

# **CROCODILE SPECIALIST GROUP NEWSLETTER**

VOLUME 39 No. 3 • JULY 2020 - SEPTEMBER 2020



# CROCODILE

## SPECIALIST

## GROUP

# NEWSLETTER

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VOLUME 39 Number 3  
JULY 2020 - SEPTEMBER 2020

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IUCN - Species Survival Commission

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COVER PHOTOGRAPH: Gharial (*Gavialis gangeticus*) hatchling sitting on the head of a Mugger crocodile (*Crocodylus palustris*), which was guarding its own creche of Mugger hatchlings, on the Rapti River, Chitwan National Park, Nepal. Gharial and Mugger use the same banks for nesting on the Rapti River, and often guard their creches in close proximity. Photograph: Prakash Basnet (2020).

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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.

## CSG Newsletter

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. It is available as a free electronic, downloadable copy from "<http://www.iucncsg.org/pages/Publications.html>".

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Fax: +61.8.89470678. E-mail: [csg@wmi.com.au](mailto:csg@wmi.com.au).

## PATRONS

We thank all patrons who have donated to the CSG and its conservation program over many years, and especially to donors in 2019-2020 (listed below).

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Crocodile Farm, Thailand.  
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George Saputra, CV Alona Jaya, Jakarta, Indonesia.  
Santa Fe College Teaching Zoo, Gainesville, Florida, USA.  
Zambia Crocodile Farmers Association, Lusaka, Zambia.

#### Contributors (\$250 - \$1000)

Cathy Shilton, Northern Territory, Australia.  
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Dresden Zoo, Dresden, Germany.  
James Hennessy, The National Reptile Zoo, Ireland.  
Zoo Atlanta, Georgia, USA.  
Zoological Society of Hertfordshire, UK.

## Editorial

The IUCN Council has announced that Dr. Bruno Oberle is the next IUCN Director General. Dr. Oberle is a Swiss national with very significant credentials in both policy and biopolitics (<https://www.resourcepanel.org/the-panel/bruno-mc-oberle>), and succeeds Inger Andersen, who served as IUCN Director General from 2015 to 2019, and then went on to become the Executive Director of UNEP. Her knowledge of the complex challenges involved in getting effective and equitable conservation - and her accolades for what has been achieved with crocodilians - is well expressed in her opening address to CITES CoP18 ([https://cites.org/eng/news/pr/opening\\_remarks\\_Executive-Director-UNEP-CoP18\\_17082019](https://cites.org/eng/news/pr/opening_remarks_Executive-Director-UNEP-CoP18_17082019)).

When one adds the credentials of Ivonne Higuero, the current Secretary General of CITES (<https://cites.org/eng/disc/sec/Secretary-General>), we really do have some very skilled people “at the top”. People who understand and appreciate that conservation cannot proceed effectively unless rural people are fully engaged. This is just so important at a time when animal rights activists are gaining more and more support, in a political world, now 56% urbanized and 44% rural versus 39% urban and 61% rural in 1980. The times are changing rapidly.

We were saddened to learn that Professor Dame Georgina Mace (67 y) passed away on 19 September 2020. As Director of Science at the Institute of Zoology in London, she was instrumental in developing the criteria for listing species in the IUCN Red List. The “Red List” leadership task that Georgina took on for IUCN was a monumental one. Risk and uncertainty in the science of predicting extinction, for both plants and animals, combined in innovative ways to produce a simplified system, that could be implemented by diverse people, and yet provide consistency over time. All within the sometimes stormy environment of conservation advocacy. I interacted with Georgina personally over crocodilians and marine turtles - both complex and controversial - and I was impressed by the calm, humble, welcoming and genuine approach she always adopted - more keen to investigate potential flaws in her creation, than to receive accolades - the mark of a true scientist. Georgina was a real icon within IUCN, with remarkable social, scientific and diplomatic skills. A truly sad passing but her story and legacy will live on. We extend our condolences to Georgina’s family.

The law to ban the sale of crocodilian goods in California reflected animal rights domination of a political environment. It was set to go into effect on 1 January 2020, but a Federal Court appeal, lodged by the State of Louisiana and group of private sector stakeholders, has allowed the trade to continue while the case is being litigated. For the CSG, the ability of consumers to purchase crocodile and alligator products is critical to sustaining the supply chains, that ultimately deliver benefits to conservation and livelihoods in the field, for at least some key species. It is not a panacea for all crocodilians - but is unequivocally important for some.

The Florida Fish and Wildlife Conservation Commission has adopted a new Alligator Hide Cutting Rule, to help create new markets in the face of declining demand for wild skins. It allows legally acquired, CITES-tagged raw alligator (*Alligator mississippiensis*) skins, to be cut into specified pieces by licensed alligator farmers, meat processors and skin buyers (see pages 8-9). This has long been a standard practice with *Caiman crocodilus* harvesting and farming, and the Florida alligator industry hopes it will enhance the value of lower-quality alligator skins in the marketplace.

The shift away from “wild-harvested” crocodilian skins globally, which has serious conservation and livelihood consequences for some countries, tends to be justified publicly on “skin quality” - but is equally driven by retailers distancing themselves from production methods that could be criticized on animal welfare grounds. The long distinction the CSG has had to battle with, between species that have commercial value, where conservation can be driven by commercial incentives, and species that do not and depend largely on philanthropy - which requires very difficult skills to sustain, is merging rapidly. New challenges for the CSG and for crocodilians.

The CSG welcomes the establishment of the Guatemalan Crocodilian Group (Grupo de Cocodrileros de Guatemala; GCG), currently represented by Valerie Corado-García, Diana Velásquez-Ramírez and Rosa Roldán-Díaz. The goal of encouraging young scientists to generate peer-reviewed manuscripts, in collaboration with recognized international crocodilian colleagues, and obtaining the knowledge base needed to further and build long-term sustainable management programs to conservation of crocodilians in Guatemala, is admirable (see pages 18-20).

Concerns have been raised by members of the Brazilian research community regarding the movement of Black caimans (*Melanosuchus niger*) out of their range, within Brazil (see pages 20-22). Whilst CSG policy opposes the movement of crocodilians outside their range, this case is a little different, as it involves movements within the one country.

Drones are increasingly being used, or investigated, by researchers and managers involved with crocodilians. A series of drone resources are now available on the CSG website (<http://www.iucncsg.org/pages/Virtual-UAS-Workshop.html>), and the first virtual zoom meeting was held on 18



September 2020. This initial meeting attracted 65 participants from around 13 countries (see pages 7-8).

The AGM of the International Association of Crocodile Specialists Inc. (IACS), which is responsible for the funding arrangements needed to sustain the CSG, was held on 5 October 2020. Although global economies are in a particularly sad state, I'm seriously grateful to all of those people/organisations who continue to provide financial support to the CSG.

It was our intention to support some people involved in the CSG "Future Leaders Program", to attend the next IUCN World Conservation Congress (Marseilles, France), which was planned for 2020 but postponed, due to the Covid-19 pandemic, until January 2021. The WCC has now been postponed again, for the same reasons, but new dates in late 2021 have not yet been finalized by the IUCN.

One of the classic works on reptile health was "Infectious Diseases and Pathology of Reptiles: An Atlas and Text" published in 2007. Since that time, a wealth of new information concerning the pathology and diseases of reptiles has been generated, and Elliott Jacobson (University of Florida) and Michael Garner (Northwest ZooPath) have joined forces to compile and publish two updated volumes of "Disease and Pathology of Reptiles" (see pages 6-7).

At the end of September, Hurricane Laura again caused considerable damage in Louisiana, USA. Both Rockefeller Refuge and McNeese State University sustained tremendous damage. Ted Joane's home was destroyed, but to our knowledge all CSG members and associates from the region are safe. At the time of writing a second hurricane is approaching! Our thoughts are with everyone affected.

On a lighter note, Stephan Reber and colleagues (Takeshi Nishimura, Judith Janisch, Mark Robertson, Tecumseh Fitch) performed an experiment to understand how alligators might communicate. Although it was a serious piece of research, its slightly comedic aspects have won the team an Ig Nobel Prize (<https://www.bbc.com/news/science-environment-54197198>), for inducing a female Chinese alligator to bellow in an airtight chamber filled with helium-enriched air.

Professor Grahame Webb, CSG Chair.

## 26th CSG Working Meeting Postponed

Due to the current COVID-19 pandemic, the 26th CSG Working Meeting to be held in Chetumal, Quintana Roo, Mexico, has been postponed to 3-6 May 2021. It will be preceded by the veterinary, drone and taxonomy workshops on 1 May 2021, and a CSG Steering Committee meeting on 2 May 2021. Organisers are tracking the Covid-19 situation, and will keep the CSG Executive Committee informed accordingly.

## CSG Student Research Assistance Scheme

The Student Research Assistance Scheme (SRAS) and Fritz Huchzermeyer Veterinary Science Student Research Assistance Scheme (FHVS-SRAS) provided funding to 7 students in the April-June 2020 quarter. Three further applications are currently under review.

1. Sigifredo Clavijo Garzon (Colombia): Atypical morphology in caimans of Hidroprado Dam, Colombia: Intraspecific hybridization, morphological variation and genetics.
2. Saurav Lamichhane (Nepal): Status and conservation threats of *Crocodylus palustris* in Ghodaghodi Lake complex of Kailali District, Nepal.
3. Paula Martin (Argentina): Development of molecular methodologies for obtaining barcodes for forensic studies in caimans.
4. Ricardo Ojeda Adame (Mexico): The socioeconomic relationship between communities on the southern coast of Jalisco and wild *Crocodylus acutus* populations.
5. Divya Bhattarai (Nepal): Distribution, status and conservation threats to Mugger crocodile (*Crocodylus palustris*) in the Koshi River, Nepal.
6. Washington da Silva Mendonça (Brazil): Population trends and stress due to tourism with caimans in the Anavilhanas National Park, Central Amazonia.
7. Javier Bentez Moreno (Mexico): Knowledge and perception of inhabitants of two communities towards crocodiles in Sian Ka'an Biosphere Reserve.

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

## Lineage Diversity in Caiman

In a new study, Igor Roberto, Tomas Hrbek and 10 other co-authors have revealed unexpected, but unsurprising, diversity among the extant caimans of South America (Roberto *et al.* 2020). The authors undertook genetic examination of 591 individuals representing all current *Caiman* taxa except *C. c. apaporiensis*, a taxon that was recently invalidated by Balaguera-Reina *et al.* (2020). Utilizing four species delimitation methods the authors provide a very robust picture of taxonomic diversity in this group and offer a cautious but quite astonishing result. The consensus estimate indicates 16 lineages of *Caiman* compared to the currently recognized 5-6 taxa. There has long been speculation that the current taxonomy of *Caiman* is not an accurate representation of the true taxonomic diversity of this genus. Discussion over the status of various subspecies (*Caiman crocodilus/chiapasius/fuscus*), the relationships of *C. crocodilus* and *C. yacare*, and the phylogenetic position of *C. latirostris* are common in literature. The recent delimitation of cryptic lineages in

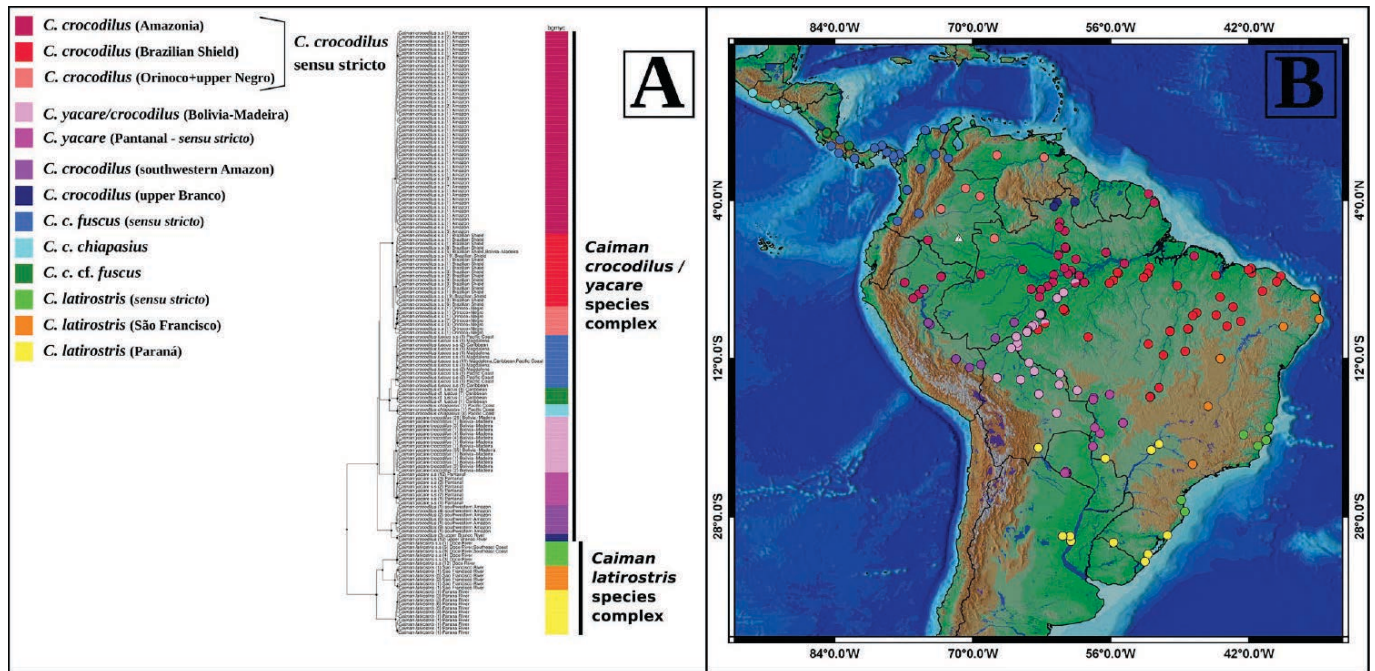


Figure 1. Figure 3 from Roberto *et al.* (2020).

*Paleosuchus*, also suggests more diversity than previously suspected (Bittencourt *et al.* 2019; Muniz *et al.* 2018).

Lack of taxonomic clarity in caiman has multiple sources, but major contributors are limited geographic sampling and their conserved morphology. The study of Roberto *et al.* (2020) overcomes these impediments with a large and geographically diverse sample based on the analysis of DNA data rather than morphological characters. Using this experimental design, the study had three goals: (1) delimit lineages within the genus *Caiman*; (2) propose a new dated phylogeny of the genus *Caiman*; and, (3) evaluate biogeographical scenarios underpinning the evolutionary history of this genus.

Fresh tissue (tail scutes removed during marking of individuals) was collected from 365 specimens between 2004 and 2018. DNA was extracted and the complete cytochrome b gene amplified and sequenced. These data were combined with additional published DNA data resulting in a dataset of 591 individuals from 169 localities in twelve countries and including samples from the type localities of *latirostris*, *yacare*, *chiapasius* and *fuscus*. Following Maximum Likelihood and Bayesian Inference phylogenetic reconstruction, the resulting phylogenies were subjected to four species discovery methods: the generalized mixed Yule-coalescent (GMYC), a Bayesian implementation of GMYC (bGMYC), the multi-rate Poisson tree process method (mPTP) and a Bayesian implementation of the PTP (bPTP). These analyses provided upper and lower lineage diversity limits, as well as a consensus estimate. The full paper (Roberto *et al.* 2020) may be consulted for detailed methods, analysis and references.

The total number of lineages discovered within *Caiman*, *Paleosuchus* and *Melanosuchus* ranged from 16 to 44. The most conservative methods (bPTP and mPTP) discovered 10 lineages of *Caiman*, five lineages of *Paleosuchus* and one lineage of *Melanosuchus*. The results of the bPTP

analysis were identical except for the subdivision of the main *Caiman crocodilus* lineage into three lineages occupying the Orinoco, the central Amazon and the Brazilian Shield. The least conservative method (GMYC) discovered 24 lineages of *Caiman*, 12 lineages of *Paleosuchus* and 8 lineages of *Melanosuchus*, however this last method tended to recover unsupported clades as lineages, and is known to delimit population structure (intraspecific diversity) as lineage diversity (interspecific divergence). Within *Caiman latirostris*, bPTP, mPTP and bGMYC recovered three lineages while GMYC recovered five lineages. Within the *Caiman crocodilus/yacare* complex, we recovered 7 (bPTP and mPTP), 10 (bGMYC) and 19 (GMYC) lineages. All lineages recovered by bPTP, mPTP and bGMYC were geographically structured.

This study is the first to incorporate all major lineages from the extant Caimaninae, covering most of their geographic distribution. The basal divergence of the *Caiman crocodilus/yacare* complex and *C. latirostris* was estimated at 27.73 Ma (95% HPD 18.5-41.98). The origin of the major clades of the *Caiman crocodilus/yacare* complex was estimated at a median age of 10.86 Ma (95% HPD 6.8-16.6). The three main lineages of *Caiman latirostris* also diverged between 10.6 and 7.5 Ma. The major clades of the *Caiman crocodilus/yacare* complex underwent further diversification during the Pliocene and Pleistocene, resulting in the formation of the lineages of *Caiman crocodilus* from Amazonia, Orinoco, upper Negro River and Brazilian Shield, the *C. crocodilus* lineages of upper Branco River and southwestern Amazon, *C. yacare*, *C. c. fuscus* and *C. c. chiapasius*.

In discussion the authors match these results to the best current understanding of biogeographic events in South America including the formation of the proto Amazon (draining to the Pacific), separation of major South American river basins and the rise of the Andes mountain ranges. The concordance

with these biogeographic events and the observed patterns of geographic structuring of caiman diversity suggests a plausible evolutionary process of caiman diversification in South America that is summarized in Figure 1.

The authors also discuss the taxonomic and conservation implications of their results, cautiously refraining from taxonomic innovation while drawing attention to the need for a taxonomic revision, especially because most of the taxa recognized as subspecies are deeply divergent lineages similar in all other aspects to other lineages considered species (eg *Caiman crocodilus* and *C. yacare*). The recognition of increased diversity will also impact on conservation of this group, since most of the discovered lineages occur in heavy impacted regions of South America.

In summary, this study involving a large, representative and geographically diverse sampling subjected to detailed multi-method genetic analyses has revealed a convincing pattern of geographically structured lineage diversity of caimans. While further resolution and clarification of these results is needed, the taxonomic and the conservation consequences are profound.

#### Literature Cited

Balaguera-Reina, S.A., Vargas-Ramírez, M., Ordóñez-Garza, N., Hernández-González, F. and Densmore, L.D. (2020). Unveiling the mystery: Assessing the evolutionary trajectory of the Apaporis caiman population (*Caiman crocodilus apaporiensis*, Medem 1955) via mitochondrial molecular makers. *Biol. J. Linn. Soc.* (<https://doi.org/10.1093/biolinnean/blaa096>).

Bittencourt, P.S., Campos, Z., Muniz, F. de L., Marioni, B., Souza, B.C., Da Silveira, R., de Thoisy, B., Hrbek, T. and Farias, I.P. (2019). Evidence of cryptic lineages within a small South American crocodilian: the Schneider's dwarf caiman *Paleosuchus trigonatus* (Alligatoridae: Caimaninae). *PeerJ* 7: e6580.

Muniz, F. de L., Campos, Z., Hernández-Rangel, S.M., Martínez, J.G., Souza, B.C., de Thoisy, B., Botero-Arias, R., Hrbek, T. and Farias, I.P. (2018). Delimitation of evolutionary units in Cuvier's dwarf caiman, *Paleosuchus palpebrosus* (Cuvier, 1807): Insights from conservation of a broadly distributed species. *Conservation Genetics* 19: 599-610.

Roberto, I.J., Bittencourt, P.S., Muniz, F.L., Hernández-Rangel, S.M., Nóbrega, Y.C., Ávila, R.W., Souza, B.C., Alvarez, G., Miranda-Chumacero, G., Campos, Z., Farias, I.P. and Hrbek, T. (2020). Unexpected but unsurprising lineage diversity within the most widespread Neotropical crocodilian genus *Caiman* (Crocodylia, Alligatoridae). *Systematics and Biodiversity* 18: 377-395.

Igor Roberto ([igorjroberto@gmail.com](mailto:igorjroberto@gmail.com)), Tomas Hrbek ([tomas@evoamazon.net](mailto:tomas@evoamazon.net)) and Perran Ross ([pross@ufl.edu](mailto:pross@ufl.edu)).

## Books

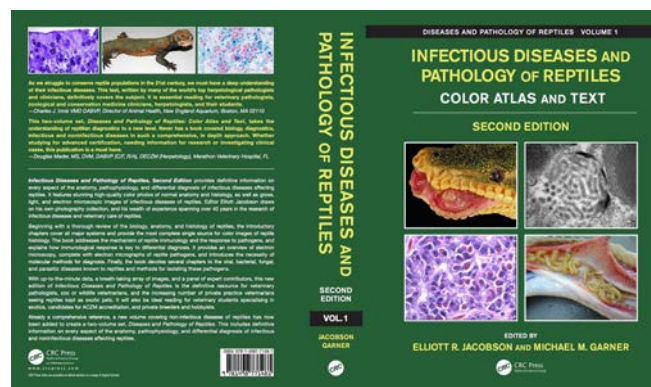
### Diseases and Pathology of Reptiles - Volumes 1 and 2

Some 13 years have passed since the publication of “Infectious Diseases and Pathology of Reptiles: An Atlas and Text” in 2007. Since that time, a wealth of new information concerning the pathology and diseases of reptiles has been published.

Elliott Jacobson (University of Florida) and Michael Garner (Northwest ZooPath) have joined forces to compile “Infectious Diseases and Pathology of Reptiles: Color Atlas and Text (Volume 1)” and “Noninfectious Diseases and Pathology of Reptiles: Color Atlas and Text (Volume 2)”.

With permission from the editors, the following information has been extracted from the prefaces of these two volumes.

### Infectious Diseases and Pathology of Reptiles, Volume 1 (edited by Elliott Jacobson and Michael Garner)



- Chapter 1: Overview of Biology, Anatomy, and Histology of Reptiles (Elliott Jacobson, Harvey Lillywhite, Daniel Blackburn) has been significantly expanded with new figures and topics, and remains the most complete single source of colour images of reptile histology.
- Chapter 2: Immunology of Reptiles (Francesco Oraggi, Marco Tecilla) is a special component of the biology of reptiles, and because of its role in the response of reptiles to pathogens. This chapter has been significantly updated, including new topics such as ecoimmunology.
- Chapter 3: Hematology of Reptiles with Focus on Circulating Inflammatory Cells (Nicole Stacy, Kendal Harr): New figures of circulating cells have been added to this chapter along with enlargement of many of the figures of cells covered in the first edition.
- Chapter 4: Reptile Necropsy Techniques (Brian Stacy) has been updated to reflect current methods and diagnostic capabilities pertinent to postmortem examination. Additional instructional photographs have been added to illustrate dissection techniques and guide evaluation.
- Chapter 5: Host Response to Infectious Agents and



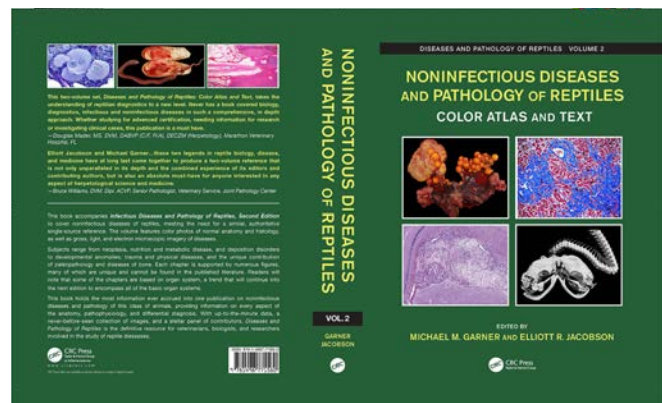
Identification of Pathogens in Tissue Section (Brian Stacy, Allan Pessier, Robert Ossiboff) has been revised to include the current literature on reptilian inflammatory response and recognition of pathogens by histology. Additional photomicrographs have been added to show key cell types, microorganisms, and important histopathological features.

- Chapter 6: Introduction to Basic Cytopathology (Nicole Stacy, Rose Raskin) is an introduction to this newly added topic, with specific application to reptiles.
- Chapter 7: Identifying Reptile Pathogens using Electron Microscopy (Elliott Jacobson, Karen Kelley) continues to provide a general overview of techniques and methods used in electron microscopy, with the inclusion of many new electron photomicrographs of reptile pathogens. Although the challenges in isolating fastidious organisms highlighted in the previous edition remain the same, giant leaps have been made in the molecular detection of these organisms.
- Chapter 8: Molecular Diagnostics (April Johnson, Francesco Origi, Mark Stenglein) reviews and summarizes the new available tools for molecular diagnostics, complementing the information already available in the previous edition.
- Chapter 9: Serodiagnostics (Francesco Origi, Elliott Jacobson) has been significantly updated thanks to the latest information from the published literature.
- Chapter 10: Viruses and Viral Diseases of Reptiles (Rachel Marschang, Francesco Origi, Mark Stenglein, Timothy Hyndman, James Wellehan, Elliott Jacobson)
- Chapter 11: Bacterial Diseases of Reptiles (Frank Pasmans, An Martel, Elliott Jacobson)
- Chapter 12: Mycotic Diseases of Reptiles (Jean Paré, Kenneth Conley)
- Chapter 13: Parasites and Parasitic Diseases of Reptiles (Heather Walden, Ellis Greiner, Elliott Jacobson)
- Chapter 14: Isolation of Pathogens (Francesco Origi, Robert Ossiboff, Jean Paré).

**Noninfectious Diseases and Pathology of Reptiles, Volume 2 (edited by Michael Garner and Elliott Jacobson)**

Each chapter is supported by numerous figures, many of which are unique and cannot be found in the published literature. Some of the chapters are based on the organ system, a trend that will continue into the next edition to encompass all of the basic organ systems.

- Chapter 1: Reptile Neoplasia (Elise Ladouceur)
- Chapter 2: Nutritional and Metabolic Diseases (Carles Juan-Sallés, Thomas Boyer)



- Chapter 3: Depositional Diseases (Erin Graham, Rachel Burns, Robert Ossiboff)
- Chapter 4: Normal and Abnormal Reptile Development (Marcelo De Carvalho, Gregory Lewbart, James Stewart, Jeanette Wyneken)
- Chapter 5: Degenerative Diseases (Nancy Stedman)
- Chapter 6: Trauma and Physical Diseases (Christine Miller)
- Chapter 7: Environmental and Miscellaneous Toxicoses in Reptiles (Jorge Orós, María Camacho, Octavio Luzardo)
- Chapter 8: Physiology and Diseases of the Reproductive System (John Roberts, Daniel Warner)
- Chapter 9: Reptile Cardiovascular System (James Bogan Jr., Joaquin Ortega)
- Chapter 10: Bone Alteration by Disease: Its Appearance, Phylogeny and Penetrance through Geologic Time (Bruce Rothschild)

Both volumes are available from CRC Press and Amazon.

## 1st Virtual Drone Workshop Live Chat

The CSG Drone Working Group held its first “Live Chat” on 18 September. Moderated by Raymond Carthy, Andrew Ortega, Carlos Piña and Lonnie McCaskill, the event attracted 65 participants from an estimated 13 countries, and lasted for almost 2 hours. Thanks to all who participated!

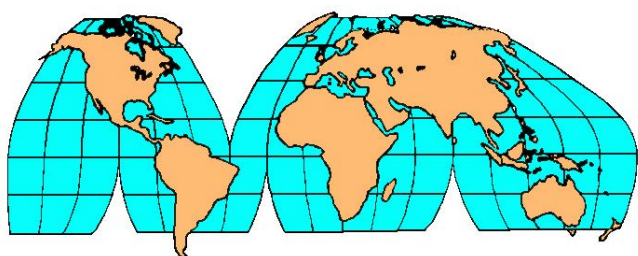
The featured speaker, Jason Holmberg, gave a fascinating presentation (“Wildbook: AI Collaboration for Wildlife Research”) on his work with [WildMe.org](https://www.wildbook.org/) and the Wildbook software used to individually identify animals. Wildbook works by using computer algorithms to classify known animals and their markings, much like the way that fingerprinting is used. Animals such as zebra, giraffe, whales and whale sharks are the focus of current tracking projects. Using photographs of individual animals from researchers and citizen science volunteers and running them through the Wildbook software can help track those individuals.

Our workshop-related activities have seen the inception of collaborative efforts to do similar work on crocodile species with scute patterns and body shapes. It is the Drone Working Group's goal to bring together people who are using drones in their crocodile conservation field work, to promote ideas, technology, and best practices more quickly through collaboration.

We hope to schedule the next live chat in the near future, and are already lining up presentations on requested topics. It will be on radio tracking crocodiles based on using drones. Any feedback or suggestions for other live chat sessions would be greatly appreciated, and the links on the CSG Drone Workshop website are always open to submit presentations and to post recent publications ([www.iucncsg.org/pages/Virtual-UAS-Workshop.html](http://www.iucncsg.org/pages/Virtual-UAS-Workshop.html)). Your engagement will help us provide the information you need to use this technology to advance crocodilian research, conservation, and management objectives. A recording of the 1st Live Chat is at: [www.youtube.com/watch?v=dvD23cdCpko&feature=youtu.be](https://www.youtube.com/watch?v=dvD23cdCpko&feature=youtu.be)

Lonnie McCaskill ([lmccaskill@wcs.org](mailto:lmccaskill@wcs.org)), Carlos Piña ([cidcarlos@infoaire.com.ar](mailto:cidcarlos@infoaire.com.ar)), Ray Carthy ([ngosi@ufl.edu](mailto:ngosi@ufl.edu)) and Andrew Ortega ([andrew.ortega@ufl.edu](mailto:andrew.ortega@ufl.edu)), *CSG Drone Working Group*.

## Regional Reports



### North America

#### USA

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION ADOPTS NEW ALLIGATOR SKIN CUTTING RULE. On 22 July 2020, the Florida Fish and Wildlife Conservation Commission (FWC) approved a rule to allow legally acquired, CITES-tagged raw alligator skins (= hides) to be cut into specified pieces by licensed alligator farmers, alligator meat processors, and alligator skin buyers. The marketplace for wild and lower-grade farmed skins has been depressed for the past several years. This rule revision was developed at the request of the Florida alligator industry to provide more flexibility in using portions of lower-quality skins to enhance the overall value of skins in the marketplace.

Skin pieces that are allowed to be produced and immediately tagged are:

1. for belly skins: two flanks or a chaleco, the belly and tail
2. for hornback skins - two flanks (each including a portion

of the belly) or chaleco, the tail and the back.

This was a major change in Florida's alligator regulations, and several CSG members expressed some concerns about the legal aspects of the rule and the traceability of alligator skin pieces. I was asked by CSG Chair Grahame Webb to provide an assessment of the rule change and address concerns of membership.

The rule was developed by the FWC Alligator Management Program Standing Team, that included CSG member Harry Dutton. I contacted Harry, who provided clarification of the process used to develop the rule. I also reviewed international, federal, and other state regulations dealing with crocodilian skin pieces. Here is what I found:

- Crocodilian skin pieces are legally and commonly traded internationally. This has been occurring with raw, crusted, and tanned caiman skin pieces for decades. Tanned alligator skin pieces have been commonly traded internationally (raw pieces less commonly). Partial skins and skin parts were approved for trade with provisions for tagging and labeling in CITES Resolution Conf. 11.12 (Rev. CoP15).
- Currently, the US Fish and Wildlife Service (the CITES Management Authority) allows the export of both raw and tanned alligator skin parts (partial skins and parts), subject to a number of conditions on tagging and labeling (50 CFR 23.70) (see <https://www.law.cornell.edu/cfr/text/50/23.70>). USFWS regulations are largely based on CITES Resolution Conf. 11.12 (Rev. CoP15). Harry Dutton reviewed the regulation and checked with Clif Horton (USFWS), to confirm that the proposed Florida rule was compatible with federal regulations.
- Louisiana's regulations have allowed the cutting of raw skins into pieces for a number of years. The proposed Florida regulations are patterned to a large extent after Louisiana's regulations. The two main differences in regulations between the states are: (1) Florida has a subset of rules for cutting and tagging skin pieces that are not intended for export; and, (2) Florida will not require state agents to oversee the application of tags to skins.
- The proposed rule for skin pieces, not intended for export, was to accommodate desired outcomes from a producer in Florida and a Florida tannery that reported that CITES tags create problems during the tanning process for cut skin pieces. Therefore, they would like to attach a type of tag on the pieces that better handles the tanning process. Similar to the process for cutting raw or tanned skins and tagging them with CITES tags, the alternate tag will stay with the skin piece per federal regulations, usually until it is manufactured into leather products.
- If, at some point the legal owner of skin pieces with alternate tags wants to export those pieces, they will have to request CITES tags for those pieces from USFWS, similar to the process that tanners and dealers currently have to undertake if they wish to export skin pieces.



- Skin pieces, with either CITES or alternate tags, will be referenced back to the original CITES tag number issued for the whole skin. The FWC currently has a searchable database available to any law enforcement agency and to the general public for determining from which whole skin the tagged pieces originated (see <https://public.myfwc.com/crossdoi/lex/gatorcitessearch.aspx>). This will be adapted to include the alternate tags. FWC also offers direct help with finding the source of any pieces or whole skins and determining their legality.
- In the 1990s, Florida discontinued having agents or employees directly apply CITES tags to alligator skins, as is done in Louisiana. This was done because the level of illegal activity (tagging of skins from illegally-taken alligators) was deemed insignificant, and that direct tagging by agents had little effect on preventing illegal harvests of alligators. The FWC relies on spot checks by law enforcement and undercover investigations of hunters, processors, and farmers to achieve compliance with regulations. The new rules will follow that precedent.
- FWC will require a eligible persons wishing to cut raw skins for domestic use to purchase their own tags. The tags will have to be reviewed and approved by FWC. USFWS does not require the use of CITES tags for domestic trade in alligator skins.
- Timetables for providing tagging information to FWC or maintaining records were based on what is considered a reasonable amount of time to expect such information to be reported or kept. If problems arise, this can be re-evaluated and adjusted as warranted.

Given the above considerations, I found that the proposed rule is compatible with and parallel to existing state, federal, and international regulations, and FWC has a mechanism for tracing the source of skins and skin pieces for law enforcement purposes. So, in my opinion, it meets or exceeds standards of the CSG for approving trade of skin pieces

Allan Woodward, *CSG Regional Co-Chair for North America*.

**HURRICANE LAURA SLAMS SOUTHWEST LOUISIANA AND ROCKEFELLER WILDLIFE REFUGE.** The state of Louisiana was severely impacted by a strong Category 4 Hurricane Laura, which made landfall about 0100 h on 27 August near Cameron. Sustained winds of up to 240 km/h (150 mph) and a massive storm surge of perhaps 4.6 m inundated the coastal area of SW Louisiana, and the sustained winds caused massive damage well into central and north Louisiana. Hurricane Laura was one of the strongest storms on record to hit the USA. The Louisiana Department of Wildlife and Fisheries' Rockefeller Wildlife Refuge is about 40 km east of where the storm made landfall.

In the days before the storm made landfall, staff at Rockefeller had evacuated airboats, trucks, and heavy equipment in advance of the storm, as well as moving computers into a

centrally located conference room in the office, in case exterior windows were broken. As the storm approached, it intensified rapidly and regional damage was extensive (Fig. 1). Rockefeller's office building sustained siding and roof damage (Fig. 2), and water leaked into the offices on the south side of the building. The General Quarters dormitory had significant roof damage. The work shop and other metal buildings (lumber shed, airboat stalls, tractor shed) were also impacted. Fortunately, the new laboratory (with which we had taken occupancy in February) was high and dry (Fig. 3), and the four residences had only minor damage. The West End dormitory had some damage as well.



Figure 1. Aerial view of headquarters at Rockefeller Wildlife Refuge following Hurricane Laura.



Figure 2. Damage to the siding of the Rockefeller Wildlife Refuge office building. Note alligator tail drags and trackways in the mud in office parking lot. Photograph: Marc Sivori.



Figure 3. Laboratory at Rockefeller Wildlife Refuge was high enough to avoid flood damage. Gravel roads are under water. Photograph: Buddy Baker.

Sadly, although we are thankful the homes of several staff members had only moderate damage that can be repaired, numerous employees with homes in Creole, Little Chenier, and surrounding communities either had the entire home washed away or had such extensive damage that the homes are a total loss.

In the immediate aftermath of the hurricane, efforts were made to salvage equipment and files from the office, which were moved to the laboratory for storage. It was inspiring to see many LDWF employees who had lost their homes already back at work during the initial clean-up efforts, working in oppressive heat and humidity in an area without power or water. Many staff members from Rockefeller have been reassigned to other regional LDWF offices until utilities (electricity and water) are restored, which could be several months in the future. Rockefeller remains closed to the public at this time as recovery efforts continue. Cameron Parish, where Rockefeller is located, is still under a mandatory evacuation order with evening curfews in place.

Louisiana's wild alligator harvest season had started on 26 August in the East Zone, and the West Zone opened on 2 September. Many trappers were impacted due to the hurricane, and we expect the quantity of alligators harvested to be lower this year than usual; due both to trappers being displaced by the storm as well as lower demand and prices in 2020. Most trappers in southeast Louisiana were able to continue hunting as normal.

The storm hit in about the middle of alligator egg hatching season. Once again, as with Hurricanes Katrina and Rita in 2005, and Hurricanes Gustav and Ike in 2008, we believe Louisiana's wild egg "ranching" program saved hundreds of thousands of eggs, which were safe in incubators on

commercial farms and likely would have perished in the wild during the storms. Some hatchlings from Rockefeller's egg collection were provided to researchers at Louisiana State University's Aquaculture Research Center for planned nutrition studies, the remaining hatchlings and juveniles were released in suitable habitat at Marsh Island.

Several alligator farms are located in Cameron Parish, in the path of Hurricane Laura. Due to poor market conditions and low demand, one farmer had elected not to collect eggs in 2020. Another farmer collected eggs, but as his facility was flooded by Hurricane Harvey in the past, he transferred his ranch eggs (N= 4601 in 2020) to another farmer for incubation. That farmer's storage buildings were destroyed but alligator houses were not impacted; he was able to incubate 8500 eggs from his egg collection permits. Sadly, one other farmer from Cameron Parish lost his home and everything else, but had moved his eggs (N= 1451) to a cooperating farmer to complete hatching. Another farmer in SW Louisiana, whose facility is further north, had substantial damage to fences and trees, but his alligator sheds were not impacted; although he still has no power and is on a generator as of this writing. Egg hatching results received thus far from these farms were very good, at 91.9%.

It is too early to assess impacts on alligators, but we anticipate this resilient species will recover quickly, as we saw after Hurricane Rita. On my first trip back to the refuge on 2 September, as we began clearing away siding that had blown off the buildings, right away an alligator was seen (Fig. 4). Adverse effects to the habitat, high salinities, and wetlands losses may be long lasting and with some potential permanent loss of habitat.



Figure 4. Alligator under siding stripped away from buildings at Rockefeller Wildlife Refuge's headquarters following Hurricane Laura. Photograph: Ruth Elsey.

Despite being about 80 km inland from the coast, McNeese State University (where the 2014 CSG Working Meeting was held) sustained extensive damage, estimated at \$200 million in wreckage, with 50 buildings losing roofs (Will Sentell, Staff Writer, Baton Rouge Morning Advocate, 17 September 2020, Capital City Press). I spoke with Ted Joanen (CSG



Honorary Steering Committee) a few days after the storm passed, and his home lost its roof, the front sitting room, and the living room walls caved in. He was busy salvaging documents, papers, and photographs from his home office, and was optimistic and determined to rebuild.

I received countless kind e-mails of concern from numerous CSG members asking about the refuge and everyone's safety; I thank all of you for your support over the years.

Ruth Elsey, *CSG Regional Co-Chair for North America*  
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## **South Asia and Iran**

### **India**

LIMB DEFORMITY OF A MALE ESTUARINE CROCODILE (*CROCODYLUS POROSUS*) IN BHITARKANIKA NATIONAL PARK, ODISHA, INDIA. Bhitarkanika National Park (BNP), in the state of Odisha, India, is renowned for having the largest population of Estuarine crocodiles (*Crocodylus porosus*) in the country. The annual census conducted in the river systems in and around the National Park/Sanctuary in late December 2019-early January 2020 reported daytime sightings of 1757 crocodiles, ranging from hatchlings to adults (Kar 2020).

During surveys, we have come across a few large male crocodiles that are missing limbs or part of their tails - most likely the result of social interactions with other crocodiles (see Webb and Messel 1977). Of particular note, we have recorded: a 4.9 m male missing both forelimbs and one hindlimb; a 4.6 m male missing one hindlimb; and, a 5.5 m male missing half of its tail. These types of injuries have become more common in large *C. porosus* as the population has recovered in the Northern Territory of Australia (C. Manolis, pers. comm.). Interestingly, we have not noted any smaller sub-adults/adults missing limbs or tail tips, nor nesting females.

While carrying out the most recent census (Kar 2020), we sighted a male crocodile, estimated to be 4.3 m TL, with a deformed hindlimb (Fig. 1). The femur of left hindlimb appears to be completely missing (or greatly reduced in size), and the tibia-fibula portion of the limb is attached directly to the body. It was not possible to discern how or whether the limb is attached to the pelvis. The other limbs appeared normal, and a small portion of the tail tip was missing.

The deformity is considered to be congenital in nature. Although the position and morphology of the 'deformed' hindlimb suggests that it may be of limited use in water or on land, the crocodile was actually observed emerging from the water onto the bank, presumably using the "normal" limbs. Indeed, for this crocodile reach this size suggests that the deformity has not restricted its ability to feed, etc.



Figure 1. Large *C. porosus* with deformed left hindlimb.  
Photograph: Nimai C. Palei.

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RECENT RECORDS ENHANCE CONSERVATION PROSPECTS OF GHARIAL IN THE INDO-NEPAL TRANSBOUNDARY GANDAK RIVER. Populations of Gharial (*Gavialis gangeticus*) occur in 6 major and 8 minor sites in the Ganges River basin in India and Nepal, and the Mahanadi River system of India. Breeding has been documented at 7 sites - Chambal River, Katarniaghat (Girwa River), Kalagarh Reservoir (Ramganga River), Yamuna River and Gandak River in India, and the Babai River and Narayani River system in Nepal (Lang *et al.* 2019; Bashyal *et al.* 2019; De *et al.* 2020). All breeding sites fall within protected areas, except the Gandak River.

The Gandak River descends from the Himalayas in Nepal and enters India at Valmikinagar in West Champaran district of Bihar State. Downstream of the barrage at the India-Nepal border, the river is known as the Gandak, whilst upstream of the barrage, in Nepal, it is called the Narayani. Gharials are found in both the Indian and Nepalese parts of this transboundary river. The Gandak River flows for about 40 km along the western part of Valmiki Wildlife Sanctuary, on its left bank, but the river is not a part of the sanctuary, and is thus not a protected area. Sohagi Barwa Wildlife Sanctuary of Uttar Pradesh State (India) runs along the right bank of the river for about 8 km. After flowing for about 325 km in India, the Gandak meets the Ganga River opposite Patna. Floodplain farming is the main use of river banks, with grasslands and forests comprising nearly 11% and human settlements restricted to about 4%. Other than a few brick-



kilns in the lower reaches, industrial activities and urban settlements are not conspicuous features of land-use along the river (WTI 2017).

The Narayani and Rapti Rivers in Nepal are well known for supporting a breeding sub-population of Gharial. The Nepalese Department of National Parks and Wildlife Conservation (DNPWC) initiated a head-starting conservation program in 1981, with subsequent releases of captive-reared Gharial from the Gharial Conservation Breeding Centre in Chitwan, into the Narayani and Rapti Rivers (Cadi et al. 2005; Lang et al. 2019). The long-term future of this small Gharial population was considered insecure, especially after construction of the barrage across the Gandak (Singh 1991).

Early records, prior to construction of the barrage in 1964-68, are very few and limited only to observations at a couple of sites (eg see Webber 1902). Records on the status of species in the Gandak River after completion of the barrage are also limited to few observations (eg Shahi 1977; Singh 1978). The first systematic survey of the Gandak River in 2010 recorded a remnant population of at least 15 Gharials, and the study recommended active conservation measures, including population strengthening through restocking (Choudhary 2010). A collaborative restocking program was subsequently initiated by the Department of Environment, Forest and Climate Change, Government of Bihar (GB), and Wildlife Trust of India (WTI), and in 2014-15, 30 captive-born and reared sub-adult Gharials (27 females and 3 males) were released into the Gandak River (Sinha *et al.* 2018). In 2018-19, the Endangered Species Project, Uttar Pradesh Forest and Wildlife Department and Turtle Survival Alliance also released 55 sub-adult Gharials into the Gandak River at Sohagi Barwa Wildlife Sanctuary (Shailendra Singh, pers. comm.).

Under the joint project, WTI conducted annual surveys (February-March) of the Gharial population in the Gandak River in 2015 and 2017-2020. The river was surveyed from Valmikinagar Barrage (27.43777N, 83.90750E) downstream to Sonpur (ie Ganga confluence; 25.65528N, 85.18916E), with a maximum river length surveyed of ~320 km (Fig. 1). In 2018 and 2019 two consecutive surveys were done. The river is braided in many stretches, hence, the navigable and deeper channel was surveyed in the daytime (0900-1700 h) using an inflatable raft with a 15HP outboard motor.

The survey team comprised 4-5 members (including boatman) experienced in Gharial spotting. At any particular time, three team members scanned potential Gharial basking sites. The team recorded visual observations using binoculars (8x42), spotting scope, and cameras (with 45x and 60x optical zoom). Sighted animals were assigned age-class as hatchlings (<60 cm TL), yearlings (60-120 cm TL), juveniles (121≤180 cm TL), (sub-adults 181≤270 cm TL) and adults (>270 cm TL) (Hussain 2009).

Sex of adult Gharials, habitat variables (water depth, channel type, basking location, etc.) and anthropogenic activities near sightings were also recorded. All sightings were geo-

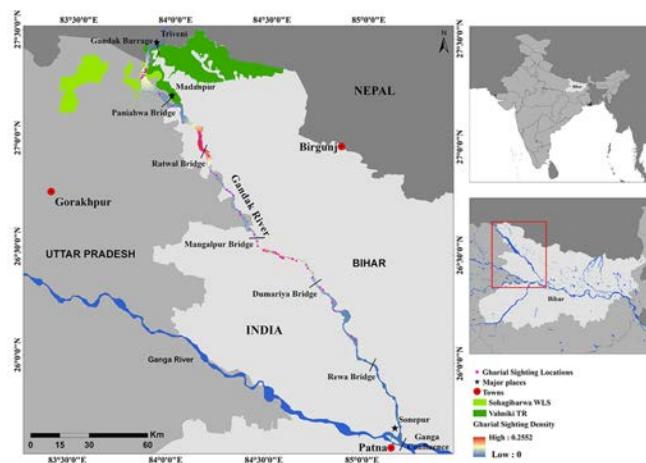


Figure 1. Gandak River, showing key landmarks.

tagged using a “Garmin eTrex 10” handheld GPS receiver. Additionally, the surveyed river stretch was divided into 2-km long segments and habitat variables - such as river channel depth, channel width, bank substrates, etc., and anthropogenic activities such as fishing, farming, ferry crossing, etc., were recorded in each segment to analyse the influences of these covariates on Gharial presence and abundance.

The team identified potential breeding sites based on the congregation of adult males and females during surveys. The high sand banks suitable for Gharial nesting near such congregation sites were monitored with the help of local farmers and fishermen from mid-March to the first week of April, which is the nesting season for Gharials in the region (Khadka 2011). Identified nests were monitored and protected until successful hatching.

### Population Status

Nair and Katdare (2014) reported 50 Gharials, including 2 males and 3 Nepal-released Gharials in the river in April 2014. The population had therefore increased naturally since 2010 (<15 sightings). The 2015 survey recorded 8 India- and 1 Nepal-released Gharial. Two consecutive surveys were done in 2018 (February) and 2019 (February and March). Surveys in February 2018 showed minor differences in the total sightings between surveys, but more yearlings were sighted in the second survey. In 2019, fewer sightings were recorded in the second survey (March), and significantly more yearling sightings. Reasons for more detection of younger Gharial in late February and March needs to be explored. In the latest survey in March 2020, 259 Gharials were sighted (Fig. 2), making the Gandak River population the second largest in the species’ range.

The proportions of sightings that were head-started Gharial were: 2014 (6.0%); 2015 (16.7%); 2018-1st survey (4.7%), 2018-2nd survey (1.8%); 2019-1st survey (2.0%), 2019-2nd survey (2.7%); and, 2020 (1.2%). The “spike” in 2015 could be due to detection of Bihar Forest Department/WTI-released Gharials in 2014-15. In 2019, Gharials released by the Uttar Pradesh Forest Department were also detected.

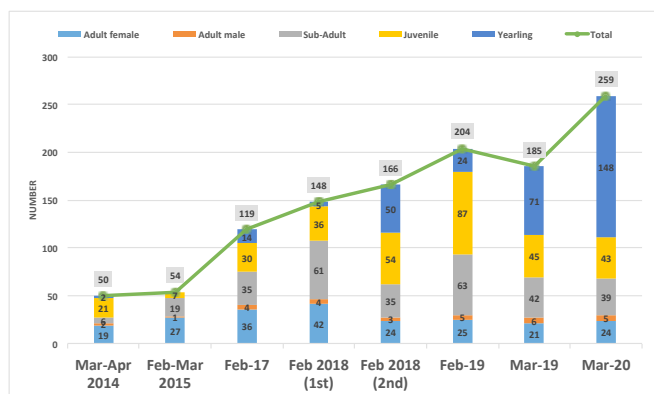


Figure 2. Gharial counts in the Gandak River, 2014-2020. Data for 2014 are from Nair and Katdare (2014). Gharials unable to be allocated to a size class have been included as sub-adults.

Since 2015, the Gharial population in the Gandak River has steadily increased (Fig. 2). The population is comprised mainly of wild individuals, together with head-started individuals from Nepal (Khadka 2020b) and India (released by Bihar and Uttar Pradesh Forest Departments). The highest number of adults ( $N=46$ ) was recorded in 2018, and these represent about 7% of the global adult population (Lang *et al.* 2019). There has been significant increase in the proportion of yearlings sighted, from 12% in 2017 to 57% in 2020 (Fig. 2), indicating successful recruitment within the Gandak River and/or the Narayani-Rapti Rivers in Nepal, where from 2017 onwards GCBC only collected nests that were deemed to be vulnerable to negative impacts of flooding and anthropogenic disturbances (Maskey 1989; Khadka 2020a).

Sightings were unevenly distributed along the river, and there were distinct “hotspots” with regard to density (Fig. 3). Overall, Gharial presence was recorded up to Rewa Ghat Bridge, about 280 km downstream from the Gandak Barrage. Increase in anthropogenic disturbance due to cultivation on mid-channel islands and ferry crossings downstream of the Rewa Ghat bridge appear to adversely affect Gharial presence in winter and summer.

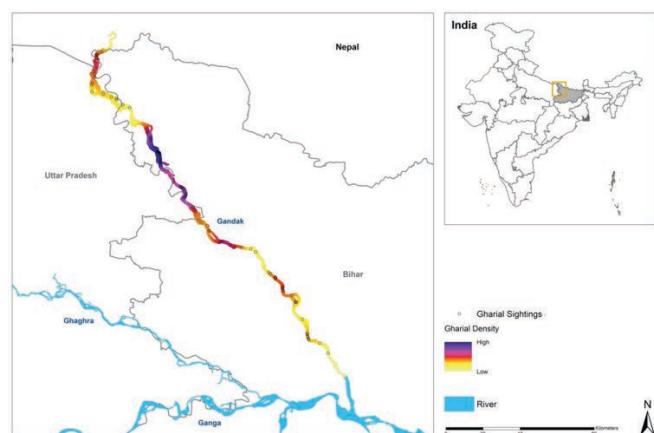


Figure 3. Gharial “hotspots” (based on relative density) in the Gandak River.

## Nesting

The first population survey in February-March 2015 confirmed adult male-female congregations. It formed the basis for further investigation on Gharial breeding in the Gandak River in subsequent years, with riverbank surveys being conducted at potential nesting sites. Local farmers and fishermen significantly helped in identifying nesting sites. In 2016, a communal nesting site with 6 nests was detected approximately 90 km downstream of the Gandak Barrage. It formed the fifth breeding Gharial sub-population in the species’ range (Lang *et al.* 2019). WTI engaged locals in nest protection until hatching. Local fishermen had also reported Gharial nesting in the same area in 2009 (Choudhary 2010).

In 2017, nests were not recorded at the 2016 site due to erosion of sand banks caused by water released from the barrage in the last week of March. However, in 2018-2020, 11 nests were detected: 2018 (2), 2019 (3), 2020 (6). Nests prone to destruction were protected by shifting them to artificially excavated nests *in-situ* and engaging nest watchers from local communities. The nesting sites on the river are clustered at three locations within a stretch of about 75 km of river, between about 5 km upstream of Ratwal Bridge (26.96235N, 84.16332E) to about 500 m downstream of Mangalpur Bridge (26.56555N, 84.44903E).

Considering the estimated number of adult females in the breeding congregations (Fig. 4), at least 8-12 more nests are expected at the Gandak River. High channel braiding poses difficulties for locating nests. The remotely located nests are prone to damage due to riverbank erosion after release of water from the Gandak Barrage, which coincides with the nesting period. It potentially limits the nesting and breeding success of the species.



Figure 4. Adult male and female Gharials basking on the Gandak River. Photograph: Subrat Kumar Behera.

## Transboundary Cooperation

In terms of length (Gharial habitat), the Gandak River is second to the Chambal River. Gharials occupy about 85% of the Gandak’s length in India, and it forms approximately one-quarter of the total river length of the six major Gharial

subpopulations. The river provides habitat to wild and head-started Gharials dispersing from the Narayani-Rapti River system in Nepal.

Gharials occupy 221 km of the Narayani-Rapti River system (Poudyal, 2018). Thus, the combined length of the Gharial-occupied Gandak-Narayani-Rapti River system is approximately 500 km. Though the Gandak barrage seems to be a hindrance for the movement of aquatic species, it is largely permeable for downstream movement of Gharials from Nepal to India (Griffith *et al.* 2000; Khadka 2020; WTI, pers. comm.). Movement of a Gharial from downstream to upstream of the barrage has also been recorded in 2016 (WTI 2017). Thus, the Gandak and Narayani-Rapti subpopulations in the transboundary river system are not completely isolated, which promises for long-term persistence of the species in the river system. It is a shared responsibility of both countries to take appropriate conservation measures. It demands structured transboundary coordination between the Government of India (through Environment and Forest Department of Bihar) and the Government of Nepal (DNPWC), especially for exchange of information and implementation of activities to enhance habitat conditions for Gharial in the Gandak-Narayani River systems.

From the middle of the Gandak River channel, for about 12 km downstream of the barrage, is regarded as the international border between India and Nepal. In this stretch, anthropogenic activities on the left bank are very limited due to the Valmiki Tiger Reserve, but sand and boulder mining and other anthropogenic activities on the right bank cause disturbance to Gharial. The Nepal Government needs to take proactive measures to reduce disturbance in this stretch. Importantly, the Gandak River is not a protected area. Hence, assigning legal protection to the river for wildlife would go a long way in conservation of Gharial and other associated threatened aquatic fauna such as the Ganges River Dolphin (*Platanista g. gangetica*), Mugger crocodile (*Crocodylus palustris*), soft and hard shell turtles and many winter migratory bird species. The middle stretch of the river in India, with a high density of Gharial, should be declared as a protected area under the provisions of the *Wildlife (Protection) Act 1972*.

#### Acknowledgements

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## Nepal

TRANSLOCATION OF MALE GHARIAL (*GAVALIS GANGETICUS*) FROM BABAI RIVER TO CHITWAN NATIONAL PARK, NEPAL. The Gharial (*Gavialis gangeticus*) is considered extinct in Myanmar, Pakistan, Bhutan and Bangladesh, and wild breeding populations now only occur in Nepal and India. In Nepal, Gharials were historically wiped out from the Mahakali, Kali Gandaki and Sapta Koshi Rivers, and now occur in the Karnali, Babai, Rapti and Narayani Rivers. During the monsoon season, they have also been reported from the Mohana River and tributaries of the Mahakali River.

To supplement the remnant wild Gharial populations in Nepal, a conservation breeding program was established in Chitwan National Park (CNP) in 1978. This program has been successful in hatching, rearing and reintroducing head-started Gharials into the main rivers of the country. As of March 2020, 1515 Gharials had been released into the wild (Khadka 2020).

Annual monitoring of the Gharial population in CNP indicated that since 2010 there was only one adult male Gharial present (Khadka 2010, 2011, 2013; Acharya *et al.* 2017), and it was killed after it became entangled in a gillnet on 24 May 2017. The loss of this male seriously threatened future egg/hatchling production in CNP. Realizing this critical situation, the Nepalese Department of National Parks and Wildlife Conservation (DNPWC) permitted the translocation of adult male Gharial from elsewhere, to CNP. Thus, CNP authorities initiated discussions with Bardiya National Park (BNP) in Nepal, and Katarniyaghat Wildlife Sanctuary (KWS; also known as Katarniyaghat Tiger Reserve) in India, to assess the possibility of acquiring male Gharial for this purpose. KWS is located on the India-Nepal border, and is some 25 km from BNP (see Fig. 2).

On 18 December 2017, a 5-man CNP team, comprising Ram Chandra Kandel (currently Deputy Director General, DNPWC), Bed Khadka (CNP) and Gharial catchers (Aitaram Bote, Sante Bote, Ram Majhi), travelled to the Gharial conservation breeding centre at Thakurdura, in BNP. Here, they were joined by two Gharial catchers (Rangila Tharu and Baliram Tharu) from BNP.

On 19 December 2017, the combined CNP and BNP teams visited the Gharial conservation centre at KWS, sharing knowledge and experiences on conservation and breeding efforts. A meeting on 20 December 2017 covered a range of topics, including: status of Gharials in KWS; availability of adult male Gharials (2-3 were known from upstream KWS); methods of capture and transportation; and, variables affecting a potential operation (eg season, water levels). A brief field trip was undertaken on the Geruwa River with KWS personnel, to examine Gharial habitat there.

Although KWS authorities had agreed to gift Gharials to Nepal, the process to acquire them was likely to be lengthy, and given the urgency of the situation a decision was made to acquire a male Gharial from the Babai River in the first instance. DNPWC had already provided permission to acquire one Gharial from either the Karnali River or Babai River, in BNP.

On the afternoon of 20 December, after arriving back from KWS, we observed two male Gharials basking with other sub-adult Gharials and Muggers (*Crocodylus palustris*) on the Babai River, below the bridge at Parewa Odar (Figs. 1 and 2). On 21 December 2017, at around 0600 h, before sunrise, Gharial catchers laid weighted netting (40 m x 3 m; like a volleyball net) underwater from a rubber boat. The net was laid such as to entangle Gharials coming out from the water to bask on the sand bank. No Gharials were caught on this first attempt.



Figure 1. Area below bridge at Parewa Odar on the Babai River. Photograph: Bed Khadka.

Later in the day, the net was laid again, and the catching team hid behind bushes on the sand banks. After Gharials had come up to bask, the catching team flushed them back into the water, but were again unsuccessful in catching any Gharial in the net - although three Muggers were caught. The process was repeated, but again with no success.

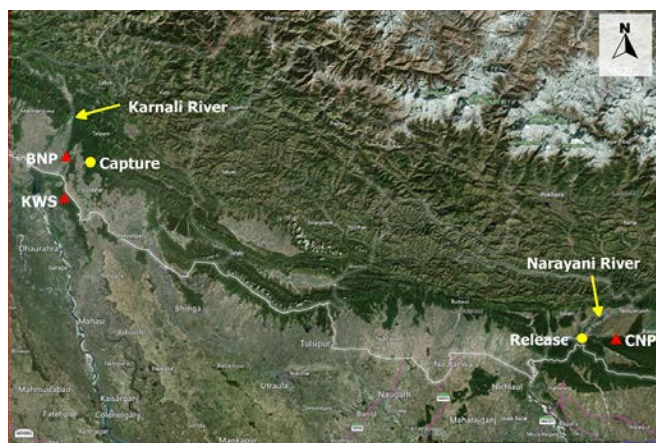


Figure 2. Capture (Bardiya NP) and release (Chitwan NP) sites for 'Babai'.

Attempts were made to push the net further underwater, but this was not possible due to submerged logs. Four catchers camped overnight near the sand bank to monitor Gharial activities/movement at night, and to assess the possibility of catching at night, but these efforts were also unsuccessful.

On 22 December 2017, we repeated the process - again, with no success. After lunch, we followed the movement of an adult male Gharial with binoculars. The male was changing positions due to our presence and activities, and was swimming slowly away from the sand bank, before submerging. The team moved to the area where the Gharial was last seen, and dragged the net where the Gharial was thought to be, and entangled it.

The net and struggling Gharial were dragged out of the water, involving some 10 minutes of struggling (Fig. 3). On the bank, the Gharial's snout and limbs were tied, the eyes covered, and it was loaded into a tarpaulin-covered truck. The animal was covered in rice hay to keep it warm, as December is the coldest winter month in Nepal.



Figure 3. 'Babai' being restrained at Parewa Odar following capture. Photograph: Ram Chandra Kandel.

Transport took place that night, to the Rapti/Narayani confluence, some 410 km away (Fig. 2). Three catchers rode on the back of the truck alongside the animal for the entire

duration of the trip - the Gharial remained calm throughout.

The following day (23 December 2017), with the assistance of CNP staff, army personnel [Batuk Dal Gan (Battalion)], the local Buffer Zone Use Committee (BZUC), local community members and hoteliers, the Gharial was unloaded from the truck, and loaded into a 7.7 m long boat (Fig. 4) for the 2-km downstream trip to the release site at Khoriyamuhan (= Khoriya), on the Narayani River (Fig. 2). Prior to the boat trip, the Gharial was physically examined, and scute-clipped (5th single tail scute removed) for identification purposes. He was nicknamed 'Babai'.



Figure 4. 'Babai' at the Rapti/Narayani confluence (left), prior to loading into boat (right) for transport to the release site. Photographs: Ram Chandra Kandel.

Following 'Babai's' release, various observations were recorded, which can be summarized as:

1. A catcher from the GCBC was responsible for tracking immediate post-release movements of 'Babai'. In the first week after release, 'Babai' was sighted swimming, and rarely basking, at Khoriyamuhan and the Rapti/Narayani confluence.
2. On 28 February 2018, 'Babai' was sighted at Budhanagarghat, on the Rapti River, about 15 km upstream of the release site (Fig. 5). The Hotel Rhino is in front of 'Babai's' basking site, and nature guides from the hotel regularly sighted the animal up until 9 March 2018.



Figure 5. 'Babai' (in background) at Budhanagarghat (Rapti River) on 28 February 2018 (68 days post-release). Photograph: Bed Khadka.

3. On 2 May 2019, 'Babai' was sighted at Siswar, on the Narayani River.



4. On 18 June 2019 (rainy season), ‘Babai’ was sighted at Bhelauji, on the Narayani River, guarding hatchlings (P. Griffith, pers. comm. 2019).
5. Additional sightings were reported in January 2020 and through the nesting period by nest watchers (5 sightings; March-April 2020).

Five “breeding groups” have been identified on the Narayani and Rapti Rivers (Fig. 6). A “breeding group” is defined as a group of two or more adult Gharial congregating at the same location during the courtship/mating season (January-March).

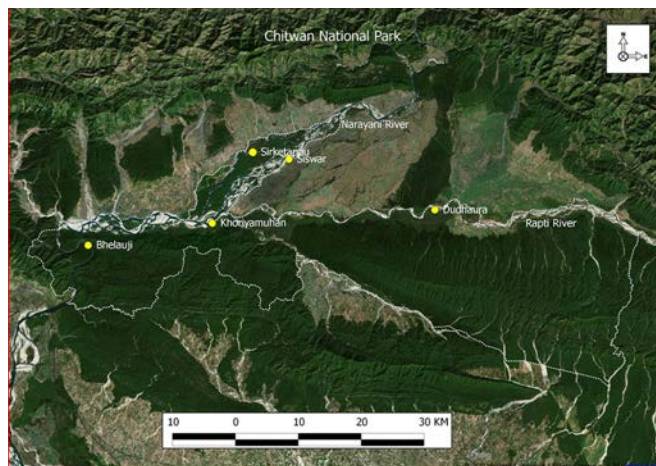


Figure 6. Gharial breeding groups on the Narayani River (Sirketappu, Siswar, Bhelauji, Khoriyamuhan) and Rapti River (Dudhaura), in Chitwan National Park.

1. Dudhaura breeding group (Rapti River): Nests were located in 2019 (N= 16) and 2020 (N= 14). There is one adult male Gharial (nicknamed ‘Dudhaura male’; Fig. 7), which is known to move up to 10 km upstream from Dudhaura to the Sauraha area, and enter Khageri and Dhungre streams, both of which are tributaries of the Rapti River. First sighted in 2017, confirmation of sex, on basis of the ghara, was not confirmed for ‘Dudhaura male’ until January 2018. Female Gharials have been recorded in both streams, and one nest hatched at Khageri stream in 2018.



Figure 7. ‘Dudhaura male’ on 3 January 2018 (left) and 15 January 2020 (right). Photographs: Bed Khadka (left) and Ranjana Bhatta (right).

2. Khoriyamuhan breeding group (Narayani River): A new adult male Gharial (nicknamed ‘Khoriya male’; Fig. 8) was confirmed on 18 January 2020. Since 2017 there had been little noticeable growth of its ghara, but sex could now be confirmed on the basis of ghara size. ‘Khoriya

male’ moves within the surroundings of Khoriyamuhan, downstream to Amaltari and upstream to the Rapti/Narayani and Reu/Rapti confluences (around 2 and 4 km respectively). He has been recorded in the vicinity of up to two females, 5 small sub-adults and 9 large sub-adults over several years, generally during January-February (courtship period). On 23 February 2017, 35 Gharials were reported at Khoriyamuhan, and it was the site of mortality of a large adult Gharial on May 2017. One nest containing infertile eggs in was located in 2019, and one nest with fertile eggs was located in 2020.



Figure 8. ‘Khoriya male’ on 18 January 2020 (left), and with a female at the Reu/Rapti confluence on 29 June 2020 (right). Photographs: Bed Khadka.

3. Bhelauji breeding group (Narayani River): Two male Gharials, one with an incomplete tail (nicknamed ‘Linde’; Fig. 9) and another with broken single tail scutes (Fig. 10), were sighted at Bhelauji on 9 January 2019 - the latter has not been sighted since then. ‘Babai’ was observed at Bhelauji on 18 June 2019, guarding “new” hatchlings (P. Griffith, pers. comm. 2019), and both ‘Babai’ and ‘Linde’ were also observed basking with 3 and 4 females, respectively. In January and February 2020, both males were observed basking about 500-800 m apart, and both were sighted again during the following nesting season (March-April 2020) at Bhelauji by two nest watchers. Nests were located in 2019 (N= 7) and 2020 (N= 7).



Figure 9. ‘Linde’ at Bhelauji on 9 January 2019 (left) and February 2020 (right). Photographs: Bed Khadka.



Figure 10. Unnamed individual (left) and ‘Babai’ (right) at Bhelauji, on 9 January 2019 and February 2020, respectively. Photographs: Bed Khadka.



4. Sirketappu breeding group (Narayani River): A new adult male (nicknamed ‘Sirke male’; Fig. 11) was confirmed at this site in 2020, on the basis of an enlarged, growing ghara relative to sightings since 2017. In January-February 2020, this male was observed basking with three females and two larger sub-adults. ‘Sirke male’ frequently moves from Sirketappu to about 10 km upstream (Kujauli) and 15 km downstream (Lamichaur) on the Narayani River. Nesting has not been confirmed at this site.



Figure 11. ‘Sirke male’ on 14 February 2020. Photographs: Bed Khadka.

5. Siswar breeding group (Narayani River): This is considered a small breeding group, with an unconfirmed sighting of an adult male on 2 May 2019, and two adult females in January 2019 and January 2020. A nest has been located here each year since 2016.

‘Babai’, at 3.92 m TL at the time of release, is larger than the other four potentially mature males that have now been identified in the Narayani and Rapti Rivers. These resident males have been associated with the same breeding groups since 2017. However, over the last two years, ‘Babai’ has been observed visiting three of the five breeding groups, and could have potentially visited Sirketappu as well.

Monitoring of the Gharial population in CNP continues, with particular attention to mature adults, and VHF and satellite telemetry is being undertaken to quantify movement patterns (Griffith *et al.* 2020). The translocation of the large male Gharial from BNP to CNP is considered to have been a success.

Every year between 2010 and 2017, 2-3 nests of infertile eggs were encountered in the Narayani River, suggesting a lack of adult male Gharials and/or lack of mating opportunities for all females (Khadka 2010, 2011, 2013; Acharya *et al.* 2017). Since the release ‘Babai’ in December 2017, we have found only one infertile nest (in 2019).

Dialogue with KWS in India continues. Although the immediate ‘problem’ has been overcome, it is considered important to maintain options, in case Gharials from elsewhere are required to supplement the CNP population and/or to increase genetic diversity.

#### Acknowledgements

We are thankful to: BNP officials and staff; KWS officials; CNP staff; skilled people of GCBC (CNP); staff of the

protection unit of CNP and BNP; and, BZUC and community members of Meghauli at CNP. We are thankful to the Zoological Society of London (Nepal) for partial support towards the translocation operation.

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## Latin America and the Caribbean

### **Guatemala**

GRUPO DE COCODRILEROS DE GUATEMALA: FIRST STEPS TO PROMOTE GUATEMALAN CROCODILIAN CONSERVATION. Guatemala is known for its wide diversity in flora, fauna and ethnic groups, however scientific research and publications within some taxonomic groups are scarce, and crocodilians are no exception. Two species of crocodile (*Crocodylus acutus* and *C. moreletii*) and one species of caiman (*Caiman crocodilus*) occur in Guatemala, and to date there are five published studies on *C. moreletii* (Lara 1990; Castañeda 1998, 2000; Castañeda *et al.* 2000; Corado-Garcia and Cajas-Castillo 2020), and none on *C. acutus* and/or *Caiman crocodilus*.

In July 2019, a training workshop entitled “Ecological Monitoring and Management of Crocodilians”, delivered by Robinson Botero-Arias, Diego Juárez-Sánchez, Valerie Corado-García, Yasmín Quintana and Rony García, with support from: the University of Florida’s Department of Wildlife Ecology and Conservation (Loiselle Lab, Romagosa Lab, Florida Invasive Ecology Lab); the Biodiversity Project of USAID-Guatemala; Yaxhá-Nakúm-Naranjo National Park; and, Guatemala’s National Council for Protected Areas (Consejo Nacional de Áreas Protegidas) and Institute of Anthropology and History of Guatemala (Instituto de Antropología e Historia de Guatemala).

The workshop was held in Yaxhá, Petén, aiming to promote environmental awareness on conservation and sustainable management research. As a result of this workshop, three passionate crocodile biologists met and decided to join efforts through the establishment of a national specialist group. The Guatemalan Crocodilian Group (Grupo de Cocodrileros de Guatemala; GCG) (Fig. 1), currently represented by Valerie Corado-García, Diana Velásquez-Ramírez and Rosa Roldán-Díaz (Fig. 2), was thus founded, on the following principles:

1. **Mission:** Generate science-based information on the three species of crocodilians in Guatemala, encouraging integrated conservation strategies, raising awareness and building strategic local alliances.
2. **Vision:** Furthering coexistence between crocodilians and humans in local ecosystems.
3. **Objectives:** To update and publish scientific information on crocodilians in Guatemala, in order to improve decision-making processes and implementation of conservation strategies at national and regional levels; to enhance human perception and tolerance of crocodilians through the development of educational programs; to improve institutional capacity in data collection, management, methodology and reporting in order to strengthen decision making processes; also, to provide technical and biological support for students, technicians, wildlife professionals, local organizations and government environmental entities in order to promote the knowledge about Guatemalan crocodilians, and identifying key actors to become part of GCG.

We hope that the GCG will encourage young scientists to generate peer-reviewed manuscripts in collaboration with recognized international crocodilian colleagues, furthering and building a long-term sustainable management program to ensure the conservation of crocodilians in Guatemala. The Crocodile Specialist Group (CSG) welcomed the initiative (see Editorial, page 3).

To learn more about crocodilian research in Guatemala, follow the GCG on Facebook (Grupo de Cocodrileros de Guatemala) or on Instagram: (cocodrilos\_gt). We are looking forward to collaborating with you.



Figure 1. GCG logo.



Figure 2. GCG Founders; from left, Diana Velásquez-Ramírez (Director, Public Relations), Valerie Corado-García (Executive Director) and Rosa Roldán-Díaz (Director, Communications).

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## Brazil

REARING BLACK CAIMAN (*MELANOSUCHUS NIGER*) OUTSIDE ITS DISTRIBUTION RANGE CONCERNS THE BRAZILIAN CROCODILIAN RESEARCH COMMUNITY. On 23 December 2019, we became aware through social media ([www.facebook.com/leandro.silveira.iop/videos/1005334836503630/](https://www.facebook.com/leandro.silveira.iop/videos/1005334836503630/)) that hundreds of Black caiman (*Melanosuchus niger*) were moved from a closed commercial breeding facility (ranching production system) in the Goiás State, central Brazil, to different locations. Over 700 individuals were allocated to the Caimasul breeding facility (<https://caimasul.com>) in Mato Grosso do Sul State, for slaughter and meat production. Around 200 *M. niger*, mainly 2-3-year-old juveniles, and at least 10 adult/sub-adults were taken to the Jaguar Conservation Fund/Instituto Onça-Pintada (IOP) facilities (53°00'16"S, 17°54'07"W), located in the municipality of Mineiros, Goiás State. The IOP is a NGO with conservation purposes, mainly promoting the conservation of the jaguar (*Panthera onca*) and its natural habitats in Brazil ([www.jaguar.org.br](http://www.jaguar.org.br)).

Several IOP social-network posts showed the translocation under improvised conditions and without regard for any technical criteria (<https://youtu.be/8iY9SFPV3wI>). In these posts, the IOP staff announced the implementation of an *ex-situ* conservation breeding program for *M. niger* as a potential genetic reservoir for an endangered species. The IOP facilities appear inadequate in terms of security, as the enclosures lack effective barriers to prevent the escape of the caimans, especially large individuals. Although the transfer of these was undertaken between locations in Goiás State, the translocation of these animals occurred between two different hydrographic basins. The IOP facilities are located in the Paraná basin, ~450 km outside the natural range of *M. niger* (Campos *et al.* 2018; Fig. 1). The record by Campos *et al.* (2015) is the most southerly location for the species in the Tocantins-Araguaia basin. In this context, the escape of individuals to the Paraná and/or the Paraguay basins could be imminent, with unpredictable ecological consequences in environments where *M. niger* has never occurred (see possible dispersal routes in Figure 2).

It is well known that crocodilians can easily escape from captivity and become established. For example, in Florida (USA), there have been records of exotic species of *Mecistops*, *Paleosuchus*, *Crocodylus* and *Caiman* in the Everglades (Krisko *et al.* 2011; Rochford *et al.* 2016), with a well-established population of *Caiman crocodilus* (Elis 1980;

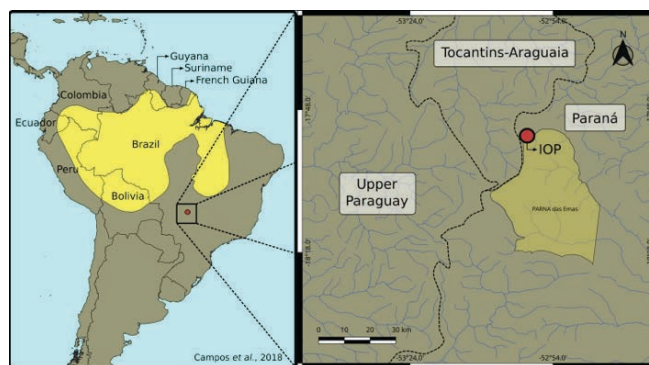


Figure 1. Distribution of *Melanosuchus niger*, location of Instituto Onça-Pintada (IOP), Paraná, Tocantins-Araguaia and Upper Paraguay Rivers basins, and Emas National Park (PARNAS EMAS).

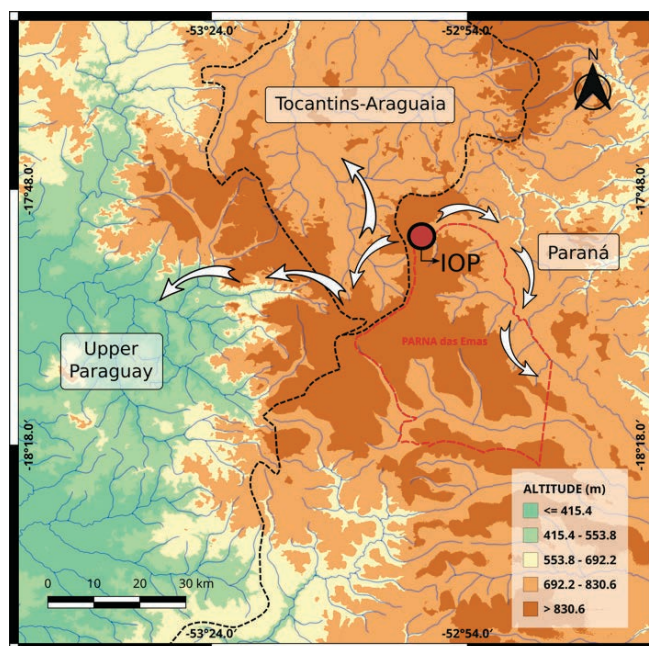


Figure 2. Potential dispersal routes (arrows) of *Melanosuchus niger* from Instituto Onça-Pintada (IOP) and the Paraná, Tocantins-Araguaia and Upper Paraguay Rivers basins.

Krisko *et al.* 2011). In México, *C. moreletii* have escaped from a farm and a new population was established out of its natural distribution on the Pacific coast of México (Rodriguez *et al.* 2008).

Until the 1990s, *M. niger* was considered one of the most threatened Neotropical crocodilians (Thorbjarnarson 2010). The species suffered serious conservation threats due to the unregulated hunting for skin and meat. The result of these uncontrolled actions was a decline in wild populations throughout the species distribution (Rebêlo and Magnusson 1983; Da Silveira and Thorbjarnarson 1999). Currently, populations of *M. niger* have recovered, and, in Brazil, the species is now classified as a LC-Least Concern species (Marioni *et al.* 2013), based on IUCN guidelines (ICMBio/MMA 2018). Currently, reports of high-density populations throughout its distribution, indicates that *M. niger* is an abundant species, only partially and locally depleted, with a tendency to recover very quickly (Da Silveira 2002). In view



of this, the proposal for an *ex-situ* conservation breeding program for *M. niger* conducted in an area outside the species distribution, is contrary to conservation-biology principles, with unclear goals, and without the understanding and support of the Brazilian crocodilian-research community.

The Black caiman is a keystone species, playing an important role in the trophic network, as an apex predator (Da Silveira and Magnusson 1999), and influencing the ecology of other organisms and their habitats (Fittkau 1970; Somaweera *et al.* 2020). The potential escape of Black caimans from the IOP facilities might involve serious consequences, and result in cascading effect on the ecosystem processes. Given its predatory role naturally, it is reasonable to assume that novel presence of Black caiman will disturb natural trophic interactions, especially impacting native predators, such as other caiman species. Besides, the dispersal of the Black caimans, and their interaction with the native wildlife, livestock or domesticated animals might increase the environmental health hazards, related with their emergence or translocation of infectious diseases, and the introduction of new pathogens (Bryan 1996; Peeler *et al.* 2011; Hulme 2014; Micheletti *et al.* 2020). The consequences are unpredictable but clearly tragic in the ecosystem structure and functioning. The Black caiman's dispersal in the Cerrado and/or Pantanal biomes, also represents a social risk, potentially creating conflicts with local communities. The negative perception about caimans might increase with the presence of a new species, particularly one that can reach more than 5 m. *Melanosuchus niger* can be a threat to local people, and their presence is likely to be seen as the introduction of a new competitor for the fisherman or a new potential predator on livestock and human attacks (Sideleau and Britton 2012; Nyhus 2016). Consequently, it might negatively influence the social dynamics and the ongoing and future conservation strategies in the region for endemic species.

The transfer of the *M. niger* to IOP facilities was approved by the Goiás State Environmental Secretariat (SEMAD), the State environmental authority. However, the main concern is because of the lack of expertise, besides the technical and scientific criteria for crocodilian management and conservation, and animal welfare issues not understood by IOP staff and SEMAD technicians. Until now, neither IOP nor SEMAD has contacted any crocodilian specialist in Brazil to assess the current state of the animals and define criteria for making decisions about their future.

The Brazilian Center for Scientific Research and Conservation of Reptiles and Amphibians [Centro Nacional de Pesquisa e Conservação de Répteis e Anfíbios - RAN ([www.icmbio.gov.br/ran/](http://www.icmbio.gov.br/ran/))] is the Federal environmental authority, and it has legal responsibility for the conservation and management actions of the reptiles and their enforcement. However, in this case, RAN staff was aware of the situation only after we sent them a letter on 11 March 2020, in which we alerted them to the situation, showed our concerns, and asked for details and explanations. However, they only replied with information provided by the SEMAD technicians and did not show concern about the conservation implications. The

lack of articulation between the state and federal authorities and their lack of attention to the concerns of the scientific community is worrying.

In conclusion, we highlight our concern about the safety of the enclosures used by IOP to avoid the escape of *M. niger* individuals larger than 1.5 m, and in any case infringes the general principle used by RAN until now that crocodilian species should only be raised in hydrographic basins within their natural range. We believe that this is a serious matter and the state of Goiás (SEMAD) and federal (RAN) institutions in Brazil need to address this subject properly to avoid unnecessary ecological damage.

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## Europe

EAZA REPORTS 2019. In August 2020, the European Association of Zoos and Aquaria (EAZA) released its “2019 EAZA Annual Report” and “Taxon Advisory Group (TAG) Report”. The following details on activities with crocodilians have been extracted from these reports.

EAZA members are currently supporting the following

projects/programs:

- Conservation of Siamese crocodile in Cambodia (Wildlife Reserves Singapore)
- *Mecistops cataphractus* conservation through human mitigation crocodile conflict in Ghana (Auckland Zoo)
- IUCN-SSC Crocodile Specialist Group (Paradise Wildlife Park)
- Saving the Gharials on the Chambal River, India (Zoo Praha)
- Securing the last population of Siamese crocodiles in Indonesia (Wildlife Reserves Singapore)
- Conservation of Gharial (through CEPA) in Nepal (Zoologischer Garten und Aquarium Berlin and Tierpark Berlin)
- Orinoco crocodile conservation in Venezuela (Aalborg Zoo)

Ivan Rehák (Prague Zoo, Czech Republic) published the studbook for the Gharial (*Gavialis gangeticus*) and Thomas Ziegler (Cologne Zoo, Germany) for the Philippine crocodile (*Crocodylus mindorensis*).

Ivan Rehák (Prague Zoo) was approved as the new ESB keeper for the Cuban crocodile (*Crocodylus rhombifer*). Topics discussed by the Reptile TAG included crocodile training with Iri Gill (Chester Zoo, UK), and how to realise logistically difficult transfers of big and/or old crocodiles by Thomas Kölpin (Wilhelma Zoo, Germany) and Michel Ansermet (Aquatilis Lausanne, Switzerland).

The Reptile TAG continues to cooperate closely with internal EAZA partners, IUCN-SSC Specialist Groups such as the CSG (including the CSG Tomistoma Task Force) and other initiatives (eg Gharial Conservation Alliance, Gharial Ecology Project).

The main papers co-authored by TAG members and their collaborators in 2019 are:

Caut, S., Francois, V., Bacques, M., Guiral, D., Lemaire, J., Lepoint, G., Marquis, O. and Sturaro, N. (2019). The dark side of the Black caiman: Shedding light on species dietary ecology and movement in Agami pond, French Guiana. PLoS ONE 14(6): e0217239.

Lemaire, J. and Marquis, O. (2019). Observation of tail outgrowth on Schneider's dwarf caiman (*Paleosuchus trigonatus*) in French Guiana. Crocodile Specialist Group Newsletter 37(2): 18-21.

Rehák, I. (2019). European Studbook for the Gharial, *Gavialis gangeticus*, 1st edition. Prague Zoo: Prague, Czech Republic.

Ziegler, T. (2019): Successful buildup of a Philippine crocodile (*Crocodylus mindorensis*) conservation breeding program in Europe. 2nd Forum on crocodiles in the Philippines, SEAMEO-Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), University

of the Philippines Los Banos, Laguna, Philippines.

Ziegler, T., Tao, N.T., Minh, N.T., Manalo, R., Diesmos, A. and Manolis, C. (2019). A giant crocodile skull from Can Tho, named "Dau Sau", represents the largest known saltwater crocodile (*Crocodylus porosus*) ever reported from Vietnam. Tap Chi Sinh Hoc 41(4): 25-30.

Ziegler, T. *et al.* (2019). Genetic analysis of Siamese crocodiles (*Crocodylus siamensis*) in Laos, Vietnam and Zoos as basis for conservation breeding and release: another successful example for the "One Plan Approach" [in German]. ZGAP Mitteilungen 34(2): 21-25

Ziegler, T. and Rauhaus, A. (2019). EAZA ESB for the Philippine Crocodile (*Crocodylus mindorensis*), 6th edition. Cologne Zoo: Cologne, Germany.

EAZA Reports can be accessed at:

- EAZA Annual Report 2019: <https://www.eaza.net/assets/Uploads/Annual-report/TAG-reports-2019-webLR.pdf>
- EAZA Tag Reports 2019: <https://www.eaza.net/assets/Uploads/Annual-report/TAG-reports-2019-webLR.pdf>
- Publications List: <https://www.eaza.net/assets/Uploads/Annual-report/Annex-TAG-AR2019-publication-list.pdf>

## Australia and Oceania

### Australia

RARE DEFORMITY IN A SALTWATER CROCODILE. The Problem Crocodile Program in the Northern Territory of Australia has operated since 1979, during which time more than 7500 wild Saltwater crocodiles (*Crocodylus porosus*) have been captured (eg see Fukuda *et al.* 2014). On 28 September 2020, we removed a 2.31 m long female *C. porosus* from a steel trap, placed in Middle Arm of Darwin Harbour.



Figure 1. "Abnormal" nostril of wild *C. porosus*.



Examination of this animal revealed that it had a single nostril, and the nasal pad was “reduced” on the right hand side (Fig. 1). There did not appear to any obvious injury to the nasal pad or surrounding area, and it is assumed that it represents a physical abnormality. Grahame Webb and Charlie Manolis, with decades of experience with the capture and handling of wild *C. porosus*, and the incubation and production of tens of thousands of hatchlings, had also never seen this specific abnormality, on either *C. porosus* or *C. johnstoni*.

We would be interested in hearing from anyone that has seen this type of abnormality in any other crocodilian.

## Literature Cited

Fukuda, Y., Manolis, C. and Appel, K. (2014). Management of human-crocodile conflict in the Northern Territory, Australia: review of crocodile attacks and removal of problem crocodiles. *The Journal of Wildlife Management* 78(7): 1239-1249.

Tom Nichols and Ian Hunt, *Parks and Wildlife Commission of the Northern Territory, Palmerston, NT 0831, Australia (tom.nichols@nt.gov.au)*.



## Recent Publications

Colston, T.J., Kulkarni, P., Jetz, W. and Pyron, R.A. (2020). Phylogenetic and spatial distribution of evolutionary diversification, isolation, and threat in turtles and crocodilians (non-avian archosauromorphs). *BMC Evolutionary Biology* (2020) 20:81

**Abstract:** Background: The origin of turtles and crocodiles and their easily recognized body forms dates to the Triassic and Jurassic. Despite their long-term success, extant species diversity is low, and endangerment is extremely high compared to other terrestrial vertebrate groups, with ~65% of ~25 crocodilian and ~360 turtle species now threatened by exploitation and habitat loss. Here, we combine available molecular and morphological evidence with statistical and machine learning algorithms to present a phylogenetically informed, comprehensive assessment of diversification, threat status, and evolutionary distinctiveness of all extant species. In contrast to other terrestrial vertebrates and their own diversity in the fossil record, the recent extant lineages of turtles and crocodilians have not experienced any global mass extinctions or lineage-wide shifts in diversification rate or body-size evolution over time. We predict threat statuses for 114 as-yet unassessed or data-deficient species and identify a concentration of threatened turtles and crocodilians in South and Southeast Asia, western Africa, and the eastern Amazon. We find that unlike other terrestrial vertebrate groups, extinction risk increases with evolutionary distinctiveness: a disproportionate amount of phylogenetic diversity is concentrated in evolutionarily isolated, at-risk taxa, particularly those with small geographic ranges. Our findings highlight the important role of geographic determinants of extinction risk, particularly those resulting from anthropogenic habitat-disturbance, which affect species across body sizes and ecologies. Extant turtles and crocodilians maintain unique, conserved morphologies which make them globally recognizable. Many species are threatened due to exploitation and global change. We use taxonomically complete, dated molecular phylogenies and various approaches to produce

a comprehensive assessment of threat status and evolutionary distinctiveness of both groups. Neither group exhibits significant overall shifts in diversification rate or body-size evolution, or any signature of global mass extinctions in recent, extant lineages. However, the most evolutionarily distinct species tend to be the most threatened, and species richness and extinction risk are centered in areas of high anthropogenic disturbance, particularly South and Southeast Asia. Range size is the strongest predictor of threat, and a disproportionate amount of evolutionary diversity is at risk of imminent extinction.

Lucifora, L.O., Bellagamba, P.J., Vega, L.E., Bó, M.S., Alvarenga, P.F. and Díaz de Astarloa, J.M. (2020). Significance of stingrays (Chondrichthyes: Myliobatiformes) as prey of crocodilians (Reptilia: Crocodylia) in non-marine environments. *Ichthyological Exploration of Freshwaters* (<http://doi.org/10.23788/IEF-1122>).

**Abstract:** Stingrays (Myliobatiformes) co-occur with many crocodilians (alligators, caimans and crocodiles) in non-marine environments of tropical and subtropical regions. However, predation by crocodilians on stingrays is rare. Here, we report two predation attempts (one unsuccessful, one unknown) on *Potamotrygon motoro*, by a southern spectacled caiman, *Caiman yacare*, in Iberá Lake, Argentina. Based on these and other observations, we discuss the hypothesis that crocodilian predation is more common on sharks and shark-like batoids than on depressed batoids, due to the fusiform body shape of the former two and the flattened shape of the latter. Within the literature, all recorded predation events on sharks were successful; one out of two observed predation attempts on shark-like batoids resulted in consumption. No successful predation attempts on depressed batoids were recorded, although only one outcome was known out of the seven events observed. The prey/predator size ratio of one of our observed events (0.263) was similar to both the mean of all predatory events ( $0.312 \pm 0.060$ ) and only successful ones ( $0.298 \pm 0.104$ ), indicating that size was less important than prey shape in determining the outcome of the interaction. We reviewed the scientific literature on diet of South American crocodilians to quantify the prevalence of stingrays as prey. No stingray remains were found in any of the 7 species studied, based on 1339 samples. The low success rate of crocodilians preying on depressed batoids, the lack of stingray remains in diet studies of South American crocodilians, and the lack of rake-like marks consistent with caiman bites on living Neotropical freshwater stingrays indicate that predation by crocodilians on stingrays is very low. This should be taken as a working hypothesis in future assessments of predation on obligate freshwater elasmobranchs.

Moleón, M.S., Merchant, M.E., Ortega, H.H. and Siroski, P.A. (2020). Comparison of complement system activity amongst wild and domestic animals. *Acta Herpetologica* 15(1): 59-64.

**Abstract:** Multiple mechanisms have evolved for the defensive recognition of foreign components, such as microorganisms. The majority of immunological studies with vertebrates have been focused on endothermic species, and relatively little attention has been directed toward ectothermic vertebrates. We employed a colorimetric assay designed to compare plasma hemolytic activities based on the serum complement system (CS) activities amongst some representative reptiles, wild and domestic birds, and mammals. Results obtained from the hemolytic assays conducted with plasma derived from all of the animal species used showed that broad-snouted caiman had the highest activity, and no differences were observed in the hemolytic activities of plasma from birds or the other reptile species. In contrast, the CS activity obtained with mammalian plasma was markedly lower than that from the other taxa. This assay has many advantages, such as the requirement of small sample volume, reproducible results, and low cost. In addition, unsensitized sheep red blood cell hemolysis can be successfully used for the evaluation of innate immune system activities in non-mammalian species; however, for mammals, it should be combined

with other immunological determinates to evaluate integral innate immunocompetence.

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Srimangkornkaew, P., Praduptong, A., Siruntawinetti, J., Chaeychomsri, S. and Chaeychomsri, W. (2020). Sub-chronic oral toxicity of *Crocodylus siamensis* bile in Sprague Dawley Rats. Bulletin of the Department of Medical Sciences 62(2): 50-55.

**Abstract:** Siamese crocodile (*Crocodylus siamensis*) bile has been widely used for traditional medicine in many countries including Thailand. However, safety evaluation has been limited. This study aimed to determine sub-chronic toxicity of dried *C. siamensis* bile in male and female Sprague Dawley rats at doses of 2.5, 25 and 250 mg/kg body weight for 90 days. The results revealed no clinical signs of toxicity at all doses. Body weights, feed and water intake, and relative organ's weights of all groups treated showed no significant difference from control groups. No significant changes on hematological parameters were observed at any concentrations. In comparison with the control groups, significant increase in levels of ALT, AST and ALP at doses of 25 and 250 mg/kg body weight was demonstrated, however, all values were not significantly different after 14 days of recovery. Cholesterol levels in both males and females were significantly lower than the controls. No treatment-related changes were macroscopically and microscopically found. Our study could suggest that oral administration of dried *C. siamensis* bile as high as 250 mg/kg body weight for 90 days showed no systematic toxicity in male and female Sprague Dawley rats.

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El-Kammar, A., El-Sankary, M., El-Azab, A. and Awad, M. (2020). Composition and radioactivity of Oligocene fossil bones and their country rocks in Gabal Qatrani, Fayoum, Egypt. Arabian Journal of Geosciences 13(570): (<https://doi.org/10.1007/s12517-020-05313-x>).

**Abstract:** Several pieces of fossil bones of scute (scutum), shells, teeth, ribs, and vertebra belonging to turtle, crocodile, hippo, and other unidentified mammals were collected from the Oligocene Qatrani Formation, Fayoum, Egypt. Natural radioactivity was measured to all samples of the country rocks (mainly sandstone, calcareous muddy sandstone and dolostone), in addition to the bone samples. Petrographic examination, XRD, SEM, and complete chemical analyses were done with an emphasis on the more radioactive samples that comprise both fossil bone samples and dolostone. The main mineral composition of these bones is carbonate fluorapatite (francolite), while dolostone consists of microcrystalline dolomite, which is cemented by gypsum and/or silica. The complete chemical analysis indicates that Ca and P are the main components of fossil bone. The high content of the redox-sensitive elements such as Cu, Zn, Se, Mo, Cd, Sn, and Pb is a diagnostic feature of the fossil bones. The total rare earth elements (REE) in fossil bones ranges between 635 and 4984 ppm but decreases to 90 ppm in the dolostone bed. The high content of the REE in fossil bones seems to be a result of interaction with fluids that were heated by the thermal gradients prevailed during the Oligocene volcanic eruptions. The available data indicate that the fossil bones are more enriched in their uranium contents (from 42 to 457 ppm), while the contents in the country rocks include the dolostone range from 1 to 31 ppm. The fraction of heavy minerals of the studied sandstone is generally enriched in magnetite, ilmenite, and leucosiderite as opaques especially magnetite and ilmenite (>50%) and contains a wide variety of non-opaques such as zircon, rutile, garnet, and kyanite among others. These non-opaque minerals have variable but insignificant impacts on the REE pattern and the natural radioactivity of the bone-bearing sediments.

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Alibardi, L. (2020). Differential cell proliferation and differentiation in developing and growing claws of turtles and alligator determine their shape. Acta Zoologica (<https://doi.org/10.1111/azo.12343>).

**Abstract:** Differential cell proliferation and differentiation in

developing and growing claws of turtles and alligator determine their shape. Acta Zoologica (Stockholm). Morphogenesis and cell proliferation in claws of turtle and alligator have been analysed by immunolabelling and thymidine autoradiography. Proliferating cells are randomly distributed in the epidermis and mesenchyme at the tip of forming digits. Developing claws elongate with a dorsal curvature forming the unguis. Numerous proliferating keratinocytes are present in the unguis at 4 hr<sup>-1</sup> day after injection of 5BrdU or by PCNA detection. Their size increases before being incorporated into the unguis corneous layer. Immunolabelling at 3–6 days post-injection of 5BrdU indicates that proliferating keratinocytes move towards the tip of the claw giving rise to the claw pad. The ventral side of the claw termed sub-unguis shows a lower proliferation that expands the surface and produces thin corneocytes that are desquamated. Autoradiography and immunolabelling indicates that proliferating cells of growing turtle claws are present along most of the germinal epidermis 7 hr<sup>-1</sup> day after injection of tritiated thymidine or 5BrdU. Low labelled corneocytes incorporated into the corneous layer are detected at 6–12 days post-injection, generally localized towards the tip of the claw, indicating they have migrated distally. The study confirms that claws of reptiles have an extended proliferative zone instead of a localized proximal germinal matrix as in mammalian claws.

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Suraweera, W., Warrell, D., Whitaker, R., Menon, G., Rodrigues, R., Fu, S.H., Begum, R., Sati, P., Piyasena, K., Bhatia, M., Brown, P. and Jha, P. (2020). Trends in snakebite deaths in India from 2000 to 2019 in a nationally representative mortality study. Elife 9: e54076 ([doi: 10.7554/eLife.54076](https://doi.org/10.7554/eLife.54076)).

**Abstract:** The World Health Organization call to halve global snakebite deaths by 2030 will require substantial progress in India. We analyzed 2833 snakebite deaths from 611,483 verbal autopsies in the nationally representative Indian Million Death Study from 2001 to 2014, and conducted a systematic literature review from 2000 to 2019 covering 87,590 snakebites. We estimate that India had 1.2 million snakebite deaths (average 58,000/year) from 2000 to 2019. Nearly half occurred at ages 30–69 years and over a quarter in children <15 years. Most occurred at home in the rural areas. About 70% occurred in eight higher burden states and half during the rainy season and at low altitude. The risk of an Indian dying from snakebite before age 70 is about 1 in 250, but notably higher in some areas. More crudely, we estimate 1.11–1.77 million bites in 2015, of which 70% showed symptoms of envenomation. Prevention and treatment strategies might substantially reduce snakebite mortality in India.

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Pan, T., Miao, J.S., Zhang, H.B., Yan, P., Lee, P.S., Jiang, X.Y., Ouyang, J.H., Deng, Y.P., Zhang, B.W. and Wu, X.B. (2020). Near-complete phylogeny of extant Crocodylia (Reptilia) using mitogenome-based data. Zoological Journal of the Linnean Society (<https://doi.org/10.1093/zoolinlean/zlaa074>).

**Abstract:** Species of the order Crocodylia are mostly large, predatory and semi-aquatic reptiles. Crocodylia, the closest living relatives of birds, first appeared in the Late Cretaceous period. In the present study, the complete mitochondrial (mt) genomes of 19 Crocodylia species, including two species (*Melanosuchus niger* and *Caiman yacare*) that have not been previously sequenced for mitogenomes, were processed through Illumina sequencing to offer genetic resources and compare with the mitogenomes of Crocodylia species reported previously. In addition, a high-resolution phylogenetic tree of nearly all current recognized species of Crocodylia is constructed based on mitogenomic data. Phylogenetic analyses support monophyly of three families: Alligatoridae (four genera: *Alligator*, *Caiman*, *Melanosuchus* and *Paleosuchus*), Crocodylidae (three genera: *Crocodylus*, *Mecistops* and *Osteolaemus*) and Gavialidae (two genera: *Gavialis* and *Tomistoma*). The tree topology is generally similar to previous studies. Molecular dating suggests that the first split within Crocodylia date back to the Upper Cretaceous

(approx. 86.75 Mya). The estimated time to the most recent common ancestor (TMRCA) of Alligatoridae is 53.33 Mya and that of Crocodylidae and Gavialidae is 50.13 Mya, which might be closely linked to climate changes during the Late Palaeocene and Early Eocene. Additionally, this study proves that the diversification rate within Crocodylia began to increase from the Late Eocene (about 36 Mya) and two diversification peak periods of Crocodylia (0-10 Mya and 10-20 Mya) are disclosed, which is roughly consistent with the estimated crocodylian species richness through time. Combining all these clues, we can suggest that climate fluctuation may have played a decisive role in the speciation of Crocodylia.

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Moore, B.C., Groenewald, H.B. and Myburgh, J.G. (2020). Histological investigation of the Nile crocodile (*Crocodylus niloticus*) phallic glands. South American Journal of Herpetology, 16(1): (<https://doi.org/10.2994/SAJH-D-18-00083.1>).

**Abstract:** The male crocodylian phallus, an intromittent organ, transfers sperm to the female cloaca during reproduction. During copulation, the distal phallic glands inflates via blood-filled spongiform tissues; it enlarges into an elaborate shape that directly interacts with the female urodeum - the cloacal chamber that contains the female reproductive tract openings. Alas, the specific mechanics of crocodylian insemination and gamete transfer remain unclear. To that end, we investigated the gross and cellular morphology of the Nile crocodile (*Crocodylus niloticus*) glands characterizing tissues types and structural morphologies to better predict how these male tissues may interact with those of the female. We tracked blood flow from the descending aorta to the phallic glands by way of sulcus spermaticus-adjacent blood vessels. Utilizing an artificial inflation technique, we documented how the glands tissue shape changes with increased hydrostatic pressure in spongiform tissues including increases in height and width and the enlargement of a cup-like distal lumen. Sectioning the glands, we traced the decrease in dense collective tissues and the proliferation of inflatable tissues moving from proximal to distal. Concomitant with the development of the inflatable glands, we identified elastin-rich tissues around the inflatable glands regions and the deep sulcus spermaticus semen conduit. Together, these observations demonstrated the dynamic nature of the tissues, where collagen fibers supply mechanical strength and elastin fibers provide resilience and recoil. We hypothesize how these glands characteristics may interact with female tissues during copulation to increase the chance of successful gamete transfer.

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Cordeiro-Rodrigues, L. (2020). Toward a decolonized healthcare ethics: Colonial legacies and the Siamese crocodile. Developing World Bioethics (doi: 10.1111/dewb.12273).

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Muafa, I.W., Awal, M., Wahyudhi, C.A., Waas, S., Noer, E. and Jusni (2020). The effect of product quality and service quality on customer satisfaction in crocodile skin crafts industry. IOP Conference Series: Earth and Environmental Science 473(1): 012028 (doi: 10.1088/1755-1315/473/1/012028).

**Abstract:** This research aimed to test and analyze the influence of product quality and service quality on customer satisfaction by submitting two research hypotheses. The number of respondents in this study was 120 respondents who were consumers of crocodile skin craftsmen in Merauke. This study uses data analysis techniques using SEM AMOS 22.0 for the development of research constructs and also hypothesis testing. From the results of data analysis that has been done, it can be concluded that the constructs formed can be accepted and then the results of the study show that the variable quality of the product and also the quality of service variables have a positive and significant effect on customer satisfaction.

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Szewczyk, P.K. and Stachewicz, U. (2020). Collagen fibers in crocodile skin and teeth: A morphological comparison using light

and scanning electron microscopy. Journal of Bionic Engineering 17 (<https://doi.org/10.1007/s42235-020-0059-7>).

**Abstract:** Collagen is one of the most versatile tissues of living organisms that comes in many shapes and sizes, providing functions ranging from tissue matrix through, ligament formation up to enabling mineralization in teeth. The detailed light microscopy and Scanning Electron Microscopy (SEM) observations conducted in this study, allowed us to investigate morphology, sizes and crimp patterns of collagen fibers observed in crocodile skin and teeth. Moreover, the microscopy study revealed that although two completely different tissues were investigated, many similarities in their structure based on collagen fibers were observed. Collagen type I is present in crocodile skin and teeth, showing the flexibility in naturally constructed tissues to obtain various functions. The crimp size investigation of collagen fibers confirmed experimentally the theoretical 67 nm D-periodicity expected for collagen type I. The collagen in teeth provides a matrix for crystal growth and in the skin provides flexibility and is a precursor for corneous scales. Importantly, these observations of the collagen in the skin and tooth structure in crocodiles play an important role in designing biomimetic materials with similar functions and properties.

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Dommain, R., Riedl, S., Olaka, L., deMenocal, P., Deino, A., Potts, R. and Strecker, M. (2020). Hydrological basin connectivity in a low-latitude rift: the impact of the Holocene African Humid Period (AHP) on fluvial activity and species dispersal in the Kenya Rift, East African Rift System (EARS). 22nd EGU General Assembly, held online 4-8 May, 2020, id.9323.

**Abstract:** As a result of sustained tectonic and magmatic processes throughout the latter half of the Cenozoic, the eastern branch of the EARS exhibits an extensional tectonic system with pronounced relief contrasts, constituting both corridors and barriers for species dispersal. The tectono-magmatic history has generated a region of highly variable topography that results in widely varying amounts of rainfall and vegetation cover. Today, the generally dry eastern branch of the EARS hosts numerous sub-basins and adjacent local high-relief areas that are hydrologically isolated, with unique microclimates, vegetation types, faunas and superposed surface processes. However, during episodes of climate change with a trend toward more humid conditions, many of these basins hosted freshwater lakes that were hydrologically connected. These areas have repeatedly exhibited freshwater conditions and likely served as gateways and migration corridors mainly for aquatic organisms, in particular fish, facilitating population expansion, dispersal and gene flow. Here, we analyze the manifold manifestations of the AHP in Kenya and adjacent sectors of the EARS to establish the timing and spatial extent of a paleo-drainage system documented by lake shorelines, deltas, overflow channels and sediments. These vestiges of fluvial connectivity in the rift have emerged as analogs for recurrent Pleistocene episodes with high lake levels and inter-basin linkage that repeatedly connected equatorial basins with regions to the north and south, respectively. For example, fossil evidence for the Pleistocene occurrence of the Nile crocodile (*Crocodylus niloticus*) as far south as equatorial Lake Bogoria (Kenya) and its present occurrence in the now closed Lake Baringo basin indicate fluvial connectivity over several degrees of latitude during more humid episodes in the past. Similarly, the occurrence of more than a dozen of the same fish species in the presently unconnected Lakes Albert and Turkana is likely due to a mutual connection during the AHP when Lake Turkana was overflowing into the White Nile. Taken together, the divergent fossil and modern faunal evidence and geomorphic and sedimentological evidence of contrasting hydrological conditions between the wet AHP and the present, suggest that the conditions during the AHP provides a template of fluvial connectivity and potential dispersal patterns for earlier humid phases during the Plio-Pleistocene.

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Chabrolles, L. (2020). Integrative study of multimodal



communication in two models of vertebrates: *Maylandia zebra* and *Crocodylus niloticus*. PhD thesis, University of Lisbon, in partnership with the Institute of Neurosciences of Paris-Saclay and Jean Monnet University.

**Abstract:** The use of multimodal communication in animals is relatively common, however most of the studies have investigated cues in isolation or in bimodal systems and did not consider how the receivers detect and process signals. This thesis aims to disentangle the complex system of multimodal communication by studying the receiver behavioural responses to unimodal or multimodal stimuli and addressing the potential influence of the receiver physiological state on these responses. I used two vertebrates models that use multimodal signals: a cichlid fish *Maylandia zebra*, and a crocodile *Crocodylus niloticus*. The results show an interaction between the different modalities, allowing to modulate and refine the information transmitted during agonistic interactions in *M. zebra*. In young Nile crocodiles, the prandial state (fasted or sated) is an important regulating factor of motivation which can influence the cross-modulation between olfactory and acoustic inputs. This thesis brings new inputs for a better understanding of multimodal communication in vertebrates. It calls for further studies, empirical, theoretical and integrative, on multimodal signalling systems that should help to clarify why animal communication became so complex.

Praduptong, A., Srimangkornkaew, P., Chaeychomsri, S., Thitipramote, N., Chaeychomsri, W. and Siruntawineti, J. (2020). Antioxidant activity of mixture herbal oil from Siamese crocodile oil (*Crocodylus siamensis*), Turmeric (*Curcuma longa*), Black Galingale (*Kaempferia parviflora*) and Plai (*Zingiber cassumunar* Roxb). *Prawarun Agriculture Journal* 17(1): 159-170.

**Abstract:** The 3 formulae of crocodile oil mixture with Thai medicinal plants *Zingiber cassumunar* Roxb (Phlai), *Curcuma longa* (Turmeric) and *Kaempferia parviflora* (Black galingale) were developed as an alternative to skincare products. The study characterized by gas chromatography, Crocodile oil contained high concentration of palmitic acid, stearic acid, oleic acid and linoleic acid, the mixture oil (3 formulas) contain same high sabinene, sabinene hydrate, and (E)-1-(3,4-dimethoxyphenyl) butadiene(DMPBD). The study shed light on 4 methods consists of phenolic content test, flavonoid content test, antioxidant efficiency test, and inhibition lipid peroxidation test of the mixture oil (3 formulas). The result indicated that crocodile oil mixed with Phlai has highest phenolic content  $35.250 \pm 0.902$  mg GAE/ml, the crocodile oil mixed with turmeric has phenolic content  $35.188 \pm 1.659$  mg GAE/ml, and the crocodile oil mixed with black galingale has phenolic content  $16.406 \pm 0.797$  mg GAE/ml. The result of flavonoid contents test indicated that crocodile oil mixed with Turmeric has highest flavonoid contents  $5.676 \pm 0.644$  mg QE/ml, crocodile oil mixed with Black galingale has flavonoid contents  $3.281 \pm 0.505$  mg QE/ml and crocodile oil mixed with Phlai has flavonoid contents  $3.275 \pm 1.132$  mg QE/ml. The result of antioxidant efficiency by DPPH assay indicated that crocodile oil mixed with Phlai has highest  $119.735 \pm 1.058$  mg TEAC/ml, crocodile oil mixed with turmeric has  $64.797 \pm 1.481$  mg TEAC/ml, and crocodile oil mixed with Black galingale has  $62.199 \pm 0.581$  mg TEAC/ml. The result of inhibition lipid peroxidation indicated that crocodile oil mixed with Turmeric has highest 40%, crocodile oil mixed with Phlai has 22%, and crocodile oil mixed with Black galingale 8%. The study showed that the mixed crocodile oils and 3 herbal plants have useful fatty acids for skincare and high antioxidant which can be developed to be massage oil and various relevant products in the future.

Azeez, O.I., Myburgh, J., Sibeko-Matjila, K., Bosman, A-M., Featherstone, J., Oosthuizen, M. and Chamunorwa, J. (2020). Pansteatitis in the Nile crocodile: A glimpse into the pathophysiology using RNA-Seq and bioinformatics. *The FASEB Journal* (<https://doi.org/10.1096/fasebj.2020.34.s1.08652>).

**Abstract:** Concerted efforts to identify the pathogenesis and mechanism(s) involved in pansteatitis, that was attributed to the recent crocodile die off in the Kruger National Park, South Africa have been in the forefront of investigation in recent time. As part of the efforts, molecular characterization of healthy and pansteatitis adipose tissue was carried out by RNA sequencing (RNA-Seq) using Next Generation Sequencing (NGS) and *de novo* assembly of the adipose transcriptome, followed by differential gene expression analysis. Healthy adipose tissue consisting of 50 samples was collected from the subcutaneous, visceral, intermuscular adipose tissues and the abdominal fat body of 10 4-year-old juvenile crocodiles from a local crocodile farm in Pretoria, South Africa. Ten pansteatitis samples were collected from visceral and intermuscular adipose tissues of five crocodiles that were dying of pansteatitis. Seventy genes were differentially expressed in pansteatitis. They include genes coding for extracellular matrix (ECM) signaling ligands, inflammatory cytokines and tumour necrosis factor alpha (TNF $\alpha$ ) receptors, fatty acid synthase and fatty acid binding proteins, peroxisome proliferator-activated receptor gamma (PPAR $\gamma$ ), nuclear factor and apoptosis signaling ligands, and mitogen activated protein kinase enzymes among others. Majority (88.6%) of the upregulated genes were found to be involved in hypoxia inducible pathways for activation of NF $\kappa$ B and inflammation, apoptosis, Toll-like receptor pathway and PPAR $\gamma$ . Bicaudal homologous 2 *Drosophila* gene (BICD2) associated with spinal and lower extremity muscle atrophy was also upregulated in pansteatitis while Sphingosine-1-phosphate phosphatase 2 (SGPP2) involved in Sphingosine-1-phosphate metabolism was downregulated. Furthermore, Doublesex-mab-related transcription factor 1 (DMRT1) responsible for sex gonad development and germ cell differentiation was also downregulated. Thus, from the present study, based on differentially expressed genes in pansteatitis, affected Nile crocodiles might have died partly due to their inability to utilize stored triglycerides as a result of inflammation induced insulin resistance, leading to starvation in the midst of plenty. Affected animals may have also suffered muscular atrophy of the lower extremities and poor fertility.

Mueller, C., Monczak, A., Soueidan, J., McKinney, B., Smott, S., Mills, T., Ji, Y. and Montie, E.W. (2020). Sound characterization and fine-scale spatial mapping of an estuarine soundscape in the southeastern USA. *Marine Ecology Progress Series* 645 (<https://doi.org/10.3354/meps13373>).

**Abstract:** Estuaries are areas known for biological diversity, and their soundscapes reflect the acoustic signals used by organisms to communicate, defend territories, reproduce, and forage in an environment that has limited visibility. These biological sounds may be rhythmic in nature, spatially heterogeneous, and can provide information on habitat quality. The goal of our study was to investigate the temporal and spatial variability of sounds in Chechessee Creek (Stns CC1 and CC2) and an adjacent saltwater impoundment (Great Salt Pond, GSP) in South Carolina, USA, from April to November 2016. Fixed recording platforms revealed that sound pressure levels (SPLs) were significantly higher in CC1 and CC2 compared to GSP. We detected some biological sounds in GSP (snapping shrimp genera *Alpheus* and *Synalpheus*, silver perch *Bairdiella chrysoura*, oyster toadfish *Opsanus tau*, spotted seatrout *Cynoscion nebulosus*, Atlantic croaker *Micropogonias undulatus*, and American alligator *Alligator mississippiensis*); however, biological sound was much more prevalent in CC1 and CC2. In Chechessee Creek, snapping shrimp, oyster toadfish, and spotted seatrout sounds followed distinct temporal rhythms. Using these data, we conducted spatial passive acoustic surveys in Chechessee Creek. We discovered elevated high frequency SPLs (representing snapping shrimp acoustic activity) near an anti-erosion wall, as well as increased low frequency SPLs (indicating spotted seatrout spawning aggregations) near the anti-erosion wall and at the mouth of Chechessee Creek. This study has demonstrated the utility of combining stationary and mobile recording platforms to detect acoustic hotspots of biological sounds.

Pritz, M.B., Ziegler, L.C., Thompson, T.N. and Hsu, E.W. (2020). Magnetic resonance diffusion tensor tractography of a midbrain auditory circuit in *Alligator*. Neuroscience Letters (<https://doi.org/10.1016/j.neulet.2020.135251>).

**Abstract:** Knowledge of brain circuitry is critical for understanding the organization, function, and evolution of central nervous systems. Most commonly, brain connections have been elucidated using histological and experimental methods that require animal sacrifice. On the other hand, magnetic resonance diffusion tensor imaging and associated tractography have emerged as a preferred method to noninvasively visualize brain white matter tracts. However, existing studies have primarily examined large, heavily myelinated fiber tracts. Whether tractography can visualize fiber bundles that contain thin and poorly myelinated axons is uncertain. To address this question, the midbrain auditory pathway to the thalamus was investigated in *Alligator*. This species was chosen because of its evolutionary importance as it is the reptilian group most closely related to birds and because its brain contains many thin and poorly myelinated tracts. Furthermore, this auditory pathway is well documented in other reptiles, including a related crocodilian. Histological observations and experimental determination of anterograde connections confirmed this path in *Alligator*. Tractography identified these tracts in *Alligator* and provided a 3-dimensional picture that accurately identified the neural elements of this circuit. In addition, tractography identified one possible unrecognized pathway. These results demonstrate that tractography can visualize circuits containing thin, poorly myelinated fibers. These findings open the door for future studies to examine these types of pathways in other vertebrates.

Moe, K.K., Zaw, T. and Hmwe, H. (2019). Sedimentary petrology of the Shwetaung-Taw Area, Tada-U Township. In Proceedings of The Third Myanmar National Conference on Earth Sciences (MNCES, 2019), 7-8 November 2019, Yadanabon University, Mandalay, Myanmar.

**Abstract:** The present area lies in the Tada-U Township, Mandalay Region. It is situated at the southeastern part of Shwebo-Monywa plain which lies in the Central Cenozoic Belt of Myanmar. This area consists mainly of Kyaukta Formation (Middle Miocene), Irrawaddy Formation (Upper Miocene to Pliocene) and Gravel Bed (Pleistocene). This sandstone consists of 63 to 68% of the detrital grains and 32 to 38% of chemical cements. According to Pettijohn's Classification (1975), the Kyaukta Formation falls within the field of "Subarkose". Kyaukta Formation is rich in cross-laminations, parting lineations and concretions. Irrawaddy Formation overlies unconformably upon the Kyaukta Formation and is composed mainly of variegated color gypsiferous massive clay and white to ash-white, soft to friable, coarsegrained to gritty sandstone and sand rock. The Irrawaddy Formation is characterized by the abundant presence of vertebrate bone fragments, crocodile teeth, shell fragments such as pelecypods, and sandstone concretions.

El-Kammar, A., El-Sankary, M., El-Azab, A. and Awad, M. (2020). Composition and radioactivity of Oligocene fossil bones and their country rocks in Gabal Qatrani, Fayoum, Egypt. Arabian Journal of Geosciences 13 (<https://doi.org/10.1007/s12517-020-05313-x>).

**Abstract:** Several pieces of fossil bones of scute (scutum), shells, teeth, ribs, and vertebra belonging to turtle, crocodile, hippo, and other unidentified mammals were collected from the Oligocene Qatrani Formation, Fayoum, Egypt. Natural radioactivity was measured to all samples of the country rocks (mainly sandstone, calcareous muddy sandstone and dolostone), in addition to the bone samples. Petrographic examination, XRD, SEM, and complete chemical analyses were done with an emphasis on the more radioactive samples that comprise both fossil bone samples and dolostone. The main mineral composition of these bones is carbonate fluorapatite (francolite), while dolostone consists of microcrystalline dolomite,

which is cemented by gypsum and/or silica. The complete chemical analysis indicates that Ca and P are the main components of fossil bone. The high content of the redox-sensitive elements such as Cu, Zn, Se, Mo, Cd, Sn, and Pb is a diagnostic feature of the fossil bones. The total rare earth elements (REE) in fossil bones ranges between 635 and 4984 ppm but decreases to 90 ppm in the dolostone bed. The high content of the REE in fossil bones seems to be a result of interaction with fluids that were heated by the thermal gradients prevailed during the Oligocene volcanic eruptions. The available data indicate that the fossil bones are more enriched in their uranium contents (from 42 to 457 ppm), while the contents in the country rocks include the dolostone range from 1 to 31 ppm. The fraction of heavy minerals of the studied sandstone is generally enriched in magnetite, ilmenite, and leucoxene as opaques especially magnetite and ilmenite (>50%) and contains a wide variety of non-opaques such as zircon, rutile, garnet, and kyanite among others. These non-opaque minerals have variable but insignificant impacts on the REE pattern and the natural radioactivity of the bone-bearing sediments.

Huang, Z., Dong, N., Shu, L., Wang, H., Sun, Q., Zhou, H., Chan, E.W.-C., Chen, S. and Gu, D. (2020). Detection and genetic characterization of the colistin resistance gene *mcr-3.3* in an *Aeromonas veronii* strain isolated from alligator feces. Journal of Global Antimicrobial Resistance (doi: 10.1016/j.jgar.2020.07.003).

Recuenco, A. (2020). Fisher survives croc attack in Palawan. Tempo, 4 July 2020 (<http://tempo.com.ph/2020/07/04/fisher-survives-crocodile-attack-in-palawan/>).

**Excerpt:** A 25-year-old fisherman was injured in a crocodile attack while fishing off the waters of Balabac, Palawan last Thursday (2 July). Police Lt. Col. Imelda Tolentino, spokesperson of the Philippine National Police-Regional Office 4-B (Mindoro Oriental and Occidental, Marinduque, Romblon, and Palawan area), said the victim, Janilon Amalong, was fishing using a spear gun at around 1 a.m. when a large crocodile attacked him. The crocodile reportedly tried to drag the victim away but Amalong was able to free himself with the help of his uncle. "As a result, he suffered injuries on the head and left eye," said Tolentino. The victim was taken to a nearby hospital for treatment of his wounds. The southernmost part of Palawan is home to saltwater crocodiles. Experts said crocodile attacks in the southern part of Palawan is a result of people invading the crocodiles' natural habitat, like constructing houses in the breeding and hunting grounds of the crocodiles.

Reigh, R.C. and Williams, M.B. (2020). Effects of relative humidity and elevated oxygen concentrations on egg-hatching success of American alligator, *Alligator mississippiensis*. Journal of the World Aquaculture Society (<https://doi.org/10.1111/jwas.12719>).

**Abstract:** Two experiments were conducted to determine effects of relative humidity (RH) and atmospheric oxygen concentration on hatching success of artificially incubated alligator eggs. In one study, 216 eggs were subjected to one of four treatments involving two levels of RH (80 or 93% RH) and two atmospheric oxygen concentrations (21 or 28% O<sub>2</sub>). Hatching success of eggs in the 80/21 and 80/28 treatments, combined, totaled only 1.8% (one hatchling produced in each treatment), while hatching success of eggs in the 93/21 and 93/28 treatments averaged 83.3% in both groups, with no significant difference ( $p > .05$ ) between treatments. In a second study, 300 alligator eggs were incubated at 93% RH and one of three atmospheric oxygen concentrations (21, 25, or 28% O<sub>2</sub>). Hatching success averaged 66.3, 56.3, and 62.5% in the 21, 25, and 28% oxygen treatments, respectively, with no significant difference ( $p > 0.05$ ) among treatments. Results of the two experiments indicated that 80% RH reduced egg-hatching success to nearly zero, regardless of atmospheric oxygen concentration, while 93% RH produced good hatching success. Elevated atmospheric oxygen concentrations up to one-third higher than ambient air had no effect

on egg-hatching success under the conditions of either study.

Delfino, M., Iurino, D.A., Mercurio, B., Piras, P., Rook, L. and Sardella, R. (2020). Old African fossils provide new evidence for the origin of the American crocodiles. *Scientific Reports* 10: 11127.

**Abstract:** Molecular and morphological phylogenies concur in indicating that the African lineages formerly referred to *Crocodylus niloticus* are the sister taxon the four Neotropical crocodiles (*Crocodylus intermedius*, *C. moreletii*, *C. acutus* and *C. rhombifer*), implying a transoceanic dispersal from Africa to America. So far the fossil record did not contribute to identify a possible African forerunner of the Neotropical species but, curiously, the oldest remains referred to the African *C. niloticus* are Quaternary in age, whereas the oldest American fossils of *Crocodylus* are older, being dated to the early Pliocene, suggesting that another species could be involved. We re-described, also thanks to CT imaging, the only well-preserved topotypic skull of *Crocodylus chechchiae* Maccagno, 1947 from the late Miocene (Messinian) African site of As Sahabi in Libya. As previously suggested on the basis of late Miocene material from Tanzania, *C. chechchiae* is a valid, diagnosable species. According to our phylogenetic analyses, *C. chechchiae* is related to the Neotropical taxa and could be even located at the base of their radiation, therefore representing the missing link between the African and the American lineages.

Lee, H.W., Esteve-Altava, B. and Abzhanov, A. (2020). Evolutionary and ontogenetic changes of the anatomical organization and modularity in the skull of archosaurs. *bioRxiv* (doi: <https://doi.org/10.1101/2020.02.21.960435>).

**Abstract:** Comparative anatomy studies of the skull of archosaurs provide insights on the mechanisms of evolution for the morphologically and functionally diverse species of crocodiles and birds. One of the key attributes of skull evolution is the anatomical changes associated with the physical arrangement of cranial bones. Here, we compare the changes in anatomical organization and modularity of the skull of extinct and extant archosaurs using an Anatomical Network Analysis approach. We show that the number of bones, their topological arrangement, and modular organization can discriminate birds from non-avian dinosaurs, and crurotarsans. We could also discriminate extant taxa from extinct species when adult birds were included. By comparing within the same framework, juveniles and adults for crown birds and alligator (*Alligator mississippiensis*), we find that adult and juvenile alligator skulls are topologically similar, whereas juvenile bird skulls have a morphological complexity and anisomerism more similar to those of non-avian dinosaurs and crurotarsans than of their own adult forms. Clade-specific ontogenetic differences in skull organization, such as extensive postnatal fusion of cranial bones in crown birds, can explain this pattern. The fact that juvenile and adult skulls in birds do share a similar anatomical integration suggests the presence of a specific constraint to their ontogenetic growth.

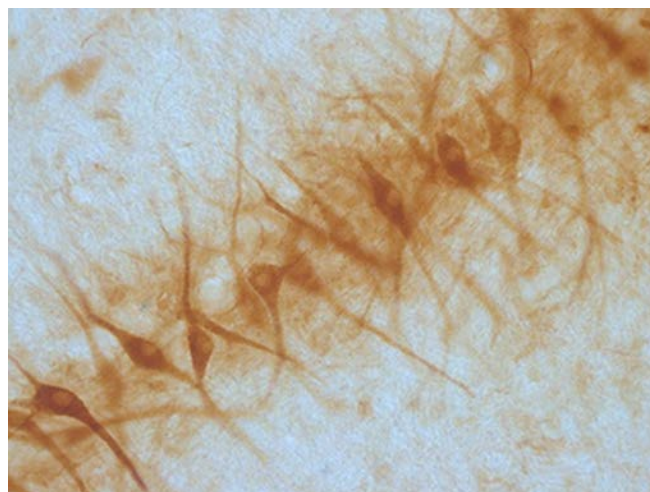
De la Quintana, P., Aparicio, J. and Pacheco, L.F. (2020). Home range and habitat use of two sympatric crocodylians (*Melanosuchus niger* and *Caiman yacare*) under changing habitat conditions. *Amphibia-Reptilia* (doi:10.1163/15685381-bja10027).

**Abstract:** We used radio-telemetry to record how *Caiman yacare* (Cy) and *Melanosuchus niger* (Mn) responded to the intrusion of the Maniqui River into Cedral Lagoon in the Bolivian Amazon. Nine *M. niger* and 3 *C. yacare* were followed between December 2015 and May 2016. Both species showed a gradual reduction in mean monthly range from December (19.96 ha Mn and 1.74 ha Cy) to May 2016 (0.08 ha Mn and 0.24 ha Cy). Habitat use was fairly constant throughout the months for both species, *Melanosuchus niger* used mainly open swampy forests and Cyperaceae Marshes, while *C. yacare* used more islands and flooded grasslands. This

study shows that both species of caimans responded to changes in depth and vegetation types, as their habitat as a whole was changed by river intrusion.

Billings, B.K., Bhagwandin, A., Patzke, N., Ngwenya, A., Rook, N., Von Eugen, K., Tabrick, S., Güntürkün, O. and Manger, P.R. (2020). Nuclear organization and morphology of catecholaminergic neurons and certain pallial terminal networks in the brain of the Nile crocodile, *Crocodylus niloticus*. *Journal of Chemical Neuroanatomy* 109: (<https://doi.org/10.1016/j.jchemneu.2020.101851>).

**Abstract:** In the current study, we use tyrosine hydroxylase (TH) immunohistochemistry to detail the nuclear parcellation and cellular morphology of neurons belonging to the catecholaminergic system in the brain of the Nile crocodile. In general, our results are similar to that found in another crocodilian (the Spectacled caiman) and indeed other vertebrates, but certain differences of both evolutionary and functional significance were noted. TH immunopositive (TH+) neurons forming distinct nuclei were observed in the olfactory bulb (A16), hypothalamus (A11, A13-15), midbrain (A8-A10), pons (A5-A7) and medulla oblongata (area postrema, C1, C2, A1, A2), encompassing the more commonly observed nuclear complexes of this system across vertebrates. In addition, TH+neurons forming distinct nuclei not commonly identified in vertebrates were observed in the anterior olfactory nucleus, the pretectal nuclear complex, adjacent to the posterior commissure, and within nucleus laminaris, nucleus magnocellularis lateralis and the lateral vestibular nucleus. Palely stained TH+neurons were observed in some of the serotonergic nuclei, including the medial and lateral divisions of the superior raphe nucleus and the inferior raphe and inferior reticular nucleus, but not in other serotonergic nuclei. In birds, a high density of TH+fibres and pericellular baskets in the dorsal ventricular ridge marks the location of the nidopallium caudolaterale (NCL), a putative avian analogue of mammalian prefrontal cortex. In the dorsal ventricular ridge (DVR) of the crocodile a small region in the caudolateral anterior DVR (ADVRL) revealed a slightly higher density of TH+fibres and some pericellular baskets (formed by only few TH+fibres). These results are discussed in an evolutionary and functional framework.



Consalo, K.Z. (2020). Fighting back from the brink: International efforts to prevent illegal trafficking in endangered species. *Environs: Environmental Law & Policy Journal* 43(1): 67-118.

Ahmad, S.F., Singchat, W., Jehangir, M., Panthum, T. and Srikulnath, K. (2020). Consequence of paradigm shift with repeat landscapes in reptiles: Powerful facilitators of chromosomal rearrangements for diversity and evolution. *Genes* (doi:10.3390/genes11070827).

**Abstract:** Reptiles are notable for the extensive genomic diversity



and species richness among amniote classes, but there is nevertheless a need for detailed genome-scale studies. Although the monophyletic amniotes have recently been a focus of attention through an increasing number of genome sequencing projects, the abundant repetitive portion of the genome, termed the “repeatome”, remains poorly understood across different lineages. Consisting predominantly of transposable elements or mobile and satellite sequences, these repeat elements are considered crucial in causing chromosomal rearrangements that lead to genomic diversity and evolution. Here, we propose major repeat landscapes in representative reptilian species, highlighting their evolutionary dynamics and role in mediating chromosomal rearrangements. Distinct karyotype variability, which is typically a conspicuous feature of reptile genomes, is discussed, with a particular focus on rearrangements correlated with evolutionary reorganization of micro- and macrochromosomes and sex chromosomes. The exceptional karyotype variation and extreme genomic diversity of reptiles are used to test several hypotheses concerning genomic structure, function, and evolution.

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Habarugira, G., Suen, W.W., Hobson-Peters, J., Hall, R.A. and Bielefeldt-Ohmann, H. (2020). West Nile Virus: An update on pathobiology, epidemiology, diagnostics, control and “One Health” implications. *Pathogens* 9: (doi:10.3390/pathogens9070589).

**Abstract:** West Nile virus (WNV) is an important zoonotic flavivirus responsible for mild fever to severe, lethal neuroinvasive disease in humans, horses, birds, and other wildlife species. Since its discovery, WNV has caused multiple human and animal disease outbreaks in all continents, except Antarctica. Infections are associated with economic losses, mainly due to the cost of treatment of infected patients, control programmes, and loss of animals and animal products. The pathogenesis of WNV has been extensively investigated in natural hosts as well as in several animal models, including rodents, lagomorphs, birds, and reptiles. However, most of the proposed pathogenesis hypotheses remain contentious, and much remains to be elucidated. At the same time, the unavailability of specific antiviral treatment or effective and safe vaccines contribute to the perpetuation of the disease and regular occurrence of outbreaks in both endemic and non-endemic areas. Moreover, globalisation and climate change are also important drivers of the emergence and re-emergence of the virus and disease. Here, we give an update of the pathobiology, epidemiology, diagnostics, control, and “One Health” implications of WNV infection and disease.

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Van der Westhuizen, D. (2019). Elemental compositions of Nile crocodile tissues (*Crocodylus niloticus*) from the Kruger National Park. MSc thesis, North-West University, South Africa.

**Abstract:** A SANParks program assessed the health of wild Nile crocodiles in the Kruger National Park (KNP) during 2010, with appropriate permits and ethical clearance. Samples were collected from sixteen shot crocodiles (8 males, 8 females) from the Sabie, Olifants, Crocodile, Levuvhu, Shingwedzi, Nwaswitsontso, and Letaba Rivers, collected by SANParks staff. The samples were collected to obtain more information on the biology, pathology, and ecotoxicology of wild crocodiles, based on the 2008/09 mass crocodile mortality events in the Olifants and Letaba Rivers. The aim of the current study was to provide an assessment of the elemental composition of legacy samples already collected and analysed. To achieve this aim, the elemental composition of five different tissues of 16 Nile crocodiles (*Crocodylus niloticus*) collected in the Kruger National Park was measured and assessed. Additionally, it was determined which tissue(s) would be representative for possible future biopsies from catch and release crocodiles to assess any changes in environmental concentrations. Muscle (from the tail) and tail fat tissue is relatively easily assessable after live capture, while liver, kidney and abdominal fat are more difficult to sample. Most of the elements that were not statistically different between muscle and the other tissues were with kidney (31 elements) and

liver (34 elements) tissues. Muscle tissue had no differences with 21 elements for both tail fat and abdominal fat. Kidney and liver shared 38 elements with no significant different concentrations, but only 10 and 16 with abdominal fat and tail fat, respectively. Only three elements were comparable between liver and tail fat, but had no significant different concentrations for 16 elements with abdominal fat. Tail fat and abdominal fat, on the other hand, had no differences whatsoever for any of the 47 elements thus compared. There were surprisingly little direct associations of concentrations between mass and length. This may be due to differences in individual life histories of long-lived animals and feeding preferences. It is clear that there is little pattern of prediction or consistency of elemental concentrations between tissues, except between the two fatty tissues, and kidney and liver to some extent. To a lesser extent, muscle and liver, and muscle and kidney had corresponding concentrations. These tissues may therefore be useful when taking biopsies from live animals to determine pollutant loads in the crocodiles. There were few patterns to discern, but mass, length, and sex did not discriminate between elemental concentrations with any confidence in any tissue. Due to the large variations in concentrations, proper scientific studies using live-captured animals would need a balanced sampling design. The numbers of individuals needed for such a scientific study for the targeted elements and organs can be calculated from my data. However, it seems that for regular and general surveys, the capture and biopsy of fewer animals with less consideration for mass, length and sex, may be appropriate. This investigation provides the largest elemental concentration dataset and baseline for any African crocodile. The data and interpretations will assist in monitoring changes and comparisons with other regions and contribute to a better understanding of the biology, ecology, and threats faced by these apex predators, the largest in Africa.

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Than, K.Z., Strine, C.T., Sritongchuy, T., Zaw, Z. and Hughes, A.C. (2020). Estimating population status and site occupancy of saltwater crocodiles *Crocodylus porosus* in the Ayeyarwady delta, Myanmar: inferences from spatial modeling techniques. *Global Ecology and Conservation* (https://doi.org/10.1016/j.gecco.2020.e01206).

**Abstract:** Saltwater crocodiles *Crocodylus porosus* are listed as critically endangered in Myanmar because they are limited to Meinmahlakyun Wildlife Sanctuary (MKWS) in the Ayeyarwady delta region. Little contemporary data exists on their distribution and population size which hinders effective conservation and management. We conducted standardized spotlight surveys and camera trap surveys along the rivers inside MKWS, and two nearby reserved forests. We used Hierarchical N-mixture models, Spatial Count models, and the relative abundance index to estimate site use by and population sizes of saltwater crocodiles in the Ayeyarwady delta. To address biases in detectability, we used maximum-likelihood and Bayesian approaches (1) to assess occupancy (site use) and population parameters of saltwater crocodiles, and (2) to assay abiotic and anthropogenic factors affecting it. Saltwater crocodiles were more likely to be abundant and occupy in the waterways inside MKWS than the reserved forests, and in the narrow and low salinity waterways than the wide and high salinity ones. Abundance of saltwater crocodiles was lower in areas with the human settlements than in areas with no settlement. Creeks within MKWS had moderate salinity and no human settlement and therefore it can be regarded as the last remaining optimal saltwater crocodile habitat of the Ayeyarwady Delta. We estimated the saltwater crocodile population sizes in MKWS were  $75 \pm 9.92$  individuals as absolute spotlight index,  $58 \pm 8.02$  individuals as the maximum likelihood estimate of the N-mixture models and  $68 \pm 10.00$  individuals as the Bayesian estimate of the spatial count models. Current population estimates of saltwater crocodiles are lower than the previously reported population size in 1999, and the declining population is now restricted to MKWS. We suggest developing buffer zones in the reserved forests around the wildlife sanctuary to increase habitat areas for saltwater crocodiles and to improve the outlook for long-term saltwater crocodile survival in Myanmar.

Poapolathep, S., Klangkaew, N., Phaochoosak, N., Wongwaipairoj, T., Giorgi, M., Chaibut, N., Trott, D.J. and Poapolathep, A. (2020). Pharmacokinetics of a long-acting formulation of oxytetracycline in freshwater crocodiles (*Crocodylus siamensis*) after intramuscular administration at three different dosages. *Animals* 10: (doi:10.3390/ani10081281).

**Abstract:** To date, the necessary pharmacokinetic information has been limited to establish suitable therapeutic plans for freshwater crocodiles. Therefore, this study was conducted to evaluate the pharmacokinetic profile of the oxytetracycline long-acting formulation (OTC-LA) in the freshwater crocodile, *Crocodylus siamensis*, following a single intramuscular (i.m.) administration at three different dosages of 5, 10 and 20 mg/kg body weight (b.w.). Blood samples were collected at assigned times up to 216 h after i.m. administration at the three different dosages. The plasma concentrations of OTC were measured using a validated liquid chromatography tandem-mass spectrometry (LC-MS/MS) method. The C<sub>max</sub> (± SD) values of OTC were 2.15 ± 0.51 µg/mL, 7.68 ± 1.08 µg/mL and 17.08 ± 2.09 µg/mL at doses of 5, 10 and 20 mg/kg b.w., respectively. The elimination half-life values were 33.59 ± 2.51 h, 38.42 ± 5.47 h and 38.04 ± 1.98 h at dosages of 5, 10 and 20 mg/kg b.w., respectively. Based on the pharmacokinetic data, the pharmacokinetic/pharmacodynamic (PK/PD) index, the susceptibility break-point and plasma protein binding, a dosage once every two weeks of 10 mg/kg b.w. OTC intramuscularly might be suitable for initiating the treatment of susceptible bacterial infections in freshwater crocodiles. However, further PK/PD studies are warranted to confirm whether the dose rates used in this study can produce longer-term antimicrobial success for diseases caused by susceptible bacteria in freshwater crocodiles.

Cossette, A.P. and Brochu, C.A. (2020). A systematic review of the giant alligatoroid *Deinosuchus* from the Campanian of North America and its implications for the relationships at the root of Crocodylia. *Journal of Vertebrate Paleontology* (doi: 10.1080/02724634.2020.1767638).

**Abstract:** *Deinosuchus* is a lineage of giant (≥10 m) Late Cretaceous crocodylians from North America. These were the largest semiaquatic predators in their environments and are known to have fed on large vertebrates, including contemporaneous terrestrial vertebrates such as dinosaurs. Fossils have been found in units of Campanian age from northern Mexico to Montana in the west and Mississippi to New Jersey in the east. Three species have been named, and recent consensus suggests that they represent a single, widely ranging species. The authors studied newly collected material from western Texas and increased sampling from throughout North America to review species-level systematics of *Deinosuchus* and help refine its phylogenetic placement among crocodylians. *Deinosuchus* from eastern and western North America can be consistently differentiated and represent different species. A phylogenetic study is conducted including new character states. This work reinforces the identity of the ‘terror crocodile’ as an alligatoroid. Reference to the holotypes indicates that the generic name holder, *Deinosuchus hatcheri*, is extremely incomplete. As a result, the three known species of *Deinosuchus* cannot be differentiated. To ensure nomenclatural stability, the type species for *Deinosuchus* should be transferred to *Deinosuchus riograndensis*, a species known from multiple mostly complete individuals. Additionally, *Deinosuchus rugosus* is based on a holotype that is not diagnostic, and a new species, *Deinosuchus swimmeri*, is named to encompass some specimens formerly assigned to *D. rugosus*.

Jodidio, R.L. (2020). The Animal Welfare Act is lacking: How to update the Federal statute to improve zoo animal welfare. *Golden Gate University Environmental Law Journal* 12(1): 53-80.

Campos, Z., Mourao, G. and Muniz, F. (2020). Uso de drone no

levantamento de ninhos de jacaré-do-pantanal. *Boletim de Pesquisa e Desenvolvimento* 141. Embrapa Pantanal: Corumbá.

**Abstract:** The management of wild animal populations, whether for the purpose of conservation or with a view to economic exploitation, requires information about their reproductive biology. Obtaining information about the reproduction of Yacare caiman is important for both conservation and management in the wild and for production in captivity systems where eggs are removed from natural environments. In this case, the official management model for economic use used in Mato Grosso do Sul allows the collection of a fraction of the number of alligator nests found each year in the ranch by the producer. In counterpart, the licensing/controlling body of the activity demands that the producer provide verifiable biological information about the managed population, e.g., the individual location of each nest and the number of eggs in the nests. Among the habitats used by the Pantanal caiman, the floating vegetation mats have been especially challenging for the location, monitoring and use of the nests, due to their difficulty of access and in viewing. The study presents a methodology based on a new, inexpensive, effective, and safe tool to assess the number and individual location of caimans nests found in hitherto inaccessible floating vegetation mats, both in the Pantanal wetland and in other humid areas in Brazil.

Campos, Z. and Mourão, G. (2020). Como o jacaré-do-pantanal, *Caiman yacare*, resiste a períodos secos na região central do Pantanal. Documento 165. Embrapa Pantanal: Corumbá.

Rubin, M. (2020). A New Alligatorine from the Middle Eocene of Utah and the Origins of Modern *Alligator*. MSc thesis, The University of Iowa, Iowa City, Iowa, USA.

**Abstract:** The Uinta Basin of Utah has many exposed layers from the middle Eocene, and nearly all 500 m of the Uinta Formation are exposed. Although this area is known for its Cenozoic mammals it also contains early crocodylids, including an unidentified alligatorine. The Uinta Formation and the alligatorine material discovered therein would fit perfectly into the ~30 mya gap between the earliest species of *Alligator*, *A. prenasalis*, and the sister taxon to *Alligator*, *Wannaganosuchus brachymanus*. We reviewed material that could be assigned to the new taxon and coded the Uinta material into an updated matrix. The Uinta material was found to have characteristics of both the more basal alligatorines while also sharing characteristics with the earliest species of *Alligator*. Like most basal alligatorines, the Uinta material has a shorter snout compared to modern *Alligator* and extremely robust posterior teeth. However, its snout is longer than those basal alligatorines and less pointed, and the morphology of the external naris is closer to that of *A. prenasalis* and the other early alligators. In this paper I describe the Uinta material as a new genus and species, *Uintachampsia elseyae*, and describe its defining characteristics. Phylogenetic analyses placed *Uintachampsia* as sister to the genus *Alligator*, but support for the nodes of the *Wannaganosuchus* + *Uintachampsia* + *Alligator* clade is relatively weak until we get to the *Alligator* genus. Despite this, if *Uintachampsia* is indeed on the *Alligator* lineage then it leads to two interesting conclusions: first, that throughout its evolution *Alligator* was moving away from a more specialized morphology towards a more generalist morphology in seeming violation of “Cope’s Law,” and second, that the reason for this shift in morphology is not related to the extinction of other large generalist crocodylians of the North American Western Interior, as *Uintachampsia* shows that this trend was beginning before the extinction took place.

Balaguera-Reina, S.A., Vargas-Ramírez, M., Ordóñez-Garza, N., Hernández-González, F. and Densmore, L.D. (2020). Unveiling the mystery: Assessing the evolutionary trajectory of the Apaporis caiman population (*Caiman crocodilus apaporiensis*, Medem 1955) via mitochondrial molecular markers. *Biological Journal of the*

**Abstract:** The Apaporis caiman (*Caiman crocodilus apaporiensis*) has been of particular interest due to its highly differentiated morphology. However, no molecular research has been done to clarify its taxonomy. We characterized the genetic variation within *C. crocodilus* by assessing the evolutionary trajectory of Apaporis caiman populations using mitochondrial molecular markers. We collected 10 Apaporis caiman samples from the middle basin of the Apaporis River, Colombia, sequenced two mitochondrial genes [cytochrome oxidase I (COI) and cytochrome B (CytB)], and analysed them together with all available sequences from homologous gene fragments at GenBank for the species. Phylogenetic reconstructions revealed three main clades clearly differentiated across the *C. crocodilus* complex. These clades matched genetically and geographically with three of the four subspecies currently recognized (*C. c. chiapasius*, *C. c. fuscus* and *C. c. crocodilus*). However, we found low to almost non-existent genetic differentiation between *C. c. crocodilus* and the until-now morphologically recognized *C. c. apaporiensis*, suggesting that the latter is part of the genetic spectrum present within *C. c. crocodilus*. We reject the hypothesis of an expected elevated level of genetic variation due to isolation (supported by morphological differentiation) and support the idea of Apaporis caiman populations as a *C. crocodilus* ecomorph.

Cidade, G.M., Rincón, A.D. and Solórzano, A. (2020). New cranial and postcranial elements of *Mourasuchus* (Alligatoroidea: Caimaninae) from the late Miocene of Venezuela and their palaeobiological implications. *Historical Biology* (<https://doi.org/10.1080/08912963.2020.1795844>).

**Abstract:** A partial skeleton of *Mourasuchus*, one of the most peculiar crocodylians of all time, that includes cranial and postcranial elements recovered from the late Miocene bone-beds of the Urumaco Formation (northwestern Venezuela) is herein described. Based on the presence of tall squamosal eminences, we assigned it to *Mourasuchus arendsi*. To provide an empirical assessment of the palaeobiological affinities of *Mourasuchus*, we performed estimations of the body mass and body length based on several *Mourasuchus* skull measurements, and an analysis of death roll capability. Our results indicate that *Mourasuchus* was indeed a large crocodylian, with a body length bigger than 9 m and weighed more than 4 tons. We find that *Mourasuchus arendsi* was incapable of executing the 'death roll' as a feeding behaviour and as such was unable to predate giant mammals, which are relatively common in the Urumaco Formation. Finally, the specimen includes a slender humerus, which may indicate that *Mourasuchus* had weak forelimbs and would spend more time in the water.

Sookias, R.B., Dilkes, D., Sobral, G., Smith, R.M.H., Wolvaardt, F.P., Arcucci, A.B., Bhullar, B.-A.S. and Werneburg, I. (2020). The craniomandibular anatomy of the early archosauriform *Euparkeria capensis* and the dawn of the archosaur skull. *Royal Society Open Science* 7: 200116.

**Abstract:** Archosauria (birds, crocodilians and their extinct relatives) form a major part of terrestrial ecosystems today, with over 10,000 living species, and came to dominate the land for most of the Mesozoic (over 150 Myr) after radiating following the Permian-Triassic extinction. The archosaur skull has been essential to this diversification, itself diversified into myriad forms. The archosauriform *Euparkeria capensis* from the Middle Triassic (Anisian) of South Africa has been of great interest since its initial description in 1913, because its anatomy shed light on the origins and early evolution of crown Archosauria and potentially approached that of the archosaur common ancestor. *Euparkeria* has been widely used as an outgroup in phylogenetic analyses and when investigating patterns of trait evolution among archosaurs. Although described monographically in 1965, subsequent years have seen

great advances in the understanding of early archosaurs and in imaging techniques. Here, the cranium and mandible of *Euparkeria* are fully redescribed and documented using all fossil material and computed tomographic data. Details previously unclear are fully described, including vomerine dentition, the epiptergoid, number of premaxillary teeth and palatal arrangement. A new diagnosis and cranial and braincase reconstruction is provided, and an anatomical network analysis is performed on the skull of *Euparkeria* and compared with other amniotes. The modular composition of the cranium suggests a flexible skull well adapted to feeding on agile food, but with a clear tendency towards more carnivorous behaviour, placing the taxon at the interface between ancestral diapsid and crown archosaur ecomorphology, corresponding to increases in brain size, visual sensitivity, upright locomotion and metabolism around this point in archosauriform evolution. The skull of *Euparkeria* epitomizes a major evolutionary transition, and places crown archosaur morphology in an evolutionary context.

Gaitán, C.A., Fuentes-Montejo, C.E., García, M.J. and Romero-Guevara, J.C. (2020). An update of the invasive *Pterygoplichthys* Gill, 1858 (Actinopterygii, Loricariidae) in Guatemala: new records and notes on its interactions with the local fauna. *Neotropical Biology and Conservation* 15(3): 285-300.

**Abstract:** Fishes have been introduced in non-native ecosystems all over the world. These introductions have been recognised for their overall negative effects on native biodiversity. Plecos (*Pterygoplichthys* Gill, 1858) have been introduced worldwide due to bad practices in the aquarium trade and, in Central America, there is little information regarding these invasive fishes. Plecos have been demonstrated to be a threat in non-native ecosystems because they interfere with their new ecosystems through bottom-up impacts, altering nutrient availability and interactions with native wildlife. Herein, new records of plecos are reported for river basins from Guatemala in northern Central America where they had not previously been reported. Evidence of interactions of plecos with the native fauna that had not been recorded to date are also included. We compiled a total of 34 records in Guatemala, with 8 new records. We present the first records of the genus in a river basin of the Caribbean drainage for Guatemala. Three new interactions of fauna preying upon plecos are presented (Black vulture, Barethroated tiger Heron and Domestic dog), along with a compilation of previously known interactions. Establishing a monitoring and surveillance programme should be a priority in Guatemala, along with other actions to safeguard the native wildlife that could be at high risk because of biological invasions, such as the one with plecos. In order to better understand this invasion, joint efforts of local fishermen and rangers with State institutions should be promoted.

Sara, J.R., Luus-Powell, W.J., Fogelson, S.B., Botha, H., Guillelte, T.C., Smit, W.J., Hoffman, A., Kunutu, K.D., Koelmel, J.P. and Bowden, J.A. (2020). A histological evaluation of pansteatitis-affected Mozambique tilapia, *Oreochromis mossambicus* (Peters 1852), from different geographical locations in South Africa. *Journal of Fish Diseases* (<https://doi.org/10.1111/jfd.13184>).

**Abstract:** Pansteatitis is the leading cause for the decline in Nile crocodile populations and the sporadic mortality of fish in the Olifants River System, South Africa. To determine the prevalence of this disease in lentic systems, Mozambique tilapia, *Oreochromis mossambicus*, were collected from Lake Loskop, Lake Flag Boshielo, Phalaborwa Barrage and Lake Luphephe-Nwanedi. The former three impoundments are located within the main stem of the Olifants River, while the latter, which is geographically isolated and situated in the Limpopo River System, served as a reference site. Mesenteric adipose, liver, serosa of the swim bladder, gill and the skeletal muscle of fish sampled were examined for gross and microscopic evidence of pansteatitis. Microscopically observed changes were used to statistically compare pansteatitis prevalence between samples and sites. Based on histopathological evaluation,



the adipose tissue in the liver, swim bladder serosa and coelom from severely debilitated individuals showed the most significant pathological changes. Lesions indicative of steatitis were observed in fish collected from Lake Loskop (75%), Lake Flag Boshielo (22%) and Lake Luphephe-Nwanedi (15%). Further investigation is warranted to understand the pervasiveness and mechanisms driving pathological changes of pansteatitis at Lake Flag Boshielo, Phalaborwa Barrage and Lake Luphephe-Nwanedi.

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Buenfil-Rojas, A.M., Alvarez-Legorreta, T., Cedeño-Vazquez, J.R., Rendon-von Osten, J. and Gonzalez-Jauregui, M. (2020). Distribution of metals in tissues of captive and wild Morelet's crocodiles and the potential of metallothioneins in blood fractions as a biomarker of metal exposure. *Chemosphere* (<https://doi.org/10.1016/j.chemosphere.2019.125551>).

**Abstract:** The distribution of Hg, Cd, Cu, and Zn in keratinized tissues, blood fractions, and excretory organs, and MTs in blood fractions and excretory organs was determined in captive, semicaptive, and wild Morelet's crocodiles and they were compared to select the most useful non-destructive tissues for the monitoring of metal exposure and to assess the potential of MTs as a biomarker. Our results indicate blood plasma, claws, and caudal scutes altogether are suitable tissues for xenobiotic metals exposure, with concentrations in blood plasma being an indicator of recent exposure, whereas concentrations in claws and caudal scutes are indicators of chronic exposure. Results in keratinized tissues suggest they are an important detoxification strategy in crocodiles, and claws presented the highest concentrations of metals in both captive ( $Hg = 0.44 \pm 0.23 \mu g g^{-1}$ ,  $Cd = 11.10 \pm 5.89 \mu g g^{-1}$ ,  $Cu = 45.98 \pm 23.18 \mu g g^{-1}$ ,  $Zn = 124.75 \pm 75.84 \mu g g^{-1}$ ) and wild populations ( $Hg = 1.31 \pm 0.32 \mu g g^{-1}$ ,  $Cd = 26.47 \pm 21.15 \mu g g^{-1}$ ,  $Cu = 191.75 \pm 165.91 \mu g g^{-1}$ ,  $Zn = 265.81 \pm 90.62 \mu g g^{-1}$ ). Thus, they are an appropriate tool for assessing metal exposure in populations where scutes clipping as a marking technique is not allowed, and their collection is less complicated than with other tissues. MTs are a suitable biomarker in blood plasma, whereas in erythrocytes detoxification processes might depend on hemoglobin, rather than MTs. Future studies should consider the implementation of these tools for the monitoring of wild populations.

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Lemaire, J., Bustamante, P., Marquis, O., Caut, S. and Brischox, F. (2020). Influence of sex, size and trophic level on blood Hg concentrations in Black caiman, *Melanosuchus niger* (Spix, 1825) in French Guiana. *Chemosphere* (<https://doi.org/10.1016/j.chemosphere.2020.127819>).

**Abstract:** Mercury (Hg) is a contaminant that is impacting ecosystems worldwide. Its toxicity is threatening wildlife and human populations, leading to the necessity of identifying the most affected ecosystems. Therefore, it is essential to identify pertinent bioindicator organisms to monitor Hg contamination. In this study, we determined the stable carbon ( $\delta^{13}C$ ) and nitrogen ( $\delta^{15}N$ ) isotope ratios in the red blood cells (RBCs), and the total Hg concentration in total blood of 72 *Melanosuchus niger* in French Guiana. The goals of our study were to assess the level of Hg contamination in total blood of Black caimans and to further investigate the influence of individual traits (ie sex, size/age, diet) on Hg concentrations. Mercury concentration in total blood of Black caimans ranged from  $0.572$  to  $3.408 \mu g g^{-1} dw$  (mean  $\pm$  SD is  $1.284 \pm 0.672 \mu g g^{-1} dw$ ) and was positively correlated to individual body size and trophic position. We did not find any sexual or seasonal effects on Hg concentrations in the blood. The use of blood of *M. niger* is relevant to determine Hg concentrations within the population and suggests that this species can be used as a bioindicator for environmental contamination. In addition, our results emphasize trophic position ( $\delta^{15}N$ ) as a major source of Hg variation and further suggest that it is essential to take trophic position into account for future studies.

Abd Rabou, A.N. (2020) How is the COVID-19 outbreak affecting wildlife around the world? *Open Journal of Ecology* 10: 497-517.

**Abstract:** The COVID-19 is the infectious disease caused by the most recently discovered coronavirus at an animal market in Wuhan, China. Many wildlife species have been suggested as possible intermediate sources for the transmission of COVID-19 virus from bats to humans. The quick transmission of COVID-19 outbreak has imposed quarantine measures across the world, and as a result, most of the world's towns and cities fell silent under lockdowns. The current study comes to investigate the ways by which the COVID-19 outbreak affects wildlife globally. Hundreds of internet sites and scientific reports have been reviewed to satisfy the needs of the study. Stories of seeing wild animals roaming the quiet, deserted streets and cities during the COVID-19 outbreak have been posted in the media and social media. The strong link between wildlife markets and COVID-19 resulted in international calls asking countries to shut down wildlife markets forever. Poorer and vulnerable people around the world overexploit natural resources including wildlife. Roadkills became minimal because of the lockdown measures. The reduction in noise pollution level is expected to improve wildlife health and ecology including breeding success. The shortage of food items provided to zoo and park animals constituted a real threat to animals and the institution harboring them. The increase in fish biomass comes as a result of the sharp decline in fishing activities. The isolation of antibodies from certain wildlife species is promising in saving humankind against COVID-19. The infection of wild and pet animals with COVID-19 virus from humans and the interspecific transmission of the infection are disastrous to animal ecology. Finally, closures may enhance people to connect more and more with nature in order to acknowledge wildlife in their surrounding environments. In conclusion, the study asks the world's different parties to conserve wildlife in a sustainable fashion and to regulate exotic animal trade in wet markets in order to lower the incidence of zoonoses.

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Ramchandani, M. and Coste-Maniere, I. (2020). Leather in the Age of Sustainability: A norm or merely a cherry on top? Pp. 11-22 *in* Leather and Footwear Sustainability. Textile Science and Clothing Technology, ed. by S. Muthu. Springer: Singapore.

**Abstract:** In the area of fashion and luxury industry, there is a growing trend in consumer awareness when it comes to leather sustainability. The current chapter aims to understand and discuss for major leather users what is considered to be the major criteria for sustainable leather consumption. For example, vegan consumers refrain from buying animal-based leather but might indulge in using PU or PVC leather or other alternatives which could be ranking low in the sustainability criteria. The current chapter uses the primary data with an interview and secondary data from the industry assessments and industry cases which highlights what could be misleading for the buyers and producers. In addition, what are the perspectives of the manufacturers to develop newer sustainable methods of leather production, recycling needs and wastage are also discussed.

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Milián-García, Y., Amato, G., Gatesy, J., Hekkala, E., Rossi, N. and Russello, M. (2020). Phylogenomics reveals novel relationships among Neotropical crocodiles (*Crocodylus* spp.). *Molecular Phylogenetics and Evolution* (<https://doi.org/10.1016/j.ympev.2020.106924>).

**Abstract:** Extant species in the order Crocodylia are remnants of an ancient lineage of large-bodied archosaur reptiles. Despite decades of systematic studies, phylogenetic relationships among members of the genus *Crocodylus* (true crocodiles) in the Neotropics are poorly understood. Here we estimated phylogenomic relationships among the four extant *Crocodylus* species in the Americas. Species-tree reconstructions using genotypic data from 17,538 SNPs collected for 33 individuals spanning six *Crocodylus* species (four ingroup and two outgroup) revealed novel relationships for all Neotropical

species. For the first time, *C. acutus*, the American crocodile, was recovered as monophyletic when individuals from Antillean and continental populations were analyzed together. Our results also contradict previous inferences based on mitochondrial DNA data and a limited number of nuclear markers by robustly grouping Morelet's crocodile (*C. moreletii*) as the sister species to *C. acutus*, suggesting a novel phylogeographic hypothesis for the group. The present study punctuates the importance of using nuclear genome-wide information and representative sampling for resolving phylogenetic relationships, especially in broadly distributed species and those with complex evolutionary histories.

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Augustine, L., Miller, K., Peters, A., Franklin, A.D., Steinbeiser, C.M., Brown, J.L. and Prado, N.A. (2020). Impacts of the season and reproductive status on fecal reproductive and adrenocortical steroid metabolites in zoo Cuban crocodiles (*Crocodylus rhombifer*). *Zoo Biology* (doi: 10.1002/zoo.21559).

**Abstract:** Conservation strategies for crocodilians often include captive breeding to create stable assurance populations. Evaluating adrenal and gonadal hormone patterns can provide animal managers with data to more effectively monitor animal welfare and reproductive status. This study evaluated the effects of season (breeding, nesting, or off), sex (male and female), and reproductive status of females (egg-laying/housed with a male or non-laying/housed solo) on concentrations of fecal glucocorticoid metabolite (FGM), fecal androgen metabolite (FAM), and fecal progesterone metabolite (FPM) in seven Cuban crocodiles, *Crocodylus rhombifer*, at the Smithsonian's National Zoological Park. Overall, seasonal changes in FGM and FPM concentrations were only observed in egg-laying females; FGM and FPM concentrations were both higher during the nesting season compared to the breeding and off seasons. Seasonal changes in FAM concentrations were only observed in males; males had higher FAM concentrations during the breeding and nesting seasons compared to the off season. Future studies investigating the use of fecal hormone metabolites in crocodilians are necessary to understand differences between individuals and species, to further elucidate the interactions between hormones and environmental factors, such as social housing, and to develop long-term datasets for the management of this species.

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Jacobson, E.R. and Garner, M.M. (Eds.) (2020). *Infectious Diseases and Pathology of Reptiles*, Volume 1. CRC Press: Oxon.

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Garner, M.M. and Jacobson, E.R. (Eds.) (2020). *Noninfectious Diseases and Pathology of Reptiles*, Volume 2. CRC Press: Oxon.

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Vashistha, G., Deepika, S., Dhakate, P.M., Khudsar, F.A. and Kothamasi, D. (2020). The effectiveness of microsatellite DNA as a genetic tool in crocodilian conservation. *Conservation Genetics Resources* (<https://doi.org/10.1007/s12686-020-01164-6>).

**Abstract:** Microsatellite DNA is among the several molecular tools used for determining genetic variability and inbreeding depression in threatened populations. It has been used extensively for population genetics studies in conservation of crocodilians. Even though single nucleotide polymorphisms have higher precision compared to microsatellite DNA markers, microsatellites offer a cost advantage which is particularly important to researchers in the global south. Here, we review the role of microsatellite DNA as a conservation tool in crocodilians. Employing appropriate keywords in three online databases, we studied 78 publications, where microsatellite DNA had been used to study crocodilian species. We found that 504 species-specific markers were designed for 13, out of a total of 24 crocodilian taxa. Genus *Crocodylus* had the highest number of species-specific markers and was the most studied taxa using microsatellites. Moreover, microsatellite markers developed for *C. porosus* were successful in cross amplification of

microsatellite markers in 19 other crocodilian species. Microsatellite based studies had highest focus on analyses of multiple populations of a single species. Based on our review of microsatellite based studies on populations of crocodilian species, we recommend that microsatellite DNA markers are an effective conservation tool that can provide critical information on population structures of threatened crocodilian species.

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Kieran, T.J., Goodman, S.J., Finger, Jr., J.W., Thomas 4th, J.C., Hamilton, M.T., Tuberville, T.D. and Glenn, T.C. (2020). Microbiota of four tissue types in American alligators (*Alligator mississippiensis*) following extended dietary selenomethionine exposure. *Bulletin of Environmental Contamination and Toxicology* (doi: 10.1007/s00128-020-02961-3).

**Abstract:** Selenium represents an essential trace nutrient that is necessary for biological functions. Deficiencies can induce disease, but excess can induce toxicity. Selenium deficiency is a major concern in underdeveloped countries, while also posing as a toxic pollutant in waterways surrounding landfills, agricultural areas, and fossil fuel production sites. We examined the microbiome of selenomethionine (SeMet) fed American alligators (*Alligator mississippiensis*) at the beginning and end of a 7-week exposure experiment. Alligators were randomly divided into three groups: control and 1000 or 2000 ppm SeMet. DNA from before exposure (oral and cloaca swabs) and post-exposure (oral, cloaca, small and large intestines) sampling were extracted and amplified for bacterial 16 s rRNA. While treatment did not seem to have much effect, we observed a predominance of Fusobacteriaceae and Porphyromonadaceae across all tissue types. *Cetobacterium* and *Clostridium* are the most abundant genera as potential indicators of the aquatic and carrion feeding lifestyle of alligators.

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Fernandez-Blanco, M.V. and Witmer, L.M. (2020). A clearing-and-staining procedure for the study of the chondrocranium and other aspects of skeletal development in crocodilian embryos. *Vertebrate Zoology* 70(3): 447-454.

**Abstract:** Skull development has been of particular interest to crocodilian researchers, largely because their highly derived skulls have obscured homology of key phylogenetic characters. The chondrocranium has been of particular interest given its role in providing the substrate for endochondral ossification and the scaffold for dermal (intramembranous) ossification. Development of the skeleton in general and chondrocranium in particular has been studied via histology and contrast-enhanced computed microtomography (microCT), but clearing and staining of whole-mount specimens remains a relatively rapid and cost-effective means of generating adequate sample sizes. Historically, there have been many protocols for clearing and staining vertebrate skeletons that produce striking specimens with bluish cartilage and reddish bone within a relatively transparent body. However, application of this technique to crocodilians has been poorly described and standardized. Crocodylia is one of only two extant clades of Archosauria (Aves being the other), and thus the study of the development of the elements of crocodilian skeletons is crucial for evolutionary and paleontological studies. In this contribution, we describe a precise procedure for clearing and staining crocodilian embryos and young post-hatchlings, focusing on three species: *Alligator mississippiensis*, *Caiman latirostris* and *C. yacare*. In brief, the steps include: initial preparation, bleaching, fixation, dehydration, cartilage and bone staining, clearing (with 0.5% KOH/glycerol series and enzymatic treatment), and storage. Using these procedures, we obtained specimens that provided clear discrimination of bony and cartilaginous anatomy, demonstrating the efficacy of this protocol for crocodilians, particularly with regard to elucidating the structure of the chondrocranium, which is illustrated here for three species.

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Yao, L. (2020). The blood expression profile of the Chinese alligator

$\beta$  defensin gene and the effect of stocking density on the expression of defensin. MSc thesis, Zhejiang University, Hanzhou, China.

**Abstract:** *Alligator sinensis* is a peculiar crocodilian in my country. It has been affected by factors such as overhunting and habitat reduction in the past 100 years, and it is still in a critically endangered state. In order to protect the Chinese alligator from extinction, my country began to establish the Chinese alligator reserve and carried out artificial breeding projects in the late 1970s. After 40 years of protection, the captive Chinese alligator population has continued to grow, providing abundant resources for the reconstruction and rejuvenation of the wild Chinese alligator population. For the re-introduction of Chinese alligator, the key to its success is to ensure the adaptation potential of captive individuals to the wild environment. However, studies have found that long-term captive animals have a reduced ability to adapt to the wild environment; and, too high a stocking density will adversely affect animal behavior, physiology and immune function. Therefore, it is necessary to carry out research on the physiology and immunity of the Chinese alligator captive population, which can provide more information for the species protection and reintroduction of Chinese alligator. In this study, the seven-year-old Chinese alligator population in the Changxing Chinese Alligator Reserve in Zhejiang Province was used as the research object, and an important component of the immune system-defensin was studied. First, reverse transcription fluorescence quantitative PCR technology was used to detect the expression of 9  $\beta$ -defensin genes in the blood of 41 7-year-old alligators, and the blood expression profile of  $\beta$ -defensin genes was obtained; then, through the analysis of different feeding densities and The difference in the relative expression of defensin genes between groups of different sexes explored the effect of stocking density on the immune function of Chinese alligators. Finally, in order to explore the regulatory mechanism of defensin genes at the epigenetic level, we chose to choose between different individuals of Chinese alligators. The AsBD8 gene with large expression difference was analyzed for the promoter DNA methylation level. Bisulfite modified sequencing method was used to detect the methylation level of the CpG site in the promoter region of the AsBD8 gene between the two groups of Chinese alligators with relatively high and low expression levels, and further analyzed its correlation with the difference in gene expression Sex. The main research results are as follows: (1) 9 qPCR primers of  $\beta$  defensin genes were successfully screened, and the blood expression profile of the  $\beta$  defensin gene family of *Alligator sinensis* was obtained. (2) The defensin genes expressed in the blood of Chinese alligator population are AsBD5 and AsBD8, and there is a significant positive correlation between the expression of the two genes. (3) Under different stocking densities, there are significant differences in the expression levels between the two Chinese alligators. The population of Chinese alligators with higher stocking density has a higher level of overall defensin expression, indicating that stocking density has a certain effect on the immune status of the Chinese alligator captive population. (4) Different Chinese alligators with large differences in AsBD8 expression levels, There is no significant difference in the methylation level of each CpG site in the promoter region, indicating that the difference in the expression level of AsBD8 between individuals has nothing to do with the regulation of epigenetic gene promoter DNA methylation. This study provides the basis for the subsequent research on the function and expression regulation mechanism of the Chinese alligator  $\beta$ -defensin gene, and provides new clues for the species protection and population management of Chinese alligator.

Tkach, V.V., Achatz, T.J., Pulis, E.E., Junker, K., Snyder, S.D., Bell, J.A., Halajian, A. and De Vasconcelos Melo, F.D. (2020). Phylogeny and systematics of the Proterodiplostomidae Dubois, 1936 (Digenea: Diplostomoidea) reflect the complex evolutionary history of the ancient digenean group. *Systematic Parasitology* (<https://doi.org/10.1007/s11230-020-09928-2>).

**Abstract:** The Proterodiplostomidae Dubois, 1936 is a relatively

small family of diplostomoidean digeneans parasitising the intestines of reptilian hosts associated with freshwater environments in tropical and subtropical regions. The greatest diversity of proterodiplostomids is found in crocodilians, although some parasitise snakes and turtles. According to the most recent revision, the Proterodiplostomidae included 17 genera within 5 subfamilies. Despite the complex taxonomic structure of the family, availability of testable morphology-based phylogenetic hypotheses and ancient hosts, molecular phylogenetic analyses of the group were practically lacking. Herein, we use novel DNA sequence data of the nuclear *lsrRNA* gene and mitochondrial *cox1* gene from a broad range of proterodiplostomid taxa obtained from crocodilian, fish, and snake hosts on four continents to test the monophyly of the family and evaluate the present morphology-based classification system of the Proterodiplostomidae in comparison with the molecular phylogeny. This first detailed phylogeny for the Proterodiplostomidae challenges the current systematic framework. Combination of molecular phylogenetic data with examination of freshly collected quality specimens and re-evaluation of morphological criteria resulted in a number of systematic and nomenclatural changes along with a new phylogeny-based classification of the Proterodiplostomidae. As the result of our molecular and morphological analyses: (i) the current subfamily structure of the Proterodiplostomidae is abolished; (ii) three new genera, *Paraproterodiplostomum* n. g., *Neocrocodilicola* n. g. and *Proteroduboisia* n. g., are described and *Pseudoneodiplostomoides* Yamaguti, 1954 is restored and elevated from subgenus to genus level; (iii) two new species, *Paraproterodiplostomum currani* n. g., n. sp. and *Archaeodiplostomum overstreeti* n. sp., are described from the American alligator in Mississippi, USA. Comparison of the structure of terminal ducts of the reproductive system in all proterodiplostomid genera did not support the use of these structures for differentiation among subfamilies (or major clades) within the family, although they proved to be useful for distinguishing among genera and species. Our study includes the first report of proterodiplostomids from Australia and the first evidence of a snake acting as a paratenic host for a proterodiplostomid. A key to proterodiplostomid genera is provided. Questions of proterodiplostomid-host associations parasitic in crocodilians are discussed in connection with their historical biogeography. Our molecular phylogeny of the Proterodiplostomidae closely matches the current molecular phylogeny of crocodilians. Directions for future studies of the Proterodiplostomidae are outlined.

Cornejo-Páramo, P., Lira-Noriega, A., Ramírez-Suástegui, C., Méndez-de-la-Cruz, F.R., Székely, T., Urrutia, A.O. and Cortez, D. (2020). Sex determination systems in reptiles are related to ambient temperature but not to the level of climatic fluctuation. *BMC Evolutionary Biology* 20: 103.

**Abstract:** Vertebrates exhibit diverse sex determination systems and reptiles stand out by having highly variable sex determinations that include temperature-dependent and genotypic sex determination (TSD and GSD, respectively). Theory predicts that populations living in either highly variable or cold climatic conditions should evolve genotypic sex determination to buffer the populations from extreme sex ratios, yet these fundamental predictions have not been tested across a wide range of taxa. Here, we use phylogenetic analyses of 213 reptile species representing 38 families (TSD= 101 species, GSD= 112 species) and climatic data to compare breeding environments between reptiles with GSD versus TSD. We show that GSD and TSD are confronted with the same level of climatic fluctuation during breeding seasons. However, TSD reptiles are significantly associated with warmer climates. We found a strong selection on the breeding season length that minimises exposure to cold and fluctuating climate. Phylogenetic path analyses comparing competing evolutionary hypotheses support that transitions in sex determination systems influenced the ambient temperature at which the species reproduces and nests. In turn, this interaction affects other variables such as the duration of the breeding season and life-history traits. Taken together, our results challenge long-standing hypotheses about the association between sex determination and



climate variability. We also show that ambient temperature is important during breeding seasons and it helps explain the effects of sex determination systems on the geographic distribution of extant reptile species.

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Obadiah, C.O., Bunza, M.D.A., Shehu, K. and Bawa, J.H. (2020). The potential roles of sacred natural site(s) and cultural values of biodiversity conservation in Zuru community of Kebbi State, Nigeria. *Unilag Journal of Medicine, Science and Technology*, 8(1): 218-236.

**Abstract:** Sacred Natural Sites (SNSs) are specific natural areas of the earth, which are believed to have spiritual, religious, cultural or historical significance to people or communities. These sites in recent times are recognized by conservationists as one of the primary networks of biodiversity conservation, because they connect people with nature. Many SNSs exist in Nigeria, but are understudied. Germache is a SNS that is located in Zuru Local Government Area of Kebbi State, Nigeria. This study determined the potential roles of Germache SNS and the cultural values of the community members on biodiversity conservation. An ethnographical research method consisting of a semi-structured questionnaire and Focus Group Discussion was used to assess and document the Indigenous Knowledge on Cultural Values of biodiversity conservation in the community. Responses from key informants who were between ages 25 and 75 years and have spent at least 20 years in the community identified crocodile (*Crocodylus porosus*) as a totem. *Adansonia digitata* and *Vitellaria paradoxa* were regarded as sacred monumental plants. About 87% of the respondents indicated an observed increased in crocodile population and vegetation cover over the years. Therefore, the site has a potential for biodiversity conservation due to restricted human access and taboos associated with any resource extraction. More so, the site is valued as a holy ground for conducting prayers and cultural festivities such as Uhola and Golmo.

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Li, H.L., Liu, X.T., Huang, S.M., Xiong, Y.X., Zhang, Z.R., Zheng, Y.H., Chen, Q.X. and Chen, Q.H. (2020). Repair function of essential oil from *Crocodylus siamensis* (Schneider, 1801) on the burn wound healing via up-regulated growth factor expression and anti-inflammatory effect. *Journal of Ethnopharmacology* (<https://doi.org/10.1016/j.jep.2020.113286>).

**Abstract:** Crocodile oil has been used by traditional physicians around the world to treat wound healing and inflammation. However, the scientific rationale and mechanism behind its use *in vivo* has not been fully researched. We mainly investigated the mechanism during crocodile oil treatment of up-regulated growth factor expression and anti-inflammatory on burn wound healing in rats. The moisture and nitric oxide (NO) levels in the skin of rats were analyzed in the first 14 days after burn and the changes of the structure of the skin tissues in the wound healing were studied by hematoxylin-eosin (H.E.) staining within 21 days after scald. The inflammatory factor on burn wound healing in rats was detected by ELISA kits and Q-PCR. the expression of a variety of growth factors (TGF- $\beta$ 1, VEGE- $\alpha$ , EGF) and PCNA in the skin tissue after burns was evaluated using immunohistochemistry. The down-regulated phosphorylation of p38 MAPK in the wound healing was confirmed by Western-blot analysis. In addition, TEM was used to observe the ultrastructure of scalded skin. This study showed that crocodile oil could significantly reduce the protein and mRNA levels of TNF- $\alpha$ , IL-1 $\beta$  and IL-6. And it was found that the phosphorylation of p38 MAPK was down-regulated in the wound healing ( $p < 0.05$ ). Meanwhile, crocodile oil can promote the expression of a variety of growth factors (TGF- $\beta$ 1, VEGE- $\alpha$ , EGF) and PCNA in the skin tissue after burns, and promote the repair of collagen fibers in the dermis, preventing the production of melanin and maintain the appearance of repaired skin.

Masroua, M., Boutakiout, M., Herrero Gascón, J., Sáinz Ruiz De Zuazo, J.L., Ochoa Martínez, R. and Pérez-Lorente, F. (2020). Footprints of *Batrachopus* isp. from the Imilchil megatracksite. Middle?-Upper Jurassic, central High Atlas (Morocco). *Journal of African Earth Sciences* (<https://doi.org/10.1016/j.jafrearsci.2020.103980>).

**Abstract:** In this work we present the description and analysis of a palaeoichnological site (7.9TAG) that only contains crocodile tracks. The site contains well preserved and abundant crocodilian manus and pes prints; there are no belly and/or tail traces. The crocodile tracks have been mapped and the biomorphic and morphometric characters of the tracks and trackways have been studied. Between the digit traces of the pes prints (not in manus prints) there is a graded depression that indicates the presence of a foot webbing. The number of crocodilian footprints (93) and trackways (8) of the site is sufficient to define, and to support with confidence the data shown in the article. As consequence a crocodiliform ichnogenus, *Batrachopus* has been defined, characterized by the presence of a trace of a probably interdigital membrane in the pes prints, the trace of a bulge on toe V, the lack of tail traces, and the very narrow gauge trackway. A comparative study is done with all the fossil crocodile footprints described so far. The 7.9TAG footprints printed on sediments of Middle?-Upper Jurassic age (Isli Formation) are the first *Batrachopus* *ichnites* described both from this age and in the African continent.

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Chen, W.M., Xie, Y.R., Sheu, D.S., Tsai, J.M. and Sheu, S.Y. (2020). *Rhodovarius crocodyli* sp. nov., isolated from a crocodile pond. *International Journal of Systematic Evolution and Microbiology* (doi 10.1099/ijsem.0.004396).

**Abstract:** Bacterial strain CCP-6T, isolated from a freshwater pond in Taiwan, was characterized using a polyphasic taxonomy approach. Phylogenetic analyses based on 16S rRNA gene sequences and an up-to-date bacterial core gene set (92 protein clusters) indicated that strain CCP-6T is affiliated with species in the genus *Rhodovarius*. Strain CCP-6T was most closely related to *Rhodovarius lipocyclicus* CCUG 44693T with a 98.9% 16S rRNA gene sequence similarity. Cells were Gram-stain-negative, aerobic, non-motile, rod-shaped and formed light pink-coloured colonies. Optimal growth occurred at 30°C, pH 6 and in the absence of NaCl. The major fatty acids of strain CCP-6<sup>T</sup> were C<sub>18:1</sub>  $\omega$ 7c, C<sub>16:0</sub> and C<sub>19:0</sub> cyclo  $\omega$ 8c. The polar lipid profile consisted of phosphatidylethanolamine, phosphatidylglycerol, phosphatidylcholine, phosphatidylmethylethanolamine, phosphatidylmethylethanolamine, diphosphatidylglycerol, three unidentified aminophospholipids and an unidentified phospholipid. The predominant polyamine was spermidine. The major isoprenoid quinone was Q-10. The DNA G+C content of the genomic DNA was 69.3 mol%. Strain CCP-6<sup>T</sup> showed 85.8% average nucleotide identity and 14.5% digital DNA-DNA hybridization identity with *Rhodovarius lipocyclicus* CCUG 44693<sup>T</sup>. On the basis of the genotypic, chemotaxonomic and phenotypic data, strain CCP-6<sup>T</sup> represents a novel species in the genus *Rhodovarius*, for which the name *Rhodovarius crocodyli* sp. nov. is proposed. The type strain is CCP-6<sup>T</sup> (=BCRC 81095<sup>T</sup>=LMG 30310<sup>T</sup>=KCTC 62188<sup>T</sup>).

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Wintrich, T., Scaal, M., Böhmer, C., Schellhorn, R., Kogan, I., van der Reest, A. and Sander, P.M. (2020). Palaeontological evidence reveals convergent evolution of intervertebral joint types in amniotes. *Scientific Reports* 10(1): 14106.

**Abstract:** The intervertebral disc (IVD) has long been considered unique to mammals. Palaeohistological sampling of 17 mostly extinct clades across the amniote tree revealed preservation of different intervertebral soft tissue types (cartilage, probable notochord) seen in extant reptiles. The distribution of the fossilised tissues allowed us to infer the soft part anatomy of the joint. Surprisingly, we also found evidence for an IVD in fossil reptiles, including non-avian dinosaurs, ichthyosaurs, plesiosaurs, and marine crocodiles.

Based on the fossil dataset, we traced the evolution of the amniote intervertebral joint through ancestral character state reconstruction. The IVD evolved at least twice, in mammals and in extinct diapsid reptiles. From this reptilian IVD, extant reptile groups and some non-avian dinosaurs independently evolved a synovial ball-and-socket joint. The unique birds dorsal intervertebral joint evolved from this dinosaur joint. The tuatara and some geckos reverted to the ancestral persisting notochord.

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Blackburn, D.G., Barnes, M.S., Reimers, C.D., Appiah, F.A., Lestz, L.L., Bonneau, L.J., Hanson, M., Smith-Paredes, D. and Bhullar, B-A. (2020). How do crocodylian embryos process yolk? Morphological evidence from the American alligator, *Alligator mississippiensis*. *Journal of Morphology* (doi: 10.1002/jmor.21252).

**Abstract:** Recent studies have demonstrated a mechanism of embryonic yolk processing in lizards, snakes and turtles that differs markedly from that of birds. In the avian pattern, cells that line the inside of the yolk sac take up products of yolk digestion and deliver nutrients into the vitelline circulation. In contrast, in squamates and turtles, proliferating endodermal cells invade and fill the yolk sac cavity, forming elongated strands of yolk-filled cells that surround small blood vessels. This arrangement provides a means by which yolk material becomes cellularized, digested, and transported for embryonic use. Ultrastructural observations on late-stage *Alligator mississippiensis* eggs reveal elongated, vascular strands of endodermal cells within the yolk sac cavity. The strands of cells are intermixed with free yolk spheres and clumps of yolk-filled endodermal cells, features that reflect early phases in the yolk-processing pattern. These observations indicate that yolk processing in *Alligator* is more like the pattern of other reptiles than that of birds.

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Pujos, F. and Salas-Gismondi, R. (2020). Predation of the giant Miocene caiman *Purussaurus* on a mylodontid ground sloth in the wetlands of proto-Amazonia. *Biology Letters* 16: 20200239.

**Abstract:** Thirteen million years ago in South America, the Pebas Mega-Wetland System sheltered multi-taxon crocodylian assemblages, with the giant caiman *Purussaurus* as the top predator. In these Miocene swamps where reptiles and mammals coexisted, evidence of their agonistic interactions is extremely rare. Here, we report a tibia of the mylodontid sloth *Pseudopreotherium* bearing 46 predation tooth marks. The combination of round and bisected, shallow pits and large punctures that collapsed extensive portions of cortical bone points to a young or sub-adult *Purussaurus* (approx. 4 m in total length) as the perpetrator. Other known crocodylians of the Pebas System were either too small at adulthood or had discordant feeding anatomy to be considered. The pattern of tooth marks suggests that the perpetrator attacked and captured the ground sloth from the lower hind limb, yet an attempt of dismembering cannot be ruled out. This discovery from the Peruvian Amazonia provides an unusual snapshot of the dietary preferences of *Purussaurus* and reveals that prior to reaching its giant size, young individuals might have fed upon terrestrial mammals of about the size of a capybara.

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Viotto, E.V., Navarro, J.L. and Piña, C.I. (2020). Growth curves of wild and reintroduced Broad-snouted caimans (*Caiman latirostris*) and their management implications. *South American Journal of Herpetology* 16: 34-41.

**Abstract:** We describe body growth functions of broad-snouted caimans (*Caiman latirostris*) for wild and reintroduced individuals. Snout-vent length (SVL, cm) and age of young individuals and adult females were recorded for two different groups: (Py) animals born in the Proyecto Yacaré ranching program, from eggs collected in the wild; and (Wy) wild caimans Class I (<25 cm SVL) whose age was determined by Size Frequency Analysis, plus females reintroduced by the Proyecto Yacaré and subsequently recaptured at reproductive

age. To describe body growth, we adjusted five models through non-linear regression: Logistic, 4-Parameter Logistic (4-PL), Gompertz, 4-Parameter Gompertz (4-G), and von Bertalanffy. Each group was analyzed separately (Py and Wy), and we selected the most parsimonious model based on the Akaike criterion. We also analyzed the possible linear growth difference using ANCOVA. For Py, the Logistic model was best, whereas for Wy the most suitable was 4-PL, in which wild animals would arrive at the inflexion point 1.4 years later on average than in Py. Analyzing the stage at which their development was linear in shape, we detected that the wild animals had a similar growth rate to reintroduced individuals. As a result, although Py animals had experienced accelerated development whilst in captivity, it did not modify their subsequent growth in the wild. The likelihood of survival in this species increases with body size, thus it is important to emphasize that reintroduced animals are larger than wild animals of the same age and that previous farming conditions seem not to affect their growth in the wild. Therefore, we expect that reintroduced caimans will exhibit greater survivorship than natural animals of the same age. Consequently, an adjustment of the current ranching program should be considered, in the sense that population viability could be achieved by reintroducing a lower number of caimans each season.

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Porras Murillo, L.P. and Mata Cambronero, E. (2020). Analysis of the interactions between humans and crocodiles in Costa Rica. *South American Journal of Herpetology* 16: 26-33.

**Abstract:** The habitat of crocodiles (*Crocodylus acutus*) and caimans (*Caiman crocodilus*) has been subjected to pressure due to human expansion. Habitat reduction, coupled with the simultaneous growth of the crocodile population, increases the number of interactions between crocodiles and humans. There is currently no official and systematized interactions database, but it is necessary to know the magnitude and nature of the interactions and establish management measures. The objective of the work was to systematize and evaluate the interactions between crocodiles and humans in Costa Rica. Historical information was collected from several sources. A total of 99 records, dated between 1990-2017, were found from press reports and the Integrated System for Processing Environmental Complaints of the Ministry of Environment and Energy (SITADA). The Fire Department recorded 123 events in 2017. All Fire Department records corresponded to encounters or sightings. Of the SITADA incident records, 35.4% were non-fatal, 27.3% were fatal, 21.2% were encounters and sightings, and the remaining 16.1% were miscellaneous situations. Most interactions occurred during the day, a fact potentially explained by human behavior of being in bodies of water or on adjacent shoreline while the sun is out. Most interactions occurred in the Central Pacific, followed by the Caribbean and then the South Pacific. The information available is brief but allows to establish management measures. The country needs to create a national database of interactions and to encourage individuals to report their interactions. Further research should continue to analyze the data for trends with the goal of building recommendations to prevent an increase in negative interactions.

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Marques, T.S., Bassetti, L.A.B., Lara, N.R.F., Portelinha, T.C.G., Piña, C.I. and Verdade, L.M. (2020). Home range and movement pattern of the Broad-snouted caiman (*Caiman latirostris*) in a silviculture dominated landscape. *South American Journal of Herpetology* 16: 16-25.

**Abstract:** Information on the home range and movement patterns of Neotropical crocodylians is scarce for most species, despite being essential for developing management and conservation plans. The broad-snouted caiman (*Caiman latirostris*) is a Neotropical crocodylian with a wide geographical distribution in South America. This species inhabits artificial reservoirs (eg small weirs) in silvicultural areas. However, its use of space in such circumstances is still unknown. The present study aims to estimate home range and movement patterns of the broad-snouted caiman in a silviculture-

dominated landscape in São Paulo state, southeastern Brazil. Eight adult caimans (four males and four females) were monitored by radiotelemetry (GPS-UHF system) from February 2010 to October 2011. The collected position points were used to estimate home range sizes and movement patterns. Mean home range size ( $\pm$  SD) of all individuals was  $96.6 \pm 183.9$  ha and  $43.2 \pm 78.6$  ha estimated by Minimum Convex Polygon (MPC) and 95% Kernel Density Estimate methods (KDE), respectively, without difference between the sexes. Individual mean daily movement was  $37.6 \pm 18.6$  m/d, being greater during the reproductive period. The surrounding matrix formed by Eucalyptus plantations was relatively permeable to caiman movement. The present results suggest that the wide variation in the home range size of the broad-snouted caiman could be a result of the space-time distribution of resources and social interactions. Further, variations in environment temperature and reproductive activities can influence the movement pattern of the species. Future studies of crocodilians in agricultural landscapes should prioritize other dimensions.

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Khan, W., Hore, U., Mukherjee, S. and Mallapur, G. (2020). Human-crocodile conflict and attitude of local communities toward crocodile conservation in Bhitarkanika Wildlife Sanctuary, Odisha, India. *Marine Policy* (<https://doi.org/10.1016/j.marpol.2020.104135>).

**Abstract:** Where conservation programs aimed at rebuilding depleted populations of saltwater crocodiles (*Crocodylus porosus*) have been successful, incentives for local people to support ongoing conservation action have been undermined by increasing rates of human-crocodile conflict (HCC), involving fatal and non-fatal attacks on people and livestock. In this study we report on HCC within the 672 km<sup>2</sup> Bhitarkanika Wildlife Sanctuary (BWS), Odisha, India. Forest Department contain records of 51 attacks on people and 57 on cattle over 21 years (1996-2016). Human attacks were both fatal (45%) and non-fatal (55%), and were highest in the monsoon season (63%) and summer (23%) and lowest in the post-monsoon (10%) and winter (4%). The activities of people attacked were: domestic chores and crossing rivers (32%), defecating (24%), Bathing (22%), fishing (10%), paddy cultivation (8%) and grazing cattle (4%). Attacks on males (70%) were more common than on females (30%). No attacks on young children (0-10 years-of-age) were reported, and the most common age of victims was 40-50 yr (29%) and 20-30 yr (26%). Semi-structured interviews with the main household earning member in villages on the periphery of BWS (n=57), revealed there was no notable influence of age, gender, and education on the perception and attitude of the local community but people who were affected negatively from the conflict tended to be negative toward the conservation of saltwater crocodiles. The findings of this research aim to serve the planning of mitigation strategies for future human-crocodile conflicts in Bhitarkanika Wildlife Sanctuary.

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Adams, A.J (2020). Reassessment of Cenozoic Longirostrine Crocodiles of East Africa. PhD thesis, University of Iowa, Iowa City, Iowa, USA.

**Abstract:** Phylogenetic analyses made using molecular and morphological datasets yield conflicting results for placement of the modern Indian gharial (*Gavialis gangeticus*) and false gharial (*Tomistoma schlegelii*) among other crocodylians. Morphological analyses indicate they are distantly related, last shared a common ancestor more than 80 million years ago and are similar because of evolutionary convergence. Molecular analyses instead support a close relationship and a divergence within the past 40 million years, with similarities resulting from common ancestry. Both arguments are well supported, with consistent, robust topologies resulting from separate morphology-, molecular-based, and combined analyses. The continued disagreement between methods limits our ability to use Crocodylia as a model clade for the integration of the earth and life sciences. Numerous undescribed Neogene slender snouted crocodylians from Kenya and Uganda reveal a substantial

diversity of gharials in the region until the Pliocene. They preserve derived characters unique to both lineages; the basioccipital is anteroposteriorly broad, and there is a long, broad descending ramus of the exoccipital along the basioccipital tuber, and the orbits are broadly upturned in a manner reminiscent of true gharials, but cranial sutural patterns are more similar to those of tomistomines. Present phylogenetic analyses draw some of these close to *Gavialis* and others close to *Tomistoma*, but this may reflect incompleteness in some forms and insufficient character sampling. Ontogeny may also be a confounding factor in assessing modern relationships. Preliminary results indicate similar morphology between juvenile *Tomistoma* and adult *Gavialis*, suggesting paedomorphosis may be inaccurately drawing gavials towards the more basal thoracosaurids. Inclusion of the novel African taxa when thoracosaurids are excluded from morphological phylogenetic analysis supports the monophyletic Gavialidae found by molecular methods. The persistence of the morphological topology when all taxa are included indicates additional sampling of both taxa and morphological characters is needed to resolve the obscured relationships of the modern gharials.

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Boucher, M., Tellez, M. and Anderson, J.T. (2020). Differences in distress: Variance and production of American crocodile (*Crocodylus acutus*) distress calls in Belize. *Ecology and Evolution* (doi: 10.1002/ece3.6556).

**Abstract:** Acoustic communication of American Crocodiles (*Crocodylus acutus*) is relatively understudied. Our overall aim was to determine the acoustic structure of wild American Crocodile distress calls, distinguish call differences among size classes (hatchling, juvenile, sub-adult, and adult), and investigate call production on a gradient of human disturbance. American Crocodile distress calls have strong frequency modulation and are comprised of multiple harmonics in a downsweeping pattern. Measured parameters (total duration, first quartile duration, maximal frequency, first quartile frequency, end frequency, slope of first quartile, slope of last quartiles) differed significantly among size classes ( $p < .05$ ). Hatchling distress calls are higher in frequency and strongly modulated, whereas calls produced by sub-adults and adults showed little modulation, are lower in frequency, and have greater overall duration. Proportion of crocodiles that produced distress calls during capture differed by size class and sampling location, particularly adult distress calls which are reported here to be produced with undocumented frequency. We determined that American Crocodiles of all size classes produce distress calls at varying rates among study sites. Our results demonstrate that American crocodiles produce distress call more frequently at sites with higher anthropogenic activity. Measured call parameters of juveniles and hatchling American crocodiles also varied among sites in relation to human disturbance. Calls recorded at sites of high anthropogenic impact have increased duration and less modulation which may adversely affect response to emitted distress calls. Proportional and call parameter variances suggest anthropogenic activity as a driver for increased call production and alteration of call parameters at high human-impacted sites.

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Platt, S.G., Elsey, R.M., Bishop, N.D., Rainwater, T.R., Thongsavath, O., Labarre, D. and McWilliam, A.G.K. (2020). Using scat to estimate body size in crocodilians: Case studies of the Siamese crocodile and American alligator with practical applications. *Herpetological Conservation and Biology* 15(2): 325-334.

**Abstract:** Models relating morphological measures to body size are of great value in crocodilian research and management. Although scat morphometrics are widely used for estimating the body size of large mammals, these relationships have not been determined for any crocodilian. To this end, we collected scats from Siamese Crocodiles (*Crocodylus siamensis*) and American Alligators (*Alligator mississippiensis*) to determine if maximum scat diameter (MSD) could be used to predict total length (TL) in these species. We obtained scats from 19 and 22 *C. siamensis* and *A. mississippiensis*,



respectively, and evaluated the relationship between MSD and TL using logarithmic regression models. We found significant positive relationships between MSD and TL for both species. We attribute this relationship to anatomical constraints imposed on MSD by pelvic aperture width, which in turn correlates to body size. We found the MSD-TL relationship is similar for *C. siamensis* and *A. mississippiensis*. Our models can be used to increase precision of body size estimates in scat-based population surveys and dietary studies, and estimate the body size of nesting females.

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Ciocan, H., Leiva, P.M.L. and Simoncini, M.S. (2020). Sexual identification of *Caiman latirostris* hatchlings by cloacal inspection. *South American Journal of Herpetology* 16: 50-55.

**Abstract:** Sexual identification of crocodilians is important in population studies and provides useful information for conservation and management plans and monitoring populations over time. It is possible to distinguish between male and female *Caiman latirostris* by cloacal palpation or eversion of the penis in individuals larger than 75 cm total length, but smaller animals possess a barely differentiable cliteropenis. In hatchlings, sex determination methods involve surgical examination, necropsy, or analysis of cranial dimorphism, which cannot be applied in the field. We classified hatchlings of *C. latirostris* by observing the color and shape of their genitals. The penis is a milky white organ with a rounded shape at the tip and a purple hue at the end, whereas the clitoris is shorter, whitish, and has a pointed end. The procedure was tested on hatchlings from three nests at the “Proyecto Yacaré” study area (Santa Fe province); half of the eggs of each nest were incubated at a constant temperature of 31°C (producing females) and the other half at 33°C (producing males). To observe the sexual organs by cloacal inspection, we used a modified instrument whose function during palpation is like that of a finger applied in large animals to evert the penis or clitoris. In the first days after hatching we correctly scored the sex of 80% of the individuals. The number of correct identifications was slightly lower for males than for females. This technique might be a useful tool for field studies, as it allows the sex of small caimans to be estimated *in situ*.

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Mora-Rivera, C., Suarez-Páez, F., Pacheco-Sierra, G., Vargas-Cuevas, L. and Padilla-Barreto, M. (2020). Tick infection of *Caiman crocodilus fuscus* at the Hidroprado Hydroelectric Dam in Colombia: New records, parasite prevalence, and blood loss rate. *South American Journal of Herpetology* 16: 42-49.

**Abstract:** The main goal of this research was to identify the hard ticks (Acari: Ixodidae) found in 10 individuals of spectacled caiman (*Caiman crocodilus fuscus*) from 349 individuals captured at the Hidroprado hydroelectric dam in the Department of Tolima, Colombia. Parasite prevalence was 2.9%. A total of 40 ticks were collected and two species identified: *Amblyomma dissimile* (n= 39) and *Rhipicephalus sanguineus* (n= 1). This is the second record of *A. dissimile* in *C. crocodilus* in Colombia and the first record of *R. sanguineus* in crocodilians. The natural infection of *C. c. fuscus* by *A. dissimile* establishes this species as a host in the life cycle of this tick. Similarly, parasitism by *R. sanguineus* indicates *C. c. fuscus* as a potential host for this tick, which is important since it is associated with domestic animals and has a high potential for transmission of zoonotic diseases. Our results highlight the parasitic relationship between ticks and one of the most resistant wild vertebrates: caimans. The prevalence, although not high, establishes the potential of ticks to parasitize different species and to be a vector of diseases for new groups of hosts.

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Parra-Torres, F., Moreno-Arias, R.A. and Montenegro, O.L. (2020). Evaluation of crocodilian populations along the Bita River (Vichada, Colombia). *Herpetological Conservation and Biology* 15(2): 416-426.

**Abstract:** We studied spatial and temporal variation of presence, abundance and population structure of crocodilian species along Bita River in Colombia and evaluated the conservation status of the Orinoco Crocodile (*Crocodylus intermedius*) along this river. We conducted night counts along 8 transects of the river in three seasons, and we observed two species, the Spectacled Caiman (*Caiman crocodilus*) and Dwarf Caiman (*Paleosuchus palpebrosus*). In spite of intense searching, we did not find *C. intermedius* in the area, suggesting that the species is either at a very low density or has become locally extinct in this river. We counted a maximum of 626 individuals, 548 of which we identified as *C. crocodilus*, 25 as *P. palpebrosus*, and 53 we could not identify to species. We estimated mean encounter rate as 3.1 individuals/km for *C. crocodilus* and 0.5 individuals/km for *P. palpebrosus*. Sightings of *C. crocodilus* were not distributed homogeneously among seasons, nor along the river. In contrast, sightings of *P. palpebrosus* did not vary among seasons. Population structure of *C. crocodilus* varied between dry and early rainy seasons, with classes I ( $\leq 50$  cm total length) and II (50.1-120 cm total length) being less frequently seen during the dry season. In general, crocodiles in classes I and II were the most abundant of the size classes during all sampling seasons. The population structure of *P. palpebrosus* was skewed toward adults over 80 cm total length.

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Bianchi, C., Adami, C., Dirrig, H., Cuff, A., d'Ovidio, D. and Monticelli, P. (2020). Mandibular nerve block in juvenile Nile crocodile: A cadaveric study. *Veterinary Anaesthesia and Analgesia* (<https://doi.org/10.1016/j.vaa.2020.04.016>).

**Abstract:** To develop a technique for performing the mandibular nerve block in Nile crocodiles, using a group of 16 juvenile Nile crocodile heads. To study the course of the mandibular nerve, one head was dissected. Computed tomography (CT) examination was performed in two heads to identify useful landmarks. Thereafter, a hypodermic needle was inserted through the external mandibular fenestra of 17 hemimandibles (13 heads) and a mixture of methylene blue and iohexol was injected. Injection volumes were 0.5 (n= 7) and 1.0 mL (n= 10) for hemimandibles  $<15$  and  $\geq 15$  cm long, respectively. Iohexol spread and nerve staining with methylene blue were assessed with CT and anatomical dissection, respectively. Data were analysed with either one sample t-test or Mann-Whitney Rank Sum test  $p < 0.05$ . Both anatomical dissection and imaging confirmed the external mandibular fenestra as a useful anatomical landmark for needle insertion. The CT images acquired after needle positioning confirmed that its tip was located on the medial bony mandibular surface formed by the fusion of the angular and coronoid bone in 100% of the cases. In all the hemimandibles, the rostro-caudal spread of contrast was greater than 23 mm. The length of the stained mandibular nerve in the temporal region and of the stained medial branch of the mandibular nerve, as well as the dorso-ventral and medio-lateral spread of iohexol, was greater in group 1.0 than in group 0.5 ( $p < 0.001$ ). The caudal spread of iohexol was greater in group 1.0 than in group 0.5 ( $p = 0.01$ ). The technique developed in this study is feasible. Both injection volumes resulted in staining of the mandibular nerve. The spread of contrast in the anatomical region of interest may result in successful sensory block.

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Musiwa, A.R. and Mhlanga, W. (2020). Human-wildlife conflict in Mhokwe Ward, Mbire District, North-East Zimbabwe. *African Journal of Ecology* (<https://doi.org/10.1111/aje.12774>).

**Abstract:** This research investigates the economic and social aspects of human-wildlife conflict (HWC) in Mhokwe, Mbire district, Zimbabwe. Data were collected through key informant interviews and a questionnaire survey. Most households in Mhokwe rely on crop and livestock production, and hence, HWC is an important factor affecting livelihoods. More than 60% of respondents experienced problems with lions (*Panthera leo* Linnaeus), spotted hyaenas (*Crocuta crocuta* Erxleben), armoured bush crickets (*Acanthopplus speiseri* Brancsik) and quelea birds (*Quelea quelea* Reichenbach). Other problem animals included elephant (*Loxodonta africana*

Blumenbach), vervet monkey (*Chlorocebus pygerythrus* Cuvier), kudu (*Tragelaphus strepsiceros* Pallas), chacma baboon (*Papio ursinus* Kerr), bushpig (*Potamochoerus porcus* Linnaeus) and common duiker (*Sylvicapra grimmia* Linnaeus). Few incidences of conflicts were reported for hippopotamus (*Hippopotamus amphibius* Linnaeus), side-striped jackal (*Canis adustus* Sundevall), porcupine (*Hystrix africaeaustralis* Peters), Nile crocodile (*Crocodylus niloticus* Laurenti), African wild cat (*Felis lybica* Forster), African python (*Python sebae* Gmelin) and guinea fowl (*Numida meleagris* Linnaeus). Livestock and crop losses were \$US45,285 and \$US57,541 in 2013 and 2014, respectively. Despite the losses, most respondents had positive attitudes towards wildlife. Construction of strong kraals and implementation of integrated pest management (IPM) can contribute to conflict reduction.

Cossette, A.P., Adams, A.J., Drumheller, S.K., Nestler, J.H., Benefit, B.R., McCrossin, M.L., Manthi, F.K., Juma, R.N. and Brochu, C.A. (2020). A new crocodylid from the middle Miocene of Kenya and the timing of crocodylian faunal change in the late Cenozoic of Africa. *Journal of Paleontology* (<https://doi.org/10.1017/jpa.2020.60>).

**Abstract:** *Brochuchus* is a small crocodylid originally based on specimens from the early Miocene of Rusinga Island, Lake Victoria, Kenya. Here, we report occurrences of *Brochuchus* from several early and middle Miocene sites. Some are from the Lake Victoria region, and others are in the Lake Turkana Basin. Specimens from the middle Miocene Maboko locality form the basis of a new species, *Brochuchus parvidens*, which has comparatively smaller maxillary alveoli. Because of the smaller alveoli, the teeth appear to be more widely spaced in the new species. We also provide a revised diagnosis for *Brochuchus* and its type species, *B. pigotti*. A phylogenetic analysis supports a close relationship between *Brochuchus* and tube-snouted *Euthecodon*, but although relationships among crocodylids appear poorly resolved in the set of optimal trees, this is because *Brochuchus* and *Euthecodon*, along with early Miocene “*Crocodylus*” *gariensis* from the early Miocene of Namibia, jointly adopt two distinct positions - either closely related to the living sharp-nosed crocodile (*Mecistops*) or to a group including the living dwarf crocodiles (*Osteolaemus*). Character support for a close relationship with *Mecistops* is problematic, and we suspect a closer relationship to *Osteolaemus* will be recovered with improved sampling, but the results here are ambiguous. In either case, *Brochuchus* is more closely related to living groups not currently found in East Africa. This material helps constrain the timing of crocodylian faunal turnover in the East African Rift Valley System, with endemic lineages largely being replaced by *Crocodylus* in the middle or late Miocene possibly in response to regional xerification and the replacement of continuous rainforest cover with open grasslands and savannas.

Philip, A.R. (2020). The taxonomy of living organisms using self-organizing map. *American Journal of Artificial Intelligence* 4(2): 50-61.

**Abstract:** The Self Organizing Map (SOM) is an unsupervised network algorithm that projects high dimensional data into low dimensional maps. The projection preserves the topology of the data so that similar data items are mapped to nearby locations on the map. The algorithm has been so popular because of its application in Computer Science and other areas; it has been applied in speech recognition, pattern identification, control engineering, earthquake detection et al. This research aimed to apply the SOM in the taxonomy of living organisms using 46 attributes. 68 animals from 6 phyla were considered and 46 attributes were used detailing their physical features, physiological features, evolution, adaptation, habitat et al. The features extracted were converted to 0s and 1s for the SOM algorithm to process. The result shows 96.569% accuracy of the SOM's classification but better accuracy can be obtained if the SOM had processed the data for about 1000 iterations. This research revealed that SOM is a veritable tool or algorithm that can be used

to classify living organisms. This research will help taxonomists, biologists and students who spend much time in classifying living organism and it will be of help to researchers who want to explore the SOM algorithm as a solution to taxonomy of living organisms. The SOM will ease taxonomy and will help to minimize the stress and time involved in classifying thousands of living organisms.

Whitaker, N. and Srinivasan, M. (2020). Human crocodile conflict on the Cauvery River delta region, Tamil Nadu, south India. *International Journal of Fisheries and Aquatic Studies* 8(5).

**Abstract:** Conflict between humans and crocodiles on the Cauvery River delta region is discussed. Four instances of situations were recorded, namely attacks on people (fatal and non-fatal), the capture of crocodiles from nearby inhabited areas, translocation of crocodiles to other areas of the river, and crocodiles entering human habitation. Distances between translocation sites and non fatal attacks averaged 10.12 km, whilst distance between fatal attacks averaged 58.73 km.

Elsay, R.M. (2020). Alligators: The Illustrated Guide to Their Biology, Behavior, and Conservation (review). *Herpetological Review* 51(3): 640-642.

Hekkala, E.R., Aardema, M.L., Narechania, A., Amato, G., Ikram, S., Shirley, M.H., Vliet, K.A., Cunningham, S.W., Gilbert, M.T.P. and Smith, O. (2020). The secrets of Sobek - A crocodile mummy mitogenome from ancient Egypt. *Journal of Archaeological Science: Reports* 33 (<https://doi.org/10.1016/j.jasrep.2020.102483>).

**Abstract:** Previous investigations of genetic diversity across the distribution of the Nile crocodile (*Crocodylus niloticus*) confirmed the existence of two genetically distinct species of true crocodile (genus *Crocodylus*) in Africa. These taxa correspond roughly to an eastern/southern African species (*C. niloticus*) and a central/western African species (*Crocodylus suchus*). Analysis of historical museum specimens demonstrated that both species existed concurrently in the Sudanese Nile until the early 20th century and genetic analyses of historical museum specimens of mummified crocodile hatchlings from Egyptian tombs located along Egyptian Nile were found to be *C. suchus*. Here we present the first assessment of mitogenomic data from an adult Egyptian crocodile mummy from a center of crocodile worship and identify this specimen as *C. suchus*. Our data suggest that *C. suchus* was selectively chosen for mummification and support an accurate Egyptian cultural taxonomy as described by Herodotus in the fourth century BC and used by Etienne Geoffroy Saint-Hilaire to describe *Crocodylus suchus* in 1807. *Crocodylus suchus* has experienced a range contraction possibly due to climate change and the drying of the Sahara over the recent past. Our data identifying an adult crocodile mummy as *C. suchus* might indicate the historical natural presence of this species in the Egyptian Nile along with *C. niloticus*. Additional samples of crocodiles from both bioarchaeological and paleontological contexts will be required to confirm this.

Haskell, M.G. and Langley, R.L. (2020). Animal-encounter fatalities, United States, 1999-2016: Cause of death and misreporting. *Public Health Reports* (<https://doi.org/10.1177/0033354920953211>).

**Abstract:** Errors and misreporting on death certificates are common, along with potential inaccuracies in cause-of-death coding. We characterized and compared fatalities by animal-encounter mentions reported as underlying cause of death (UCD) with animal-encounter mentions reported as multiple cause of death (MCD) to determine factors associated with misreporting UCD. We analyzed fatality data from 1999-2016 from the Centers for Disease Control and Prevention Wide-ranging Online Data for Epidemiologic Research by UCD and MCD animal-encounter mentions (International Classification of Diseases, 10th Revision codes W53-59, X20-27 and X29, T63.0-

63.6, T63.8-63.9, and T78.2-78.4). We examined differences in reporting by age, sex, race, autopsy (yes, no, unknown), allergic reactions, and toxicities. The number of animal-encounter mentions by UCD was 3638 (202 average per year) and by MCD was 4280 (238 average per year), a difference of 18% ( $n=642$ ; 36 average per year) by MCD analysis. The number of nonvenomous animal-encounter mentions increased 20% (from 2138 UCD to 2567 MCD), and the number of venomous animal-encounter mentions increased 14% (from 1500 UCD to 1713 MCD). Decedents aged  $\geq 65$  had the highest additional number of animal-encounter mentions among all age groups, primarily encounters with other reptiles ( $n=113$ ), other mammals ( $n=71$ ), and dogs ( $n=42$ ). Of 642 MCD additional animal-encounter mentions, heart disease ( $n=211$ , 33%) and infections ( $n=146$ , 23%) represented more than half of the UCD. Of 553 dog-encounter fatalities, 165 (30%) were among children aged  $\leq 4$ . Animal-encounter fatalities, analyzed by UCD alone, may be underreported. An initiating animal injury, complicated by comorbidities and fatality, may obscure the causal chain, resulting in misreporting UCD. Ongoing training for medical certifiers is recommended, highlighting accurate identification of UCD and contributing causes in the causal chain of death.

Cao, R., Somaweera, R., Brittain, K., FitzSimmons, N.N., Georges, A. and Gongora, J. (2020). Genetic structure and diversity of Australian freshwater crocodiles (*Crocodylus johnstoni*) from the Kimberley, Western Australia. Conservation Genetics (<https://doi.org/10.1007/s10592-020-01259-5>).

**Abstract:** The Australian freshwater crocodile (*Crocodylus johnstoni*) is endemic to the northern mainland tropics of Australia and is widespread across the Kimberley region in the northwest Australia. Currently, there is limited understanding of the genetic structure and diversity of these populations, which impacts on our ability to evaluate the conservation status of the species. Population genetic analyses of 173 freshwater crocodiles from the Ord River, Fitzroy River, and Lennard River basins were conducted using single-nucleotide polymorphisms (SNPs). After filtering, 1185 SNPs were retained for downstream population genetic analysis. STRUCTURE and principal component analyses identified three clusters consistent with the three river basins. Population differentiation gave an  $F_{ST}$  of 0.15 between western and eastern Kimberley and the pairwise  $F_{ST}$  range was 0.06-0.18 among the three river basins. Assignment tests identified three migration events between the adjacent Fitzroy River and Lennard River basins, which may be explained by possible overland movement across these river basins. The population structure found here indicates that delimitation of management units should be based on river basins with the proximity of adjacent river basins taken into consideration when gene flow exists. Estimates of effective population size showing a low ratio of effective population size to census size in Lake Argyle may raise the concern of future monitoring in this area. Further population genetic studies across the species' full range are required to better understand the extent of river basins acting as discrete population units, gene flow, population dynamics, and demographic history

Gobbi, M., Corneli, S., D'Avino, N., Manuali, E., Di Paolo, A., Sebastiani, C., Ciullo, M., Tentellini, M., Pacciarini, M.L., Sebastianelli, M., Pavone, S. and Mazzone, P. (2020). Granulomatous pneumonia in a Nile crocodile (*Crocodylus niloticus*) caused by a member of *Mycobacterium chelonae/abscessus* group. Preprints (doi: 10.20944/preprints202009.0309.v1).

**Abstract:** A 40-year-old male Nile crocodile (*Crocodylus niloticus*) was diagnosed with pulmonary mycobacteriosis caused by a member of *Mycobacterium chelonae/abscessus* group. Post-mortem examination showed a severe systemic visceral granulomatous involvement, with lesions in lungs, heart, liver, spleen and kidneys. Histopathological examination of lung, spleen, heart and liver revealed multifocal to coalescing granulomas showing epithelioid cells in central zone and outer rim of epithelioid histiocytes, multinucleated

giant cells and lymphocytes. The Ziehl-Neelsen histological staining revealed rare vacuoles containing numerous alcohol-acid resistant bacteria. Mycobacterial infection was confirmed by culture and PCR targeting rRNA 16S gene. Sequence analysis of the DNA amplicon revealed a 100% homology with the *M. chelonae/abscessus* group. Even if the classification of the member of this group is still on updating, to the best of our knowledge, this is the first report of *M. chelonae/abscessus* member infection in a Nile crocodile species.

Fauble, K., Adams, J., Gerdes, M., Vansickle, C. and Young, B.A. (2020). Compressive biomechanics of the reptilian intervertebral joint. Journal of Zoological Research 2(4) (<https://doi.org/10.30564/jzr.v2i4.2259>).

**Abstract:** This study compared the pre-sacral intervertebral joints of the American alligator (*Alligator mississippiensis*) with those from specimens of *Varanus*. These two taxa were chosen because they have similar number of pre-sacral vertebrae and similar body weights; however, *Varanus* can move bipedally and has diarthrotic intervertebral joints, whereas *Alligator* has intervertebral discs and cannot move bipedally. This study consisted of three objectives; 1) to document the anatomy of the intervertebral joint, 2) to quantify the compressive biomechanics of the intervertebral joints and explore which features contributed to compression resistance, and 3) to quantify the impact of compression on the intervertebral foramen and spinal nerves in these two taxa. The experimental results revealed that the diarthrotic intervertebral joints of *Varanus* were significantly (4x) stiffer than the intervertebral disc of *Alligator*, and that a significant component of this increased stiffness arose from the facet joints. Compressing the intervertebral joints of the two taxa caused a reduction in foraminal area, but the magnitude of this reduction was not significantly different. We hypothesize that the main factor preventing spinal nerve impingement in *Varanus* during gravitational compression is the relatively small size of the spinal ganglion/nerve relative to the foraminal area.

Humphries, M.S., Myburgh, J.G., Campbell, R., Buah-Kwofie, A. and Combrink, X. (2020). Organochlorine pesticide bioaccumulation in wild Nile crocodile (*Crocodylus niloticus*) fat tissues: Environmental influences on changing residue levels and contaminant profiles. Science of the Total Environment (doi: 10.1016/j.scitotenv.2020.142068).

**Abstract:** Biologically significant concentrations of organochlorine pesticides (OCPs) continue to be reported in wildlife populations and are of particular concern in species that occupy the highest trophic levels. Nile crocodiles (*Crocodylus niloticus*) are important apex predators occurring throughout much of tropical and subtropical sub-Saharan Africa, where they inhabit estuarine and freshwater habitats often impacted by contamination. In this study we examined pesticide residue accumulation in fat tissue from Nile crocodiles at Lake St Lucia, South Africa, where historically large quantities of OCPs have been used for agriculture and disease control. During 2019, we collected tail fat samples from wild ( $n=21$ ) and captive ( $n=3$ ) individuals to examine the influence of habitat, body size and sex on variations in bioaccumulation. The principal contaminant found was p,p'-DDE, a major persistent metabolite of DDT, which continues to be used in the region for combating malaria. Tissue p,p'-DDE concentrations in wild crocodiles (95-1200 ng g<sup>-1</sup> ww) were significantly ( $p<0.05$ ) higher compared to captive individuals (23-68 ng g<sup>-1</sup> ww) and strongly correlated ( $R^2>0.70$ ) to body length. Male ( $n=14$ ) and female ( $n=7$ ) wild crocodiles exhibited similar contaminant body burdens, however, total concentrations were substantially lower than those measured in the same population during 2016/2017. Marked differences in residue levels and profiles appear to reflect changes in food availability and dietary exposure associated with a shift in environmental conditions. These findings suggest that periods of environmental stress may be associated with enhanced toxicological risk in crocodiles. Additional work is needed to better understand contaminant accumulation and elimination



mechanisms in crocodiles, and their potential effects on reproductive health.

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Corso, J.D., Bernardi, M., Sun, Y., Song, H., Seyfullah, L.J., Preto, N., Gianolla, P., Ruffell, A., Kustatscher, E., Roghi, G., Merico, A., Hohn, S., Schmidt, A.R., Marzoli, A., Newton, R.J., Wignall, P.B. and Benton, M.J. (2020). Extinction and dawn of the modern world in the Carnian (Late Triassic). *Sci Adv* 6(38):eaba0099.

**Abstract:** The Carnian Pluvial Episode (Late Triassic) was a time of global environmental changes and possibly substantial coeval volcanism. The extent of the biological turnover in marine and terrestrial ecosystems is not well understood. Here, we present a meta-analysis of fossil data that suggests a substantial reduction in generic and species richness and the disappearance of 33% of marine genera. This crisis triggered major radiations. In the sea, the rise of the first scleractinian reefs and rock-forming calcareous nannofossils points to substantial changes in ocean chemistry. On land, there were major diversifications and originations of conifers, insects, dinosaurs, crocodiles, lizards, turtles, and mammals. Although there is uncertainty on the precise age of some of the recorded biological changes, these observations indicate that the Carnian Pluvial Episode was linked to a major extinction event and might have been the trigger of the spectacular radiation of many key groups that dominate modern ecosystems.

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Tkach, V.V., Achatz, T.J., Pulis, E.E., Junker, K., Snyder, S.D., Bell, J.A., Halajian, A. and de Vasconcelos Melo, F.T. (2020). Phylogeny and systematics of the Proterodiplostomidae Dubois, 1936 (Digenea: Diplostomoidea) reflect the complex evolutionary history of the ancient digenean group. *Systematic Parasitology* 97(5): 409-439.

**Abstract:** The Proterodiplostomidae Dubois, 1936 is a relatively small family of diplostomoidean digeneans parasitising the intestines of reptilian hosts associated with freshwater environments in tropical and subtropical regions. The greatest diversity of proterodiplostomids is found in crocodilians, although some parasitise snakes and turtles. According to the most recent revision, the Proterodiplostomidae included 17 genera within 5 subfamilies. Despite the complex taxonomic structure of the family, availability of testable morphology-based phylogenetic hypotheses and ancient hosts, molecular phylogenetic analyses of the group were practically lacking. Herein, we use novel DNA sequence data of the nuclear 18S rRNA gene and mitochondrial *cox1* gene from a broad range of proterodiplostomid taxa obtained from crocodilian, fish, and snake hosts on four continents to test the monophyly of the family and evaluate the present morphology-based classification system of the Proterodiplostomidae in comparison with the molecular phylogeny. This first detailed phylogeny for the Proterodiplostomidae challenges the current systematic framework. Combination of molecular phylogenetic data with examination of freshly collected quality specimens and re-evaluation of morphological criteria resulted in a number of systematic and nomenclatural changes along with a new phylogeny-based classification of the Proterodiplostomidae. As the result of our molecular and morphological analyses: (i) the current subfamily structure of the Proterodiplostomidae is abolished; (ii) three new genera, *Paraproterodiplostomum* n. g., *Neocrocodylicola* n. g. and *Proteroduboisia* n. g., are described and *Pseudoneodiplostomoides* Yamaguti, 1954 is restored and elevated from subgenus to genus level; (iii) two new species, *Paraproterodiplostomum currani* n. g., n. sp. and *Archaeodiplostomum overstreeti* n. sp., are described from the American alligator in Mississippi, USA. Comparison of the structure of terminal ducts of the reproductive system in all proterodiplostomid genera did not support the use of these structures for differentiation among subfamilies (or major clades) within the family, although they proved to be useful for distinguishing among genera and species. Our study includes the first report of proterodiplostomids from Australia and the first evidence of a snake acting as a paratenic host for a proterodiplostomid.

A key to proterodiplostomid genera is provided. Questions of proterodiplostomid-host associations parasitic in crocodilians are discussed in connection with their historical biogeography. Our molecular phylogeny of the Proterodiplostomidae closely matches the current molecular phylogeny of crocodilians. Directions for future studies of the Proterodiplostomidae are outlined.

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Platt, S.G., Thongsavath, O., Hallam, C.D. and Rainwater, T.R. (2020). *Crocodylus siamensis* (Siamese Crocodile). Nesting and nest attendance. *Herpetological Review* 51(3): 589-590.

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Boylan, S., Parrott, B.B., Lowers, R.H., Platt, S.G., Mazzotti, F.J. and Rainwater, T.R. (2020). *Crocodylus moreletii* (Morelet's Crocodile). Adult mortality. *Herpetological Review* 51(3): 587-588.

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Charruau, P., Flores-Escalona, C.I., Morales Garduza, M.A. and Barba-Macias, E. (2020). First record of the freshwater limpet *Hebetancylus excentricus* (Morelet, 1851) as epibiont of *Crocodylus moreletii* (Duméril and Bibron, 1851) in southern Mexico (Crocodylia: Crocodylidae). *Herpetological Notes* 13: 627-629.

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Charruau, P., Ocegüera-Figueroa, A., Cedeño-Vázquez and Pérez-Rivera, S.D. (2020). Record of *Haementeria acuecuyetzin* (Ocegüera-Figueroa, 2008) in Morelet's crocodiles from Quintana Roo, Mexico. *Comp. Parasitol.* 87(1): 89-92.

**Abstract:** Herein, we present the first Mexican record of Morelet's crocodile, *Crocodylus moreletii*, as a host for the proboscis-bearing leech, *Haementeria acuecuyetzin*. From November 2004 to October 2017, we captured 111 crocodiles during spotlight surveys in lagoons of the Dziuché ejido, municipality of José María Morelos, Quintana Roo, Mexico. Twenty-one (18.9%) individuals had leeches identified as *H. acuecuyetzin*. It is the first report of *H. acuecuyetzin* for the State of Quintana Roo, Mexico, and the northernmost record of the species. This is also the second case of leech parasitism in *C. moreletii*. *Haementeria acuecuyetzin* likely parasitize a large array of vertebrates, and its role as a potential vector of blood parasites in *C. moreletii* requires further investigation.

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Soria-Ortiz, G.J., Charruau, P. and Reynoso, V.H. (2020). Variation in diet of hatchlings, juveniles and sub-adults of *Caiman crocodilus chiapasius* in La Encrucijada, Chiapas, Mexico. *Revista Mexicana de Biodiversidad* 91: e912852.

**Abstract:** Little is known about the diet of the Chiapas spectacled caiman, *Caiman crocodilus chiapasius* (Bocourt, 1876), in the southern coast of Mexico. Herein, we analyzed the stomach content of 44 caimans divided into 3 size classes in La Encrucijada, Chiapas, Mexico. Within the contents we identified insects, crustaceans, arachnids, fishes, and birds. Hatchlings fed mainly on insects and arachnids, juveniles on crustaceans and insects and sub-adults on crustaceans and fish. Our data show that while the invertebrate intake decreased along different size classes, vertebrates intake increased, and that diet overlapped greater in adjacent size classes. No differences were found in niche breadth ( $p > 0.05$ ), diet composition ( $Q = 2.0$ ,  $p = 0.3678$ ) and prey abundance ( $X^2 = 1.9756$ ,  $p = 0.3759$ ) among size classes. *Caiman crocodilus chiapasius* is protected by the Mexican law in the category of "special protection".

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Gerber, R., Bouwman, H., Govender, D., Ishizuka, M., Ikenaka, Y., Yohannes, Y.B., Smit, N.J. and Wepener, V. (2020). Levels of DDTs and other organochlorine pesticides in healthy wild Nile crocodiles (*Crocodylus niloticus*) from a flagship conservation area. *Chemosphere* (<https://doi.org/10.1016/j.chemosphere.2020.128368>).

**Abstract:** Mass Nile crocodile (*Crocodylus niloticus*) deaths in Africa's premier conservation area, the Kruger National Park (KNP), prompted numerous studies to determine possible causes of the sudden die-offs. The majority highlighted the involvement of the anthropocene to crocodile mass mortalities. One of the potential causative agents was identified as legacy compounds such as organochlorine pesticides (OCPs) present in the various aquatic ecosystems of the KNP. Thus, this study aimed to quantify OCP levels in wild crocodiles from the aquatic systems associated with the KNP. As part of a larger study, muscle tissue samples were collected from tails of 12 wild crocodiles. Results indicated that eight of the 19 OCPs analyzed for were quantifiable. These included DDTs (2130 - 167,968 ng/g lw), chlordanes (BD - 872 ng/g lw) and cyclodecins (BD - 7583 ng/g lw). Measured concentrations indicated spatial- and sex-related differences in accumulation patterns. DDT and its metabolites, particularly p,p'-DDE accumulated to the highest concentrations of the OCP groups. Levels of the different groups of OCPs were the highest recorded in recent history from any crocodilian tissue. The different measured OCP residues were between 2.5 to 120 times higher than levels reported in literature, depending on the compound. These results are of ecotoxicological significance and have several management implications. In view of individuals being sampled from a conservation area it emphasizes the fact that pollutants know no boundaries and that premier conservation areas such as the world renowned KNP may be some of the most contaminated areas of the world.

Chala, G., Aychiluhim, T.B. and Karthikeyan, M.R. (2020). A systematic study on Nile crocodile (*Crocodylus niloticus*) skins for the preparation of leather products. International Journal of Development Research, 10(8): 39605-39614.

**Abstract:** Leathers made from crocodile skins have very good market value. The beauty, durability, texture, and extraordinary properties of these leathers have fascinated more people. As a result of increased popularity and use, there is a critical need for baseline information so that the industry can effectively market exotic leather products. In Ethiopia, crocodiles are available in good numbers in the rivers, lakes, and in the ranch. Ethiopia is considerably exporting the raw crocodile skins to other countries from Arba Minch Crocodile farm. This is due to lack of awareness and technology among the Ethiopian tanners to convert the unique skin into high-value leather products. Exporting crocodile leather products will add manifold foreign exchange earnings compared to raw skins. Hence, in this research, an attempt was made to investigate the processing technology to convert the Nile crocodile skins into finished leather and leather products by developing suitable process technology. Tanning studies were carried out on raw skins to standardize the process technology for the conversion of the unique skin into the leather using chrome, mimosa, and combination type procedures. The physico-chemical properties of the resulting leathers were analyzed using standard procedures. The combination tanning method shows better shrinkage temperature ( $108.83 \pm 0.73^\circ\text{C}$ ), tensile strength ( $34.42 \pm 0.26 \text{ N/mm}^2$ ), % elongation ( $56.71 \pm 0.17$ ), and tear strength ( $82.39 \pm 0.12 \text{ N/mm}$ ) compared to other tanning methods. This study reveals that chrome, mimosa, and combination (Veg-Al, Al-Veg) tanned leather are all exhibit satisfactory quality and performance. Vegetable and combination tanning methods are environmentally friendly and promising options. So, among the exotic skins, crocodile skins are considered as promising raw materials for making leather on large scale in the Ethiopian scenario.

Rodgers, E.M. and Franklin, C.E. (2020). Aerobic scope and climate warming: Testing the “plastic floors and concrete ceilings” hypothesis in the estuarine crocodile (*Crocodylus porosus*). JEZ-A Ecological and Integrative Physiology (<https://doi.org/10.1002/jez.2412>).

**Abstract:** Ectotherms are predicted to show a reduction in absolute aerobic scope (AAS=maximum–standard metabolic rates) if

habitat temperatures surpass optima. However, thermal phenotypic plasticity may play a protective role in the maintenance of AAS. In fishes, resting physiological rates (“physiological floors,” eg standard metabolic rates [SMR]) are typically thermally phenotypically plastic whilst maximum physiological rates (“physiological ceilings,” eg maximum metabolic rate [MMR]) are typically fixed. This observation led to the “plastic floors and concrete ceilings” hypothesis. The applicability of this hypothesis to nonavian reptiles remains untested, despite this group being at risk of climate warming-induced extinction. We tested this hypothesis in juvenile estuarine crocodiles (*Crocodylus porosus*) by maintaining animals at a water temperature indicative of current summer conditions ( $28^\circ\text{C}$ ) or at a water temperature reflecting a high magnitude of warming ( $34^\circ\text{C}$ ; ie thermal acclimation treatments) for 6 months. Metabolic traits (SMR, MMR, and AAS) were subsequently quantified between  $28$ – $36^\circ\text{C}$ . A twofold increase in SMR was observed between  $28^\circ\text{C}$  and  $36^\circ\text{C}$  in both thermal acclimation treatments (pooled  $Q_{10}=3.2$ ). MMR was thermally insensitive between  $28^\circ\text{C}$  and  $36^\circ\text{C}$  in  $28^\circ\text{C}$ -acclimated crocodiles but doubled between  $28^\circ\text{C}$  and  $36^\circ\text{C}$  in  $34^\circ\text{C}$ -acclimated crocodiles. These findings demonstrate thermal phenotypic plasticity in a “physiological ceiling” (MMR) and rigidity in a “physiological floor” (SMR), showing the opposite pattern to many fishes. Overall, crocodiles displayed impressive aerobic capacity at temperatures reflecting climate warming scenarios. AAS remained unchanged across an  $8^\circ\text{C}$  temperature range in  $28^\circ\text{C}$ -acclimated animals and doubled in  $34^\circ\text{C}$ -acclimated animals.

Chambert, T., Enot, G. and Khanh, P.H. (2019). Monitoring of Siamese crocodiles (*Crocodylus siamensis*) in Bàu Sầu Lake, Vietnam. Cat Tien National Park: Vietnam.

**Abstract:** The Siamese crocodile is a highly threatened species of South-east Asia listed as critically endangered (CR) by the IUCN. During the 1990's, it had totally disappeared in Vietnam, but in the early 2000s a population was reintroduced in the lake of Bàu Sầu, located in the Cat Tien National Park. This population originated from 60 adults that were released between 2000 and 2004. Since this reintroduction, Siamese crocodiles of Bàu Sầu have never been monitored on a regular basis, using a standardized protocol. In spring 2019, 15 years after this reintroduction, we conducted 11 standardized counting surveys on Bàu Sầu lake to obtain updated information on the local abundance of Siamese crocodiles. Counts were performed at night with a flashlight (spotlighting technique), along a 1.5 km transect covering the entire length of the lake. We were able to differentiate adults from juveniles, which provided us with basic but important information on the age structure of the population. The highest count obtained on a single survey event was 286 crocodiles (58 adults and 228 juveniles), but because detectability is imperfect the population is likely larger than that. We found a significant effect of moon phase and wind strength on the detection of crocodiles. Highest counts occurred during the first and last quarters of the moon (intermediate brightness), and at low wind. Without additional information to disentangle detectability and abundance, we cannot estimate absolute population size. To solve this issue, we recommend using a combination of mark-recapture and double-observer approaches.

Gesemann, M. and Neuhauss, S.C.F. (2020). Selective gene loss of visual and olfactory guanylyl cyclase genes following the two rounds of vertebrate specific whole genome duplications. Genome Biology and Evolution (doi: 10.1093/gbe/evaa192).

**Abstract:** Photoreceptors convey visual information and come in two flavours; dim-light and bright-light dedicated rod and cones. Both cell types feature highly specialized phototransduction cascades that convert photonic energy into intracellular signals. While a substantial amount of phototransduction gene ohnologs are expressed either in rods or cones, visual guanylyl cyclases (GCs) involved in the calcium ( $\text{Ca}^{2+}$ ) dependent feedback regulation of phototransduction are neither rod nor cone specific. The co-existence of visual GCs

in both photoreceptor types suggests that specialization of these ohnologs occurred despite their overlapping expression. Here, we analyse gene retention and inactivation patterns of vertebrate visual and closely related olfactory GCs following two rounds (2R) of vertebrate specific whole genome duplication events (2R WGD). While eutherians generally use two visual and one olfactory GCs, independent inactivation occurred in some lineages. Sauropsids (birds, lizards, snakes, turtles and crocodiles) generally have only one visual GC (GC-E). Additionally turtles (testodes) also lost the olfactory GC (GC-D). Pseudogenization in mammals occurred in specific species/families likely according to functional needs (i.e. many species with reduced vision only have GC-E). Likewise, some species not relying on scent marks lack GC-D, the olfactory GC enzyme. Interestingly, in the case of fish, no species can be found with fewer than three (two visual and one olfactory) genes and the teleost specific 3R WGD can increase this number to up to five. This suggests that vision in fish now requires at least two visual GCs.

Seopela, M.P., McCrindle, R.I., Combrinck, S. and Augustyn, W. (2020). Occurrence, distribution, spatio-temporal variability and source identification of n-alkanes and polycyclic aromatic hydrocarbons in water and sediment from Loskop dam, South Africa. *Water Research* (doi: 10.1016/j.watres.2020.116350).

**Abstract:** In this study, the spatial and temporal variations in the levels of C8-C40 n-alkanes and 18 polycyclic aromatic hydrocarbons (PAHs) in water and sediment from Loskop Dam (Mpumalanga Province South Africa), were investigated between 2015 and 2017. In addition, their sources, which have not been well defined, were also studied over the period. This water body is sourced from a historically contaminated water body, the Olifants River, which flows through areas where a range of industrial and agricultural activities take place. Mass crocodile and fish mortalities have been recorded in this aquatic system, and contamination by organic pollutants were highlighted as a contributing factor. The total average n-alkane concentrations in water and sediments ranged from  $0.574 \pm 0.0811$  to  $18.8 \pm 1.39 \mu\text{g/L}$  and  $4760 \pm 243$  to  $30,700 \pm 906 \mu\text{g/kg}$ , respectively. Similarly, PAHs were detected at total average concentrations of between  $0.150 \pm 0.0494$  and  $49.8 \pm 6.86 \mu\text{g/L}$  in water and  $61.6 \pm 5.95$  to  $2618 \pm 300 \mu\text{g/kg}$ . n-Alkane and PAH diagnostic ratios indicated a mixture of sources of these compounds, attributed to terrestrial, submerged and floating plant material, as well as petrogenic and pyrogenic combustion. Inlet, middle and upper segment site clustering was observed with non-metric multidimensional scaling (NMDS) and hierarchical cluster analysis (HCA), mainly driven by the prevalence of PAHs at the inlet sites and n-alkanes in the upper reaches. By using indicator compounds, the sources of contamination could be predicted. The strategy described here can be applied to any water body for continuous long-term monitoring of pollutant levels and to identify sources attributing to water pollution.

Simora, R.M.C., Li, S., Abass, N.Y., Terhune, J.S. and Dunham, R.A. (2020). Cathelicidins enhance protection of channel catfish, *Ictalurus punctatus*, and channel catfish F × blue catfish, *Ictalurus furcatus* M hybrid catfish against *Edwardsiella ictaluri* infection. *Journal of Fish Diseases* (doi: 10.1111/jfd.13257).

**Abstract:** Cathelicidins are a class of antimicrobial peptides (AMPs) known to possess rapid and direct antimicrobial activities against a variety of microorganisms. Recently identified cathelicidins derived from alligator and sea snake were found to be more effective in inhibiting microbial growth than other AMPs previously characterized. The ability of these two cathelicidins along with the peptides, cecropin and pleurocidin, to protect channel catfish (*Ictalurus punctatus*, Rafinesque) and hybrid catfish (*I. punctatus* F × blue catfish, *Ictalurus furcatus*, Valenciennes M) against *Edwardsiella ictaluri*, one of the most prevalent pathogens affecting commercial catfish industry, was investigated. Cathelicidin-injected fish ( $50 \mu\text{g ml}^{-1} \text{ fish}^{-1}$ ) that were simultaneously challenged with

*E. ictaluri* through bath immersion at a concentration of  $\sim 1 \times 10^6$  CFU/ml had increased survival rates compared with other peptide treatments and the infected control. Bacterial numbers were also reduced in the liver and kidney of channel catfish and hybrid catfish in the cathelicidin treatments 24 hr post-infection. After 8 days of challenge, serum was collected to determine immune-related parameters such as bactericidal activity, lysozyme, serum protein, albumin and globulin. These immune-related parameters were significantly elevated in fish injected with the two cathelicidins as compared to other peptide treatments. These results indicate that cathelicidins derived from alligator and sea snake can stimulate immunity and enhance the resistance to *E. ictaluri* infection in channel catfish and hybrid catfish.

Sellés, A.G., Blanco, A., Vila, B., Marmi, J., López-Soriano, F.J., Llácer, S., Frigola, J., Canals, M. and Galobart, A. (2020). A small Cretaceous crocodyliform in a dinosaur nesting ground and the origin of sebecids. *Scientific Reports* 10: 15293.

**Abstract:** Sebecosuchia was a group of highly specialized cursorial crocodyliforms that diversified during the Cretaceous and persist until the end of the Miocene. Their unique combination of cranial and postcranial features indicates that they were active terrestrial predators that occupied the apex of the Late Cretaceous terrestrial ecosystems, even competing with theropod dinosaurs. Here, we report the discovery of the earliest sebecid worldwide, and the first from Eurasia, *Ogresuchus furatus* gen. et sp. nov., based on a semi-articulate specimen located in a titanosaurian sauropod nesting ground. The new taxon challenges current biogeographical models about the early dispersal and radiation of sebecid crocodylomorphs, and suggests an origin of the group much earlier than previously expected. Moreover, the new taxon suggests a potential convergent evolution between lineages geographically isolated. Taphonomic evidences suggest that *Ogresuchus* died almost in the same place where fossilized, in a dinosaur nesting area. Biometric and morphologic observations lead to speculate that *Ogresuchus* could easily predate on sauropod hatchlings.

Balaguera-Reina, S.A., Moncada-Jimenez, J.F., Prada-Quiroga, C.F., Hernandez-Gonzalez, F., Bolaños-Cubillos, N.W., Farfán-Ardila, N., Garcia-Calderón, L.M. and Densmore, III, L.D. (2020). Tracking a voyager: Mitochondrial DNA analyses reveal mainland-to-island dispersal of an American crocodile (*Crocodylus acutus*) across the Caribbean. *Biological Journal of the Linnean Society* (https://doi.org/10.1093/biolinnean/blaa121).

**Abstract:** Conservation efforts have allowed American crocodile (*Crocodylus acutus*) populations to recover to the point that dispersal movements are beginning to be documented. The environmental authority of San Andres Island in Colombia reported, for the first time, the arrival of two *C. acutus* from unknown localities in 2012 and 2018. The former was sacrificed, and the latter was captured and kept in captivity to determining its potential origin. We used wildlife forensics to establish the origin of the animal that arrived in 2018 based on two mitochondrial genes (COI and Cytb). Additionally, five other samples from Tayrona National Natural Park (TNNP), and Salamanca Island Road Park (SIRP) were sequenced for molecular attribution of these populations to the currently described lineages. Phylogenetic and phylogeographic analyses showed that the American crocodile found in San Andrés belongs to a continental evolutionary lineage endemic to Colombia, showing also a strong genetic similarity with animals from SIRP. Thus, the most likely origin for this individual was not the nearest continental area but somewhere around the central Colombian Caribbean, located ~700 km from the island. We discuss the implication of our findings in the systematics and conservation of the species and the potential of mitochondrial DNA analysis to identify such migrants.

Chang, W.S., Li, C.X., Hall, J., Eden, J.S., Hyndman, T.H., Holmes,



E.C. and Rose, K. (2020). Meta-Transcriptomic discovery of a divergent circovirus and a chaphamaparvovirus in captive reptiles with proliferative respiratory syndrome. *Viruses* 12(10) (doi: 10.3390/v12101073).

**Abstract:** Viral pathogens are being increasingly described in association with mass morbidity and mortality events in reptiles. However, our knowledge of reptile viruses remains limited. Herein, we describe the meta-transcriptomic investigation of a mass morbidity and mortality event in a colony of central bearded dragons (*Pogona vitticeps*) in 2014. Severe, extensive proliferation of the respiratory epithelium was consistently found in affected dragons. Similar proliferative lung lesions were identified in bearded dragons from the same colony in 2020 in association with increased intermittent mortality. Total RNA sequencing identified two divergent DNA viruses: a reptile-infecting circovirus, denoted bearded dragon circovirus (BDCV), and the first exogenous reptilian chaphamaparvovirus-bearded dragon chaphamaparvovirus (BDchPV). Phylogenetic analysis revealed that BDCV was most closely related to bat-associated circoviruses, exhibiting 70% amino acid sequence identity in the Replicase (Rep) protein. In contrast, in the nonstructural (NS) protein, the newly discovered BDchPV showed approximately 31%-35% identity to parvoviruses obtained from tilapia fish and crocodiles in China. Subsequent specific PCR assays revealed BDCV and BDchPV in both diseased and apparently normal captive reptiles, although only BDCV was found in those animals with proliferative pulmonary lesions and respiratory disease. This study expands our understanding of viral diversity in captive reptiles.

Lee, H.W., Esteve-Altava, B. and Abzhanov, A. (2020). Evolutionary and ontogenetic changes of the anatomical organization and modularity in the skull of archosaurs. *Scientific Reports* 10(1) (doi: 10.1038/s41598-020-73083-3).

**Abstract:** Comparative anatomy studies of the skull of archosaurs provide insights on the mechanisms of evolution for the morphologically and functionally diverse species of crocodiles and birds. One of the key attributes of skull evolution is the anatomical changes associated with the physical arrangement of cranial bones. Here, we compare the changes in anatomical organization and modularity of the skull of extinct and extant archosaurs using an Anatomical Network Analysis approach. We show that the number of bones, their topological arrangement, and modular organization can discriminate birds from non-avian dinosaurs, and crurotarsans. We could also discriminate extant taxa from extinct species when adult birds were included. By comparing within the same framework, juveniles and adults for crown birds and alligator (*Alligator mississippiensis*), we find that adult and juvenile alligator skulls are topologically similar, whereas juvenile bird skulls have a morphological complexity and anisomerism more similar to those of non-avian dinosaurs and crurotarsans than of their own adult forms. Clade-specific ontogenetic differences in skull organization, such as extensive postnatal fusion of cranial bones in crown birds, can explain this pattern. The fact that juvenile and adult skulls in birds do share a similar anatomical integration suggests the presence of a specific constraint to their ontogenetic growth.

Kosch, J.C.D. and Zanno, L.E. (2020). Sampling impacts the assessment of tooth growth and replacement rates in archosaurs: Implications for paleontological studies. *PeerJ* 8: e9918.

**Abstract:** Dietary habits in extinct species cannot be directly observed; thus, in the absence of extraordinary evidence, they must be reconstructed with a combination of morphological proxies. Such proxies often include information on dental organization and function such as tooth formation time and tooth replacement rate. In extinct organisms, tooth formation times and tooth replacement rate are calculated, in part via extrapolation of the space between incremental lines in dental tissues representing daily growth (von

Ebner Line Increment Width; VEIW). However, to date, little work has been conducted testing assumptions about the primary data underpinning these calculations, specifically, the potential impact of differential sampling and data extrapolation protocols. To address this, we tested a variety of intradental, intramandibular, and ontogenetic sampling effects on calculations of mean VEIW, tooth formation times, and replacement rates using histological sections and CT reconstructions of a growth series of three specimens of the extant archosaurian *Alligator mississippiensis*. We find transect position within the tooth and transect orientation with respect to von Ebner lines to have the greatest impact on calculations of mean VEIW—a maximum number of VEIW measurements should be made as near to the central axis (CA) as possible. Measuring in regions away from the central axis can reduce mean VEIW by up to 36%, causing inflated calculations of tooth formation time. We find little demonstrable impact to calculations of mean VEIW from the practice of subsampling along a transect, or from using mean VEIW derived from one portion of the dentition to extrapolate for other regions of the dentition. Subsampling along transects contributes only minor variations in mean VEIW (<12%) that are dwarfed by the standard deviation (SD). Moreover, variation in VEIW with distance from the pulp cavity likely reflects idiosyncratic patterns related to life history, which are difficult to control for; however, we recommend increasing the number of VEIW measured to minimize this effect. Our data reveal only a weak correlation between mean VEIW and body length, suggesting minimal ontogenetic impacts. Finally, we provide a relative SD of mean VEIW for Alligator of 29.94%, which can be used by researchers to create data-driven error bars for tooth formation times and replacement rates in fossil taxa with small sample sizes. We caution that small differences in mean VEIW calculations resulting from non-standardized sampling protocols, especially in a comparative context, will produce inflated error in tooth formation time estimations that intensify with crown height. The same holds true for applications of our relative SD to calculations of tooth formation time in extinct taxa, which produce highly variable maximum and minimum estimates in large-toothed taxa (eg 718-1331 days in *Tyrannosaurus*).

Campos, Z., Muniz, F., Mourão, G. and Magnusson, W.E. (2020). Responses of crocodilians to construction of a hydroelectric dam on the Madeira River in the Brazilian Amazon. *Herpetological Journal* 30: 215-221.

**Abstract:** The spillways of the Santo Antônio Hydro-electric Dam on the Madeira River in Brazilian Amazonia were closed in November 2011, inundating more than 100 km of river and reducing the annual fluctuations in water level. We surveyed the crocodilians in the affected area for two years before and for 8 years after dam filling in order to evaluate the effects of the dam on the size structure of the population, the distribution of each species, and the detectability of individuals to interpret changes in apparent density. Our methodology was probably not appropriate to evaluate trends in population characteristics of *Paleosuchus palpebrosus* or *P. trigonatus*, but there was little evidence of an effect of the dam on the numbers of *Caiman crocodilus* and *Melanosuchus niger* in the area, and the distributions of all caiman species along the river changed only slightly after the dam was constructed. However, the proportions of small *C. crocodilus* and large *M. niger* detected in surveys increased 8 years after dam filling. Despite having detectable effects on some population characteristics, the dam does not appear to represent a threat to the persistence of the species in the area if deforestation along the banks of the reservoir can be avoided.

Balaguera-Reina, S.A., Pinzón-Barrera, C., Farfán-Ardila, N., Vargas-Ortega, D. and Densmore III, L.D. (2020). Individual identification patterns as a monitoring strategy for American crocodiles: Tayrona National Natural Park as a study case. *Amphibia-Reptilia* (doi: <https://doi.org/10.1163/15685381-bja10033>).

**Abstract:** Population numbers of the American crocodile in Colombia

have shown an increasing trend during the last decades. However, the lack of monitoring programs has restricted our understanding about this species' ecology, limiting the ability to develop sound conservation plans. We assessed the effectiveness and robustness of the Individual Identification Pattern Recognition (IIPR) method for remotely monitoring American crocodile populations based on photographs taken by researchers, tourists, locals, and employees at the Tayrona National Natural Park (TNNP). We catalogued a total of 97 events from 2008 to 2020; 34.02% of which were suitable to analyze using IIPR. We identified eight individuals across 33 events that required only  $4.71 \pm 1.70$  transverse scute lines to obtain complete identification, with the lowest levels of variation in the post occipital and nuchal regions compared with the dorsal area. The probabilities of repeating both the most and least common patterns found in the TNNP were  $1.88 \times 10^{-6}$  and  $1.81 \times 10^{-12}$ , respectively, and the probabilities of repeating the same pattern of each individual identified ranged between  $48.73 \times 10^{-11}$  and  $15.24 \times 10^{-8}$ . Animals B and C were continuously identified between 2012 and 2020 along the Arrecife beach coastline, whereas animals A, H, E, and F were occasionally registered between 2008 and 2019 at the Cañaveral beach. Overall, the IIPR method looks as a promising tool for monitoring American crocodile populations in the TNNP albeit some improvements in data collection that must be done to increase the number of useful events and analysis quality.

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Marshall, B.M., Strine, C. and Hughes, A.C. (2020). Thousands of reptile species threatened by under-regulated global trade. *Nature Communications* 11: 4738.

**Abstract:** Wildlife trade is a key driver of the biodiversity crisis. Unregulated, or under-regulated wildlife trade can lead to unsustainable exploitation of wild populations. International efforts to regulate wildlife mostly miss 'lower-value' species, such as those imported as pets, resulting in limited knowledge of trade in groups like reptiles. Here we generate a dataset on web-based private commercial trade of reptiles to highlight the scope of the global reptile trade. We find that over 35% of reptile species are traded online. Three quarters of this trade is in species that are not covered by international trade regulation. These species include numerous endangered or range-restricted species, especially hotspots within Asia. Approximately 90% of traded reptile species and half of traded individuals are captured from the wild. Exploitation can occur immediately after scientific description, leaving new endemic species especially vulnerable. Pronounced gaps in regulation imply trade is having unknown impacts on numerous threatened species. Gaps in monitoring demand a reconsideration of international reptile trade regulations. We suggest reversing the *status quo*, requiring proof of sustainability before trade is permitted.

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Rizzolo, J.B. (2020). Wildlife farms, stigma and harm. *Animals* 10: 1783 (doi:10.3390/ani10101783).

**Abstract:** Wildlife farming, the commercial breeding and legal sale of non-domesticated species, is an increasingly prevalent, persistently controversial, and understudied conservation practice. The adoption or rejection of wildlife farms is a complex process that incorporates

numerous ethical considerations: conservation, livelihoods, animal welfare, and cultural practices. This paper uses qualitative interview data with key informants (academics) to analyze (a) the harms and benefits of wildlife farms and (b) the factors that influence whether wildlife farms are stigmatized or accepted. In evaluations of wildlife farming's harms and benefits, respondents incorporated multiple considerations: animal welfare, environmental impacts, scale disparities between sustenance and commercial farms, consumer preferences, species differences, the substitutability and accessibility of wildlife products, and governance. The results further indicated that the stigmatization or acceptance of wildlife farms is affected by the "wildlife farm" label, if there is a stigma around use of a species, a form of production, or the perceived quality of a wildlife product, cultural differences in wildlife use, wildlife consumer typology, geopolitical factors, and demand reduction efforts. This paper analyzes the complexities of wildlife farming such that stakeholders can understand the impacts of this practice on species, human communities, individual animals, and the legal and illegal wildlife trades.

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Inchuai, R., Weerakun, S., Nguyen, H.N. and Sukon, P. (2020). Global prevalence of chlamydial infections in reptiles: A systematic review and meta-analysis. *Vector Borne Zoonotic Diseases* (doi: 10.1089/vbz.2020.2654).

**Abstract:** *Chlamydia* spp. are potential zoonotic pathogens that can infect a wide range of animal hosts. In reptiles, *Chlamydia* can cause hepatitis, pneumonitis, and conjunctivitis and it can cause high mortality in young animals. The objectives of this study were to estimate the pooled prevalence of chlamydial infections in reptiles and to assess the trend of these infections over time. The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Relevant studies were retrieved from PubMed, Scopus, and Web of Science. The retrieved studies were screened for eligibility. Then, important data were extracted from the included studies. A random effects model was used for all analyses. Subgroup analysis was used to assess heterogeneity for orders of reptiles, continents where the studies were conducted, and types of specimens. Cumulative meta-analysis and meta-regression were used to determine the trend of the prevalence over time. The quality of each included study was evaluated. Of 106 studies (with a total of 2607 samples), 20 met the inclusion criteria and were included in the meta-analysis. The pooled prevalence of chlamydial infections in reptiles was 23.5% (95% confidence interval [CI]: 15.4-34.0). The trend of chlamydial infections increased from 1990 to 2008; thereafter, it was almost stable at slightly over 20%. The most commonly reported *Chlamydia* spp. were *Chlamydia psittaci*, *Chlamydia pneumoniae*, *Chlamydia pecorum*, and *Chlamydia caviae*. Among reptiles, the prevalence of chlamydial infections was highest in crocodiles (57.3% [95% CI: 32.5-78.9]). Among continents, the prevalence of chlamydial infections was highest in Australia (68.6% [95% CI: 36.8-89.1]). Based on the included studies, the prevalence of chlamydial infections in reptiles was high, especially in crocodiles. Because *C. psittaci* and *C. pneumoniae* are commonly found in reptiles and are well-known zoonotic pathogens, they should be of concern for human health.

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