

# CROCODILE SPECIALIST GROUP NEWSLETTER

VOLUME 33 No. 1 • JANUARY 2014 - MARCH 2014



# CROCODILE

# SPECIALIST

# GROUP

# NEWSLETTER

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VOLUME 33 Number 1  
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IUCN - Species Survival Commission

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**CHAIRMAN:**

Professor Grahame Webb  
PO Box 530, Karama, NT 0813, Australia

**EDITORIAL AND EXECUTIVE OFFICE:**

PO Box 530, Karama, NT 0813, Australia

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**COVER PHOTOGRAPH:** Karin Ebey (10 y), long-time donor to the Crocodile Specialist Group, designed a calendar for 2014, depicting 12 species of crocodilian. This issue's cover shows some of Karin's drawings.

[You can download Karin's calendar at [www.iucncsg.org](http://www.iucncsg.org)].

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**EDITORIAL POLICY:** All news on crocodilian conservation, research, management, captive propagation, trade, laws and regulations is welcome. Photographs and other graphic materials are particularly welcome. Information is usually published, as submitted, over the author's name and mailing address. The editors also extract material from correspondence or other sources and these items are attributed to the source. If inaccuracies do appear, please call them to the attention of the editors so that corrections can be published in later issues. The opinions expressed herein are those of the individuals identified and are not the opinions of CSG, the SSC or the IUCN unless so indicated.

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The CSG Newsletter is produced and distributed by the Crocodile Specialist Group of the Species Survival Commission (SSC) of the IUCN (International Union for Conservation of Nature).

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.

The CSG Newsletter is available as:

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CSG Executive Office, P.O. Box 530, Karama, NT 0813, Australia.  
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We thank all patrons who have donated to the CSG and its conservation program over many years, and especially to donors in 2013-2014 (listed below).

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East Coast Zoological Society (Brevard Zoo), FL, USA.

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Crocodile Park, Malaga, Spain.

Vic Mercado, Microlab, Philippines.

The Ebey family, New Mexico, USA.

Nao Thouk, Phnom Penh, Cambodia.

Marco Schultz, Germany.

## Editorial

Once again it is very saddening to learn of the passing of two of our well-respected CSG members. Dr. Fritz Huchzermeyer was known to most CSG members, and was one of the world’s leading crocodylian veterinarians (see pages 4-5). His book “Crocodiles: Biology, Husbandry and Diseases” remains a pivotal and classic reference source. He was just a great guy, always willing to help anyone who asked for his advice. Dr. Peter McInnes was another great guy. He was particularly well known in Australia, where for 20 years he was a research manager with the Rural Industries Research and Development Corporation (RIRDC), one of the only organisations funding research on crocodile farming. The CSG is one of the larger Specialist Groups within the SSC, but I suspect one with some of the oldest members! We really need to encourage new and younger members, which is what our Student Research Assistance Scheme (SRAS; <http://www.iucncsg.org/pages/General-Information.html>) is all about.

In early March I wrote to Mr. John Scanlon, Secretary General of CITES, regarding compliance issues with *Caiman c. fuscus* farming in Colombia. These issues were raised by the CITES Standing Committee. For the last 20 years, the CSG has been well aware that compliance with Colombia’s national legislation had been an ongoing problem. Skins from wild caimans, especially adults in which the flanks are valuable, are simply trimmed to meet the prescribed size limits. There is no basis for those prescribed limits, which are in direct contradiction to the hard scientific data available. Large wild-caught caimans have been exported continually and in large numbers. This does not constitute a conservation problem as such, because the high biological productivity of *C. c. fuscus* may compensate for the harvest. However,

it is a CITES compliance problem, because taking animals from the wild is in direct contravention of Colombian law. The good news is that the Colombian CITES Management Authority, working with the regions and farms, are doing farm audits with a view to identifying and shutting down illegal producers and traders. In the opinion of the CSG, now is the time for the CITES Secretariat to assist the Colombian CITES Management Authority to clean up what has become a messy compliance issue.

The Christmas CrocFest 2013, a fundraiser for crocodylian conservation, took place in December 2013 at Shawn and Jen Heflick’s facility in Palm Bay, Florida, USA, and raised \$US15,000. Together with the Summer CrocFest (June 2013), these events have raised a total of \$US26,000, which on the basis of a lot of discussion and action by CSG members, will go to *Crocodylus acutus* conservation and management in Jamaica (see pages 7-8).

On 24-25 April 2014 the Executive Officer and I will attend a “Siamese Crocodile Conservation and Husbandry Meeting” and a “Siamese Crocodile Task Force Meeting”, to be held again at Mahidol University, Bangkok, Thailand. We are hoping for further constructive discussion of the CITES-related issues on *Crocodylus siamensis* utilisation within the East and Southeast Asian region that were identified at the regional *C. siamensis* meeting in April 2011.

The “2nd Symposium on Colombian Crocodylians”, with the theme of “Crocodylian Conservation - An Opportunity for Communities” will be held on 2 December 2014, under the auspices of the “5th Colombian Congress of Zoology” (1-5 December 2014), in Cartagena, Colombia. An invitation containing information can be downloaded from the homepage of the CSG website ([www.iucncsg.org](http://www.iucncsg.org)). People can contact the symposium organisers ([simposiococodrilos@gmail.com](mailto:simposiococodrilos@gmail.com)) for any additional details.

The 27th meeting of the CITES Animals Committee will be held in Veracruz, Mexico, from 28 April to 3 May 2014. As usual, a few CSG members will be present in different capacities. Mexico is hosting a side meeting to discuss some aspects of its *Crocodylus moreletii* management program, and a Swiss NGO called RESP will be presenting its ideas about trade in crocodylian skins. It is important that all CSG members, from industry to science, are fully aware that there is no formal link between the CSG and RESP. The ideas expressed by RESP, to date, do not reflect in any way the opinions of the CSG.

In terms of global issues concerning conservation, management and trade in world crocodylians, let me again stress the importance of the 23rd Working Meeting of the CSG (McNeese University, Lake Charles, Louisiana, USA; 26-30 May 2014), to be held 3 weeks after the CITES Animals Committee meeting. It promises to be one of the biggest working meetings of the CSG yet held. I urge all CSG members and others interested in crocodylian conservation and trade to register and book accommodation as soon as possible ([www.CSG2014louisiana.com](http://www.CSG2014louisiana.com)).

Lastly, I am happy to announce that my new book *Wildlife Conservation: In the Belly of the Beast* (see page 6) has been published by Charles Darwin University Press. Some 11 years in development, and containing many of the cartoons I have used in different lectures and talks, this book presents many of the ideas discussed with various CSG members over many years. It has so far attracted some great reviews from some eminent wildlife management practitioners, so hopefully, it will do some good! For me ... I'm just glad it is finished.

Professor Grahame Webb, CSG Chairman.

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## Obituary

**Fritz Huchzermeyer**

(12 January 1930 - 3 March 2014)



Fritz Huchzermeyer lived a rich 84 years, touched by a wide range of stimulating people sharing his curiosity and creativity. Fritz loved science and knowledge, but also enjoyed painting, sketching, sculpting, cooking, blowing the trumpet, writing and running. Beside his contribution to Veterinary Science, he has left many rich memories plus an archive ranging from Comrades Marathon silver medals (long-distance running) to poetry collections and colourful abstract paintings. The latter, he enjoyed having around him in the so-called 'gallery', his short-lived home in the German Old Age Home in Pretoria until 3 March 2014.

Fritz had an interesting and adventurous childhood on his father's small-holding near Herford in Germany. His teenage years were marked by World War II with all its threats and dark shadows. During studies in theology in Vienna, he fell

in love with Hildegard, whom he had asked to type up an assignment. A change in academic direction was followed by marriage, and soon Hildegard joined him in the study of Veterinary Science at the University of Hanover. Here they were surrounded by a circle of family and of individualistic, open-minded and international friends and fellow students. As a student in post-war Germany, Fritz was a co-founder of the FIBIS (Frei Internationaler Bund Individualistischer Studenten). A close-knit life-long friendship with diverse fellow students and later colleagues continues to this day. The shared ideals of this group were celebrated in later years by annual reunions, one of which was hosted by Fritz and Hildegard in 2005.

Life revolved around an ever-growing collection of books. As a young boy Fritz enjoyed learning classical languages, and as a Theology student in Vienna became proficient in Latin, Greek and Hebrew. French was learnt during an exchange year in Paris where both he and Hildegard studied at the Ecole Veterinaire Maisons Alfort. Later in life he learnt Spanish and Guarani, the official languages of Paraguay. The diverse languages were represented in the collection of books he read. As many guests will remember, time between supper and going to sleep was reserved for reading and he was not to be disturbed.

Open to adventure Fritz accepted a posting to the then Rhodesia (Zimbabwe) as field veterinarian for Her Majesty's Service during 1963. Fritz moved his young family, which by now included David, to Gweru in Rhodesia, with Hildegard expecting their second child, Philippa. Further moves were made to Buluwayo and then Salisbury (now Harare), where Marie was born. Fritz followed his leisure-time interests during 10 happy years on a small holding in Welston outside Salisbury, while working as Poultry Specialist for the Veterinary Laboratory in Causeway. Many new and interesting people joined the ever-growing number of close friends. Unfortunately, the untenable security in Rhodesia led to a reluctant move to South Africa in 1975.

In 1975 Fritz took up a senior lecturer post in Poultry Diseases at the Faculty of Veterinary Science at the University of Pretoria, South Africa. Hildegard became his colleague across the road at the Onderstepoort Veterinary Institute (OVI). Refuge from the segregated and regulated South African society was found on a beautiful thornveld small-holding in Buffeldrift with many unconventional pets and in a growing collection of books in the various languages mastered by Fritz. From senior lecturer in Poultry Diseases at the Faculty of Veterinary Science, Fritz moved over to the OVI where he led the Poultry Section until its closure.

In 1980 the family spent a year working at the Veterinary Faculty in Asuncion as part of a technical exchange between South Africa and Paraguay. This was at the height of Fritz's marathon running. Always looking for new challenges, he transferred his extensive experience in fitness training to swimming. He crossed the Lago Ypacarai in Paraguay, a distance of several kilometres, swimming non-stop for 6 hours, accompanied by his daughter, Philippa, for most of the



way. In South Africa he ran 6 Comrades Marathons (distance: 90 km) and won 5 silver medals and one bronze, as well as a host of other marathons, some run with his faithful canine running companion, Steffy. Ultimately it was the Washy 100 mile race from Port Alfred to Port Elizabeth that concluded his running career at the age of 54. He finished in 17th place out of the 60 runners who completed the marathon.

A move from the Poultry Section to the Pathology Section at the OVI allowed him to follow his interest in ostrich and crocodile diseases - interests he had developed while in Rhodesia. In this time he wrote and published the first authoritative book on the diseases of ostriches. After retiring from the OVI in 1995 he completed his PhD on malaria in game birds, a project that had occupied him for a number of years.

He continued his work on ostriches and crocodiles, and soon wrote and published the first authoritative book on crocodilian diseases. Fritz chaired the Veterinary Science Group of the IUCN-SSC Crocodile Specialist Group for many years. This was particularly dear to him and his close contact with this special group of friends continued up to the time of his death. Fritz traveled the world until recently. He remained much sought after as crocodile and ostrich specialist, writing and publishing authoritative texts and being invited by farmers and associations around the world (particularly as chair of the CSG's Veterinary Science Group).

Fritz's adventures studying crocodiles in remote regions were numerous. But his one particular interest was the Dwarf crocodile (*Osteolaemus tetraspis*). To study this species he traveled to remote regions of the Republic of Congo. One such trip in 1994 involved an 11-day crossing of the uninhabited and uncharted Likouala Swamp, on foot. At 64 he was the oldest member of that expedition. On a subsequent journey to study Congo Dwarf crocodiles he was caught in the north-east of Congo at the outbreak of civil war. Three weeks later he emerged in Cameroon, stranded, with no money and no air ticket. He had hidden with American researchers in the Nouabale-Ndoki Nature Reserve. Eventually he was flown out by a logging company to Cameroon. His grandchildren, to whom he has been a huge inspiration, loved hearing the detail of this and his many other adventures.

More recently Fritz was involved with several paleontology projects that drew on his anatomical knowledge of birds and reptiles and his interest in fossils and evolution. As co-author with a team of Chinese researchers he was proud to see this work published in the prestigious Nature journal. Fritz continued his research at the Pathology Section of the Faculty of Veterinary Science, University of Pretoria, as an extraordinary lecturer until just before his death. He shared his extensive knowledge, and his enquiring mind drew collaborations with many colleagues. This provided the most fulfilling years of his career and he was still actively involved until two months before his death when he handed his accumulated collections over to colleagues at the Faculty of Veterinary Science, University of Pretoria, whom he had mentored.

Tortoises and other interesting animals were part of his home life, and these featured in his most pleasant dreams. He has left us a rich legacy of family history, scientific knowledge and cherished memories.

The following poem was written by Fritz during the CSG working meeting held in Montélimar, France, in June 2006.

To the Sacred Crocodiles of Burkina Faso

Feared and ferocious predator what is it  
That you can live in harmony with man  
When you are sacred and revered  
And when you are accepted as an equal  
That even when your lake is dry  
The villagers will share their home with you?

We know already that you are a gentle parent  
And yet it is so difficult to understand  
Your very motions and emotions  
We cannot read expressions in your face  
And only barely in your voice  
In our ignorance we will behave  
So much more brutally than you

It is my dream that all of us  
Could live in harmony with all the crocodiles  
As is the case in a small part  
Of Africa.

Robert Chabreck's obituary appeared in the previous Newsletter [32(4)], and since then Ruth Elsey has uncovered some old photos of Bob and colleagues. Thanks Ruth.



Bob Chabreck (far left), and colleagues. Photograph: LDWF.



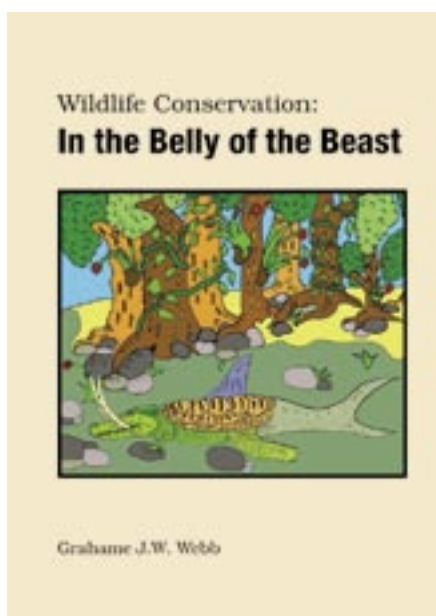
Bob Chabreck (l) and Ted Joanan (r). Photograph: LDWF.



“Notching” an alligator, with Bob Chabreck (left) recording.  
Photograph: LDWF.

## Book Review

### Wildlife Conservation: In the Belly of the Beast



CSG Chairman Grahame Webb's new book, *Wildlife Conservation: In the Belly of the Beast* breaks new ground in our understanding of wildlife conservation - locally, nationally and internationally.

Published by Charles Darwin University Press, the book comprises 45 chapters (342 pages) that are a journey into the heart of wildlife conservation - seen and told by someone who has “been there and done it”. The book is easy to read and illustrated with 87 of Grahame Webb's original cartoons - challenging convention in their own right - and 30 photographs, it is a handsome colour volume on high quality paper.

Grahame Webb is well known for his pioneering work on crocodile conservation and research around the world, but he is equally respected internationally for his contribution to the role of sustainable use in conservation. He has been personally involved with some of the world's most controversial conservation issues (whales, elephants, sea

turtles, seals, fisheries, sharks, snakes and more), and with the people and organisations championing all sides of the highly charged debates.

The book starts by establishing some simple rules about what is and what is not wildlife conservation, and then examines the critical role that knowledge has and should play in conservation - despite it being eroded and threatened continually by “biopolitics”.

The crocodile case histories (3 chapters) examine conservation and management at local, national and international levels. Risk and uncertainty have been the constant companions of crocodilian conservation and management, and boldness and adaptive management have been the two great pillars of success.

Scrutiny of some of the major wildlife conservation battlegrounds around the world highlights the uneasy interplay that often exists between science and politics. In some cases, efforts to enhance conservation have simply failed!

The key players and perceptions in conservation are examined with probing insights into the assumptions that many in the public accept somewhat uncritically. The gulf between rural and urban people over wildlife values is getting bigger and bigger, for the wrong reasons.

Rare insights into the underbelly of wildlife conservation come from examining the international arenas within which wildlife conservation battles are fought, and the strategies used within them by opposing sides. Pivotal in these conflicts is the role of the media, which can either fuel conflict or help build learning ... and bridges.

Lastly, the lessons and frustrations encountered along the way have some common causes. “Righting the Wrongs” (3 chapters), examine how to be more vigilant about spin and hype, and look more carefully at the real problems at hand. These are often “wicked problems”, with so many interacting variables, that simple solutions rarely work. Regardless, if we heed the many messages in this book, the “way forward” will be better than the “way back”.

Amongst the many positive reviews, ex-CSG Chairman Emeritus Professor Harry Messel recommends that it “should be compulsory reading for every member of the IUCN's Species Survival Commission, every delegate to CITES and all NGOs working with wildlife conservation”.

“The Beast”, as Grahame Webb sees it, is the real world of wildlife conservation, as distinct from the sanitised view to which the public is often exposed. His main goal in writing the book was to “stimulate others to think in more depth about conservation”, and there is little doubt that this has been achieved.

Order forms for the book are available at: [www.crocodyluspark.com.au/pages/Wildlife-Conservation-%252d-In-the-Belly-of-the-Beast.html](http://www.crocodyluspark.com.au/pages/Wildlife-Conservation-%252d-In-the-Belly-of-the-Beast.html).



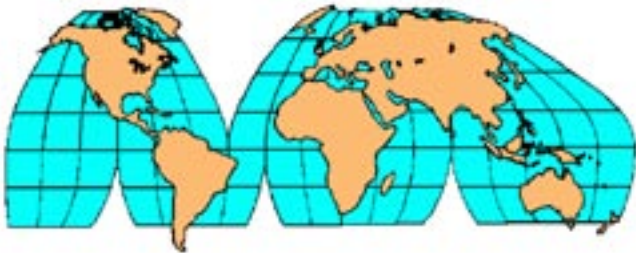
## CSG Student Research Assistance Scheme Update

The CSG Student Research Assistance Scheme (SRAS; <http://www.iucncsg.org/pages/General-Information.html>) provided funding to three students in the January-March 2014 quarter. Three further applications are under consideration.

1. Jazmin Bauso (Argentina): Presence of *Leptospirosis* in *Caiman latirostris* populations.
2. Andre Costa Pereira (Brazil): Population study and investigation of human pressures and hunting of crocodilians in Tocantins, Brazil.
3. Giovany Gonzales-Desales (Mexico): Nesting ecology of *Caiman crocodilus* in the Biosphere Reserve Crossroads, Mexico.

Tom Dacey, CSG Executive Officer, <[csg@wmi.com.au](mailto:csg@wmi.com.au)>.

## Regional Reports



### North America

CHRISTMAS CROCFEST 2013 RAISES ANOTHER \$15,000 FOR JAMAICAN CROCODILE CONSERVATION. Christmas CrocFest 2013, a fundraiser for crocodilian conservation, took place on 7 December 2013 at Shawn and Jen Heflick's facility in Palm Bay, Florida, USA, and raised \$US15,000 for Jamaican crocodiles, *Crocodylus acutus*. Summer CrocFest and Christmas CrocFest are annual, grass-roots fundraisers supported by private individuals, businesses, and zoos, all with a common interest in conserving crocodilians. The funds raised from Summer CrocFest (June 2013) and Christmas CrocFest in December totalled \$US26,000, all of which benefit American crocodiles in Jamaica. These funds have been transferred to the Caribbean Wildlife Alliance based in Fort Worth, Texas, and are being distributed to support population studies, nest site enhancement, and education. Jamaican crocodiles are facing increased persecution from development and direct killing for food. Conservation intervention is desperately needed if this population is to remain on Jamaica.

CrocFests have evolved into family-friendly events. Christmas CrocFest 2013 attracted nearly 200 attendees who were treated to live animal displays and presentations (courtesy of Gator Adventure Productions), BBQ (prepared fresh, on

site), open bar, fishing, kayaking, and a rousing live auction conducted by Shawn Heflick. Event-goers were also treated to a tour of Shawn's lab, where scenes in episodes of Nat Geo Wild's Python Hunters have been filmed.

Rapport between Shawn and the audience made for a very entertaining and profitable live auction. Everyone enjoyed great food and camaraderie while bidding on unique items, including an impressive 84 cm (33") replica of an American crocodile skull, courtesy of Live Auction sponsor, Bone Clones, Inc. Many other items were donated by zoos, businesses and individuals from around the country and beyond.



Dinner time!



Alligator demonstration.



Auctioneer at work.

We would like to express our appreciation to our corporate sponsors (Ship Your Reptiles/The Reptile Report, Canadian Reptile Breeders Expo, Bone Clones Inc., Gator Adventure Productions, Crocodile Manor, ZooMed). Without their support, we could not easily sustain the growth this event has enjoyed over the past two years.

We also want to thank all of the individuals, businesses and zoos that supported this fundraising event, including but not limited to: Shawn and Jen Heflick, Flavio Morrissiey, Curt Harbsmeier, Colette Adams, Megan Terry, Ty Park, Chicago Herpetological Society, Swamp Men: Cattail and OneBear, Kevin Earley, Mike Mangine, Devyn Cummings, Sam and Rae Heflick, Brent Fannin, Kimi Halloran, Paul Bodnar, Penny Felski, Norman Benoit, Bill Ziegler, Joe Wasilewski, Emily Maple, Randal Berry, Florida Python Hunters, Michael Dee, Luis Caraballo, Candace Donato, Steve Featherstone, Patrick Delaney (FWC), Chuck Schaffer, Indigenous Arts (David Kledzik Arts), John Than, Greg Lepera, Andy Daneault, Marty Penny, Lonnie McCaskill, Russ Johnson, Josh Walton, Gold Coast Reptiles (Craig Tillem), Chris Gillette, Ashley Lawrence, Ernie and Nancy Little, John and Cindy Johnson, Dr. O's Tie Dyed Chameleons, Zach Cooney, Morgan Cooney, Ron Stigall, Matt Stigall, Rob Art, Russell Lawson, Bruce Shwedick, Angelique Adams, Carolyn Hutchins Claws, Paws & Jaws, Tara Byers, Trey Davis, BAAZK (Arica O'Sullivan), Jim Murphy, Wildlife Discovery Center (Rob Carmichael), The Florida Aquarium (John Than), Zoos Victoria/Melbourne Zoo (Chris Banks), Lion Country Safari (Terry Wolfe), Virginia Zoo, Zoo Miami (Steve Conners), Virginia Aquarium (Mark Swingle/Chip Harshaw), Ellen Trout Zoo & FOETZ (Gordon Henley), Black Hills Reptile Gardens (Terry Phillip), Central Florida Zoo (Joe Montesano), Florida Association of Zoos & Aquariums, Tampa's Lowry Park Zoo (Larry Kilmar), Busch Gardens (Mike Malden), Zoo Atlanta (Dwight Lawson), Palm Beach Zoo at Dreher Park (Emily Maple), Zoological Society of Trinidad & Tobago (John Seyjagat).

## **Australia and Oceania**

### **Australia**

**INGESTION OF A FOREIGN OBJECT BY A JUVENILE SALTWATER CROCODILE.** On 10 February 2014 the Queensland Department of Environment and Heritage Protection captured a 1.39 m male Saltwater crocodile (*Crocodylus porosus*). The animal was caught using a noose in close proximity to a boat ramp at Blackfellow Creek, near Edmonton, Cairns, in Far North Queensland.

During the capture, wildlife rangers observed an object lodged inside the mouth of the crocodile (Fig. 1). The object, a rubber ball (55 mm diameter), was lodged between the bottom jaw. The ball was successfully removed by the rangers, however it appeared to have caused some abrasion and necrosis on the roof of the animal's mouth and along its tongue (Fig. 2).

The crocodile weighed 6.1 kg, appeared malnourished and

with poor body condition (a wild crocodile of this length would be expected to be around 8-9 kg). It appears that the ball had impacted on the crocodile's ability to successfully hunt and feed, which could explain why it had been persistent around the boat ramp where discarded bait and fish are often observed. This case further highlights the impact of ingestion of foreign objects and litter within the crocodile's natural environment.

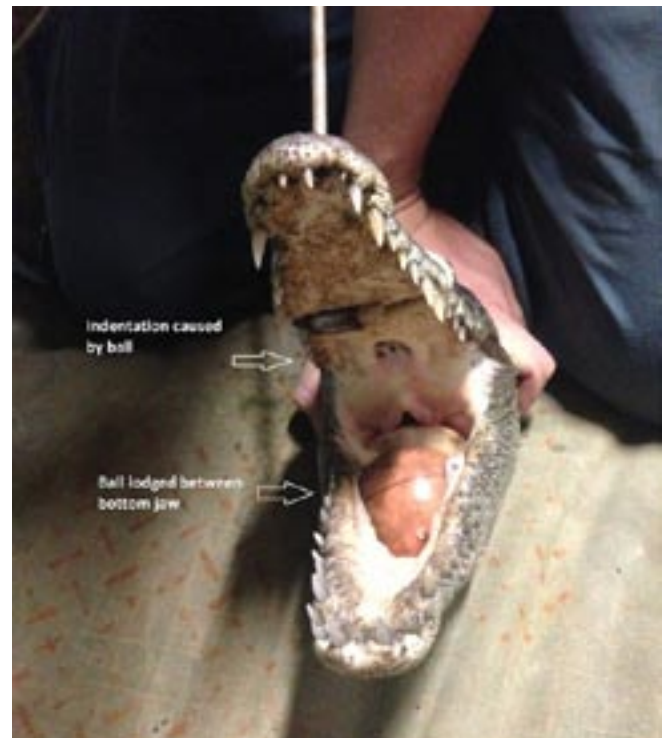


Figure 1. Rubber ball lodged in bottom jaw.



Figure 2. Indent on tongue where rubber ball was lodged. ball lodged in bottom jaw.

T. Lawton and J. van der Reijden, 38-40 Tingira Street, Cairns, Queensland 4870, Australia.

**ATTACK CONSIDERED A CASE OF MISTAKEN IDENTITY.** An 8-year-old girl swimming with her parents at Geikie Gorge in the central Kimberley, Western Australia, in November 2013, was bitten on the leg by an Australian Freshwater crocodile (*Crocodylus johnstoni*). The girl was not



seriously injured, and WA Department of Parks and Wildlife staff consider the attack a case of mistaken identity. There are no plans to trap or kill the crocodile.

Source: *Freshwater croc bite a case of 'mistaken identity'*, ABC News, 7 November 2013.

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## **East and South Africa**

### **South Africa**

NATIONAL EXOTIC LEATHER CLUSTER (NELC) LAUNCHED. On 17 October 2013 the South African Department of Trade and Industry formally approved support for the formation of the National Exotic Leather Cluster (NELC). This follows more than two years of research, analysis and collaborative input from Government, the University of Pretoria and the Exotic Leather Industry.

Financial support for NELC is anticipated to come from Government over the next 5 years, with activities aimed at establishing a sustainable, world class exotic leather industry in South Africa. Specifically, these activities will aim to overcome challenges facing the domestic exotic leather industry and to exploit the opportunities presented by the growth in the international luxury market. Although crocodile leather will be the initial focus, ostrich and exotic leathers will follow. NELC aims to develop strategies promoting South Africa as a source of both raw and tanned exotic leather and leather products.

Source: *Adapted from press release on Cape Cobra Leathercraft website (www.capecobra.co.za/establishment-of-nelc), authored by Stefan van As, CEO, Le Croc Pty. Ltd., and Chairman, NELC.*

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## **East and Southeast Asia**

### **Vietnam**

A HISTORICAL PHOTOGRAPHIC RECORD OF *CROCODYLUS POROSUS* FROM THE MEKONG DELTA OF VIETNAM. Two species of crocodile historically occurred in Vietnam; the Siamese crocodile (*Crocodylus siamensis*) which inhabited freshwater wetlands from the Mekong Delta northwards into the Central Highlands, and the Saltwater crocodile (*C. porosus*) which was restricted to the Mekong Delta and several offshore islands (Thorbjarnarson 1992; Cuc 1994; Cao and Jenkins 1998). To our knowledge, there are few verifiable records of wild *C. siamensis* or *C. porosus* from Vietnam, and consequently the historic distribution of both species within the country remains ill-defined. Because wild populations of *C. siamensis* and *C. porosus* are extinct or nearly so in Vietnam, and reintroduction has been recommended as a potential management strategy for both species (Simpson and Bezuijen 2010; Webb *et al.* 2010),

reconstructing past geographic distributions is important for establishing conservation priorities (Stangl and Young 2011).

To that end, we present a hitherto over-looked photographic record of *C. porosus* from the Mekong River delta of southern Vietnam. The Mekong Delta is one of the largest river deltas in the world, draining a catchment area that includes parts of Tibet, China, Myanmar, Thailand, Laos, Cambodia, and Vietnam (Osborne 2000). Although the delta is now largely converted to rice-fields, the region was formerly characterized by extensive seasonally and permanently inundated wetland habitats that included peat swamp, flooded grasslands, swamp forest, and mangroves (Kiet 1994; Biggs 2011).

The photo-record was found in a book authored by Jimmy R. Bryant (1998), which describes his wartime experiences in Vietnam during 1968-69. Bryant served aboard a U.S. Navy patrol boat operating as part of Task Force 116 (Operation Game Warden; Cutler 1988), assigned to patrol the Mekong Delta with the objectives of interdicting the flow of enemy supplies and combating Vietnamese Communist (Viet Cong) forces (Bryant 1998). On page 185, a small juvenile crocodile is pictured sitting atop a case of military rations (Fig. 1). The caption below the photograph reads "A baby crocodile one of our guys came up with. We kept him a couple of days, but he would not eat our c-rations [pre-packaged military food] so we had to let him go." The photograph is credited to Darryl C. Hutchinson, a crew-member serving on the same patrol boat as Bryant.



Figure 1. Hatchling Saltwater crocodile (*Crocodylus porosus*) photographed in the Mekong Delta of southern Vietnam during the late 1960s by crewmen of a United States Navy river patrol boat. Photograph reproduced from Bryant (1998).

No mention is made of this crocodile in the text and the circumstances surrounding its capture are unknown. Because Bryant was involved in extended combat operations in the delta south of Saigon (now Ho Chi Minh City) as well as the Plain of Reeds near the Cambodian border, the crocodile most likely originated from one of these areas. Although *C. siamensis* and *C. porosus* are thought to have occurred sympatrically in the Mekong Delta (Stuart *et al.* 2002), when the photograph is enlarged, the absence of post-occipital scales indicates the crocodile is most likely *C. porosus* (Brazaitis

1973). The small body size (TL ca. 40-45 cm) of the pictured crocodile suggests it is less than one year of age.

Bryant (1998) makes further mention of crocodiles in the Mekong Delta on page 67. While conducting a patrol near the confluence of the Dong Tranh and Long Tao Rivers, Bryant came upon an elderly villager with a dead crocodile estimated to be 12 feet (3.65 m) long lashed to the side of a small sampan. Bryant and his crew assisted the villager with skinning and dismembering of the carcass, which was presumably destined for human consumption. Bryant also states that a fellow crewman claimed to have tossed a concussion grenade at a “large crocodile” but was unable to determine if the animal had been killed.

Because *C. porosus* can attain lengths up to 6 m, while *C. siamensis* rarely exceed 3 m (see Platt *et al.* 2006), the estimated body size of the dead crocodile suggests the former. However, distinguishing the two species solely on the basis of body size is problematic as adult male *C. siamensis* occasionally reach lengths of 4 m (Thorbjarnarson 1992). Moreover, there is no way to assess the accuracy of the size estimate given by Bryant. The account was written many years after Bryant returned from Vietnam, and Magnusson (1983) convincingly demonstrated that even size estimates made by trained biologists while capturing crocodiles are subject to considerable error. While the identity of neither crocodile mentioned on page 67 can be reliably established, together these anecdotes suggest that crocodiles remained fairly common in the Mekong Delta during the late 1960s. Furthermore, the juvenile *C. porosus* pictured in the book provides unequivocal evidence that reproduction was occurring among Saltwater crocodiles in the Mekong Delta during the same period.

Extant wild populations of *C. porosus* (or *C. siamensis*) apparently no longer remain in the Mekong Delta, although the timing of this extinction remains an open question (Webb *et al.* 2010). According to Cuc (1994), only 100 *C. porosus* survived in the Mekong Delta by the late 1940s, but the anecdotal evidence provided by Bryant (1998) suggests this estimate was unreasonably low. Cao and Jenkins (1998) claimed that as late as the mid-1990s, about 100 *C. porosus* persisted in the U Minh Thuong Swamp; however, after surveying the area Stuart *et al.* (2002) concluded this population was almost certainly driven to extinction by the 1970s. Webb *et al.* (2010) considered it likely that *C. porosus* persisted in the Mekong Delta until about 10-20 years ago. The extinction of *C. porosus* in the Mekong Delta is attributed to habitat destruction resulting from the conversion of natural wetlands to agricultural lands, commercial skin hunting, and direct persecution where crocodiles were perceived as a threat to humans and livestock (Cuc 1994; Cao and Jenkins 1998; Stuart *et al.* 2002; Webb *et al.* 2010). The widespread application of military defoliants during the Vietnam War undoubtedly hastened the demise of *C. porosus* by destroying significant areas of mangrove forest in the lower Mekong Delta (National Academy of Sciences 1974).

In conclusion, the photograph provided by Bryant (1998) represents one of the few verifiable records of *C. porosus* from anywhere in Vietnam, and underscores the value of non-traditional data sources in reconstructing historic baseline conditions (eg Kay *et al.* 2000; McClenachan 2009; Bezuijen and Engelmann 2011). Indeed, non-traditional data sources such as historic photographs, journals, and travelogues are an under-utilized source of information that warrant increased attention by those involved in the study of wildlife biology, ecology, and conservation.

#### Acknowledgements

We thank Madeline Thompson for assistance in locating several obscure literature references, Adam Britton for confirming our identification of *C. porosus*, and Lewis Medlock for commenting on an early draft of this manuscript. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the United States Fish and Wildlife Service.

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Steven G. Platt (*Wildlife Conservation Society-Myanmar Program, Office Block C-1, Aye Yeik Mon 1st Street, Hlaing Township, Yangon, Myanmar; sgplatt@gmail.com*), Thomas R. Rainwater (*U.S. Fish and Wildlife Service, South Carolina Field Office, 176 Croghan Spur Road, Charleston, South Carolina, 29407, USA; trrainwater@gmail.com*) and Brandon Sideleau (*2900 Bayham Circle, Thousand Oaks, California, 91362, USA; BSideleau@gmail.com*).

## Science



### Recent Publications

Molnar, J.L., Pierce, S.E. and Hutchinson, J.R. (2013). An experimental and morphometric test of the relationship between vertebral morphology and joint stiffness in Nile crocodiles (*Crocodylus niloticus*). *Journal of Experimental Biology* 217: 758-768.

Abstract: Despite their semi-aquatic mode of life, modern crocodylians use a wide range of terrestrial locomotor behaviours, including asymmetrical gaits otherwise only found in mammals. The key to these diverse abilities may lie in the axial skeleton. Correlations between vertebral morphology and both intervertebral joint stiffness and locomotor behaviour have been found in other animals, but the vertebral mechanics of crocodylians have not yet been experimentally and quantitatively tested. We measured the passive mechanics and morphology of the thoracolumbar vertebral column in *Crocodylus niloticus* in order to validate a method to infer intervertebral joint stiffness based on morphology. Passive stiffness of eight thoracic and lumbar joints was tested in dorsal extension, ventral flexion and mediolateral flexion using cadaveric specimens. Fifteen measurements that we deemed to be potential correlates of stiffness were taken from each vertebra and statistically tested for correlation with joint stiffness. We found that the vertebral column of *C. niloticus* is stiffer in dorsoventral flexion than in lateral flexion and, in contrast to that of many mammals, shows an increase in joint stiffness in the lumbar region. Our findings suggest that the role of the axial column in crocodylian locomotion may be functionally different from that in mammals, even during analogous gaits. A moderate proportion of variation in joint stiffness ( $R^2=0.279-0.520$ ) was predicted by centrum width and height, neural spine angle and lamina width. These results support the possible utility of some vertebral morphometrics in predicting mechanical properties of the vertebral column in crocodiles, which also should be useful for forming functional hypotheses of axial motion during locomotion in extinct archosaurs.

Marzola, M., João Russo, J. and Mateus, O. (2014). Identification and comparison of modern and fossil crocodylian eggs and eggshell structures. *Historical Biology: An International Journal of Paleobiology* (doi: 10.1080/08912963.2013.871009).

Abstract: Eggshells from the three extant crocodylian species *Crocodylus mindorensis* (Philippine Crocodile), *Paleosuchus palpebrosus* (Cuvier's Smooth-fronted Caiman or Musky Caiman) and *Alligator mississippiensis* (American Alligator or Common Alligator) were prepared for thin section and scanning electron microscope analyses and are described in



order to improve the knowledge on crocodylian eggs anatomy and microstructure, and to find new apomorphies that can be used for identification. Both extant and fossil crocodylian eggs present an ornamentation that vary as anastomo-, ramo- or the here newly described rugosocavate type. The angusticaniculate pore system is a shared character for Crocodylomorpha eggshells and some dinosaurian and avian groups. Previously reported signs of incubated crocodylian eggs were found also on our only fertilised and hatched egg. *Paleosuchus palpebrosus* presents unique organization and morphology of the three eggshell layers, with a relatively thin middle layer characterised by dense and compact tabular microstructure.

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Pooley, S. (2014). Invasion of the crocodiles. Pp. 239-25 in *Rethinking Invasion Ecologies from the Environmental Humanities*, ed. by J. Frawley and I. McCalman. Routledge Environmental Humanities: Oxon, UK.

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Pooley, S. (2013). 'No Tears for the Crocodiles: Representations of Nile Crocodiles and the Extermination Furore in Zululand, South Africa, from 1956-8'. Pp. 142-162 in *Wild Things: Nature and the Social Imagination*, ed. by W. Beinart, K. Middleton and S. Pooley. The White Horse Press: Cambridge.

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La Grange, L.J. and Mukaratirwa, S. (2014). Distribution patterns and predilection muscles of *Trichinella zimbabwensis* larvae in experimentally infected Nile crocodiles (*Crocodylus niloticus* Laurenti). *Journal of Veterinary Research* 81(1), Art. #652.

**Abstract:** No controlled studies have been conducted to determine the predilection muscles of *Trichinella zimbabwensis* larvae in Nile crocodiles (*Crocodylus niloticus*) or the influence of infection intensity on the distribution of the larvae in crocodiles. The distribution of larvae in muscles of naturally infected Nile crocodiles and experimentally infected caimans (*Caiman crocodilus*) and varans (*Varanus exanthematicus*) have been reported in literature. To determine the distribution patterns of *T. zimbabwensis* larvae and predilection muscles, 15 crocodiles were randomly divided into three cohorts of five animals each, representing high infection (642 larvae/kg of bodyweight average), medium infection (414 larvae/kg of bodyweight average) and low infection (134 larvae/kg of bodyweight average) cohorts. In the high infection cohort, high percentages of larvae were observed in the triceps muscles (26%) and hind limb muscles (13%). In the medium infection cohort, high percentages of larvae were found in the triceps muscles (50%), sternomastoid (18%) and hind limb muscles (13%). In the low infection cohort, larvae were mainly found in the intercostal muscles (36%), longissimus complex (27%), forelimb muscles (20%) and hind limb muscles (10%). Predilection muscles in the high and medium infection cohorts were similar to those reported in naturally infected crocodiles despite changes in infection intensity. The high infection cohort had significantly higher numbers of larvae in

the sternomastoid, triceps, intercostal, longissimus complex, external tibial flexor, longissimus caudalis and caudal femoral muscles ( $p < 0.05$ ) compared with the medium infection cohort. In comparison with the low infection cohort, the high infection cohort harboured significantly higher numbers of larvae in all muscles ( $p < 0.05$ ) except for the tongue. The high infection cohort harboured significantly higher numbers of larvae ( $p < 0.05$ ) in the sternomastoid, triceps, intercostal, longissimus complex, external tibial flexor, longissimus caudalis and caudal femoral muscles compared with naturally infected crocodiles. Results from this study show that, in Nile crocodiles, larvae of *T. zimbabwensis* appear first to invade predilection muscles closest to their release site in the small intestine before occupying those muscles situated further away. The recommendation for the use of masseter, pterygoid and intercostal muscles as sampling sites for the detection of *T. zimbabwensis* in crocodiles is in contrast to the results from this study, where the fore- and hind limb muscles had the highest number of larvae. This study also supports the use of biopsy sampling from the dorso-lateral regions of the tail for surveillance purposes in both wild and commercial crocodile populations.

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Li, T., Zhao, B., Zhou, Y.K., Hu, R. and Du, W.G. (2014). Thermoregulatory behaviour is widespread in the embryos of reptiles and birds. *American Naturalist* 183(3): 443-451.

**Abstract:** Recent studies have demonstrated that thermoregulatory behavior occurs not only in posthatching turtles but also in turtles prior to hatching. Does thermoregulatory behavior also occur in the embryos of other reptile and bird species? Our experiments show that such behavior is widespread but not universal in reptile and bird embryos. We recorded repositioning within the egg, in response to thermal gradients, in the embryos of three species of snakes (*Xenochrophis piscator*, *Elaphe bimaculata*, and *Zaocys dhumnades*), two turtles (*Chelydra serpentina* and *Ocadia sinensis*), one crocodile (*Alligator sinensis*), and four birds (*Coturnix coturnix*, *Gallus gallus domesticus*, *Columba livia domestica*, and *Anas platyrhynchos domestica*). However, we detected no significant thermoregulation by the embryos of two lizard species (*Takydromus septentrionalis* and *Phrynocephalus frontalis*). Overall, embryonic thermoregulatory behavior is widespread in reptile as well as bird species but may be unimportant in the small eggs laid by most lizards.

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Johnston, S., Lever, J., McLeod, R., Qualischefski, S., Brabazon, S., Walton, S. and Collins, S.N. (2014). Extension, osmotic tolerance and cryopreservation of Saltwater Crocodile (*Crocodylus porosus*) spermatozoa. *Aquaculture* (dx.doi.org/10.1016/j.aquaculture.2014.02.014).

**Abstract:** Semen collected from 10 saltwater crocodiles (*Crocodylus porosus*) was used to investigate sperm in vitro manipulation and preservation. Preliminary studies revealed that phosphate buffered saline (PBS) without  $Ca^{2+}$ ,  $Mg^{2+}$  and egg yolk (EY) was a suitable extender for studies of sperm

physiology. Spermatozoa diluted in PBS showed no change in survival [% motility (M), rate of sperm movement (R) and % plasma membrane integrity (PI)] when diluted over a range of 1:1 to 1:16. Except for a small decline in PI, there was no change in sperm survival when semen diluted without EY was cooled rapidly to and rewarmed from 0°C. Addition of EY (0, 5, 10 and 20% V/V) had no beneficial effect on sperm survival when incubated in PBS for 1 h at 30°C or after 24 h storage at 4°C. Whilst crocodile spermatozoa exposed to a range of anisotonic media and then returned to solutions of 390 mOsmKg<sup>-1</sup> retained their M from 220-390 mOsmKg<sup>-1</sup>; PI remained high in hypotonic media (25-280 mOsmKg<sup>-1</sup>); spermatozoa showed an increase (P<0.05) in the incidence of flagellar coiling (FC) with increasing hypotonic conditions. The adverse effect of anisotonic conditions on sperm M and FC recovered somewhat when sperm were returned to the 390 mOsmKg<sup>-1</sup> media, but not to pre-treatment levels. Exposure of crocodile spermatozoa to respective concentrations of 0.68 M, 1.35 M and 2.7 M glycerol, dimethylsulphoxide (DMSO), dimethylacetamide (DMA) after 2 h storage at 4°C (equilibration) resulted in a reduction in M, but no change in PI. Sperm cryopreserved in the same cryoprotectant media within 0.25 mL straws at -6°C/min in a programmable freezer and thawed at 37°C for one minute, showed a major decline (P<0.05) of M but there was moderate protection of PI (DMA 2.7 M - 17.7 ± 4.4; DMSO 2.7 M - 22.7 ± 1.4 and glycerol 2.7 M - 25.7 ± 6.4). Sperm thawed and immediately washed to remove the cryoprotectant, showed an improvement (P<0.05) in PI but not M. Future studies of crocodile sperm preservation should explore the apparent disjunction between low levels of M and the high tolerance of the plasma membrane to anisotonic conditions and cryoprotectant toxicity.

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Johnston, S., Lever, J., McLeod, R., Oishi, M. and Collins, S. (2014). Development of Breeding Techniques in the Crocodile Industry. RIRDC Publication No. 13/097. RIRDC: Canberra.

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Vásquez, P. (2014). Estado del conocimiento de los caimanes distribuidos en la Amazonia Peruana, basado en el análisis de la literatura disponible. Centro de Datos para la Conservación - Universidad Nacional Agraria La Molina/Ministerio del Ambiente/Agencia de los Estados Unidos de América para el Desarrollo Internacional: Lima. 96 pp. [Status of Knowledge on Caimans Distributed in the Peruvian Amazon, based on Analysis of Available Literature].

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Pauvolid-Corrêa, A., Campos, Z., Juliano, R., Velez, J., Nogueira, R.M.R. and Komar, N. (2014). Serological evidence of widespread circulation of West Nile Virus and other flaviviruses in equines of the Pantanal, Brazil. *PLoS Neglected Tropical Diseases* 8(2): e2706 (doi:10.1371/journal.pntd.0002706).

**Abstract:** A recent study reported neutralizing antibodies to West Nile virus (WNV) in horses from four ranches of southern Pantanal. To extend that study, a serosurvey for WNV and 11 Brazilian flaviviruses was conducted with 760 equines, 238

sheep and 61 caimans from 17 local cattle ranches. Among the tested equines, 32 were collected from a ranch where a neurologic disorder outbreak had been recently reported. The sera were initially screened by using a blocking ELISA and then titrated by 90% plaque-reduction neutralization test (PRNT90) for 12 flaviviruses. Employing the criterion of 4-fold greater titer, 78 (10.3%) equines were seropositive for Ilheus virus, 59 (7.8%) for Saint Louis encephalitis virus, 24 (3.2%) for WNV, two (0.3%) for Cacipacore virus and one (0.1%) for Rocio virus. No serological evidence was found linking the neurological disease that affected local equines to WNV. All caimans and sheep were negative by blocking ELISA for flaviviruses. There were no seropositive equines for Bussuquara, Iguape, Yellow fever and all four Dengue virus serotypes. The detection of WNV-seropositive equines in ten ranches and ILHV and SLEV-seropositive equines in fourteen ranches of two different subregions of Pantanal is strong evidence of widespread circulation of these flaviviruses in the region.

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Yang, L., Tan, Z., Wang, D., Xue, L., Guan, M., Huang, T. and Li, R. (2014). Species identification through mitochondrial rRNA genetic analysis. *Scientific Reports* 4(4089): doi:10.1038/srep04089.

**Abstract:** Inter-species and intraspecific variations in mitochondrial DNA (mtDNA) were observed in a bioinformatics analysis of the mitochondrial genomic sequences of 11 animal species. Some highly conserved regions were identified in the mitochondrial 12S and 16S ribosomal RNA (rRNA) genes of these species. To test whether these sequences are universally conserved, primers were designed to target the conserved regions of these two genes and were used to amplify DNA from 21 animal tissues, including two of unknown origin. By sequencing these PCR amplicons and aligning the sequences to a database of non-redundant nucleotide sequences, it was confirmed that these amplicons aligned specifically to mtDNA sequences from the expected species of origin. This molecular technique, when combined with bioinformatics, provides a reliable method for the taxonomic classification of animal tissues.

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Shriyam, S., Mishra, A., Nayak, D. and Thakur, A. (2014). Design, fabrication and gait planning of alligator-inspired robot. *International Journal of Current Engineering and Technology, Special Issue 2 (Engineering and Technology International Conference on Advances in Mechanical Sciences)*, 567-575. DOI: <http://dx.doi.org/10.14741/ijcet/spl.2.2014.108>.

**Abstract:** This paper reports design, fabrication, and gait planning based on high walk diagonal trot gait pattern of an alligator - inspired robot having 8 degrees of freedom. Each leg of the robot described in this paper has two revolute joints representing the hip and knee respectively which are actuated by servo motors. The body of the robot was fabricated on a CO2 laser cutting machine. The 3D leg design was divided into two 2D components to enable manufacturing on a laser

cutting machine to reduce fabrication cycle time. Finally, a general - purpose kinematics based model has been reported that is used to design and implement a high-walk gait on the developed robot.

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Jaratlerdsiri, W., Isberg, S.R., Higgins, D.P., Miles, L.G. and Gongora, J. (2014). Selection and trans-species polymorphism of Major Histocompatibility Complex class II genes in the Order Crocodylia. PLoS ONE 9(2): e87534.

**Abstract:** Major Histocompatibility Complex (MHC) class II genes encode for molecules that aid in the presentation of antigens to helper T cells. MHC characterisation within and between major vertebrate taxa has shed light on the evolutionary mechanisms shaping the diversity within this genomic region, though little characterisation has been performed within the Order Crocodylia. Here we investigate the extent and effect of selective pressures and trans-species polymorphism on MHC class II  $\alpha$  and  $\beta$  evolution among 20 extant species of Crocodylia. Selection detection analyses showed that diversifying selection influenced MHC class II  $\beta$  diversity, whilst diversity within MHC class II  $\alpha$  is the result of strong purifying selection. Comparison of translated sequences between species revealed the presence of twelve trans-species polymorphisms, some of which appear to be specific to the genera *Crocodylus* and *Caiman*. Phylogenetic reconstruction clustered MHC class II  $\alpha$  sequences into two major clades representing the families Crocodylidae and Alligatoridae. However, no further subdivision within these clades was evident and, based on the observation that most MHC class II  $\alpha$  sequences shared the same trans-species polymorphisms, it is possible that they correspond to the same gene lineage across species. In contrast, phylogenetic analyses of MHC class II  $\beta$  sequences showed a mixture of subclades containing sequences from Crocodylidae and/or Alligatoridae, illustrating orthologous relationships among those genes. Interestingly, two of the subclades containing sequences from both Crocodylidae and Alligatoridae shared specific trans-species polymorphisms, suggesting that they may belong to ancient lineages pre-dating the divergence of these two families from the common ancestor 85-90 million years ago. The results presented herein provide an immunogenetic resource that may be used to further assess MHC diversity and functionality in Crocodylia.

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Bassetti, L.A.B., Marques, T.S., Malvasio, A., Pina, C.I. and Verdade, L.M. (2014). Thermoregulation in captive broad-snouted caiman (*Caiman latirostris*). Zoological Studies 53: 9.

**Abstract:** Crocodylians are ectothermic animals. For this reason, the environmental temperature has substantial effects on their physiology and behavior. The thermoregulatory behavior of these animals involves the selective use of different types of environments. This behavior enables them to reach the temperature level for their metabolic activities. This study aimed to determine the influence of sex, body size, and reproductive stage on the body temperature ( $T_b$ ) of

adult broad-snouted caiman (*Caiman latirostris*) in captivity. Thermal sensors were surgically implanted in the peritoneal cavity of 16 adult females and 4 adult males and programmed to register  $T_b$  hourly during 6 months. The diel  $T_b$  pattern of the broad-snouted caiman reflected the variation among the microenvironmental temperatures used by the species (water surface, pool bottom, and ground). The sex of the animals had influence on their  $T_b$ , but body size did not. Reproductive females had higher  $T_b$  than non-reproductive females during October to early November. It is possible that this difference is a result of the ovulation period of the species. Sick animals appeared to show behavioral fever. The results of the present study suggest that several factors can affect the  $T_b$  of adult broad-snouted caiman in captivity. Future studies should focus on the possible effect of thermoregulatory behavior on individuals' growth rate and reproductive performance

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Hastings, A.K., Krigbaum, J., Steadman, D.W. and Albury, N.A. (2014). Domination by reptiles in a terrestrial food web of the Bahamas prior to human occupation. Journal of Herpetology.

**Abstract:** Human activities in the Bahamas and other oceanic islands have damaged the terrestrial ecosystems irreparably through the extinction of indigenous species. Tortoise and crocodile bones from Abaco Island in the Bahamas sampled for 14C-dating revealed a small overlap between the last occurrence of these large reptiles and early human settlement in the Bahamas. Before their extermination approximately 1000 years ago, the dominant herbivore and carnivore on Abaco Island were the endemic Albury's Tortoise (*Chelonoidis alburyorum*) and the formerly widespread Cuban Crocodile (*Crocodylus rhombifer*). Stable isotope data from carbon ( $\delta^{13}C$ ) and nitrogen ( $\delta^{15}N$ ) in bone collagen from Late Holocene fossils suggest that these large reptiles were part of a terrestrial rather than marine or estuarine food web. Our proposal that Cuban Crocodiles were once the apex terrestrial predator in the Bahamas is supported by comparisons with published  $\delta^{13}C$  values for modern marine/estuarine crocodylians as compared to those of nonmarine reptilian and mammalian carnivores. For reptiles to occupy terrestrial trophic roles distinguishes Bahamian Islands from nearby Greater Antillean Islands (Cuba, Jamaica, Hispaniola, Puerto Rico) where endemic mammals represent the largest herbivores and carnivores in prehuman times. This distinction is even greater when compared with Late Quaternary mammals of prehuman vertebrate communities in neighboring North America.

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Chowfin, S. and Leslie, A.J. (2014). A multi-method approach for the inventory of the adult population of a critically endangered crocodylian, the Gharial (*Gavialis gangeticus*) at Dhikala, Corbett Tiger Reserve incorporating direct counts and trail cameras. International Journal of Biodiversity and Conservation 6(2): 148-158.

**Abstract:** The Corbett Tiger Reserve (CTR), a very highly rated protected area in the State of Uttarakhand, India,



is home to the third largest breeding population of adult Gharial globally. It contributes 20% to the estimated global population of 200-250 adults of the taxon and it is also the only known population of the taxon that lives predominantly in a lake-like environment. CTR was surveyed for Gharial in 2008, which was the first systematic survey with regard to the taxon since 1974, and the meta-population here was found distributed amongst 6 sub-populations in the Sarpduli, Dhikala, Kalagarh, Sonanadi, Palain and Adnala Ranges of the Reserve. This paper documents a multi-method approach for the estimation of Gharial at Dhikala (Dhikala Range) namely: at the confluence of the Ramganga River with the Kalagarh Reservoir. It details the use of trail cameras combined with boat surveys along the shoreline and stationary counts for estimating the adult population of Gharial at Dhikala, the site of the largest sub-population of Gharial in CTR. Using this multi-method approach to count basking animals, we estimated the adult population in the area to consist of 32 adults (inclusive of 7 adult males) based on the maximum  $\pm$  minimum (MM) method. We also considered the unknown proportion of adults that may have gone undetected during these surveys by subjecting the data to a Double Sampling analysis. The results are indicative that we were able to sample 88.9% of the adult Gharial population at Dhikala using this Multi-Method Approach. Based on our three population estimates ( $n=29, 32$  and  $36$ ) we averaged the adult population at Dhikala as  $32.3 \pm 1.69$  adults (mean  $\pm$  SE) with an encounter rate of  $4.01 \pm 0.33$  adults/km over 8.06 km of shoreline. Further, comparing population estimates between 2008 and 2013 based on the maximum  $\pm$  minimum (MM) method, we estimated that the number of adults in Dhikala increased by 77.8% between 2008 and 2013. This increase in adult Gharial numbers detected in the study area between 2008 and 2013 is primarily a result of: (1) Improved survey techniques which detected more number of animals in the area due to the cumulative effects of population growth from sub-adults to adults, in-migration and the possibility of some animals being missed during the 2008 surveys; (2) improved knowledge and familiarity with the study area; (3) effective protection measures already in place in CTR particularly in Corbett National Park (CNP), which has allowed the adult population to increase naturally without any disturbances. The ability of this multi-method approach in detecting these changes in numbers is important for monitoring the taxon and studying population trends within CNP.

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Dinets, V., Britton, A. and Shirley, M. (2013). Climbing behaviour in extant crocodylians. *Herpetology Notes* 7: 3-7.

**Abstract:** Although arboreality in extinct crocodylians is frequently suggested, the climbing abilities of extant crocodylians have never been discussed in any detail in scientific literature. We present an overview of published and anecdotal information on climbing in extant crocodylians, as well as original observations on four species representing two crocodile genera. These data suggest that climbing behaviour is common among crocodylians and might have multiple functions. The fact that at least some extant crocodylians are capable of climbing arboreal vegetation despite lacking

any obvious morphological adaptations for arboreality must be taken into account by paleontologists trying to elucidate behavioural clues from the morphology of fossil taxa.

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Moyle, B.J. (2013). Conservation that's more than skin-deep: alligator farming. *Biodiversity and Conservation* 22(8): 1663-1677.

**Abstract:** Wildlife farming is a contentious conservation measure. In Louisiana alligator farming has generated significant conservation gains. This case study is used to test several assumptions employed in debates about wildlife farming. These include whether farming 'floods' the market to depress prices and deter poaching, whether it encourages wild harvest and whether it can compete against wild harvest. Data from over three decades is used to model harvest behaviour with OLS and SUR models. This shows strong separation between the market between farmed and wild alligator skins. Immense rises in farmed output have not caused prices to collapse, however poaching has collapsed. This highlights that farming can have important non-price effects on poaching. Assumptions that are commonly used to debate wildlife farming are not supported in this example. Such assumptions, including open-access of the wildlife, inert and exogenous wildlife managers and excluding indirect benefits of wildlife farming tend to bias policy away from farming. Using these assumptions makes it harder to identify cases where wildlife farming could assist conservation objectives.

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Mathevon, N., Vergne, A. and Aubin, T. (2013). Acoustic communication in crocodiles: How do juvenile calls code information? *Proceedings of Meetings on Acoustics* 19: 010001 (<http://dx.doi.org/10.1121/1.4799192>).

**Abstract:** In spite of its importance for the understanding of the evolution of sound communication, information concerning the vocal world of crocodylians is limited. Experimental works have brought evidence of the biological roles of juvenile sound signals, with "hatching calls" eliciting care by the mother and synchronizing clutch hatching, "contact calls" gathering groups of juveniles, and "distress calls" inducing maternal protection. Recently, we investigated the question of species-specific information coding within juvenile calls. The analysis of signal acoustic structure shows inter-specific differences between calls. However, using playback experiments, we bring the evidence that these differences are not relevant to animals, either juveniles or adults. By using calls modified in the temporal and the frequency domains, we isolate the acoustic cues necessary to elicit a behavioral response from receivers, underlying the importance of the frequency modulation slope. Considering previous results underlying the absence of information about individual identity in juvenile calls, we make the hypothesis that these signals basically support a "crocodylian" identity.

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Leitch, D.B. (2013). Comparative Topics in Vertebrate Mechanoreception with a Special Focus on the Crocodylians.

PhD thesis, Vanderbilt University, Nashville, Tennessee, USA.

**Abstract:** Insights into the organization of vertebrate nervous systems have often arisen through systematic examinations of specific behaviors and their possible neural substrates. This approach is even more effective when diverse groups can be assessed in order to identify commonalities in innervation, anatomy, or nervous system representation. Throughout this collection of investigations, we have examined a wide-ranging group of semi-aquatic vertebrates possessing peripheral nervous system specializations related to mechanotransduction. These included a range of insectivores such as the American water shrew (*Sorex palustris*), the smallest homeothermic diver with an elaborate array of whiskers. We also analyzed the behavior and central nervous system representations of the tentacled snake (*Erpeton tentaculatus*) in the process of identifying the sensory function of the unique paired facial appendage. More extensive observations were collected from two members of the order Crocodylia - the Nile crocodile (*Crocodylus niloticus*) and the American alligator (*Alligator mississippiensis*) - with particular attention devoted to their integumentary sensory organs (ISOs). These ubiquitous dome-shaped protuberances speckle the jaws of all crocodylians and are also found on the bodies of members of the families Crocodylidae and Gavialidae, yet their precise function and the behaviors they mediate have remained ambiguous. We suggest that the ISOs impart an exquisite level of tactile sensitivity, even exceeding that of the primate fingertip, thereby providing a sophisticated sense of touch to an otherwise armored body surface and draw comparisons between the sensory system organization of mammalian and reptilian taxa.

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Tucker A.S. and Fraser, G.J. (2014). Evolution and developmental diversity of tooth regeneration. *Semin. Cell Dev. Biol.* (<http://dx.doi.org/10.1016/j.semcdb.2013.12.013>).

**Abstract:** This review considers the diversity observed during both the development and evolution of tooth replacement throughout the vertebrates in a phylogenetic framework from basal extant chondrichthyan fish and more derived teleost fish to mammals. We illustrate the conservation of the tooth regeneration process among vertebrate clades, where tooth regeneration refers to multiple tooth successors formed de novo for each tooth position in the jaws from a common set of retained dental progenitor cells. We discuss the conserved genetic mechanisms that might be modified to promote morphological diversity in replacement dentitions. We review current research and recent progress in this field during the last decade that have promoted our understanding of tooth diversity in an evolutionary developmental context, and show how tooth replacement and dental regeneration have impacted the evolution of the tooth-jaw module in vertebrates

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Ruiz, T., Campos, W.N.S., Peres, P.S.T., Gonçalves, G.F., Ferraz, R.H.S., Néspoli, P.E.B., Sousa, V.R.F. and Ribeiro, A.P. (2013). Intraocular pressure, ultrasonographic and

echobiometric findings of juvenile Yacare caiman (*Caiman yacare*) eye. *Veterinary Ophthalmology* (doi: 10.1111/vop.12146).

**Abstract:** The aim was to determine the intraocular pressure (IOP), the ultrasonographic and echobiometric findings in the eyes of 22 healthy juvenile Yacare caiman (*Caiman yacare*) from a breeding farm in the Brazilian Pantanal. Intraocular pressure was measured under physical restraint and topical anesthesia by applanation tonometry. Five individual measurements of each eye were recorded by the same examiner. B-mode ultrasonography was performed with a 10-MHz linear transducer, and the anterior chamber depth, lens thickness, vitreous depth, and axial globe length were measured. Unpaired and paired t-tests were used to assess data. Pearson's test was used to assess correlations between IOP and ocular structures ( $P < 0.05$ ). Mean  $\pm$  SD IOP of the 44 eyes studied was  $9.56 \pm 2.69$  mmHg, (range 5.4–15.6 mmHg). IOP did not differ significantly between right and left eyes or between genders ( $P > 0.05$ ). Echobiometric measurements did not differ significantly between eyes and genders ( $P > 0.05$ ). Intraocular structures measured in male and female subjects were, respectively,  $2.61 \pm 0.13$  and  $2.55 \pm 0.18$  mm for anterior chamber depth,  $7.60 \pm 0.17$  and  $7.54 \pm 0.20$  mm for lens thickness,  $6.83 \pm 0.20$  and  $6.90 \pm 0.22$  mm for vitreous chamber depth, and  $17.55 \pm 0.25$  and  $17.54 \pm 0.29$  mm for axial globe length. Correlations were not observed ( $P > 0.05$ ). Reference values of tonometry and distances of intraocular structures of Yacare caiman were described. IOP did not correlate with echobiometric measurements in this crocodylian. The ultrasonographic appearance was similar to other domestic and wild species.

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Villegas, A. and Reynoso, V.H. (2013). Relative abundance and habitat preference in isolated populations of Morelet's crocodile (*Crocodylus moreletii*) along the coast of the Gulf of Mexico. *Herpetological Conservation and Biology* 8(3): 571-580.

**Abstract -** Recently CITES removed the Morelet's crocodile (*Crocodylus moreletii*) from Appendix I to II based on a rangewide population viability analysis. The Comisión Nacional para el Conocimiento y Uso de la Biodiversidad in Mexico is coordinating monitoring surveys to support that status change. However, more population studies on *C. moreletii* are needed to accurately assess its conservation status. We recorded the abundance and habitat preference of *C. moreletii* in Veracruz and Tamaulipas, Mexico. In Veracruz we obtained an encounter rate of 5.2 crocodiles/km along 8 km of waterway in 2008 and 5.5 crocodiles/km along 10 km of waterway in 2009. In Tamaulipas, we recorded a wide variation in crocodile encounter rates from 2010 to 2012, ranging from 0.4 crocodiles/km in Laguna Champayán to 27.5 crocodiles/km in Laguna del Carpintero. Through 2011 to 2012, we found differences in the population size-class structure in Tamaulipas Lagoon complex only ( $t = 2.86$ ,  $df = 4$ ,  $P < 0.05$ ). In Veracruz, juveniles had a higher preference for aquatic vegetation habitats ( $\chi^2 = 61.3$ ,  $df = 4$ ,  $P < 0.05$ ), whereas in Tamaulipas juvenile crocodiles preferred wooded habitats

( $\chi^2=72$ ,  $df=4$ ,  $P<0.05$ ). Only in Veracruz were crocodile sex ratios strongly male biased (1:3.5;  $\chi^2=73.3$ ,  $df=1$ ,  $P<0.05$ ). Population isolation and habitat fragmentation are factors that impact the crocodile population size and size class structure in these two regions. Continuous monitoring will be needed to detect significant changes in Morelet's crocodile populations in Veracruz and Tamaulipas overtime.

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Challender, D.W.S. and MacMillan, D.C. (2014). Poaching is more than an enforcement problem. *Conservation Letters* (doi: 10.1111/conl.12082).

**Abstract:** Today record levels of funding are being invested in enforcement and antipoaching measures to tackle the “war on poaching,” but many species are on the path to extinction. In our view, intensifying enforcement effort is crucial, but will ultimately prove an inadequate long-term strategy with which to conserve high-value species. This is because: regulatory approaches are being overwhelmed by the drivers of poaching and trade, financial incentives for poaching are increasing due to rising prices and growing relative poverty between areas of supply and centers of demand, and aggressive enforcement of trade controls, in particular bans, can increase profits and lead to the involvement of organized criminals with the capacity to operate even under increased enforcement effort. With prices for high-value wildlife rising, we argue that interventions need to go beyond regulation and that new and bold strategies are needed urgently. In the immediate future, we should incentivize and build capacity within local communities to conserve wildlife. In the medium-term, we should drive prices down by reexamining sustainable off-take mechanisms such as regulated trade, ranching and wildlife farming, using economic levers such as taxation to fund conservation efforts, and in the long-term reduce demand through social marketing programs.

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Kellner, A.W.A., Pinheiro, A.E.P. and Campos, D.A. (2014). A new sebecid from the Paleogene of Brazil and the crocodyliform radiation after the K-Pg Boundary. *PLOS ONE* 9(1): e81386.

**Abstract:** A new crocodyliform, *Sahitisuchus fluminensis* gen. et sp. nov., is described based on a complete skull, lower jaw and anterior cervical vertebrae collected in the São José de Itaboraí Basin of Rio de Janeiro, Brazil. The specimen is one of the best preserved crocodyliforms from Paleocene deposits recovered so far and represents a sebecosuchian, one of the few clades that survived the Cretaceous-Paleogene biotic crisis. The new taxon is found in the same deposit as an alligatoroid, a group that experienced large diversification in the Paleogene. The sebecosuchian record suggests that after the Cretaceous-Paleogene biotic crisis, the less specialized members of this clade characterized by a higher number of teeth compared to the baurusuchid sebecosuchians survived, some having terrestrial habits while others developed a semi-aquatic life style (eg *Lorosuchus*). Starting in the Eocene, sebecid sebecosuchians became specialized with a more accentuated oreinirostry as observed in *Sebecus* and

in *Langstonia*, but not showing the typical reduced dentition developed by the Cretaceous baurusuchid sebecosuchians. The basal position of *Barinasuchus arveloi*, a high-snouted Miocene sebecid, indicates the occurrence of an independent lineage sometime after the K-Pg biotic crisis that developed accentuated oreinirostry, suggesting a more complex history of the post-K-Pg crocodyliform radiation.

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Nifong, J.C., Nifong, R.L., Silliman, B.R., Lowers, R.H., Guillette, L.J., Jr., Ferguson, J.M., Welsh, M., Abernathy, K. and Marshall, G. (2014). Animal-borne imaging reveals novel insights into the foraging behaviors and diel activity of a large-bodied apex predator, the American alligator (*Alligator mississippiensis*). *PLOS ONE* 9(1): e83953.

**Abstract:** Large-bodied, top- and apex predators (eg crocodylians, sharks, wolves, killer whales) can exert strong top-down effects within ecological communities through their interactions with prey. Due to inherent difficulties while studying the behavior of these often dangerous predatory species, relatively little is known regarding their feeding behaviors and activity patterns, information that is essential to understanding their role in regulating food web dynamics and ecological processes. Here we use animal-borne imaging systems (Critttercam) to study the foraging behavior and activity patterns of a cryptic, large-bodied predator, the American alligator (*Alligator mississippiensis*) in two estuaries of coastal Florida, USA. Using retrieved video data we examine the variation in foraging behaviors and activity patterns due to abiotic factors. We found the frequency of prey-attacks (mean= 0.49 prey attacks/hour) as well as the probability of prey-capture success (mean= 0.52 per attack) were significantly affected by time of day. Alligators attempted to capture prey most frequently during the night. Probability of prey-capture success per attack was highest during morning hours and sequentially lower during day, night, and sunset, respectively. Position in the water column also significantly affected prey-capture success, as individuals' experienced two-fold greater success when attacking prey while submerged. These estimates are the first for wild adult American alligators and one of the few examples for any crocodylian species worldwide. More broadly, these results reveal that our understandings of crocodylian foraging behaviors are biased due to previous studies containing limited observations of cryptic and nocturnal foraging interactions. Our results can be used to inform greater understanding regarding the top-down effects of American alligators in estuarine food webs. Additionally, our results highlight the importance and power of using animal-borne imaging when studying the behavior of elusive large-bodied, apex predators, as it provides critical insights into their trophic and behavioral interactions.

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Shepherd, S.M. and Shoff, W.H. (2013). An urban northeastern United States alligator bite. *The American Journal of Emergency Medicine* (doi: 10.1016/j.ajem.2013.11.004).

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Weber, R.E., Fago, A., Malte, H., Storz, J.F. and Gorr, T.A.



(2013). Lack of conventional oxygen-linked proton and anion binding sites does not impair allosteric regulation of oxygen binding in dwarf caiman hemoglobin. *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology* 305(3): R300-312.

**Abstract:** In contrast to other vertebrate hemoglobins (Hbs), whose high intrinsic O<sub>2</sub> affinities are reduced by red cell allosteric effectors (mainly protons, CO<sub>2</sub>, organic phosphates and chloride ions), crocodilian Hbs exhibit low sensitivity to organic phosphates and high sensitivity to bicarbonate (HCO<sub>3</sub><sup>-</sup>), which is thought to augment Hb-O<sub>2</sub> unloading during diving and postprandial 'alkaline tides' when blood HCO<sub>3</sub><sup>-</sup> levels as well as metabolic rates increase. Examination of  $\alpha$ - and  $\beta$ -globin amino acid sequences of dwarf caiman (*Paleosuchus palpebrosus*) revealed a unique combination of substitutions at key effector binding sites compared to other vertebrate - and crocodilian - Hbs:  $\beta$ 82Lys--Gln,  $\beta$ 143His--Val, and  $\beta$ 146His--Tyr. These substitutions delete positive charges and - along with other distinctive changes in residue charge and polarity - may be expected to disrupt allosteric regulation of Hb-O<sub>2</sub> affinity. Strikingly, however, *P. palpebrosus* Hb shows a strong Bohr effect, as well as marked deoxygenation-linked binding of organic phosphates (ATP and DPG) and of CO<sub>2</sub> as carbamate (contrasting with HCO<sub>3</sub><sup>-</sup> binding in other crocodilians). Unlike other Hbs, it polymerizes to large complexes in the oxygenated state. The highly unusual properties of *P. palpebrosus* Hb align with a high content of His residues (potential sites for oxygenation-linked proton binding) and distinctive surface Cys residues that may form intermolecular disulfide bridges upon polymerization. Based on its singular properties, *P. palpebrosus* Hb provides a unique opportunity for studies on structure-function coupling and the evolution of compensatory mechanisms for maintaining tissue O<sub>2</sub> delivery in Hbs that lack conventional effector-binding residues.

Shilton, C., Brown, G.P., Chambers, L., Benedict, S., Davis, S., Aumann, S. and Isberg, S.R. (2013). Pathology of runting in farmed Saltwater Crocodiles (*Crocodylus porosus*) in Australia *Veterinary Pathology* (doi: 10.1177/0300985813516642).

**Abstract:** Extremely poor growth of some individuals within a birth cohort (runting) is a significant problem in crocodile farming. We conducted a pathological investigation to determine if infectious disease is associated with runting in farmed saltwater crocodiles (*Crocodylus porosus*) and to look for evidence of other etiologies. In each of 2005 and 2007, 10 normal and 10 runt crocodiles, with an average age of 5.5 months and reared under identical conditions, were sampled. Laboratory testing included postmortem; histological examination of a wide variety of tissues (with quantitation of features that were noted subjectively to be different between groups); hematology; serum biochemistry (total protein, albumin, globulins, total calcium, phosphorus, and iron); bacterial culture of liver and spleen (2005 only); viral culture of liver, thymus, tonsil, and spleen using primary crocodile cell lines (2007 only); and serum corticosterone

(2007 only). The only evidence of infectious disease was mild cutaneous poxvirus infection in 45% of normal and 40% of runt crocodiles and rare intestinal coccidia in 5% of normal and 15% of runt crocodiles. Bacterial and viral culture did not reveal significant differences between the 2 groups. However, runt crocodiles exhibited significant (P<0.05) increases in adrenocortical cell cytoplasmic vacuolation and serum corticosterone, decreased production of bone (osteoporosis), and reduced lymphoid populations in the spleen, tonsil, and thymus. Runts also exhibited moderate anemia, hypoalbuminemia, and mild hypophosphatemia. Taken together, these findings suggest an association between runting and a chronic stress response (hyperactivity of the hypothalamic-pituitary-adrenal axis).

McCarthy, F., Braun, E.L., Gabaldon, T., Gongora J., Green, R., Gresham, C., Isberg, S.R., Jaratlerdsiri, W., Kern, C., Moran, C., Schmidt, C.J. and Ray, D. (2014). Crocodylian genomics: Unraveling evolution, development and traditional medicine. Abstract W386, Plant and Animal genome XXII, San Diego 11-15 January 2014.

**Abstract:** Crocodylians have a long held a place in human mythology and history, with the first written record of crocodiles appearing as early as the 5th century BC. Crocodiles and alligators have been farmed since the early 20th century for tourism and, more recently, their skins and meat. Moreover, crocodile products are also valued in traditional medicine and several research groups are investigating the anti-microbial properties of crocodile sera. We report on an international effort to sequence three representative crocodilian species (*Crocodylus porosus*, *Alligator mississippiensis* and *Gavialis gangeticus*). We have produced a completed genome sequence for each species, predicted genes and proteins and provided preliminary gene names and predicted functions for these gene products. Alligator (the species with the best assembly and annotation) has 23,323 predicted genes, comparably with other vertebrate species. Phylogenetic analysis of crocodylian genes with other vertebrate genes identified 337 core gene families present in all vertebrates analyzed and 5,000 predicted genes were restricted to the three crocodylian species. Crocodylians have a slow rate of morphological and karyotype evolution. This slow rate of evolution is recapitulated at the nucleotide level. Moreover, our sequence data indicates that each of the three crocodilian species suffered a reduction in population size through the Pleistocene epoch. The slow rate of karyotypic and molecular evolution within the two extant orders of archosaurs has the potential to illuminate key features of the biology of their common ancestor, a subject of intense interest.

Ngwenya, A., Patzke, N., Spocter, M.A., Kruger, J.-L., Dell, L.-A., Chawana, R., Mazenganya, P., Billings, B.K., Olalaye, O., Herculano-Houzel, S. and Manger, P.R. (2013). The continuously growing central nervous system of the Nile Crocodile (*Crocodylus niloticus*). *Anat. Rec.* 296: 1489-1500.

**Abstract:** It is a central assumption that larger bodies require larger brains, across species but also possibly within species with continuous growth throughout the lifetime, such as the crocodile. The current study investigates the relationships between body growth (length and mass) and the rates of growth of various subdivisions of the central nervous system (CNS) (brain, spinal cord, eyes) in Nile crocodiles weighing between 90 g and 90 kg. Although the brain appears to grow in two phases in relation to body mass, initially very rapidly then very slowly, it turns out that brain mass increases continuously as a power function of body mass with a small exponent of 0.256, such that a 10-fold increase in body mass is accompanied by a 1.8-fold in brain mass. Eye volume increases slowly with increasing body mass, as a power function of the latter with an exponent of 0.37. The spinal cord, however, grows more rapidly in mass, accompanying body mass raised to an exponent of 0.54, and increasing in length as predicted, with body mass raised to an exponent of 0.32 (close to the predicted 1/3). While supporting the expectation formulated by Jerison that larger bodies require larger brains to operate them, our findings show that: (1) the rate of increase in brain size is very small compared to body growth; and (2) different parts of the CNS grow at different rates accompanying continuous body growth, with a faster increase in spinal cord mass and eye volume, than in brain mass.

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Seymour, R.S., Gienger, C.M., Brien, M.L., Tracy, C.R., Manolis, S.C., Webb, G.J.W. and Christian, K.A. (2013). Scaling of standard metabolic rate in estuarine crocodiles *Crocodylus porosus*. *J. Comp. Physiol. B* 183: 491-500.

**Abstract:** Standard metabolic rate (SMR, ml O<sub>2</sub> min<sup>-1</sup>) of captive *Crocodylus porosus* at 30C scales with bodymass (kg) according to the equation,  $SMR = 1.01 M^{0.829}$ , in animals ranging in body mass of 3.3 orders of magnitude (0.19-389 kg). The exponent is significantly higher than 0.75, so does not conform to quarter-power scaling theory, but rather is likely an emergent property with no single explanation. SMR at 1 kg body mass is similar to the literature for *C. porosus* and for alligators. The high exponent is not related to feeding, growth, or obesity of captive animals. The log-transformed data appear slightly curved, mainly because SMR is somewhat low in many of the largest animals (291-389 kg). A 3-parameter model is scarcely different from the linear one, but reveals a declining exponent between 0.862 and 0.798. A non-linear model on arithmetic axes overestimates SMR in 70% of the smallest animals and does not satisfactorily represent the data.

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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: 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.

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Behera, S.K., Singh, H. and Sagar, V. (2014). Indicator Species (Gharial and Dolphin) of Riverine Ecosystem: An Exploratory of River Ganga. Pp. 121-141 in *Our National River Ganga - Lifeline of Millions*, ed. by R. Sanghi. Springer International Publishing: Switzerland.

**Abstract:** The Ganga River sustains diverse group of flora and fauna including the endangered Ganges River dolphin (*Platanista gangetica gangetica*) and critically endangered Gharial (*Gavialis gangeticus*). Because, of the highest productivity and most populous regions on earth there is a strong demand and competition for natural resources, which threatened the survival of indicator species such as Gharial and dolphin in the Ganga River. There are several riverine indicator species that are threatened by human activities in the Ganga basin. However, the Ganges River dolphin and Gharial are reliable indicator species to understand the health of the Ganga River ecosystem. Studying indicator species could create the basis for a sustained research program to see how the changes of the said species can be related to the health of the river system. This would help to implement various program for restoration of the river system. Human perturbations and anthropogenic disturbances have led to drastic declines in dolphin and Gharial populations over much of their distribution ranges during the last several decades. However, due to active involvement of WWF-India in dolphin conservation in certain areas the recent survey reported interesting trends in terms of a stable dolphin population. Stretches that reported stable dolphin population were areas where there had been some interventions taken by local communities, forest departments, and other non-government organizations.

Du, W.-G. and Shine, R. (2014). The behavioural and physiological strategies of bird and reptile embryos in response to unpredictable variation in nest temperature. *Biological Reviews* (doi: 10.1111/brv.12089).

**Abstract:** Temperature profoundly affects the rate and trajectory of embryonic development, and thermal extremes can be fatal. In viviparous species, maternal behaviour and physiology can buffer the embryo from thermal fluctuations; but in oviparous animals (like most reptiles and all birds), an embryo is likely to encounter unpredictable periods when incubation temperatures are unfavourable. Thus, we might expect natural selection to have favoured traits that enable embryos to maintain development despite those fluctuations. Our review of recent research identifies three main routes that embryos use in this way. Extreme temperatures (i) can be avoided (eg by accelerating hatching, by moving within the egg, by cooling the egg by enhanced rates of evaporation, or by hysteresis in rates of heating versus cooling); (ii) can be tolerated (eg by entering diapause, by producing heat-shock proteins, or by changing oxygen use); or (iii) the embryo can adjust its physiology and/or developmental trajectory in ways that reduce the fitness penalties of unfavourable thermal conditions (eg by acclimating, by exploiting brief windows of favourable conditions, or by producing the hatchling phenotype best suited to those incubation conditions). Embryos are not simply passive victims of ambient conditions. Like free-living stages of the life cycle, embryos exhibit behavioural and physiological plasticity that enables them to deal with unpredictable abiotic challenges.

Skutschas, P.P., Danilov, I.G., Kodrul, T.M. and Jin, J. (2014). The first discovery of an alligatorid (Crocodylia, Alligatoroidea, Alligatoridae) in the Eocene of China. *Journal of Vertebrate Paleontology* 34(2). (doi: 10.1080/02724634.2013.809725).

Ezcurra, M.D., Scheyer, T.M. and Butler, R.J. (2014). The origin and early evolution of sauria: reassessing the permian saurian fossil record and the timing of the crocodile-lizard divergence. 9(2): e89165.

**Abstract:** Sauria is the crown-group of Diapsida and is subdivided into Lepidosauromorpha and Archosauromorpha, comprising a high percentage of the diversity of living and fossil tetrapods. The split between lepidosauromorphs and archosauromorphs (the crocodile-lizard, or bird-lizard, divergence) is considered one of the key calibration points for molecular analyses of tetrapod phylogeny. Saurians have a very rich Mesozoic and Cenozoic fossil record, but their late Paleozoic (Permian) record is problematic. Several Permian specimens have been referred to Sauria, but the phylogenetic affinity of some of these records remains questionable. We reexamine and review all of these specimens here, providing new data on early saurian evolution including osteohistology, and present a new morphological phylogenetic dataset. We support previous studies that find that no valid Permian record for Lepidosauromorpha, and

we also reject some of the previous referrals of Permian specimens to Archosauromorpha. The most informative Permian archosauromorph is *Protorosaurus speneri* from the middle Late Permian of Western Europe. A historically problematic specimen from the Late Permian of Tanzania is redescribed and reidentified as a new genus and species of basal archosauromorph: *Aenigmastropheus parringtoni*. The supposed protosauromorph *Eorasaurus olsoni* from the Late Permian of Russia is recovered among Archosauriformes and may be the oldest known member of the group but the phylogenetic support for this position is low. The assignment of *Archosaurus rossicus* from the latest Permian of Russia to the archosauromorph clade Proterosuchidae is supported. Our revision suggests a minimum fossil calibration date for the crocodile-lizard split of 254.7 Ma. The occurrences of basal archosauromorphs in the northern (30°N) and southern (55°S) parts of Pangea imply a wider paleobiogeographic distribution for the group during the Late Permian than previously appreciated. Early archosauromorph growth strategies appear to be more diverse than previously suggested based on new data on the osteohistology of *Aenigmastropheus*.

Platt, T.R., Hoberg, E.P. and Chisolm, L.A. (2013). On the morphology and taxonomy of *Griphobilharzia amoena* Platt and Blair, 1991 (Schistosomatoidea), a dioecious digenetic trematode parasite of the freshwater crocodile, *Crocodylus johnstoni*, in Australia. *J. Parasitol.* 99(5): 888-891.

**Abstract:** *Griphobilharzia amoena* Platt and Blair, 1991 was originally described as a dioecious trematode, parasitic in the circulatory system of the Australian freshwater crocodile, *Crocodylus johnstoni*, with the female completely enclosed in a gynecophoric chamber of the male and the 2 worms oriented anti-parallel to each other. A recent publication questions the original description, arguing that *G. amoena* is monoecious and, as a consequence, the species was transferred to *Vasotrema* Stunkard, 1928 (Spirorchhiidae) as *Vasotrema amoena* n. comb. We provide photomicrographic evidence that the original description of *G. amoena* is correct and that *Griphobilharzia* Platt and Blair, 1991, is a valid monotypic genus containing *G. amoena*. An accurate understanding of the anatomy of *G. amoena* is not trivial and has implications for revealing the complex origins and evolution of the dioecious condition within the Schistosomatoidea.

Van Wilpe, E. and Groenewald, H.B. (2014). Kupffer cell structure in the juvenile Nile crocodile, *Crocodylus niloticus*. *J Morphol.* 275(1): 1-8.

**Abstract:** The morphology of Kupffer cells was examined in the liver of the juvenile Nile crocodile using light microscopy and transmission electron microscopy. Pleomorphic Kupffer cells were located in the sinusoids, in the space of Disse, in the hepatic parenchyma and often connected adjacent sinusoids. The cell surfaces were irregular due to the presence of filopodia and lamellipodia with phagocytosis of white blood cells, red blood cells and thrombocytes being evident. The cells were in close contact with endothelial cells and pit



cells in the sinusoidal lumen and with stellate cells in the space of Disse. The cytoplasm contained large phagosomes comprising a combination of ceroid pigment, melanosomes and siderosomes. The nuclei were often indented and eccentrically placed due to the presence of the phagosomes. Conspicuous clusters of membrane-bound tubular organelles with a filamentous or crystalline interior were observed in the cytoplasm. The clusters were sometimes separated into smaller groups around phagosomes. A clear zone existed between the limiting membrane and the interior of these tubular organelles with the electron-dense interior profiles being, respectively, circular, angular or divided. The tubular organelles have not previously been described in Kupffer cells and possibly represent lysosomes with specialized functions. Mitochondria, microtubules, Golgi profiles, granular and smooth endoplasmic reticulum, and a few cytoplasmic lipid droplets were also present. The presence of the tubular organelles and the occurrence of the Kupffer cells in different locations in the liver of the juvenile Nile crocodile are indicative of particularly active and mobile cells.

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Weeks, O., Bhullar, B.A. and Abzhanov, A. (2013). Molecular characterization of dental development in a toothed archosaur, the American alligator *Alligator mississippiensis*. *Evol. Dev.* 15(6): 393-405.

Abstract: Few skeletal structures are as informative of the adaptive natural history of vertebrate animals as their teeth. Understanding principles of tooth development is key to understanding evolution of the vertebrate dentition in general and emergence of multiple specialized tooth types in particular. Morphological and phylogenetic considerations suggest that crocodylians have the most primitive mode of dentition within extant tetrapods, displaying simple, conical, socketed, and continuously replaced teeth. Previous histological studies revealed several dental fates, including functional and non-functional teeth (rudiments) in the developing alligator embryos. We analyze expression of key odontogenic regulators and markers to better characterize the molecular patterning of crocodylian dentition. Importantly, we demonstrate that the morphologically distinct tooth types in *Alligator mississippiensis* are distinguishable by differences in their developmental programs. We also present evidence showing that tooth maturation is accompanied by dynamic gene expression in the epithelial and mesenchymal cells involved in tooth development. Our data reveal a significant morphological and genetic variation in early dental fates. We believe that this underlying developmental variation reflects modularity, or the ability of teeth to develop semi-autonomously along the alligator jaw. We propose that such modularity may have been a crucial for adaptive evolution within Amniota, allowing for the progressive modifications to tooth replacement, number, and shape.

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Kik, M.J. (2013). Disseminated *Mycobacterium intracellulare* infection in a broad-snouted caiman *Caiman latirostris*. *Dis. Aquat. Organ.* 107(1): 83-86.

Abstract: A 10 yr old broad-snouted caiman *Caiman latirostris* from a small Dutch animal park was presented with long-term variable periods of anorexia and weight loss. Blood chemistry showed slightly elevated uric acid levels and low ionised calcium concentration. Ultrasonographical thickening of the intestinal wall in the region of the duodenum was evident. Pathological changes were a thickening of the wall of 90% of the small intestines, enlarged spleen with multifocal white foci and an enlarged light-brown liver. Histopathological lesions consisted of disseminated granulomas in the intestinal wall, the liver and the spleen. Multinucleated giant cells and epithelioid macrophages were abundant. Ziehl-Neelsen staining showed numerous intralosomal acid-fast bacteria. Polymerase chain reaction for *Mycobacterium intracellulare* was positive.

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Makanyanga, T.B., Mutema, G., Mukarati, N.L., Chikerema, S.M., Makaya, P.V., Musari, S. and Matope, G.. (2014). Microbial quality of frozen Nile crocodile (*Crocodylus niloticus*) meat samples from three selected farms in Zimbabwe. *Int. J. Food Microbiol.* 170: 44-47.

Abstract: Microbial quality of frozen Nile crocodile (*Crocodylus niloticus*) meat from three farms in Zimbabwe was assessed based on 2051 samples collected for pre-export testing during 2006 to 2011. Data were perused by season and year in terms of aerobic plate (APC), coliform (CC), *Escherichia coli* (ECC) and *Listeria monocytogenes* (LMC) counts and the presence of *Salmonella* spp. The log<sub>10</sub>-transformed data were compared among the farms and seasons using the Kruskal-Wallis test. Microbial quality of the samples was graded based on the EC No. 2073.2005 criteria for beef. The mean APC and CC for the crocodile meat differed significantly (P= 0.000) among the farms with the highest APC (3.2±0.05 log<sub>10</sub> cfu/g) and the lowest (2.7±0.05 log<sub>10</sub> cfu/g) recorded from farms A and C, respectively. There were no significant differences (P>0.05) in ECC and LMC among the farms, while *Salmonella* spp. were only isolated from one farm. Although the microbial quality of frozen crocodile meat from these farms was generally within acceptable limits, the isolation of *E. coli* and *Salmonella* spp. is of public health concern. Thus, implementing of measures to control the pasteurizing process and to minimize bacterial contamination of crocodile meat after pasteurization need to be carefully considered.

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Farlow, J.O., Schachner, E.R., Sarrazin, J.C., Klein, H. and Currie, P.J. (2014). Pedal proportions of *Poposaurus gracilis*: convergence and divergence in the feet of Archosaurs. *Anat. Rec. (Hoboken)*. (doi: 10.1002/ar.22863.).

Abstract: The crocodile-line basal suchian *Poposaurus gracilis* had body proportions suggesting that it was an erect, bipedal form like many dinosaurs, prompting questions of whether its pedal proportions, and the shape of its footprint, would likewise “mimic” those of bipedal dinosaurs. We addressed these questions through a comparison of phalangeal, digital, and metatarsal proportions of *Poposaurus* with those of

extinct and extant crocodile-line archosaurs, obligate or facultatively bipedal non-avian dinosaurs, and ground birds of several clades, as well as a comparison of the footprint reconstructed from the foot skeleton of *Poposaurus* with known early Mesozoic archosaurian ichnotaxa. Bivariate and multivariate analyses of phalangeal and digital dimensions showed numerous instances of convergence in pedal morphology among disparate archosaurian clades. Overall, the foot of *Poposaurus* is indeed more like that of bipedal dinosaurs than other archosaur groups, but is not exactly like the foot of any particular bipedal dinosaur clade. *Poposaurus* likely had a digitigrade stance, and its footprint shape could have resembled gallatorid ichnotaxa, unless digit I of the foot of *Poposaurus* commonly left an impression.

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Lane, E.P., Huchzermeyer, F.W., Govender, D., Bengis, R.G., Buss, P.E., Hofmeyr, M., Myburgh, J.G., Steyl, J.C., Pienaar, D.J. and Kotze, A.. (2013). Pansteatitis of unknown etiology associated with large-scale Nile crocodile (*Crocodylus niloticus*) mortality in Kruger National Park, South Africa: pathologic findings. *J. Zoo Wildl. Med.* 44(4): 899-910.

**Abstract:** Annual mortality events in Nile crocodiles (*Crocodylus niloticus*) in the Olifants River Gorge in Kruger National Park, South Africa, were experienced between 2008 and 2012, during which at least 216 crocodiles died. Live crocodiles were lethargic. Necropsy examination of 56 affected crocodiles showed dark yellow-brown firm nodules in both somatic fat and the abdominal fat body. In all of the 11 crocodiles submitted for histology, degenerative, necrotic, and inflammatory changes supported a diagnosis of steatitis in both fat types. Crocodiles are apex predators in this anthropogenically changed aquatic ecosystem that is used by humans upstream and downstream from the park for domestic, agricultural, fishing, and recreational purposes. This pathologic review of pansteatitis in crocodiles in the Olifants River system was part of a broad multidisciplinary research program. To date, no definitive causative agent has been identified. Epidemiologic evidence suggests that this event may have been a one-time event with long-standing repercussions on the health of the crocodiles. Pathologic findings are rarely documented in wild crocodylians. This study also reports on other conditions, including the presence of coccidian oocysts, capillarid and filaroid nematodes, digenetic trematodes, and pentastomes.

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Isberg, S.R. and Shilton, C.M. (2013). Stress in farmed saltwater crocodiles (*Crocodylus porosus*): no difference between individually- and communally-housed animals. *SpringerPlus* 2013: 2:381.

**Abstract:** Minimising stress in farmed crocodiles is not only important for improving animal welfare, but may also improve skin blemish healing and infection resistance, which influence the quality of the final skin product. Forty near-harvest size saltwater crocodiles (1.6-1.8 m TL) from two Australian farms were sampled to evaluate the effect of different pen types (communal pens n= 20; individual pens

n= 20) on stress as indicated by plasma corticosterone. Blood samples were taken within three minutes of immobilisation and analysed using a commercial enzyme immunoassay kit. There was no relationship with animal size (P= 0.16), between farms (P= 0.86), pen types (P= 0.69), communal pens between farms (P= 0.28) or individual pens between farms (P= 0.24). Based on corticosterone levels, it appears that individual pens do not cause significantly more stress on harvest-size animals than communal pens. Individual pens meet their design specifications by achieving comparable healing rates of belly skin blemishes as communal pens without compromising animal welfare and minimising the possibility of new blemishes.

## **Submitted Publications**

WHEN A WHOLE BIG TRANSVERSE ROW OF NUCHAL SCALES BECOMES ONE INDIVIDUAL SUPERSCUTE. Concerning the cervical dorsal armor shield (the nuchal scales) in the modern Crocodylia, it was formerly believed that when there was only one single individual scale representing any transverse row of crocodylian nuchals, then it was located in the neck row closest to the body, and this row across the base of the neck had ancestrally and recently been composed of two scales, but that one of these two elements has today (this individual from birth) newly become vestigial and has functionally been lost. Thus it was formerly true that if any transverse row of the cervical shield consisted of a single nuchal scale, then the row in question was vestigial and what remained of it was bilaterally asymmetrical, and its placement was to one side or the other in relation to the long-axis midline of the animal. However, two cases (one living and one fairly recent fossil) have been reported where a whole and complete transverse row of nuchal scales can consist of a single and remarkably large individual functional superscale (and when ossified a superscute) that is not vestigial in any sense, and is boldly and distinctly an example of bilateral symmetry. The old generality newly has some exceptions.

The exceptional living example (n= 2), reported by De Boer (2011), is in *Osteolaemus tetraspis osborni*, and the phenomenon happens independently in both of the conspicuous two, large and obvious transverse rows of the cervical shield. Thus, in both individuals, two scales in one ancestral nuchal row have become an entire derived row that is newly one transverse superscale, and separately the normal scales in the nuchal row adjacent to it have also become fused together into a superscale. On each animal, four ancestral scales have become two, as illustrated in Figures 3.2a and 3.2b in De Boer (2011), and he commented on the fact that the amount of bone in these two *Osteolaemus* was remarkably similar to the neck protection that had formerly been provided by the immediately ancestral two rows of two scales each.

The fossil example of a large and conspicuous transverse row of nuchals that has had all of its ancestral elements newly become fused together into a single superscale, reported by Brochu (2007), is in the former *Crocodylus robustus* (see Ross 2006), newly recombined with the new genus *Voay*

Brochu, 2007, as *Voay robustus* from Madagascar. In this case the entire transverse row is one functional piece of bone, and the nature and placement of the two distinctly raised keels on this remarkably transverse nuchal bone make it obvious that it bridged the animal's midline, and clearly balanced on the neck and was bilaterally symmetrical. However, because it is a loose piece of fossil, it is not known what the transverse row of nuchals next to it looked like. The *Voay* isolated transverse nuchal row of one superscale is shown in Figure 15 in Brochu (2007). Before this complete *Voay* nuchal row became a single superscute, the prior condition could have been four individual scales (scutes), or alternatively a three scales stage, or it could have been already reduced to just two functional elements.

One crocodylian genus is known to sometimes exhibit a large and conspicuous transverse row of nuchal scales that is bilaterally symmetrical and yet composed of three scales. In *Paleosuchus* a row of four nuchals can reduce to three scutes across by the fusion (crossing the midline) of the median pair. This was illustrated for both *P. trigonatus* and *P. palpebrosus* in Ross and Mayer (1983), and in some cases the middle scute has the remains of two keels, but in other cases the keel(s) on the center scale are essentially lost.

I do not know if Brochu's (2007) Figure 15 *Voay robustus* complete transverse nuchal row as one superscute is four scales linked together into one superscale, or if a hypothetical four had already become three (like *Paleosuchus* sometimes does), or alternatively if this Malagasy fossil nuchal row was created by a complete row of two large and obvious scales (each of which may have been the result of an earlier transverse fusion) becoming fused together into a superscale that is bilaterally symmetrical and fully functional. If the latter, then it is the same thing as De Boer's (2011) superscutes in *Osteolaemus*.

De Boer (2011) said that he found various anomalous kinds of nuchals in both subspecies of *Osteolaemus tetraspis*, and that the nuchal scales are generally not sufficient for confidently separating *O. t. tetraspis* from *O. t. osborni*. Further, the popular literature allegation concerning the post-occipitals in *Osteolaemus* also does not always work. However, the most obvious case (n= 2) of transverse superscales occurs in these two Ubangui River drainage (Likouala River) bushmeat captives examined in Brazzaville, which, because of their locality of origin data, were identified by De Boer (2011) and by Roland Zoer (2010) as the *osborni* subspecies (type locality the Ituri Forest including the very upper Ubangui). The provenance of the 2006 Brazzaville bushmeat sample is detailed in Zoer (2010), including the fact that the specimens illustrated in De Boer (2011), and the rest of the Likouala River sample, were later killed and butchered and sold in 2006 as fresh meat (for human consumption) by their Brazzaville owner. Only field notes and photos remain.

Based primarily on skull and mandible characters, Brochu (2007) asserted that *Voay robustus* is most closely related to the *osborni* group of *Osteolaemus* (his *O. osborni* as a full species), and that its second closest relative is the other

kind of *Osteolaemus* that lives west of and outside of the Congo Basin. If the *Voay* transverse superscale was derived directly from a regular row of four scutes, or alternatively from a bilaterally symmetrical row of three scales, then the *Voay* nuchals are unlike those in *Osteolaemus* including the *osborni* kind. However, if *Voay* had a complete row of just two scales (one left, one right), then De Boer's (2011) observation directly supports Brochu's (2007) taxonomic (close relationship) hypothesis, because the only two crocodylian taxa known to reduce the number of scales in a complete and entire transverse row of ancestral nuchals to become newly one (one scute= one scale) by the method of creating a superscale the size of the sum of all of the former parts are Brochu's (2007) *Voay robustus* fossil from subrecent Madagascar, and De Boer's (2011) *O. t. osborni* bushmeat from the Ubangui drainage of northern Congo.

The phenomenon of a properly midline-crossing central scale in a transverse nuchal row of three scales total (*Paleosuchus*) is different from the phenomenon of a whole transverse nuchal row of multiple scales becoming unified into a single rigid bone of supersize in *Voay* and *Osteolaemus*, and we know that in two cited examples of *O. t. osborni* from the Likouala River of northern interior Congo it was a total transverse row of two modern scales (Ross and Mayer 1983; De Boer 2011) that fused together and became newly a superscale.

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For further information on the CSG and its programs, on crocodile conservation, biology, management, farming, ranching, or trade, contact the Executive Office (csg@wmi.com.au) or Regional Chairmen

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**CSG IUCN Red List Authority:** Dr. Perran Ross, Department of  
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