-relief of Angkor Wat and the Bayon, carved in the 12th and 13th centuries. Fish and crocodiles were used to represent the rivers, but we can also see them eating men who fell from their boats during naval battles. Crocodiles are much more than large terrifying beasts for Cambodians. They play an important role in their rituals, myths and legends. They relate to the Chthonian divinities. The underworld is the realm of the nagas/neak and the crocodiles. Evelyne Porée-Maspéro (1962) did show that they are linked to the neak or water divinities, and also to Kron Pali, the "Master of Earth". This is why they are strongly associated with death rituals, as funerals require ground and earth. When someone dies, white banners in the shape of a crocodile, *ton kraboe*, are hung in front of the house of the deceased. In the plains of Cambodia, red *ton kraboe* are also used during the Khmer New Year, a time of festivities. Crocodile, *kraboe*, thus appears as a very ambiguous creature for the Khmer people: a threat or a protector, a wild beast or a divinity. In the oral literature, it is often associated with ingratitude [eg the tale of Neang Keo Pi Poa (=Lady Jewel of Two Colors)]. This ambivalent nature of the crocodile appears also in non-Khmer Cambodian cultures such as that of the Pear people in the Cardamom Mountains. Baradat (1941), a French veterinarian, explained that in the districts of Pralay and Chumneap, people worshiped the crocodile god. "They care not to disturb it. Rather than upsetting it, they make a detour while the oar hits the water smoothly and quietly. The meat of this animal is taboo." Such beliefs are still followed in these areas today (Daltry *et al*. 2003).

The first Western explorers who travelled to Cambodia noticed the large number of crocodiles in the rivers, the estuaries, and the Tonle Sap Great Lake. They seemed to be particularly abundant in the Sangke River that links Battambang town to the Great Lake, and in the Mekong River between Kratie and Stung Treng. All the early French explorers, from Henri Mouhot to Louis Delaporte or Auguste Pavie, saw crocodiles basking on the banks of the rivers and the shores of the Great Lake. In 1860, the Journal of the Royal Geographical Society published an account compiled from manuscripts of E.F.J. Forrest on Cambodia, in which it was remarked that "crocodile is very common and forms an article of trade with the Cochin Chinese" (Campbell *et al*. 1860) [Cochinchina was the then southern portion of today's Viet Nam, under the rule of the French]. Indeed, in the early years of the French protectorate, a French settler by the name of Paul Le Faucheur claimed to have brought two boats full of crocodiles to Cochinchina. Despite the fact that one of the boats sank during the journey, he still made a profit (Le Faucheur 1872). From the 1860s onward, after the conquest of Cochinchina and the establishment of the French protectorate over Cambodia, trade between Cambodia and Cochinchina was facilitated. The number of crocodiles exported for food consumption from Cambodia to Saigon (now Ho Chi Minh City) and Cholon seemed to have been on the rise even if no reliable data are available. According to Charles Dumas, who authored a book on the fauna of Cambodia in the 1940s, meat, liver and teeth were sold in Indochina, respectively as food, traditional medicine or lucky charms, and the skin was exported (Dumas 1944).

If some traders like Le Faucheur could see a business opportunity in the presence of a large population of crocodiles, most of the French administrators would consider them as a danger for the people. In fact, crocodile attacks on humans did occur. A series of administrative reports from the Stung Treng Province is kept in the National Archives in Phnom Penh, Cambodia (NAC), and the Archives Nationales d'Outre-Mer in Aix-en-Provence, France (ANOM) [Stung Treng was one of the most remote and most forested areas in Cambodia, and situated ~700 km upstream on the Mekong River]. These reports cover 80% of the period between 1905 and 1922 (NAC/rsc 14425+, ANOM/rsc 389+). During this 18-year period, six major incidents involving crocodiles were reported. In August 1906, a crocodile attacked two fishermen. In 1913, a crocodile killed a teenager. In December 1915, another crocodile mauled a Chinese man to death. Two women who were taking a bath in the river in the summer of 1916 and another one in December 1918 were also killed by crocodiles. This list is however incomplete. In 1916, the Administrator of Stung Treng wrote to the resident supérieur of Cambodia to complain about the rise of the death toll due to crocodiles. In his letter, he stated that 4 people died from crocodile attacks in 1914 in the province, 4 in 1915 and 9 in 1916. Even if these incidents were not very common, they could explain why crocodiles could be considered as a threat to humans. At the climax of the series of incidents, the administrator of Stung Treng emphasized that "the death of the victims is not the only thing to be deplored for the fear that seized neighbouring populations, a fear that quickly gave birth to legends, brought a real disruption to the ordinary life of the population." He informed his hierarchy that people did not dare to bathe in the river if not protected by a fence and that the fishermen refused to go out fishing (NAC/rsc 24967). The threat constituted by the presence of crocodiles explained a ritual witnessed by Evelyne Porée-Maspéro in 1947 in Kandal Province: "In Wat Lva, Khsach Kandal, water battle games are organized to make sure that crocodiles will not prey on the local people" (Porée-Maspero 1962).

For the French, as for most Europeans at that time, fauna could be divided into three categories: domesticated animals; useful animals; and animals that were a nuisance to man and thus should be considered as pests. Crocodiles, because they could be a danger for humans and because they were competing with humans for fish stocks, were soon considered as part of the latter category, and therefore were to be eradicated. French settlers and colonists shot crocodiles each time they had a chance to do so. However, the population of crocodiles seems to have succeeded in maintaining itself at least until the end of the 19th century. Then, the French implemented a policy against pests in Indochina, similar to the one that they had designed in their homeland, which had led to the extinction of wolves. An eradication program against animals classified as vermin was set up and bounties were offered. To the French, the worst and most feared predator in Indochina was the tiger. As early as 1861, the Admiral Governor of

Cochinchina offered bounties for each tiger killed (Guerin 2010). At the beginning of the 20th century, such bounties were introduced in Cambodia, first against big cats and then against crocodiles.

In 1916, after several people were killed while bathing in the rivers, especially in Stung Treng Province, bounties were offered against crocodiles: P0.10 for an egg, and bounties ranging from P0.30 to P6.00 for a crocodile depending on its size. For example, P0.30 for a crocodile less than 1 m long, P2.50 for a 3 m long individual, P5.00 for a 5 m long individual [P =Indochinese piastre. The daily salary of most paid workers and coolies was between P0.25-0.30, so the bounties were very attractive] (NAC/rsc 24967a). Ironically, the bounties were suspended 6 months later as they were too expensive for the local budget, and then reduced to P0.10 per egg, P0.30 per crocodile less than 1 m long, P1.00 per crocodile between 1 m and 3 m long, and P2.00 for crocodiles more than 3 m long. However, picking up eggs on the bank of the river proved particularly easy for the local people during the dry season. In November 1918, a new reduced bounty of P0.30 per head was set up by Order, but it was considered as too low to be effective as the French administrator of Stung Treng complained (ANOM/rsc 390). The current nesting season in Cambodia for *C. siamensis* is the mid-dry season to the early wet; from February-June (Simpson and Bezuijen 2010).

When the French took control over the provinces, they started to hunt crocodiles or motivated locals to hunt them through the bounty system. This was implemented first in Cochinchina, then in Cambodia, Annam (~central Viet Nam) and Laos. The bounty policy combined with the demand for crocodile products had an adverse effect on the crocodile population. After the bounties were introduced in 1916, Dr Dufossé indicated that in March and April 1917, 93 crocodiles and 2695 eggs had been destroyed in the district of Kompong Svay alone (Dufosse 1918). This would equate to ~110 *C. siamensis* nests, at 25 eggs per clutch. In Stung Treng Province, 1164 crocodiles and 3728 eggs (~150 clutches) were destroyed within 6 months (ANOM/rsc 390), while in Battambang Province, P2445 was spent on bounties for eggs and small crocodiles within two months, representing the destruction of over 20,000 eggs and young crocodiles (NAC/rsc 24967b). Modern-day conservationists would find these numbers appalling. Crocodiles were still abundant in the 1910s (Dufosse 1918) before the effects of the bounty system were felt. Twenty years later however, crocodiles were disappearing from the waters of Cambodia. In 1944, Charles Dumas wrote in his hunting book: "nowadays, crocodiles are still common, but we have to look for them in the more remote areas and large specimens have disappeared" (Dumas 1944).

The same process was reproduced in different parts of French Indochina. Bordeneuve (1925) estimated in 1925 that approximately 20,000 crocodiles were slaughtered every year in Indochina. This estimate approximates the figure provided by Teston and Percheron (1931) in their Encyclopedia of French Indochina. For them, in 1929, 17,000 crocodiles were captured or killed, for bounty or for their skin and flesh. This might have been the turning point for the population of crocodiles in French Indochina (Cambodia, Laos, Viet Nam). The number of crocodiles killed greatly exceeded the number of births, while dozens, if not hundreds of thousands of eggs were destroyed every year. The process towards the complete eradication of crocodiles was launched. The works of Peter Boomgaard on the Malay World show that the example of the management of crocodile population in Cambodia and the rest of Indochina by the French administration was not an exception (Boomgaard 2001, 2007). After Western powers imposed a policy of eradication of pests during the colonial era in Southeast Asia, we now have to deal with a fading level of biodiversity in the region.

Figure 1. From Edgar Boulangier. Un hiver au Cambodge, chasses au tigre, à l'éléphant et au buffle savage. Souvenirs d'une mission officielle remplie en 1880-1881, Tours: Mame, 1887, p. 89. [A Winter in Cambodia, hunts of the tiger, the elephant and savage buffalo. Memories of an official mission completed in 1880-1881. Mame: Tours. 1887, p. 89].

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[Ed: Mathieu Guérin worked in Cambodia from 1997-2001 at the Royal University of Phnom Penh, the French Cultural Centre and the University of Economic Science. Boyd Simpson provided comments on an earlier draft of this paper].

Science

Recent Publications

Finger, J.W, Jr. and Gogal, R.M., Jr. (2013). Endocrine-disrupting chemical exposure and the American alligator: a review of the potential role of environmental estrogens on the immune system of a top trophic carnivore. Archives of Environmental Contamination and Toxicology (doi: 10.1007/s00244-013-9953-x).

Abstract: Endocrine-disrupting chemicals (EDCs) alter cellular and organ system homeostasis by interfering with the body's normal physiologic processes. Numerous studies have identified environmental estrogens as modulators of EDC-related processes in crocodilians, notably in sex determination. Other broader studies have shown that environmental estrogens dysregulate normal immune function in mammals, birds, turtles, lizards, fish, and invertebrates; however, the effects of such estrogenic exposures on alligator immune function have not been elucidated. Alligators occupy a top trophic status, which may give them untapped utility as indicators of environmental quality. Environmental estrogens are also prevalent in the waters they occupy. Understanding the effects of these EDCs on alligator immunity is critical for managing and assessing changes in their health and is thus the focus of this review.

Griebeler, E.M. (2013). Body Temperatures in Dinosaurs: What Can Growth Curves Tell Us? PLoS ONE 8(10): e74317. doi:10.1371/journal.pone.0074317.

To estimate the body temperature (BT) of seven dinosaurs Gillooly, Alleen, and Charnov (2006) used an equation that predicts BT from the body mass and maximum growth rate (MGR) with the latter preserved in ontogenetic growth trajectories (BT-equation). The results of these authors evidence inertial homeothermy in Dinosauria and suggest that, due to overheating, the maximum body size in Dinosauria was

ultimately limited by BT. In this paper, I revisit this hypothesis of Gillooly, Alleen, and Charnov (2006). I first studied whether BTs derived from the BT-equation of today's crocodiles, birds and mammals are consistent with core temperatures of animals. Second, I applied the BT-equation to a larger number of dinosaurs than Gillooly, Alleen, and Charnov (2006) did. In particular, I estimated BT of Archaeopteryx (from two MGRs), ornithischians (two), theropods (three), prosauropods (three), and sauropods (nine). For extant species, the BT value estimated from the BT-equation was a poor estimate of an animal's core temperature. For birds, BT was always strongly overestimated and for crocodiles underestimated; for mammals the accuracy of BT was moderate. I argue that taxon-specific differences in the scaling of MGR (intercept and exponent of the regression line, log-log-transformed) and in the parameterization of the Arrhenius model both used in the BT-equation as well as ecological and evolutionary adaptations of species cause these inaccuracies. Irrespective of the found inaccuracy of BTs estimated from the BT-equation and contrary to the results of Gillooly, Alleen, and Charnov (2006) I found no increase in BT with increasing body mass across all dinosaurs (Sauropodomorpha, Sauropoda) studied. This observation questions that, due to overheating, the maximum size in Dinosauria was ultimately limited by BT. However, the general high inaccuracy of dinosaurian BTs derived from the BT-equation makes a reliable test of whether body size in dinosaurs was ultimately limited by overheating impossible.

Oriá, A.P., Oliveira, A.V.D., Pinna, M.H., Filho, E.F.M., Estrela-Lima, A., Oeixoto, T.C., Da Silva, R.M.M., Santana, F.O., Meneses, I.D.S., Requião, K.G. and Ofri, R. (2013). Ophthalmic diagnostic tests, orbital anatomy, and adnexal histology of the broad-snouted caiman (*Caiman latirostris*). Veterinary Ophthalmology (doi: 10.1111/vop.12115).

The aim of this study was to establish normal ophthalmic parameters for selected diagnostic tests, and to describe the orbital anatomy and adnexal histology of the broad-snouted caiman. A total of 35 *Caiman latirostris* that were free of obvious ocular diseases were used to measure the parameters in this investigation. Ages ranged from 5 to 15 years. Ophthalmic diagnostic tests were conducted, including evaluation of tear production with Schirmer Tear test-1 (STT1), culture of the conjunctival bacterial flora, applanation tonometry, conjunctival cytology, nictiating membrane incursion frequency test (NMIFT), endodontic absorbent paper point tear test (EAPPTT), palpebral fissure length measurement (PFL) and B-mode ultrasonography. Adnexal histology and skull samples were studied. Mean (±SD) STT1 was 3.4 ± 3.6 mm/min (95% confidence interval of 2.01-4.78 mm/min), intraocular pressure (IOP) was 12.9 ± 6.2 mmHg, NMIFT was 6.0 ± 3.5, EAPPTT was 17.1 ± 2.5 mm/min, PFL was 28.9 ± 3.0 mm, anterior chamber depth was 3.1 ± 0.3 mm, lens axial length was 8.4 ± 0.6 mm, vitreous chamber depth was 7.9 ± 0.7 mm and axial globe length was 19.9 ± 1.3 mm. For all animals evaluated, *Bacillus* sp., Diphteroids and *Staphylococcus* sp. were predominant.

Merchant, M., Determan, C., Falconi, R. and Shirley, M. (2013). Serum complement activity in two species of divergent Central African crocodiles. Entomol. Ornithol. Herpetol. 2: 2 (http://dx.doi.org/10.4172/2161-0983.1000110).

Abstract: Serum complement in the serum of two divergent Central African crocodiles, the African dwarf crocodile (*Osteolaemus tetraspis*) and the slender-snouted crocodile (*Mecistops cataphractus*) was assessed using a sheep red blood cell (SRBC) hemolytic assay. The hemolysis for both crocodilian species was serum volume-, time-, and temperature-dependent. Although the serum volume-dependent activities were similar for both species (CH50 = 81 µL for *O. tetraspis* and 96 µL for *M. cataphractus*), the kinetic curves show a greater amount cooperativity, and thus more rapid SRBC lysis, for *O. tetraspis*. In addition, the hemolytic activities were very similar at 10-35°C, but the serum from *O. tetraspis* was more active than that of *M. cataphractus* at the temperature extremes tested (5°C and 40°C). The activities for both species were almost completely inhibited by 1 mM EDTA, indicating the dependency on divalent metal ions. However, the EDTA-inhibited hemolysis could be restored by the addition of excess Mg^{2+} and Ca^{2+}, but not Ba^{2+}, Cu^{2+}, or Fe^{2+}, which exhibited the specificity for Mg^{2+} or Ca^{2+}. These data indicate that these sympatric, but evolutionarily and ecologically divergent crocodile species have similar SRBC hemolysis activities with similar mechanisms, thus reinforcing the idea that serum complement is an ancient, innate immunity host defence system.

Brunell, A.M., Delaney, J.P., Spratt, R.G., Carbonneau, D.A. and Waller, J.E. (2013). Record total lengths of the American alligator in Florida. Southeastern Naturalist 12(4): N9-N17.

Abstract: Claims of unusually large crocodilians are often questionable because of the lack of physical evidence and a verification process. We report on the longest *Alligator mississippiensis* (American Alligator) that has been officially measured in Florida. The state record for the longest alligator is 435.5 cm (14 ft 3.5 in) and is only the third specimen in Florida known to exceed 426.5 cm (14 ft). Discussion is presented about the measurements taken, techniques used to obtain the measurements, and personnel required for officially recognizing record specimens. We emphasize the importance of having qualified biologists verify measurements using standardized techniques and recommend that other states within the alligator's range develop a protocol similar to Florida's for measuring exceptionally large alligators.

Liu, V. (2013). Genetic Variation in the Mitochondrial DNA of Chinese Alligator Among Different Captive Populations.

Abstract: Due to overhunting and habit loss, there are fewer than 130 Chinese alligators in the wild. To save this critically endangered species, a breeding center was established in the United Statesin 1976 and in 1979, two similar breeding centers were established in China. Due to founder effect, the captive bred Chinese alligators suffer from severe inbreeding

depression. This report explores the more rapidly evolutionary control region of the maternally inherited mitochondrial DNA (mtDNA) of the Chinese alligator to determine if the captive bred Chinese alligators from the United States exhibit genetic variation in comparison to the native Chinese alligators. To test genetic variation, the non-repeating D-loop segment of the mtDNA control region was amplified by a Polymerase Chain Reaction. The resulting DNA sequences were aligned and compared. Although the Chinese alligators from the United States enjoy more favorable conditions than the native Chinese alligators, they still fail to show genetic variation compared to the native Chinese alligators. These results strongly indicate that the captive bred Chinese alligator populations suffer from low genetic diversity. This report calls for further research into other segments of the mtDNA and joint efforts among breeding centers to focus on genetic screening to prevent further loss of genetic diversity

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Young, M.T., Beatty, B.L., Brusatte, S.L. and Steel, L. (2013). First evidence of denticulated dentition in teleosaurid crocodylomorphs. Acta Palaeontologica Polonica http://dx.doi.org/10.4202/app.00002.2013.

Abstract: Teleosauridae was a group of largely marine Mesozoic crocodylomorphs, typically considered as akin to "marine gavials" due to their elongate, tubular, polydont rostra that are indicative of a piscivorous diet. We here show that these extinct crocodylomorphs were more anatomically, and perhaps ecologically, varied than previously thought. We report the first evidence of denticles in a teleosaurid tooth, revealed by scanning electron microscopic (SEM) analysis of a tooth from the holotype of "*Steneosaurus*" *obtusidens*. These denticles are cryptic, because they are microscopic, notcontiguous along the carinae (instead forming short series), and are detectable only using SEM. This incipient denticle morphology is similar to that recently discovered in a closely related group of marine crocodylomorphs, the Metriorhynchidae. In particular, the denticulation morphology of "*Steneosaurus*" is similar to that of the geosaurin metriorhynchid *Torvoneustes*, indicating that these two taxa may have employed similar feeding styles and that "*S.*" *obtusidens* may have been a nearshore ecological analogue to the more offshore, fast-swimming geosaurins. Previous authors have considered "*S.*" *obtusidens* and *Machimosaurus* to be durophagous, but the discovery of denticulated teeth indicates that they had a more varied diet and feeding style, and included flesh slicing as part of their feeding toolkit. It is currently unknown how extensive denticulate carinae may be in Teleosauridae, and we hypothesise that cryptic denticles may also be present in other marine crocodylomorphs once they are subjected to SEM study.

Rosenblatt, A.E., Heithaus, M.R., Mazzotti, F.J., Cherkiss, M. and Jeffery, B.M. (2013). Intra-population variation in activity ranges, diel patterns, movement rates, and habitat use of American alligators in a subtropical estuary. Estuarine, Coastal and Shelf Science http://dx.doi.org/10.1016/j.ecss.2013.10.008http://www.sciencedirect.com/science/help/doi.htm.

Abstract: Movement and habitat use patterns are fundamental components of the behaviors of mobile animals and help determine the scale and types of interactions they have with their environments. These behaviors are especially important to quantify for top predators because they can have strong effects on lower trophic levels as well as the wider ecosystem. Many studies of top predator movement and habitat use focus on general population level trends, which may overlook important intra-population variation in behaviors that now appear to be common. In an effort to better understand the prevalence of intra-population variation in top predator movement behaviors and the potential effects of such variation on ecosystem dynamics, we examined the movement and habitat use patterns of a population of adult American alligators (*Alligator mississippiensis*) in a subtropical estuary for nearly four years. We found that alligators exhibited divergent behaviors with respect to activity ranges, movement rates, and habitat use, and that individualized behaviors were stable over multiple years. We also found that the variations across the three behavioral metrics were correlated such that consistent behavioral types emerged, specifically more exploratory individuals and more sedentary individuals. Our study demonstrates that top predator populations can be characterized by high degrees of intra-population variation in terms of movement and habitat use behaviors that could lead to individuals filling different ecological roles in the same ecosystem. By extension, one-size-fits-all ecosystem and species-specific conservation and management strategies that do not account for potential intra-population variation in top predator behaviors may not produce the desired outcomes in all cases.

Ouchley, Kelby (2013). American Alligator: Ancient Predator in a Modern World. University Press of Florida: USA.

Having survived since the Mesozoic era, alligators teetered on the brink of extinction in the 1960s. Their recovery in the 1970s and 1980s was largely due to legislative intervention, and today populations are closely monitored throughout their range. American Alligator is the most up-to-date and comprehensive treatment of this resilient relic, a creature with a brain weighing less than half an ounce that has successfully adapted to a changing Earth for more than 200 million years. Kelby Ouchley chronicles the evolution of *Alligator mississippiensis* from "shieldcroc"- the last common ancestor of modern-day alligators, crocodiles, caimans, and the gharial - to its current role as keystone of the ecological health of America's southern swamps and marshes. In Florida, the apex predator uses its snout and feet to clear muck from holes in the limestone bedrock. During the dry season, these small ponds or "alligator holes" provide refuge, food, and water for a variety of wildlife. In Louisiana, millions of dollars are spent on the bounty of the non-native nutria that overgraze marsh vegetation, but alligators prey on these coastal rodents free of charge. Today only 23 species of crocodilians remain. That the alligator lineage survives at all, having successfully weathered millions of years of environmental change, speaks to an impressive degree of fitness and adaptability. The loss of the American alligator would be a blow to biodiversity and

an ecosystem disruption affecting all levels of the food chain. While the U.S. Fish and Wildlife Service removed it from the endangered species list in 1987 and today regulates the legal trade of the animal and its products, Ouchley cautions us not to forget the lessons learned: human activities, from urban development to energy production, can still threaten the future of the gator and its southern wetland habitat.

Mobaraki, A., Abtin, E., Kami, H.G. and Kiabi, B.H. (2013). Reproductive biology of the Mugger Crocodile, *Crocodylus palustris*, in Iran (Reptilia: Crocodylidae). 59(3): 207-213.

Abstract: A small population of Mugger crocodiles occurs in the southeastern part of Iran, in Sistan & Baluchestan Province, at the westernmost global range of the species. The peak nesting season is May and consequently the eggs hatch in July, but the nesting season can be extended. In four nests found in the wild, 24, 26, 21 and 13 eggs were counted. A 2.2 m long female, which fell in an overflow pond, laid 21 eggs on a concrete surface exposed to the air. A female kept in captivity laid 18 and 25 eggs in two consecutive years. The mean size for the eggs in the last three nests was calculated as 75.7 x 47.7 mm and 91.27 g in weight. The mean total length and weight for 19 hatchlings was 30.47 cm (29.2 to 33.9 cm) and 84.3 g (66.2 to 90.3 g) respectively. Based on the number of observed hatchlings compared with the clutch size, it seems that hatchlings have a high mortality rate in the early stages after hatching as a result of natural threats.

Dinets, V. (2013). Long-distance signaling in Crocodylia. Copeia 2013(3): 517-526.

Abstract: Long-distance signals such as bellows, roars, headslaps, and infrasound pulses are important components of crocodilian behavioral repertoire, yet there is little or no published information on signaling for many species. Here, original data augmented with a compilation of published and unpublished sources are presented for 24 species of crocodilians. Their analysis shows that crocodilians adapt their signal composition to habitat structure by choosing physically different components. Flexible multi-component composition might partially explain the extraordinary evolutionary longevity of crocodilian signaling. Comparative analysis provides novel evidence for solving the long-standing debate about the phylogeny of the genus *Tomistoma*, supporting its affinities with crocodiles rather than true gharials. It also suggests that the absence of species with adult male length of less than 120 cm among extant crocodilians might be caused by the necessity of producing infrasound as an honest signal of status.

Enax, J., Fabritius, H.-O., Rack, A., Prymak, O., Raabe, D. and Epple, M. (2013). Characterization of crocodile teeth: Correlation of composition, microstructure, and hardness. Journal of Structural Biology (dx.doi.org/10.1016/j.jsb.2013.09.018).

Abstract: Structure and composition of teeth of the saltwater crocodile *Crocodylus porosus* were characterized by several high-resolution analytical techniques. X-ray diffraction in combination with elemental analysis and infrared spectroscopy showed that the mineral phase of the teeth is a carbonated calcium-deficient nanocrystalline hydroxyapatite in all three tooth-constituting tissues: Dentin, enamel, and cementum. The fluoride content in the three tissues is very low (<0.1 wt.%) and comparable to that in human teeth. The mineral content of dentin, enamel, and cementum as determined by thermogravimetry is 71.3, 80.5, and 66.8 wt.%, respectively. Synchrotron X-ray microtomography showed the internal structure and allowed to visualize the degree of mineralization in dentin, enamel, and cementum. Virtual sections through the tooth and scanning electron micrographs showed that the enamel layer is comparably thin (100-200 μm). The crystallites in the enamel are oriented perpendicularly to the tooth surface. At the dentin-enamel-junction, the packing density of crystallites decreases, and the crystallites do not display an ordered structure as in the enamel. The microhardness was 0.60 ± 0.05 GPa for dentin, 3.15 ± 0.15 GPa for enamel, 0.26 ± 0.08 GPa for cementum close to the crown, and 0.31 ± 0.04 GPa for cementum close to the root margin. This can be explained with the different degree of mineralization of the different tissue types and is comparable with human teeth.

Tomida, S. (2013). A fossil scute of Crocodile from the Miocene Mizunami Group, central Japan. Bulletin of the Mizunami Fossil Museum 39: 123-124.

Bonito, C., Sisti, G. and Fambrini, M. (2013). Clinical image: crocodile bite. J. Pak. Med. Stud. 3(3): 118-119.

Abstract: We present images of severe injury from a crocodile bite. This is the left leg of a 29-year-old woman who was suddenly attacked and bitten by a crocodile while she was washing her clothes in a river in Nigeria.

Campbell, H.A., Sissa, O., Dwyer, R.G. and Franklin, C.E. (2013). Hatchling crocodiles maintain a plateau of thermal independence for activity, but at what cost? Journal of Herpetology 47(1): 11-14.

Abstract: Crocodilians show a broad plateau of thermal independence for sustained activity. It has been hypothesized that this reflects a performance breadth necessary for carrying out ecologically important behaviors across a range of ambient temperatures. Here, we swam Saltwater Crocodiles (*Crocodylus porosus*) in a thermally controlled flume at 23, 28, and 33°C and recorded oxygen consumption (VO2) before and after swimming activity. Ambient temperature altered spontaneous VO2 in a positively linear manner, but there was no significant difference in the distance the crocodiles would swim voluntarily. Excess postexercise oxygen consumption (EPOC) increased 10-fold between swimming trials at 28 and 33°C, and the anaerobic debt took 3 times longer to clear at

the higher temperature. The results show that, although *C. porosus* demonstrated a broad thermal breadth for swimming performance, a higher degree of anaerobic metabolism was required to sustain activity at the upper limits of the thermal plateau. Why crocodiles should choose to sustain an anerobic debt rather than reduce their swimming activity when exposed to high experimental temperatures is perplexing, but the study findings provide a physiological rationale for some of the diel and seasonal activity patterns observed in wild crocodilians.

Hutson, J.D. and Hutson, K.N. (2013). Using the American alligator and a repeated-measures design to place constraints on in vivo shoulder joint range of motion in dinosaurs and other fossil archosaurs. J. Exp. Biol. 216: 275-284.

Abstract: Using the extant phylogenetic bracket of dinosaurs (crocodylians and birds), recent work has reported that elbow joint range of motion (ROM) studies of fossil dinosaur forearms may be providing conservative underestimates of fully fleshed in vivo ROM. As humeral ROM occupies a more central role in forelimb movements, the placement of quantitative constraints on shoulder joint ROM could improve fossil reconstructions. Here, we investigated whether soft tissues affect the more mobile shoulder joint in the same manner in which they affect elbow joint ROM in an extant archosaur. This test involved separately and repeatedly measuring humeral ROM in *Alligator mississippiensis* as soft tissues were dissected away in stages to bare bone. Our data show that the ROMs of humeral flexion and extension, as well as abduction and adduction, both show a statistically significant increase as flesh is removed, but then decrease when the bones must be physically articulated and moved until they separate from one another and/or visible joint surfaces. A similar ROM pattern is inferred for humeral pronation and supination. All final skeletonized ROMs were less than initial fully fleshed ROMs. These results are consistent with previously reported elbow joint ROM patterns from the extant phylogenetic bracket of dinosaurs. Thus, studies that avoid separation of complementary articular surfaces may be providing fossil shoulder joint ROMs that underestimate in vivo ROM in dinosaurs, as well as other fossil archosaurs.

Pressinotti, L.N., Borges, R.M., De Lima, A.P.A., Aleixo, V.M., Iunes, R.S., Borges, J.C.S., Cogliati, B. and Da Silva, J.R.M.C. (2013). Low temperatures reduce skin healing in the Jacaré do Pantanal (*Caiman yacare*, Daudin 1802). Biology Open 000: 1-8 (doi: 10.1242/bio.20135876).

Abstract: Studies of skin wound healing in crocodilians are necessary given the frequent occurrence of cannibalism in intensive farming systems. Air temperature affects tissue recovery because crocodilians are ectothermic. Therefore, the kinetics of skin wound healing in *Caiman yacare* were examined at temperatures of 33°C and 23°C. Sixteen caiman were selected and divided into two groups of eight maintained at 23°C or 33°C. The studied individuals' scars were photographed after 1, 2, 3, 7, 15 and 30 days of the experimental conditions, and samples were collected for histological processing after 3, 7, 15 and 30 days. Macroscopically, the blood clot (heterophilic granuloma) noticeably remained in place covering the wound longer for the caiman kept at 23°C. Microscopically, the temperature of 23°C slowed epidermal migration and skin repair. Comparatively, new blood vessels, labeled using von Willebrand factor (vWF) antibody staining, were more frequently found in the scars of the 33°C group. The collagen fibers in the dermis were denser in the 33°C treatment. Considering the delayed healing at 23°C, producers are recommended to keep wounded animals at 33°C, especially when tanks are cold, to enable rapid wound closure and better repair of collagen fibers because such lesions tend to compromise the use of their skin as leather.

Sicuro, F.L., Iack-Ximines, Wogel, H. and Bilate, M. (2013). Vocal patterns of adult female and juvenile *Caiman yacare* (Crocodilia: Alligatoridae) in Brazilian Pantanal wetland. Rev. Biol. Trop. 61 (3): 1401-1413.

Abstract: The Paraguayan caiman (*Caiman yacare*) is the main Caimaninae species occurring in the Brazilian Pantanal Wetland. Despite the relative availability of works focused on biology and conservation of the Paraguayan caiman, almost nothing is known about its vocal structure and behaviour. We recorded aggressive calls of adult caiman females guarding nests and, afterwards, the distress calls of the newborn juvenile caimans in seasonally flooded areas of the Nhecolândia (Southern Pantanal). The results of both observations and sonographic analyses diverged from studies with other crocodilian species. Aggressive vocalization of adult females of the Paraguayan caiman was longer and more complex than the same vocalization of larger Alligatoridae species. Vocalizations of the young caimans presented interspecific differences with other crocodilian offsprings. Moreover, we found statistically significant intraspecific variation in the distress call structure among different pods, even separated by few kilometres. Differences in distress call structure were tested by Canonical Discriminant Analysis (CDA). We obtained the squared Mahalanobis distances between the acoustic multivariate spaces of each pod provided by the CDA and compared with the geographic distance between the bays of origin of each pod through Mantel Test. The geographic distance by itself did not explain the differences found in the structure of the vocalization of young caimans from different pods. The adult females of Paraguayan caiman positively responded to playbacks of calls from juvenile caimans from pods of other regions, as well as to rough imitations of distress call. Since the adult caimans showed protective responses to quite heterogeneous vocalizations of distress by juveniles, we hypothesized that the variation in the distress call pattern may be associated to a low specificity in sound recognition by adult caimans.

Huchzermeyer, F., Groenewald, H., Myburgh, J., Steyl, J. and Crole, M. (2013). Osteoarthropathy of unknown aetiologyin the long bones of farmed and wild Nile crocodiles (*Crocodylus niloticus*). Journal Of The South African Veterinary Association, 84(1). (doi: 10.4102/jsava.v84i1.975).

Abstract: Humeri of farmed and wild Nile crocodiles (*Crocodylus niloticus*) collected during routine post-mortem examinations were boiled, cleaned and examined for lesions. Various degrees of gross bone and articular pathology were found. The lesions were situated predominantly at the proximal and distal epiphyseal and metaphyseal regions of the bone, where growth and bone remodelling occurs. In advanced cases partial collapse of the articular surface could be identified. From the collection of crocodile bones five particular cases are described. Because of the wide distribution of origin of the affected animals, nutritional or toxicological causes seem unlikely. One of the cases presented was associated with mycoplasmosis. These forms of crocodilian bone pathology need further investigation.

Erickson, G.M., Gignac, P.M., Lappin, A.K., Vliet, K.A., Breuggen, J.D. and Webb, G.J.W. (2013). A comparative analysis of ontogenetic bite-force scaling among Crocodylia. Journal of Zoology DOI: 10.1111/jzo.12081.

Abstract: Interspecific adult bite forces for all extant crocodylian species are now known. However, how bite forces scale during ontogeny across the clade has yet to be studied. Here we test the hypotheses that extant crocodylians share positively allometric and statistically comparable developmental scaling coefficients for maximal bite-force capacity relative to body size. To do this, we measured bite forces in the Australian freshwater crocodile *Crocodylus johnstoni* and the Saltwater crocodile *C. porosus*, and determined how performance changed during ontogeny. We statistically compared these results with those for the American alligator *Alligator mississippiensis* using 95% prediction intervals and interpreted our findings in a phylogenetic context. We found no observable taxon-specific shifts in the intraspecific scaling of biomechanical performance. Instead, all bite-force values in our crocodylid dataset fell within the bounds of the *A. mississippiensis* 95% prediction intervals, suggesting similar bite-force capacity when same-sized individuals are compared. This holds true regardless of differences in developmental stage, potential adult body size, rostro-dental form, bone mineralization, cranial suturing, dietary differences or phylogenetic relatedness. These findings suggest that intraspecific bite-force scaling for crocodylians with feeding ecologies comparable with those of extant forms has likely remained evolutionarily static during their diversification.

Royston, A. (2014). Alligator: Killer King of the Swamp. Windmill Books: New York.

Akkapinya, P., Sae-lim, S., Su-angkavathin, V., Chaeychomsri, W. and Itharat, A. (2013). Effect of crocodile serum on neurite outgrowth and MEK-1 synthesis in PC12 culture. Thammasat Medical Journal 13(4): 487-495.

Abstract: Crocodile blood was used as single drug or as combined recipe in traditional medicine as nootropic drug and chronic disease therapy. Insulin-like growth factor-1 (IGF-1), found in crocodile serum, was reported to protect neuronal cell dead when cultured in serum-free medium. The assessments of neurite outgrowth and mitogen activated protein kinase (MAPK) or MEK-1, producing while cell proliferated and differentiated, are striking mechanisms in nootropic drugs research. The aim of this study was to verify the effect of crocodile serum on neurite outgrowth and MEK-1 synthesis in PC12 culture. PC12 was cultured with freeze-dried serum obtained from 10 crocodiles. The percentage of neurite outgrowth bearing cell was counted and the amount of MEK-1 was assessed by enzyme immunoassay. The IC50 of crocodile serum was 25.26 mg/ml. Serum at concentration of 4 mg/ml with NGF 2 ng/ml group potentiated proliferation and neurite outgrowth (9.04 ± 3.42%) more than the negative control group with NGF 2 ng/ml (3.05 ± 1.32%) but lesser than the positive control group with NGF 50 ng/ml (14.81 ± 3.79%) ($p<0.05$). The amount of MEK-1 was also increase in the treatment of 4 mg/ml group as 204.83 ± 28.91% and the positive control group as 253.26 ± 34.2% ($p<0.05$). The diluted serum of 2 and 0.4 mg/ml with NGF 2 ng/ml had no effect on neurite outgrowth and MEK-1 synthesis. This effect might due to the IGF-1 and other active substances contained in crocodile blood. As the therapeutic window of the crocodile serum was rather narrow, so for nootropic use, the repeated small doses of the serum should be suggested.

Theansungnoen, T., Yaraksa, N., Daduang, S., Dhiravisit, A. and Thammasirirak. S. (2013). Purification and characterization of antioxidant peptides from leukocyte extract of *Crocodylus siamensis*. The Protein Journal (doi: 10.1007/s10930-013-9536-8).

Abstract: Antioxidant peptides were isolated from the leukocyte extract of the Siamese crocodile, *Crocodylus siamensis*. Crocodile leukocyte was extracted by a combination of methods including freeze-thawing, acetic acid extraction and homogenization. The peptides in the leukocyte extract were purified by anion exchange chromatography and reversed phase-high performance liquid chromatography. The 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging assay was used to evaluate the antioxidant activity of the elution peaks at each purification step. As a result, there were two purified peptides exhibiting strong antioxidant activity in reducing free radicals on DPPH molecules. The amino acid sequences of these peptides were determined by LC-MS/MS as TDVLGLPAK (912.5 Da) and DPNAALPAGPR (1,148.6 Da), and their IC50 values were 153.4 and 95.7 μM, respectively. The results of this study therefore indicate that leukocyte extract of *C. siamensis* contains peptides with antioxidant activity which could be used as a novel antioxidant.

Somaweera, R., Brien, M. and Shine, R. (2013). The role of predation in shaping crocodilian natural history. Herpetological Monographs 27(1): 23-51.

Abstract: Although adult crocodilians have few predators (mostly humans and other crocodilians), hatchlings and eggs are killed and consumed by a diverse array of invertebrates,

fishes, anurans, reptiles, birds, and mammals. We review published literature to evaluate the incidence of predation in crocodilian populations, and the implications of that mortality for crocodilian life-history evolution. Presumably because predation is size-dependent, small-bodied crocodilian taxa appear to be more vulnerable to predation (across a range of life stages) than are larger-bodied species. Several features of crocodilian biology likely reflect adaptations to reducing vulnerability to predation. For example, the threat of predation may have influenced the evolution of traits such as nest-site selection, maternal care of eggs and hatchlings, crèche behavior in hatchlings, and cryptic coloration and patterning. Even for such large and superficially invulnerable taxa such as crocodilians, the avoidance of predation appears to have been a significant selective force on behavior, morphology, and ecology.

Fijn, N. (2013). Living with Crocodiles: Engagement with a Powerful Reptile Being. Animal Studies Journal 292: 1-27.

Abstract: As an animal, crocodiles loom large in the human imagination. Crocodiles also grow to very large sizes in the real world, large enough to consume humans. Eco-philosopher Val Plumwood came to the realisation, while being churned under water within a crocodile's jaws, that for the crocodile she was food, merely a piece of meat. The intention of this paper is to instigate thought on how views can differ from the portrayal of the crocodile as a primitive monster. In northeast Arnhem Land, the saltwater crocodile is commonly encountered as a moving shape out on the water, or through fresh signs of large lumbering tracks upon a beach. For individual Yolngu, whose clan totem includes the saltwater crocodile, or Bäru, this being is an integral part of social existence. Bäru features in ceremony, within song, dance and in bark paintings. I examine how Yolngu negotiate with the saltwater crocodile as a very real threat to human life; but also how Yolngu have a deep respect for the crocodile through a mutual essence and connection to country

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Young, M.T., De Andrade, M.B., Etches, S. and Beatty, B.L. (2013). A new metriorhynchid crocodylomorph from the Lower Kimmeridge Clay Formation (Late Jurassic) of England, with implications for the evolution of dermatocranium ornamentation in Geosaurini. Zoological Journal of the Linnean Society 169(4): 820-848.

Abstract: A new metriorhynchid crocodylomorph from the Lower Kimmeridge Clay Formation (Kimmeridgian, Upper Jurassic) of England is described. This specimen, a three-dimensionally preserved skull and left mandibular ramus, is referred to a new species: *Torvoneustes coryphaeus* sp. nov. Within the genus *Torvoneustes*, *T. coryphaeus* sp. nov. is unique as it has a long anteromedial process of the frontal, ornamented dermatocranium, and the supraorbital notch forms a strongly acute angle. Our phylogenetic analysis confirms the placement of this specimen in *Torvoneustes*. The dentition of *T. coryphaeus* sp. nov., like that of the type species, has a blunt apex, crown basal-mid regions with numerous tightly packed apicobasally aligned ridges, and apical region with an anastomosed pattern of ridges that interact with the carinae. Within Thalattosuchia these dental characteristics are only found in Torvoneustes and the teleosaurid *Machimosaurus*. The heavily ornamented dermatocranium of *T. coryphaeus* sp. nov. is in contrast to the unornamented (nasals and frontal)-lightly ornamented (maxillae and premaxillae) pattern seen in *Torvoneustes carpenteri*. Curiously, this pattern of reduction and loss of dermatocranium ornamentation is also observed in *Metriorhynchus*, *Dakosaurus*, and the subclade Rhacheosaurini. We hypothesize that the 'smooth' dermatocranium of Late Jurassic metriorhynchids evolved independently in each subclade (parallel evolution), and would have reduced drag, thereby making locomotion through water more energy efficient.

Kim, K.T. and Kwak, D. (2013). Case of *Aeromonas hydrophila* infection due to captivity-induced stress in a Spectacled caiman (*Caiman crocodilus*). The Journal of Animal & Plant Sciences 23(6): 1761-1763.

Abstract: *Aeromonas hydrophila* is a facultative anaerobic, Gram-negative bacterium often regarded as an opportunistic pathogen in animals. A 4-year-old male spectacled caiman (*Caiman crocodilus*) died after 4 days of anorexia and depression. Necropsy was performed during which mild swelling and ash gray discoloration of the liver was observed. Additionally, the gall bladder was enlarged and elongated. Rod-shaped bacteria were found in the liver by Giemsa staining and identified as *A. hydrophila*. The animal had been exposed to stressful conditions prior to death, and decreased immune system functioning may have contributed to *A. hydrophila* infection of the animal.

Dinets, V., Breuggen, J.C. and Breuggen, J.D. (2013). Crocodilians use tools for hunting. Ethology, Ecology and Evolution (doi: 10.1080/03949370.2013.858276).

Abstract: Using objects as hunting lures is very rare in nature, having been observed in just a handful of species. We report the use of twigs and sticks as bird lures by two crocodilian species. At least one of them uses this method predominantly during the nest-building season of its prey. This is the first known case of a predator not just using objects as lures, but also taking into account the seasonality of prey behavior. It provides a surprising insight into previously unrecognized complexity of archosaurian behavior.

Marques, T.S., Bassetti, L.A.B., Lara, N.R.F., Araújo, M.S., Piña, C.I., Camargo, P.B. and Verdade, L.M. (2013). Isotopic discrimination factors (Δ13C and Δ15N) between tissues and diet of the Broad-snouted caiman (*Caiman latirostris*). Journal of Herpetology.

Abstract: Natural variation in stable isotope ratios is a useful tool in diet studies. However, the correct interpretation of isotopic data is reliant on proper estimates of discrimination factors. This study aimed to describe the magnitude of the discrimination factors of carbon and nitrogen isotopes between

diet and tissues ($\Delta 13C_{tissue\text{-}diet}$ and $\Delta 15N_{tissue\text{-}diet}$) of the Broad-snouted caiman (*Caiman latirostris*) and to verify potential differences between age classes. The isotopic ratios of carbon and nitrogen (δ13C and δ15N) were determined in samples of two tissue types (claw and scute) collected from 18 captive animals and in 15 samples of their diet. The $\Delta 13C_{tissue\text{-}diet}$ was 1.2 ± 0.1‰ for claw and 0.9 ± 0.2‰ for scutes; the $\Delta 15N_{tissue\text{-}diet}$ was 1.1 ± 0.1‰ for claw and 0.8 ± 0.2‰ for scutes. These values were much lower than the values assumed commonly in ecological studies (3-5‰), and similar to a previous study with crocodilians. Our results emphasize the need to determine discrimination factors specific to taxa instead of assuming average values derived from the literature.

Maders, D.R. and Divers, S.J. (eds) (2014). Current Therapy in Reptile Medicine and Surgery. Elsevier: St. Louis, Missouri.

Brien, M.L., Lang, J.W., Webb, G.J., Stevenson, C. and Christian, K.A. (2013). The good, the bad, and the ugly: agonistic behaviour in juvenile crocodilians. PLOS ONE (doi: 10.1371/journal.pone.0080872).

Abstract: We examined agonistic behaviour in 7 species of hatchling and juvenile crocodilians held in small groups (N= 4) under similar laboratory conditions. Agonistic interactions occurred in all 7 species, typically involved two individuals, were short in duration (5-15 seconds), and occurred between 1600-2200 h in open water. The nature and extent of agonistic interactions, the behaviours displayed, and the level of conspecific tolerance varied among species. Discrete postures, non-contact and contact movements are described. Three of these were species-specific: push downs by *C. johnstoni*; inflated tail sweeping by *C. novaeguineae*; and, side head striking combined with tail wagging by *C. porosus*. The two long-snouted species (*C. johnstoni* and *G. gangeticus*) avoided contact involving the head and often raised the head up out of the way during agonistic interactions. Several behaviours not associated with aggression are also described, including snout rubbing, raising the head up high while at rest, and the use of vocalizations. The two most aggressive species (*C. porosus*, *C. novaeguineae*) appeared to form dominance hierarchies, whereas the less aggressive species did not. Interspecific differences in agonistic behaviour may reflect evolutionary divergence associated with morphology, ecology, general life history and responses to interspecific conflict in areas where multiple species have co-existed. Understanding species-specific traits in agonistic behaviour and social tolerance has implications for the controlled raising of different species of hatchlings for conservation, management or production purposes.

Shirley, M.H., Vliet, K.A., Carr, A.N. and Austin, J.D. (2014). Rigorous approaches to species delimitation have significant implications for African crocodilian systematics and conservation. Proc. R. Soc. B 281(1776): 20132483.

Abstract: Accurate species delimitation is a central assumption of biology that, in groups such as the Crocodylia, is often hindered by highly conserved morphology and frequent introgression. In Africa, crocodilian systematics has been hampered by complex regional biogeography and confounded taxonomic history. 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. Speciation probability was assessed by using 11 mitochondrial and nuclear genes, and cranial morphology for over 100 specimens, representing the full geographical extent of the species distribution. Molecular Bayesian and phylogenetic species delimitation showed unanimous support for two *Mecistops* species isolated to the Upper Guinean and Congo (including Lower Guinean) biomes that were supported by 13 cranial characters capable of unambiguously diagnosing each species. Fossil-calibrated phylogenetic reconstruction estimated that the species split ± 6.5-7.5 Ma, which is congruent with intraspecies divergence within the sympatric crocodile genus *Osteolaemus* and the formation of the Cameroon Volcanic Line. Our results underscore the necessity of comprehensive phylogeographic analyses within currently recognized taxa to detect cryptic species within the Crocodylia. We recommend that the community of crocodilian researchers reconsider the conceptualization of crocodilian species especially in the light of the conservation ramifications for this economically and ecologically important group.

Parachú Marcó, M.V., Larriera, A. and Piña, C.I. (2013). Impacts of red imported fire ants *Solenopsis invicta* on survivorship of hatchlings of the broad-snouted caiman *Caiman latirostris*. Zoological Studies 52: 52.

Abstract: Oviparous vertebrate species are often vulnerable to predation by red imported fire ants (RIFAs, *Solenopsis invicta*) in natural environments. The necrotic action of the venom can cause localized infections, with subsequent effects on survival and growth. Despite the significant impacts of RIFAs in regions where they have been introduced, very little is known about the competitive mechanisms of RIFAs with other species in their native habitat. We tested whether the survival and growth of hatchlings of the broad-snouted caiman *Caiman latirostris* were affected by different exposure times to RIFAs. We observed that an increased exposure time to RIFAs caused a decrease in *C. latirostris* survival. However, the subsequent growth of *C. latirostris* hatchlings was not affected by the time of exposure to the ants. *S. invicta* can cause negative effects for other species in places where it is native. The mechanisms of *S. invicta* toxicity to caimans are not known; these data could help model the effects of *S. invicta* on *C. latirostris* survival, in turn fostering a better understanding of wild population dynamics.

Da Silveira, R., Campos, Z., Thorbjarnarson, J. and Magnusson, W.E. (2013). Growth rates of black caiman (*Melanosuchus niger*) and spectacled caiman (*Caiman crocodilus*) from two different Amazonian flooded habitats. Amphibia-Reptilia 34: 437-449.

Abstract: Rates of growth and survival in wild populations are affected by the physical environment, biotic interactions, and density-dependent processes, such as growth and fecundity. However, the relative importance of these factors in long-lived reptiles is poorly understood. We analyzed growth rates of *Melanosuchus niger* and *Caiman crocodilus* coexisting in two areas of the Brazilian Amazon with very different environmental characteristics. Growth rates of *Caiman crocodilus* at the two sites were similar, but *M. niger* grew more slowly in the area with higher productivity and higher density of caimans. Growth rates of the same species from other sites and of the temperate-zone *Alligator mississippiensis* indicate large differences among sites, but little evidence that these differences are primarily due to differences in productivity or temperature. Demographic models used to estimate sustained yields from caiman harvests should take into account the likely importance of density-dependent growth.

Marques, T.S., Lara, N.R.F., Bassetti, L.A.B., Piña, C.I., Camargo, P.B. and Verdade, L.M. (2013). Intraspecific isotopic niche variation in broad-snouted caiman (*Caiman latirostris*). Isotopes in Environmental and Health Studies 49(3): 325-335.

Abstract: Strategies to minimise intraspecific competition are common in wild animals. For example, individuals may exploit food resources at different levels of the food chain. Analyses of stable isotopes are particularly useful for confirming variations in an intraspecific niche because the chemical composition of animals tends to reflect both the food consumed and the habitats occupied by the species. However, studies using this methodology to investigate neotropical crocodilians are scarce. This study aimed to verify the existence of ontogenetic and sexual niche variation in broad-snouted caiman in a silvicultural landscape in Brazil through the use of carbon and nitrogen stable isotopes. The isotopic ratios of carbon and nitrogen were determined in claw samples collected from 24 juveniles, 8 adults, and 16 hatchlings of *C. latirostris*. We identified a discrete ontogenetic variation in the isotopic niche and sexual difference only for juveniles. These results may indicate differences in the exploitation resources and a consequent reduction in competition between age classes.

Johnston, S.D., Lever, J., McLeod, R., Oishi, M., Qualischefski, E., Omanga, C., Leitner, M., Price, R., Barker, L., Kamau, K., Gaughan, J. and D'Occhio, M. (2013). Semen collection and seminal characteristics of the Australian saltwater crocodile (*Crocodylus porosus*). Aquaculture 422-423: 25-35.

Abstract: The development of a reliable non-invasive method of crocodile semen collection is fundamental 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 (*Crocodylus porosus*), this study developed a successful, reliable method of semen collection using cloacal digital manipulation of the terminal segment of the ductus deferens. Semen was recovered from 30 of 31 collection attempts from a total of 24 sedated males ranging from 197 cm to 400 cm in body length. Seminal characteristics (including abnormal sperm morphology) and bacteriology were documented for the first time. Mean (± SEM) seminal volume, pH, osmolality, sperm concentration, percentage of motile sperm and the percentage of sperm with an intact membrane measured 0.91 ± 0.16 mL, 7.3 ± 0.1, 335.5 ± 9.0 mOsm kg^{-1}, 2.29 ± 0.26 × 109, 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. Most semen samples contained spermatozoa with what are presumed to be cytoplasmic droplets but the confirmation and then significance of this phenomenon as a sperm maturational pathology require further validation. 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. While a diverse range of bacteria were identified, the majority were sensitive to gentamicin. This study represents the first step towards assessment of breeding soundness examination and the use of artificial insemination technology in the saltwater crocodile industry.

Enax, J., Fabritius, H.-O., Rack, A., Prymak, O., Raabe, D. and Epple, M. (2013). Characterization of crocodile teeth: Correlation of composition, microstructure, and hardness.

Abstract: Structure and composition of teeth of the saltwater crocodile *Crocodylus porosus* were characterized by several high-resolution analytical techniques. X-ray diffraction in combination with elemental analysis and infrared spectroscopy showed that the mineral phase of the teeth is a carbonated calcium-deficient nanocrystalline hydroxyapatite in all three tooth-constituting tissues: Dentin, enamel, and cementum. The fluoride content in the three tissues is very low (<0.1 wt%) and comparable to that in human teeth. The mineral content of dentin, enamel, and cementum as determined by thermogravimetry is 71.3, 80.5, and 66.8 wt%, respectively. Synchrotron X-ray microtomography showed the internal structure and allowed to visualize the degree of mineralization in dentin, enamel, and cementum. Virtual sections through the tooth and scanning electron micrographs showed that the enamel layer is comparably thin (100-200 μm). The crystallites in the enamel are oriented perpendicularly to the tooth surface. At the dentin-enamel-junction, the packing density of crystallites decreases, and the crystallites do not display an ordered structure as in the enamel. The microhardness was 0.60±0.05 GPa for dentin, 3.15±0.15 GPa for enamel, 0.26±0.08 GPa for cementum close to the crown, and 0.31±0.04 GPa for cementum close to the root margin. This can be explained with the different degree of mineralization of the different tissue types and is comparable with human teeth

Parrott, B.B., Kohno, S., Cloy-McCoy, J.A. and Guilette, L.J., Jr. (2013). Differential incubation temperatures result in dimorphic DNA methylation patterning of the SOX9 and aromatase promoters in gonads of Alligator (*Alligator mississippiensis*) embryos. Biology of Reproduction (doi: 10.1095/biolreprod.113.111468).

Abstract: Environmental factors are known to influence sex determination in many non-mammalian vertebrates. In all crocodilians studied thus far, temperature is the only known determinant of sex. However, the molecular mechanisms mediating the effect of temperature on sex determination are not known. Aromatase (CYP19A1) and SOX9 play critical roles in vertebrate sex determination and gonadogenesis. Here, we utilize a variety of techniques to investigate the potential role of DNA methylation patterning on CYP19A1 and SOX9 expression in the American alligator, an organism that relies on temperature dependent sex determination. Our findings reveal that developing gonads derived from embryos incubated at a male producing temperature (MPT) show elevated CYP19A1 promoter methylation and decreased levels of gene expression relative to incubations at a female producing temperature (FPT). The converse was observed at the SOX9 locus, with increased promoter methylation and decreased expression occurring in embryonic gonads resulting from incubations at FPT relative to MPT. We also examine the gonadal expression of the three primary, catalytically active DNA methyltransferase enzymes and show that they are present during critical stages of gonadal development. Together, these data strongly suggest that DNA methylation patterning is a central component in coordinating the genetic cascade responsible for sexual differentiation. In addition, these data raise the possibility that DNA methylation could act as a key mediator integrating temperature into a molecular trigger that determines sex in the alligator.

Jaratlerdsiri, W., Isberg, S.R., Higgins, D.P., Ho, S.Y.W., Salomonsen, J., Skjodt, K., Miles, L.G. and Gongora, J. (2013). Evolution of MHC class I in the Order Crocodylia. Immunogenetics 66(1): 53-65.

Abstract: The major histocompatibility complex (MHC) is a dynamic genomic region with an essential role in the adaptive immunity of jawed vertebrates. The evolution of the MHC has been dominated by gene duplication and gene loss, commonly known as the birth-and-death process. Evolutionary studies of the MHC have mostly focused on model species. However, the investigation of this region in non-avian reptiles is still in its infancy. To provide insights into the evolutionary mechanisms that have shaped the diversity of this region in the Order Crocodylia, we investigated MHC class I exon 3, intron 3, and exon 4 across 20 species of the families Alligatoridae and Crocodilidae. We generated 124 DNA sequences and identified 31 putative functional variants as well as 14 null variants. Phylogenetic analyses revealed three gene groups, all of which were present in Crocodilidae but only one in Alligatoridae. Within these groups, variants generally appear to cluster at the genus or family level rather than in species-specific groups. In addition, we found variation in gene copy number and some indication of interlocus recombination. These results suggest that MHC class I in Crocodylia underwent independent events of gene duplication, particularly in Crocodilidae. These findings enhance our understanding of MHC class I evolution and provide a preliminary framework for comparative studies of other non-avian reptiles as well as diversity assessment within Crocodylia.

Campos, Z., Magnusson, W.E. and Marques, V. (2013). Growth rates of *Paleosuchus palpebrosus* at the southern limit of its range. Herpetologica 69(4): 405-410.

Abstract: We estimated growth rates of Dwarf Caiman (*Paleosuchus palpebrosus*) with capture-recapture data from 40 individuals collected over 6 years in streams surrounding the Brazilian Pantanal, near the southern limit of the species' distribution. Repeated recaptures of 8 animals indicate that within-individual variation is much greater than between-individual variation, possibly reflecting climatic influences. Growth rates of juveniles increased linearly until individuals were about 28 cm snout-vent length (SVL), and then growth rates decreased gradually after attaining that size. The rate of decrease, however, differed between males and females. Data for 30 juveniles of known age were used to validate the growth curve based on the growth rate-on-size analysis. The length of the smallest female recorded nesting (SVL= 60 cm) allowed us to estimate the age at first reproduction to be about 8 years for females. Our data do not support our initial hypothesis that *P. palpebrosus* would have slow growth rates and relatively old age at first reproduction, as has been suggested for *Paleosuchus trigonatus*.

Submitted Publications

THE CROCODILE MUZZLE: AN EXPERIMENTAL METHOD FOR PACIFYING CAPTURED CROCODILIANS. Crocodilians are predatory, semi-aquatic reptiles which vary in size, morphology, behaviour and ecology. Yet, all species pose certain challenges to capture for research or re-location purposes. Capture and handling techniques are therefore critical to ensure safety of both the crocodilian and the capture team.

There are many capture methods documented for crocodilians, each with its own merits, including snares, catch poles, tongs, nooses, harpoons, traps and nets (Chabreck 1963; Jones 1966; Murphy and Fendley 1973; Webb and Messel 1977; Walsh 1987; Mazzotti and Brandt 1988; McDaniel and Hord 1990; Forster 1991; Woodward and David 1994; Leslie 1997; Cherkiss *et al*. 2004; Mazzotti 2012).

Post-capture requires crocodilians to remain relatively calm for physical examination or data capture to occur. Here we document a method of reducing stress and improving pacification of crocodilians without the use of drugs. The technique involves reducing sensory stimuli through the application of a muzzle, reducing vision, hearing and stress from touching sensitive facial domed pressure receptors. The

muzzle also serves as a jaw restraint, preventing potential bite injury to capture teams.

The principle method of capture that facilitates applying a muzzle to a crocodilian is a rope jaw-noose. Once the specimen has been caught and beached on a shoreline using a jaw-noose, then application of a muzzle becomes an option. The set-up of operators and equipment is shown in Figure 1.

Figure 1. Applied 'Croc Muzzle'.

Firstly the method requires a minimum of three operators and preferably in an open area (we recommend a fourth to be a look-out and as many extras to assist the first operator as required). The tested method involves:

1. The first person holds the animal on the end of the taut jaw-rope. The second and third operators assist the first to slide the muzzle over the end of the jaw-rope.

2. The second and third operators then disperse away slowly from the first to create an approximate 45° angle to keep the muzzle open.

3. The second and third operators then slowly draw the muzzle down toward the face of the crocodilian using the guide ropes. NB: distance is critical at this stage to not stress the animal and there is no guidance for specific species. We recommend operators remain a minimum of 3 metres from the captured specimen.

4. When the muzzle is closer to the specimen the second and third operators swiftly slide the muzzle onto the animal's face in unison and keep the guide ropes secure and in place.

5. The first operator then proceeds to pull him/her self along the jaw-rope toward the animal's muzzled face.

6. Provided the animal does not twist, turn, stress or try to retract into the water, the animal can be approached and possibly subdued by all three operators.

Application of the muzzle on various crocodilian species takes less than 3 minutes post jaw-rope capture. On occasions where the muzzle was applied, crocodilians suspended rolling and other movements to attempt escape, and became visibly calmer. It is important to note however, that the material used to form the muzzle needs to be of sufficient strength and durability. The application of the muzzle has been overseen by the Ugandan Wildlife Centre and veterinarians from the University of Toronto, Canada, and was considered a valuable tool promoting safety of both captured animals and the capture team.

The successful capture and subsequent pacifying of crocodilians is an essential part of veterinary work, zoo-keeping, conservation biology and human conflict control. With this short pilot technique we hope to provide interest and discussion from all experts in crocodilian research about the use of blindfold techniques to calm specimens post-capture. The muzzle we display was conceived, designed and tested by PP. It is a preliminary device that later will receive modification to hone its intended purpose. We believe the equipment has potential to be used with many crocodilian species. However, the prototype's formal release requires further testing on more key crocodilian species and under a variety of environmental conditions before we could deem its conclusive safe use.

We believe the technique has the potential to improve the safety and opportunity to perform basic morphometrics, simple veterinary procedures and possibly enhance education about crocodilians. It is our hope that the device may become useful to other herpetologists and in future perhaps become a retailed commodity that could raise funds for crocodilian projects around the world.

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ALLIGATOR COWIEII ANDREW SMITH, 1831, DID NOT ORIGINATE IN 1937 IN HEWITT, BUT RATHER IN SMITH (1831), One of the junior synonyms of *Crocodylus niloticus* has so often been cited with a misleading origination reference that it deserves our conscious attention, and today should be immediately corrected at the IUCN-SSC "Species+" website. The currently popular allegation that Sir Andrew Smith's "*Alligator Cowieii*" (sometimes unnecessarily shortened to *cowiei* with the single-i ending) originated in 1937 in Smith in Hewitt is wrong. The book Hewitt (1937) is more than 100 years younger than Smith (1831), which is the real origin of *Alligator cowieii* as a species, and also indirectly of *Crocodylus niloticus cowieii* as a subspecies.

The species-group name *Alligator cowieii* A. Smith, 1831, was coined in the South African Quarterly Journal (Cape Town), in what is technically Volume 2, Series 1, Number 5, page 15, and continued on page 16. It just says "No. V." and the date "October 1831" on it, but Branch and Bauer (2005a) have recently clarified the volume and series data, and have explained that this magazine is extremely rare. Science failed to notice the name *Alligator cowieii* before Loveridge (1957) recently listed it, and this long omission was because the Smith (1831) paper was so remarkably obscure. It is also relevant that Andrew Smith (1849) did not apply this name to this animal (Ross 2005).

Andrew Smith knew that there is a Cowie River near the modern city of Elizabeth, Republic of South Africa, but Smith's (1831) "*Alligator Cowieii*" is not named for the river that empties into the Indian Ocean at Port Alfred, but rather and explicitly for a physician friend of his, Dr. Cowie, who got sick at Delagoa Bay (Baía da Lagoa, now the Baía de Maputo, in Mozambique) and died. The geographical range of *Alligator cowieii* A. Smith, 1831, was that it "abounds in the rivers beyond Currichane, and in those towards Natal and Delagoa Bay." Later rephrased with a different spelling, Smith (1849) said "in the rivers of a district north of Kurrichane, between 24 degrees and 22 degrees south latitude" and more recently Arthur Loveridge (1957) astutely and judiciously edited the type locality to become "rivers beyond Currichane" in quotation marks, followed by the modernization to "Rustenburg, western Transvaal".

The following 11 quotations are absolute synonyms of *Alligator cowieii* Andrew Smith, 1831, a species-group name that has "Cayman of the Cape Colonists" (Smith 1849) as its common name.

1. "1831. *Alligator cowieii* A. Smith, S. African Quart. Journ. 5: 15: 'Rivers beyond Currichane,' i.e. Rustenburg, western Transvaal" (Loveridge 1957: 177).
2. "1937 *Alligator cowieii* A. Smith in Hewitt, Guide Vertebr. Faun. east. Cape Prov. 2:2. - Terra typica: Süd-Afrika" (Wermuth and Mertens 1961: 365).
3. "*Crocodylus niloticus cowieii* (A. Smith)" with no further details (Fuchs 1974: 128).
4. "1937 *Alligator cowiei* A. Smith in Hewitt, Guide Vertebr. Fauna east. Cape Prov. 2:2. - Terra typica: Süd-Afrika" (Fuchs et al. 1974: 112).
5. "1937 *Alligator cowiei* A. Smith in Hewitt, Guide Vertebr. Fauna east. Cape Prov. 2:2. Terra typica: Süd-Afrika" (Wermuth & Mertens, 1977: 145).
6. "*Crocodylus niloticus cowiei* (Smith)" with no further details (Wermuth and Fuchs 1978: 67).
7. "*Crocodylus niloticus cowiei* (Smith, 1937)" with no further details (Wermuth and Fuchs 1983: L-306.002.001.006d).
8. "*Crocodylus niloticus cowiei*" with no further details (Charette 1995: dark gray B4).

9. "1937 *Alligator cowiei* A. Smith in Hewitt, Guide Vertebr. Faun. east. Cape Prov. 2:2. - Terra typica: South Africa" (Trutnau and Sommerlad 2006: 498).
10. "*Crocodylus niloticus cowiei* Smith, 1937" with no further details (Fuchs 2006: 109).
11. "*Alligator cowieii* Smith, 1937" with no further details (Species+ web site as recently as November 2013).

Everyone agrees that the taxon is South African, and almost everyone agrees that it is a junior synonym of the Nile crocodile of continental distribution, *Crocodylus niloticus* Laurenti, 1768. Their context indicates that Fuchs (1974) and Wermuth and Fuchs (1978) and Charette (1995) were all following the mistaken Wermuth and Mertens (1961) tradition, as opposed to the correct information from Loveridge (1957). In essence, everything germane after 1957 (i.e. #'s 2-11 above) has been in technical error, but fortunately the functional meaning has always been clearly the same biological animal (Sir Andrew Smith's crocodile taxon). The position in Fuchs (2006) is the most deviant from the norm, because he recognized *Crocodylus suchus* as a species, and therefore his *C. niloticus* species had a distribution that did not include the part of Africa that was his alleged *C. suchus*. The two species of the Nile crocodile hypothesis from Fuchs (2006) has wisely not been followed by the Species+ web site, who correctly list "*Crocodilus suchus* Geoffroy, 1807" as a junior synonym of *Crocodylus niloticus*.

Because Smith (1849) is relatively rare, and because I am unsure if the crocodile text in the appendix of Smith (1849) was included in the reprinting of Smith (1849) with emphasis on the plates in Smith (1977), I will quote the whole entry because it is surely the exact same animal, and because it today belongs in the synonymy of *Alligator cowieii* A. Smith, 1831. Note that although Smith (1831) had originally put his genus *Alligator* in the family Crocodilidae in the order Emydosauri, clearly following Gray (1825) and in agreement with Gray (1831), he later modernized that classification in Smith (1849) by adopting the order Sauria from Duméril and Bibron (1836). Also note that Smith's (1849) "Port Natal" is today Durban, RSA.

The relevant text from Smith's (1849) appendix is as follows. "Sauria. *Crocodilus marginatus*. Geoff. Croc. d'Egypt. page 165. *Crocodilus Vulgaris*, var. C. Dum. et Bib. Erpet. Gener. tom. iii. page 110. Cayman of the Cape Colonists. Specimens are occasionally found in the rivers west of Port Natal, and abundantly in those to the eastwards and northward, and occur in such numbers in a district north of Kurrichane, between 24 degrees and 22 degrees south latitude, that the natives who used to reside there were known by the appellation Baquana - the people of the Crocodile."

In addition to not seeing Smith (1977), I have not seen Hewitt (1937), and my bibliographic entries for these two books are from Branch and Bauer (2005a) and from Pooley (1982a), respectively. It is of no taxonomic importance, but I observe that the Rustenburg (and from it towards Maputo and Durban) crocodile is the population that Anthony (Tony) Charles Pooley (1982b) wrote about in his MSc thesis. Further I stress that Rustenburg and the rivers immediately north of it are in the drainage of the Limpopo River, and additionally I observe that the mouth of the Limpopo is situated midway between Maputo (the capital of Mozambique) and Durban (on the Natal coast). The entirety of Krüger Park is within the range of Smith's (1831) taxon, and so also is the St. Lucia Estuary.

I find it significant that although Pooley (1982c) in 1980 had seen Fuchs *et al*. (1974), he did not follow the 7 subspecies model from 1974, but instead, as he had earlier done in Pooley (1982b), he recognized *Crocodylus niloticus* without any subspecies. This fact suggests to me that Wermuth and Fuchs (1983) acted alone when they declared *Crocodylus niloticus cowieii* to be a CITES regulated taxon, and I further note that Roeper and Hemley (1984), in their 1982 listing "of all Crocodilian Species listed on the U.S. Endangered Species Act (ESA), the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), and the IUCN Red Data Book (RDB)", which included some subspecies in some crocodilian taxa, did not include any subspecies in *Crocodylus niloticus*.

As recently reminisced in Ross (2012), I personally remember those 1974 to 1982 times, and although the Fuchs (1974), Fuchs *et al*. (1974), Wermuth and Mertens (1977) and Wermuth and Fuchs (1978) publications were known about in 1982, there was a conscious and collective decision to ignore them all and to hope that the German subspecies of *C. niloticus* would be somehow forgotten. For example, Charles Ross at the Smithsonian, and Greg Mayer and myself at Harvard, all knew in 1982 that most of the Fuchs (1974) and Fuchs *et al*. (1974) Nile crocodile subspecies names were nomenclatural problems (*cowieii* was the wrong year and publication, chamses had an inappropriately restricted distribution, *africanus* is not an African crocodilian, and *suchus* had an inappropriately restricted distribution). Further, when Mayer attempted to identify the Museum of Comparative Zoology's Nile crocodile collection to the 1974 subspecies by the ventral scale counts in Fuchs *et al*. (1974), the results were very unsatisfactory. Three out of 7 alleged by geography *madagascariensis* worked, zero out of 5 alleged *suchus* worked, zero out of one alleged *pauciscutatus* worked, and zero out of one alleged *africanus* worked. Thus, in his estimation, only 3 out of 14 were correctly identified by their number of ventral transverse rows between the collar and the cloacal disturbance, and the number of scales per row across at mid-belly level.

To its credit, the Species+ website's subspecies category for *C. niloticus* is empty, and I think it should purposefully stay that way until possibly *C. niloticus viridis* from the Senegal River is some day in the future demonstrated to be of practical value. All that the Species+ web site needs to do today is to correct the *Alligator cowieii* A. Smith name's official date of availability to 1831, and thereby correct its literature citation to Smith (1831).

The type description of *Alligator cowieii* and the whole Smith (1831) paper are facsimile reprinted in Branch and Bauer (2005b), and it is helpful to know that his description

of the dorsal scales starts with the post-occipitals, the "scutis nuchae" of Gray (1831), and then proceeds posteriorly to the "upper part of the neck" which is the "scutis cervicalis" of Gray (1831), and today called the nuchals. It is partly to avoid this old "nuchals" versus new "nuchals" dichotomy that I today prefer to call the nuchals of CITES the cervical shield, but even this jargon has problems because "shield" has in the past meant scale or scute, while I am referring to a contiguous and continuous amalgamation or cluster of individual scales or scutes. Also, when Smith (1831) said "back with eight longitudinal rows of carinated scutae", his technical untruth was similar to that in John Edward Gray's characterization of the carapace on *Crocodylus porosus* as "the back has eight rows of oval plates" (Gray, 1831). We know today that the carapace on the trunk narrows in the thoracic and pelvic regions to fewer than 8 scales across, and thus Smith (1831) meant 8 scales across at the widest transverse level across the "back" of this animal.

Regardless of whether Smith (1831) had read Gray (1825, 1831) or not, I consider his *Alligator cowieii* to have been named in a constructive and well-intentioned way that was presented in the style of his time. He did not distinguish his new taxon from its nearest relatives, as the Code of Zoological Nomenclature demands today, but Smith (1831) was published before this requirement became official. However, to his credit, he did tell us something about the animal's physical appearance, and it is only subjectively that today I consider his description to match *C. niloticus*.

The binomen *Alligator cowieii* A. Smith, 1831, was overlooked for such a long time that some would consider it to be an officially forgotten name, but under the circumstances that Loveridge (1957) listed it, and that it later became regulated by CITES in 1983 and 1995 as the *Crocodylus niloticus cowieii* subspecies, it is impossible to ignore it today. It is possible that there was no local crocodile material in Cape Town in 1831, and that thus this type description was based entirely on observations made in the field. In either case, the exact place where the crocodile(s) lived in the wild is unknown, but within his defined region. It could likely have been Rustenburg, but not necessarily. Nonetheless, the treatment in Loveridge (1957) is confidently recommended.

Relatedly, I congratulate and thank the editor(s) of the Crocodylia Loveridge, 1946, section in the IUCN-SSC Species+ list, because there is no *Crocodylus niloticus africanus* from Fuchs (1974), Fuchs *et al*. (1974), Wermuth and Mertens (1977), Wermuth and Fuchs (1978, 1983), Charette (1995), Trutnau and Sommerlad (2006) or Fuchs (2006) in the correctly empty subspecies category. Additionally and also correctly, there is no *Crocodylus africanus* Laurenti, 1768, entry in the synonyms category. For reasons explained in Ross (2006), it is today okay to purposefully delete and omit *C. africanus* from the Crocodylia and explicitly from the synonymy of *C. niloticus* Laurenti, 1768, because none of the three pictures that form its basis are identifiable as African animals, and further they all look like lizards to me. Alternatively, Loveridge (1957) included this old name in his Nile crocodile synonymy as follows: "1768. *Crocodylus africanus* Laurenti (part; with part lizard, so unidentifiable), Syn. Rept., p. 54: No locality."

It will be helpful for people searching the South African Museum in Cape Town for the holotype or syntypes of *Alligator cowieii* to know that later than 1831, he donated three crocodiles and two skeletons of crocodiles collected during his 1834 expedition and reported in 1836, and further that Smith killed at least one large crocodile "inhabiting the principal rivers beyond Kurrichane" during that same 1834 expedition (Branch and Bauer 2005a). Thus, there could be crocodile specimen(s) in the South African Museum that were collected at Rustenburg by Smith, but were not yet individually known to him in 1831. If so, such topotypes are of special importance to zoological nomenclature, and the individual(s) should be safeguarded for possible (if needed) neotype designation.

In addition to Rustenburg (and north of it), I would also consider crocodiles from Pretoria (and north of it) to be topotypes, because both cities are near tributaries of the Crocodile River, which is a tributary of the "grey-green greasy Limpopo River" where Rudyard Kipling's elephant's child inquisitively went in its quest to find out what the crocodile eats for lunch. The route that it followed ("He went from Graham's Town to Kimberley, and from Kimberley to Khama's Country, and from Khama's Country he went east by north, eating melons all the time, till at last he came to the banks of the grey-green greasy Limpopo") is purely South African, and Sir Andrew Smith's crocodile fits the description. It is an iconic (for intelligence, cunning and dangerousness) reptile.

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