

# CROCODILE SPECIALIST GROUP NEWSLETTER

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# CROCODILE

# SPECIALIST

# GROUP

# NEWSLETTER

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IUCN - Species Survival Commission

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COVER PHOTOGRAPH: Taxidermied, 4.54 m long Nile crocodile (*Crocodylus niloticus*) integrated into a diorama of the Upper Nile landscape in Sudan, at Zoologisches Forschungsmuseum Alexander Koenig (ZFMK), Bonn, Germany. Photograph: Morris Flecks. See pages 13-14.

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EDITORIAL POLICY: All news on crocodylian 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 crocodylians, 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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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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Singapore Reptile Skin Trade Association, Singapore.

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Mainland Holdings, Lae, Papua New Guinea.

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Santa Fe College Teaching Zoo, Gainesville, Florida, USA.

Zambia Crocodile Farmers Association, Lusaka, Zambia.

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James Hennessy, The National Reptile Zoo, Ireland.

Frank Robb, Florida, USA.

Zoo Atlanta, Georgia, USA.

Zoological Society of Hertfordshire, UK.

## Editorial

We were saddened to hear that long-time CSG member and owner of Vermilion Gator Farms, Wayne Sagrera, passed away. Wayne was a pioneer in the alligator farming industry, having started some 30 years ago and implementing the approach developed by researchers at Rockefeller Wildlife Refuge. From humble beginnings, Wayne built up the farm, which now involves his sons and grandsons, who continue on with his legacy (see Obituary on page 4).

Frank Ramirez (70 y), a dear friend and colleague of Steve Gorzula, who carried out some of the first work on *Caiman crocodilus* haematology (Ramirez *et al.* 1975, 1978), also recently passed away in Caracas, from COVID-19 complications.

CSG member and journalist Mushtaq Ahmed (53 y) has been an indirect victim of COVID-19. Taking to social media to criticize the Government of Bangladesh over its COVID-19 response, he and a colleague were deemed to have breached a law restricting such criticism, and taken into custody. After 9 months in custody, his death in Dhaka prison on 24 February 2021 outraged journalists nationally and internationally, generating a procession of protests in different countries (<https://www.aljazeera.com/news/2021/2/26/anger-in-bangladesh-over-prominent-writers-death-in-prison>). Mushtaq was the entrepreneur who started crocodile farming in Bangladesh.

Against this very sad news, there is good news. Congratulations to our youngest CSG member, Karin Ebey (17 y), who was recently included in the “Society for Science’s Top 300 Scholars” in the “Regeneration Science Talent Search 2021” in USA, for her project entitled “Climate Change on Crocodylians: Modeling the Effects of Variations in Rainfall on Crocodylians and their Ecosystem” (see page 12). A truly remarkable person and contribution to science.

The Zoological Society for Species and Population Conservation (ZGAP) has chosen endangered crocodylians as “Species of the Year 2021”. This campaign aims to raise awareness of the threats and conservation needs of lesser-known wildlife species, kept in German-speaking zoos in Europe, and to raise funds for conservation projects on them (see pages 12-13).

I am most grateful to Sally Isberg for taking over responsibility the CSG Red List Authority. Sincere thanks are due to Perran Ross, for getting the Red List Authority up and operating, coordinating and updating our Red List assessments, and for introducing and mentoring Sally to the task. It is one of the

key contributions CSG makes to IUCN.

China has continued its program for the reintroduction of captive-bred Chinese alligators (*Alligator sinensis*), specifically in Gaojingmiao Forest Reserve (GFR) in Anhui Province. Recent releases are significant because they involve much larger numbers of animals being released - 120 alligators were released in June 2020, compared with 93 alligators between 2006 and 2016 (see pages 23-25).

The US Fish and Wildlife Service (USFWS) has issued a proposed rule to change Federal regulations that control trade in American alligators (*Alligator mississippiensis*) in the USA. It would remove a provision that requires the sale/transfer of any alligator, or its parts or products, to be made in accordance with the laws and regulations of the state in which the sale/transfer occurs. This provision was intended to regulate trade in products that pose health and disease risks, and was not meant to foster individual state controls on trade in CITES-listed species, which takes place in accordance with CITES protocols and the stricter domestic measures adopted at the Federal level after consultation with states. The USFWS-proposed rule would clear up the confusion which surrounded California’s proposed ban on trade, and ensure other states do not implement a mosaic of separate species-specific trade bans which would confound legal trade in CITES-listed species.

The CSG Drone Working Group held its 5th virtual meeting on 19 February 2021. Guest speaker Keeyen Pang (Hornbill Surveys, Indonesia) presented his work on making low-cost drones more accessible to researchers. The presentation will soon be available on Youtube, and details posted on the CSG website.

The results of surveys of the Orinoco Crocodile (*Crocodylus intermedius*) in Venezuela has been published (Velasco *et al.* 2020; see page 35 for Abstract). Special thanks go to the authors, Alvaro Velasco, Omar Hernández, Ricardo Babarro and Roldan De Sola, and their colleagues, for coordinating and completing this research during these difficult times. Thanks also to CrocFest for providing funding to support yet another important project.

The IUCN World Conservation Congress (WCC) is still proposed to take place on 3-11 September 2021. The current membership of the Commissions for 2017-2020 will be extended until after the WCC. The CSG Executive Officer will be contacting CSG members in due course on the process that will be adopted by the IUCN-SSC for confirmation of membership for the 2021-2024 quadrennium.

The next CSG Working Meeting is still planned for 21-27 November 2021, but this will be subject to the COVID-19 pandemic being brought under control. See pages 4-5 for details.

Professor Grahame Webb, *CSG Chair*.

## Obituary

### Wayne Sagrera (1944-2020)

In 1983, Wayne Sagrera, a struggling cattle rancher and rice farmer, was approached by the folks over at Rockefeller Refuge to give alligator farming a try. The concept was not very appealing to him, as it seemed to be a very risky proposition. At the time, the American alligator was a protected species. Ted Joanen, Larry McNease, David Richard and their team at Rockefeller had the idea to team up with the private sector and create an industry that could utilize a natural resource, that otherwise would perish if left in the wild. It was a novel idea and, if successful, it could bring the alligator population back to previous levels and provide jobs for local communities.

No-one, including Wayne Sagrera, thought that this was a slam dunk proposition, but for whatever reasons, he decided to take the gamble. He had no money for this project, and so he so he went considerably further into debt. He started with one barn, and as I recall, it housed 230 alligators. He borrowed more money and built another barn in 1985 and two more in 1986.

At that time, profits were enough to pay the banknotes and family living expenses, but nothing more. It was at that time that he started to believe in the potential of this endeavor. He hired his first employee to feed and wash the alligators, which would allow him time to travel overseas and introduce himself directly to the tanneries that were purchasing his alligator skins. I can remember that he did not like to fly at all at that time, but he knew it was the only way to take his business to the next level. He would travel to France, Italy, Japan, Hong Kong and Mexico, and his name was quickly established worldwide.

In early 1987, as a recent graduate of USL, I approached my father to join him in the business. He was a bit reluctant to have me take this gamble at that time. I told him that I am young and if this doesn't work out that I had plenty of time to find another career. He finally agreed, and the first of his sons officially joined the business.

The business grew quite slowly over the next few years, and in 1990 little did we know that things were about to change. A chance meeting between my father and Mr. C.H. Koh from Heng Long Leather, at Rockefeller Refuge, was the beginning of a 30-year business/personal relationship that continues to this day.

In 1991 the business was incorporated as Vermilion Gator Farm Inc. (VGF). In 1992 his second son Kevin would join the company, and in 1994 his third son Craig would join, and by 1998 Vermilion Gator Farm would be the largest exporter of American alligator skins in the world. In 2000, his youngest son Raphael would join the business, and in recent years he would be joined by two of his grandsons, Matthew and Jacob.

A good example of my father's character and his ability to judge the character of others, was when he made a deal involving millions of dollars of skins with a handshake. No lawyers, no contracts! Over the last 36 years of his life, Wayne Sagrera always had an open door. He helped many people get their farms started, and he never kept any secrets. He helped some enter into the alligator meat business and never thought of anyone as a competitor. In his opinion, there was room in this industry for anyone interested.

He was very passionate about the sustainable use of this precious natural resource, and worked hand-in-hand with LDWF biologists, industry leaders, local landowners, and government officials to ensure that the alligator farming industry would provide the finances necessary to support the American alligator's full recovery. My father was instrumental in creating the Louisiana Alligator Farmers and Ranchers Association, and he served on the Louisiana Wildlife and Fisheries Commission and the Alligator Advisory Council.

Today, VGF has approximately 40 employees - that's 40 families that support VGF and are supported by VGF. Well over 100 different people have worked at the farm over the years, as well as many high school and college kids who have had summer jobs here. Several military veterans joined us after finishing their service. This was very important to my father. Remember, this is Mouton Cove, rural Vermilion Parish, Louisiana. He felt a sense of obligation to employ as many people as possible and provide an opportunity for as many as possible.

I spoke with a Mr. Zvi Friedman from Italy, with whom my father had worked for the past 30 years, who summed up the sentiment of many people who had met my father, and many who knew of him but never met him. He said there were three things that summarized the reputation of Wayne Sagrera: honesty, quality and transparency.

I will close with these few thoughts. I know for a fact that he felt incredibly blessed to be able to have all of his sons and grandsons by his side. He would be the first to say he could not have been successful without our help, perhaps, but I know for a fact that we would not have been successful without his leadership. He worked tirelessly for over 30 years to provide for his family and community. He was an imperfect man, but the perfect husband, father and grandfather. A dedicated husband and family man. Wayne James Sagrera, my father, our father, our Dad!

Stephen Sagrera, *Vermilion Gator Farm*.

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### 26th CSG Working Meeting Postponed Again

Due to the ongoing COVID-19 pandemic, the 26th CSG Working Meeting to be held in Chetumal, Quintana Roo, Mexico, has been postponed to 21-27 November 2021. It will be preceded by the veterinary, drone and taxonomy

workshops on 19 November 2021, and a CSG Steering Committee meeting on 20 November 2021.

Organisers are tracking the COVID-19 situation, and will keep the CSG Executive Committee informed accordingly.

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

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### 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 two students in the January-March 2021 quarter.

1. Maria Pinzón Barrera (Colombia): Spatial ecology of the American crocodile in Tayrona Natural National Park: A tool for conservation.
2. Caleb Gordon (USA): Identifying the developmental basis of snout width and associated craniofacial anomalies in crocodylians.

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

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### Gharial Library Now Online

The Gharial Library is now online (<https://sites.google.com/view/gharial-library/about>). It builds on the now discontinued Gharial Information Database, and is an ongoing attempt to compile relevant information to assist Gharial research and conservation. The library currently includes over 1300 references from the year 1756 onwards, and as a work in progress will continue to be updated. Feedback on missing publications, incorrect information, take-down requests, etc., can be directed to: [gharial.info@gmail.com](mailto:gharial.info@gmail.com).

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### Addressing Colonial Science

Recently, there have been calls to address the issue of “Colonial Science” (or “Parachute Science”) in modern academia. This “movement” aims to eliminate, or at least mitigate, the disproportionate legacy of European thought and culture in education in developing countries (eg Schiebinger 2005; Osborne 2001; Wight 2020). We recommend reading a recent article by Ashley Yeager, published in *The Scientist* (Yeager 2021), on “decolonizing science”.

In particular, we draw attention to 6 recommendations that Yeager has drawn from various sources, as to how researchers can assist efforts to decolonize science:

1. Ask questions. “Listen to local researchers and community members and commit to humility - you don’t know everything about another person’s country, laws, and customs, nor what’s best for them”, says Larry Crowder, Stanford University marine ecologist.

2. Check your frame of mind. “When entering a collaborative or public engagement project, ask yourself and your colleagues: What are the historical factors, unconscious biases, systemic barriers, or inequalities that might affect this project? Redressing any issues and being mindful of the points of view of the people you’re working with will make it more inclusive”, notes Mark Nesbitt of Kew Gardens.
3. Practice cultural sensitivity. “Watch your language”, Crowder says, “because offending a researcher you’d like to collaborate with in another country can close doors quickly”. In addition, learn about the colonial context within which Western science developed. That awareness builds an appreciation for other types of knowledge, according to Dina Gilio-Whitaker of California State University San Marcos.
4. Let local scientists lead. “Build collaborations that allow in-country researchers to take the lead on field projects. Identify the needs of the community and the interests of local researchers, and don’t impose outside ideas on people with inside knowledge of a country’s political and cultural frameworks”, says Asha de Vos of Oceanswell.
5. Return specimens to their home countries. “Repatriating plants, fossils, and other specimens allows local researchers to take charge of botanical or archeological investigations within their countries”, anthropologist Eleanor Scerri of the Max Planck Institute in Germany told *The Scientist* last year.
6. Share publication authorship. “Include local scientists who took part in the work on the list of authors for papers and reports from the project, giving them lead author position if they spearheaded the work”, editors at *The Lancet Global Health* argued in 2018.

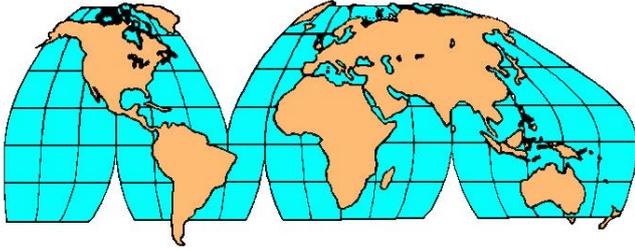
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Source: Yeager, A. (2021). *Steps to end “Colonial Science” slowly take shape*. *The Scientist*, 1 January 2021.

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# Regional Reports



## Latin America and the Caribbean

### Brazil

DAWN OF TELEMETRY TRACKING OF CAIMANS IN THE ATLANTIC FOREST OF BRAZIL. Tracking of crocodylians by telemetry date back to the 1970s (Joanen and McNease 1970), and since then it has been applied in all continents where crocodylians occur (eg Wang *et al.* 2011; Balaguera-Reina *et al.* 2016; Combrink *et al.* 2017; Baker *et al.* 2019; Campos 2019; Strickland *et al.* 2020; Fukuda *et al.* 2019). Over the past five decades, the technology used for describing and monitoring movement patterns and home ranges of aquatic organisms has evolved enormously (Franklin *et al.* 2009), including lighter and cheaper transmitters, increased battery life and the introduction of satellite and GPS-based transmissions. Such improvements have, to some extent, allowed for an increase in the number of population and behavioural studies of crocodylians based on telemetry, especially in developing countries.

In Brazil, the first studies applying radio-telemetry were carried out in the 1990s by Magnusson and Lima (1991) and Martin and Silva (1998), who tracked *Paleosuchus trigonatus* and *Melanosuchus niger* in the Amazon forest, and described some of their movement patterns. Years later, radio-telemetry was also applied in the study of the movement patterns of *Caiman yacare* in the Pantanal floodplains of southwestern Brazil (Campos *et al.* 2006), the relationships between spatial ecology of *Caiman crocodylus* and *M. niger*, and predation pressure imposed by jaguars in floodplains of central Brazilian Amazonia (Da Silveira *et al.* 2010). More recently, using GPS-tracking, Marques *et al.* (2020) studied the home range and movement patterns of *Caiman latirostris* in an area severely impacted by forestry in the Cerrado biome of Brazil.

Whereas telemetry-based studies shed light on many interesting aspects of the ecology of South American crocodylians, the vast majority of extant crocodylian populations in Brazil were never subject to evaluations of individual home range, movement patterns or territoriality. In the Brazilian Atlantic Forest, a highly impacted and fragmented biome currently covering only 8% of its original area (Cunha *et al.* 2019), monitoring of crocodylians by telemetry is still insipient, without any published information.

In a pioneering effort, the Projeto Caiman (Instituto Marcos Daniel; IMD) recently initiated the first monitoring study of *Caiman latirostris* movement and home ranges based on

GPS tracking of 7 individuals in protected Atlantic rainforest fragments. The methods involve GPS/GSM technology in association with a Sigfox mobile network. All gear was developed and adapted by Nortronic, a Brazilian company specializing in technology for animal tracking. The first caimans monitored by the IMD team were tagged with GPS transmitters (Fig. 1) and released in a protected area within the city of Serra, in southeastern Brazil, in April 2019 (Fig. 2). Data on home range and movement patterns of these caimans were presented in an undergraduate thesis elaborated by one of the authors (GGD), who is currently part of the IMD staff.



Figure 1. Fitting of GPS transmitters on *Caiman latirostris* by Eduardo Lázaro (veterinarian, Projeto Caiman), on the right. From left to right: Lucas Fraga (veterinary student, FAESA), Paulo Braga Mascarenhas Júnior (biologist, Projeto Jacaré); Gabriel Dias (biologist, Projeto Caiman), Thassiane Targino da Silva (Veterinarian, Projeto Caiman), Eduardo Lázaro.



Figure 2. Release of a *Caiman latirostris* tagged with a GPS transmitter in a protected area in the Municipality of Serra, Espírito Santo.

Following these first steps, a research program was established to apply GPS tracking in the study of *Caiman latirostris* populations in the north Atlantic Forest of Brazil. The program (Projeto Jacaré) is currently integrated by students and faculty of the Universidade Federal Rural de Pernambuco (UFRPE) and the Universidade Federal de Pernambuco (UFPE). In August 2020, our research proposal to monitor caiman population in a water reservoir in the outskirts of the city of Recife was selected by the Rufford Foundation to receive a small grant of £5770. Research will be led by PBMJ as part of his doctoral thesis, and will focus on GPS tracking of caimans in both protected areas and areas subject to net fishing in the same reservoir. Most of the fund will be spent in fieldwork and in acquiring the GPS transmitters and receiver. All gear and protocols will follow those already in use by the IMD in southeastern Brazil, allowing for future exchange and comparison of results.

The partnership between IMD and Projeto Jacaré was greatly facilitated through the 2018 CSG Meeting in Santa Fe, Argentina. Since then, several collaborations have been articulated and consolidated between the two initiatives. We hope that spatial data collected in the forthcoming years will help us understand how *Caiman latirostris* populations occupy, move, feed and reproduce in such impacted environments as the periurban rivers and reservoirs of the Brazilian Atlantic forest. We also expect that home range and movement data will be useful in pointing out the main causes of disturbance and avoidance by caimans, thus providing guidelines for informed conservation action.

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## Cuba

NEWS FROM THE CAPITAL OF THE CUBAN CROCODILE. The last remaining wild population of the Cuban crocodile (*Crocodylus rhombifer*) is found in a core area at the southwestern region of Zapata Peninsula, mainland Cuba. Besides being the last reservoir of this charismatic species in the wild, it is a unique natural “laboratory” that provides opportunities to study the evolutionary and ecological processes of this and other species. In this context, experts from Zapata Swamp Crocodile Farm - under the “Enterprise for the Conservation of the Zapata Swamp” - and colleagues from several Cuban and American institutions have developed and carried out a series of research and monitoring programs to inform management and conservation of threatened species, including the endemic Cuban crocodile.

As part of the Cuban crocodile conservation program, experts and staff of ZCF deployed 5 satellite transmitters on wild *C. rhombifer* during an expedition to Zapata Swamp National Park on 16-26 October 2020 (Fig. 1). This is the first time that satellite transmitters have been used on Cuban crocodiles. The information provided by this tracking study will be key to better understanding movement, territoriality and other behavioural traits of the species.



Figure 1. Female Cuban crocodile with satellite tag.

The transmitters were attached to the nuchal scutes of the individuals, following standardized protocols for satellite tag deployment and animal care. The satellite tags are transmitting the geographical positions of one male and four female *C. rhombifer*, captured in different locations within their core area in Zapata.

We considered that translocation could provide information on territoriality and homing ability, and so four of the crocodiles (1M, 3F) were released 0.25 km (N= 1), 0.4 km (N= 1) and 0.8 km (N= 2) from their capture site, respectively. One female was released at her capture site (Fig. 2). Release sites were selected after taking into account the ecosystem from which crocodiles were initially captured. Two of them were moved from the flooded savanna to flooded mangrove forest, and the others were released into the same type of habitat.

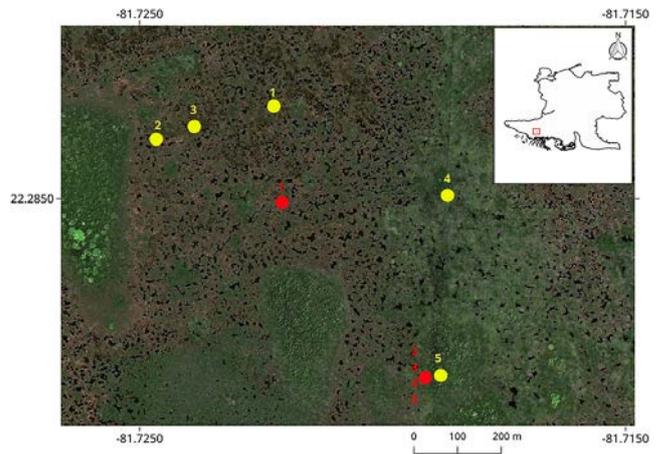


Figure 2. Capture (yellow points) and release (red points) sites of 5 Cuban crocodiles (1-5) involved in this study.

The information collected during the first three months provides evidence of territoriality of *C. rhombifer*. The four translocated crocodiles returned to their habitat, regardless of the area of release, and their home range did not exceed a radius of one kilometre. However, some crocodile movement triggers, such as water level and breeding season, remain without significant changes. Therefore, the information about their movement in the coming months, and increasing the number of individuals in this study, will be crucial to developing this project.

### Acknowledgements

This work was possible due to the support of CrocFest 2017, and many Cuban and American colleagues and institutions committed to the conservation of the Cuban crocodile and Zapata Swamp.

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## Mexico

MONITORING *CROCODYLUS MORELETII* IN EL CARPINTERO LAGOON AND ESTABLISHMENT OF “SOSCOCODRILOTAMPICOGROUP” INTAMAULIPAS, MEXICO. The Swamp crocodile (*Crocodylus moreletii*) is endemic to Mexico, with distribution ranging from the centre of the state of Tamaulipas, through the Gulf of Mexico slope (85%), and to Belize and Guatemala (15%). In Mexico, *C. moreletii* is considered under special protection on the list of threatened species of the Official Mexican Standard (NOM-ECOL-059-2010). At a global level, the species is considered of “Least Concern” by the IUCN Red List, and is listed on CITES Appendix II.

Since the 19th century, the presence of *C. moreletii* has been recorded in the state of Tamaulipas by different authors (eg

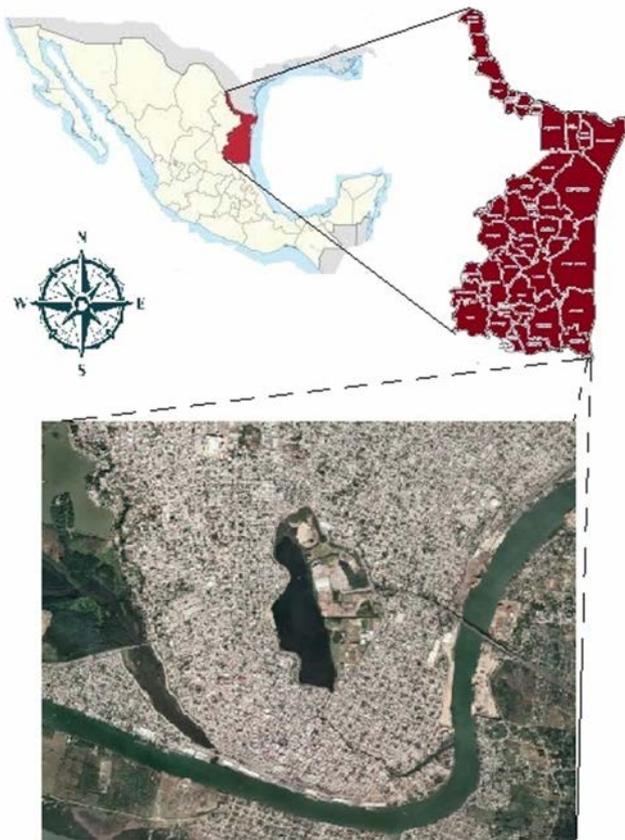


Figure 1. Location of El Carpintero Lagoon.



Figure 2. El Carpintero Lagoon.

Bocourt 1869; Argüelles 1910; Schmidh 1924; Dunkle 1935; Smith and Taylor 1950; Martin 1958; Baker and Webb 1966; Ross 1987; Flores-Villela 1993; Hinojosa and Lavín 2001a,b; Hinojosa 2002; Carrera 2004; Domínguez-Laso 2005; Rivera-Téllez *et al.* 2017; Cedillo-Leal *et al.* 2019). In 1954, the Government of the state of Tamaulipas decreed a “total ban” on crocodile hunting, although there was already a history of decrees (eg “temporary ban for capture”) in the states of Tabasco, Chiapas, Veracruz, Oaxaca, Sinaloa, Nayarit, Campeche, Quintana Roo and Yucatán. In 1970, the Federal Government decreed a “total ban” throughout Mexico (SEDESOL 1999).

In November 2020, the “SOS Cocodrilo Tampico Group” was established, with specific goals with respect to *C. moreletii* in El Carpintero Lagoon and the Municipality of Tampico (Figs. 1-2):

- Estimate the size and structure of the *C. moreletii* population in El Carpintero Lagoon.
- Quantify the conservation status, including population trends for *C. moreletii* in El Carpintero Lagoon.
- Quantify habitat characteristics and nesting/reproduction areas (including hatching success) in El Carpintero Lagoon.
- Identify known and potential threats for *C. moreletii* in El Carpintero Lagoon.
- Determine the different types of Human-Crocodilian Contingencies, and identify areas prone to human-crocodile interaction in El Carpintero Lagoon.
- Implement the Protocol for Attention to Human-Crocodilian Contingencies (PACH-C) in the Municipality of Tampico.
- Train first responders (eg civil protection, firefighters, Mexican Red Cross) and other personnel (eg academics, federal, state and municipal authorities) on the importance, management and containment of crocodiles in the Municipality of Tampico.
- Implement environmental education strategies in the Municipality of Tampico to support *C. moreletii* conservation actions.

The first negative contingencies between humans and crocodiles in Tamaulipas date back to 1901 (CrocBite 2021). More recently, negative contingencies were recorded in 2008, 2009, 2014, 2018, 2019 and 2020 (3 fatal, 2 non-fatal) in El Carpintero Lagoon.

#### Study Area

El Carpintero Lagoon is an urban waterbody (Figs. 1-2), located in the municipality of Tampico, in the state of Tamaulipas (22° 12'25" and 22° 12'01" N; 97° 50'11" and 97° 57'10" W). It has a ‘water’ area of 77 ha, and has 80 ha of land associated with it. The habitat around the lagoon is not pristine, and has been modified. The lagoon is located within Hydrological Region N° 26 Río Panuco, in the Lower Hydrological Basin of the Río Tamesí.

This southern region of Tamaulipas has a tropical, sub-humid

climate, with rains in summer (June-October). The mean annual temperature is 24°C (mean maximum= 36.8°C, mean minimum= 9.7°C). Annual rainfall ranges between 789 and 1044 mm (Fig. 1).

### Progress Made

The study will have a duration of 6 months, with El Carpintero Lagoon to be visited twice per month. For monitoring, the four methods (EMH, DVN, MRE and USN) indicated in the “Procedures Handbook of the Swamp Crocodile (*Crocodylus moreletii*) Monitoring Program” will be used (Sánchez Herrera *et al.* 2011).

In December 2020 we carried out an initial evaluation of the habitat (EMH) through daytime surveys in a boat with an outboard motor and by walking the margins of the lagoon. This evaluation allowed us to confirm habitat characteristics, as well as human activities and modifications of the habitat (Fig. 2). In February 2021, we began night surveys by carrying out four monitoring activities in El Carpintero Lagoon. To date, we have observed and captured a greater number of juveniles and hatchlings, than sub-adults and adult *C. moreletii* (Fig. 3).



Figure 3. Monitoring the crocodile population.



Figure 4. Signage placed at El Carpintero Lagoon.

Assessment of human-crocodile interaction in El Carpintero Lagoon was carried out using the methodology proposed by the “Protocol of Attention to Human-Crocodilian Contingencies (PACH-C)” (SEMARNAT 2018). Potential sites (eg basking sites, nesting areas, open areas without protection) were identified, and four types of sign were approved by the Municipality of Tampico and placed (with information on prevention and biology of the species) on banks and crowded places of El Carpintero Lagoon; approximately 60 signs were placed throughout the lagoon (Fig. 4).

For the establishment of SOS Cocodrilo Tampico Group, the first step involved a request for the permit (SEMARNAT-08-041: “Authorization for the management, control or remediation of problems associated with specimens or populations that become harmful”). This was processed by the Municipality of Tampico in the Hunting and Sport Fishing Commission of the state of Tamaulipas.

The Group will comprise specialists in the field, Civil Protection personnel, firefighters, Mexican Red Cross and municipal/state/federal authorities. It will be responsible for attending and monitoring all incidents that occur between crocodiles and humans, as well as advising on and carrying out best management practices for the species in the El Carpintero Lagoon (Fig. 5). In February 2021, training on the handling and containment of crocodiles was carried out for all members of the Group (Fig. 6).



Figure 5. SOS Cocodrilo Tampico Group.



Figure 6. Training of SOS Cocodrilo Tampico Group members.

#### Acknowledgements

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## North America

### USA

YOUNGEST CSG MEMBER NAMED AS TOP SCHOLAR. We recently learned that CSG member Karin Ebey (17 y) was included in the “Society for Science’s Top 300 Scholars” in the “Regeneron Science Talent Search 2021”, the USA’s oldest and most prestigious science and math competition for high school seniors. The Regeneron Science Talent Search scholars were selected from 1760 applications received from 611 high schools across 45 states, Washington DC, Puerto Rico and 10 countries. Scholars were chosen based on their exceptional research skills, commitment to academics, innovative thinking and promise as scientists. The 300 scholars and their schools will be awarded \$2000 each.

The Regeneron Science Talent Search provides students with a national stage to present original research and celebrates the hard work and discoveries of young scientists who are bringing a fresh perspective to significant global challenges. This year, research projects cover topics from bioinformatics to public health and energy efficiency.

*“The remarkable drive, creativity and intellectual curiosity that each one of these scholars possesses represents a hopeful outlook for our future and our collective wellbeing,”* said Maya Ajmera, President and CEO of Society for Science, Publisher of Science News. *“At a time when many students’ educational experiences are being disrupted by the COVID-19 pandemic, I am incredibly humbled to see gifted young scientists and engineers eager to contribute fresh insights to solving the world’s most intractable problems.”*

*“An exceptional group of student leaders and innovators comprise this year’s Regeneron Science Talent Search scholars, with an array of projects that demonstrate the power of science,”* said Hala Mirza, Senior Vice President of Corporate Communications and Citizenship at Regeneron.

*“We are honored to celebrate the next generation of young scientists and inventors who can elevate the STEM community and our broader society through their high-quality research and novel discoveries. These are the inspiring problem solvers who will help address the current and future challenges facing our world.”*

Karin, a student at Los Alamos High School, New Mexico, was selected for her project entitled “Climate Change on Crocodylians: Modeling the Effects of Variations in Rainfall on Crocodylians and Their Ecosystem” (download at: [https://terra-docs.s3.us-east-2.amazonaws.com/IJHSR/Articles/2020\\_V2I1\\_p18\\_Ebey.pdf](https://terra-docs.s3.us-east-2.amazonaws.com/IJHSR/Articles/2020_V2I1_p18_Ebey.pdf)). Karin has been a member of the CSG since 2014, and attended her first CSG working meeting that same year in Lake Charles, Louisiana. She also attended the 2018 CSG working meeting in Santa Fe, Argentina, and her poster on “Modeling American Alligator Population Dynamics” won her one of the student prizes for outstanding presentations. Karin will be starting college next fall, and we look forward to following her continued academic success and crocodylian research.

Alumni of the Regeneron Science Talent Search program include recipients of the world’s most coveted science and math honors, including 13 Nobel Prizes, 11 National Medals of Science, 6 Breakthrough Prizes, 21 MacArthur Foundation Fellowships and 2 Fields Medals.

This article has been compiled from information contained on the Society for Science website (<https://www.societyforscience.org/regeneron-sts/2021-scholars/>). Learn more at: <https://www.societyforscience.org/regeneron-sts/> and <https://medium.com/regeneron-science-talent-search>. Media Contact: Gayle Kansagor, Society for Science ([gkansagor@societyforscience.org](mailto:gkansagor@societyforscience.org)).

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## Europe

### Germany

ENDANGERED CROCODYLIANS CHOSEN AS “SPECIES OF THE YEAR 2021”. The Zoological Society for Species and Population Conservation (ZGAP) has chosen endangered crocodylians as “Species of the Year 2021”. This campaign aims to raise awareness of the threats and conservation needs of lesser-known wildlife species kept in zoos, and raising funds for conservation projects. During the year-long campaign, German-speaking zoos will be engaged in lobbying activities for three crocodile species, and raising funds to support three *in-situ* conservation projects, specifically:

- Cuban crocodile (*Crocodylus rhombifer*) in Zapata Swamp, Cuba - Global Wildlife Conservation
- Philippine crocodile (*Crocodylus mindorensis*) on Siargao

- Island, Philippines - *Crocodylus Porosus* Philippines Inc.
- Siamese crocodile (*Crocodylus siamensis*) in Kalimantan, Indonesia - Yayasan Kolaborasi Inklusi Konservasi

The campaign has developed a positive image nationwide, and presents species protection and conservation breeding work of zoos (ie *in-situ* and *ex-situ* components of the IUCN “One Plan Approach to Conservation” for visitors. With easily understandable and tangible examples, the campaign helps promote the important work of zoos and other partners in species conservation.

In order to achieve as much as possible for the species in focus, such as public relations and conservation measures, four partners are joining forces: the Zoological Society for Conservation of Species and Populations (ZGAP); institutions and members of the German Society for Animal Parks (Deutsche Tierpark-Gesellschaft e.V.; DTG); the Association of Zoological Gardens (ZdZ); and, the Community of German Patronisers (Gemeinschaft der Zooförderer; GdZ).

Zoos keep and breed endangered species, and offer their visitors interesting and unique insights into biological and ecological inter-relationships and species biology. They also inform about *in-situ* and *ex-situ* conservation projects in which zoos are involved. Many zoos in Germany, Austria, Switzerland, Netherlands and Luxembourg take part in the campaign by installing posters, organising events, generating media coverage and informing visitors about the importance of conservation work for the selected species. Together, zoos in German-speaking countries reach more than 42 million visitors each year.

Source: Media Release “Zootier des Jahres 2021” and Thomas Ziegler, Cologne Zoo, Germany.

SOME LARGE CROCODILIAN SKULLS IN THE COLLECTION OF THE ZOOLOGISCHES FORSCHUNGSMUSEUM ALEXANDER KOENIG. In their paper with the slightly strange, ambiguous title “Who’s got the biggest?”, Whitaker and Whitaker (2008) write about the fascinating feeling induced by “finding the biggest”, as related to maximum-sized specimens of crocodiles. And indeed, many curators of zoological collections can understand this feeling, including myself. In my 40 years as curator of the herpetology section of the Zoologisches Forschungsmuseum Alexander Koenig (ZFMK) in Bonn, Germany, my attention was drawn to voucher specimens that would reach the upper limit of the size classes known for the respective species.

ZFMK belongs to the six major natural history museums in Germany, of which it is by far the youngest. It was founded by Alexander Koenig in 1912 as a private museum, but due to World War I and many subsequent problems, it could not open until 1934, by which time it had transformed into a state museum. The other significant German natural history museums are all roughly one century older than ZFMK. However, ZFMK’s missing historical dimension could be

partly countered by the transfer of the herpetological holdings of the historically important zoological museum in Göttingen, which founded at the end of the 18th century. Among several other important type specimens, there were two paralectotypes of *Crocodylus porosus* and one of *Paleosuchus trigonatus*, both described by Schneider (1801), which finally found their way to Bonn (see Böhme 2014).

Generally, turtles, tortoises and crocodylians were not the primary focus of herpetological collecting efforts in Bonn. But there were two remarkable pieces within the relatively small collection of crocodylian skulls, which were present before the 1930s (ie two decades before the employment of a first herpetological curator in 1951). Since they were in the public exhibition, they had no locality or collection data.

Throughout this article, head/skull length (HL) defines the distance from the tip of the snout to the posterior margin of the cranial platform.

The first is a large Saltwater crocodile (*C. porosus*) skull, measuring 62.0 cm (HL), and with a mandible length of 79.5 cm (Fig. 1). Whitaker and Whitaker (2008) list 40 of the “largest known” crocodylian skulls of extant species, with 18 *C. porosus* on the list, ranging from 55.0 cm to 76.0 cm. The largest on the list is a *C. porosus* skull of 76.0 cm HL, at the Muséum National d’Histoire Naturelle (MNHN) in Paris.



Figure 1. Lateral and dorsal views of large *Crocodylus porosus* skull at ZFMK. Photograph: Morris Flecks.

Recently, Ziegler *et al.* (2019) and Ziegler (2020) reported on a huge *C. porosus* skull (70.7 cm HL) from a river bed in Vietnam. Fukuda *et al.* (2013) also described two large *C. porosus* skulls (70.6 and 70.1 cm HL) from the Lee Kong Chian Natural History Museum, in Singapore. The ZFMK skull would thus rank as 18th on the list of “Top 20” large *C. porosus* skulls.

There are two large Gharial (*Gavialis gangeticus*) skulls [75.0 (Fig. 2) and 72.5 cm HL (ZFMK 93018)] at ZFMK. According to the list compiled by Whitaker and Whitaker

(2008), these would represent the 3rd and 4th largest Gharial skulls known to date, exceeded and/or equalled only by two specimens at the Zoologische Staatssammlung (ZSM) in Munich (77.3 and 75.0 cm HL), and a skull at MNHN (75.3 cm HL). Including three more *G. gangeticus* skulls listed by Whitaker and Whitaker (2008), the large skulls of this species range from 65.5 to 77.3 cm, with the two ZFMK specimens being in the Top 5. It will be interesting to see where the two giant mounted Gharials on display at the Naturhistorisches Museum (NHMW) in Vienna (Schweiger and Koch 2021) lie relative to these other Gharial skulls.



Figure 2. Lateral and dorsal views of one of the two large *Gavialis gangeticus* skulls at ZFMK (ZFMK uncatalogued). Photograph: Morris Flecks.

The fourth remarkably large skull (53.0 cm HL) in the ZFMK collection is that of an American alligator (*Alligator mississippiensis*) (Fig. 3). It was confiscated by German Customs in Leverkusen, near Cologne, but unfortunately without any collection and locality data. Although 11 cm shorter than the biggest *A. mississippiensis* skull listed by Whitaker and Whitaker (2008), it would nonetheless be placed at 4th.



Figure 3. Lateral and dorsal views of large *Alligator mississippiensis* skull at ZFMK. Photograph: Morris Flecks.

ZFMK's herpetological collection has a strong African focus, but relatively small skulls are present in the collection. However, ZFMK does have a large complete specimen in our public exhibits, integrated in a diorama of the Upper Nile landscape in Sudan. The taxidermied specimen is 4.54 m long (TL), and has a HL of 62.0 cm. Relative to the three largest *C. niloticus* (67.3 to 68.6 cm HL) listed by Whitaker and Whitaker (2008), all from Lake Chamo, Ethiopia, our mounted specimen (see front cover of Newsletter) is not that much smaller than them.

#### Acknowledgements

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## South Asia and Iran

### India

CENSUS OF ESTUARINE CROCODILES IN RIVER SYSTEMS OF BHITARKANIKA NATIONAL PARK,

ODISHA, INDIA, 2021. The annual census of Estuarine crocodiles (*Crocodylus porosus*) was conducted in the river systems of Bhitarkanika Wildlife Sanctuary/National Park and the Mahanadi delta region between 15 January and 21 January 2021. Twenty-five census units were engaged to count the crocodile population in 52 segments within the identified rivers and creeks.

Surveys were carried out during the day and night (Fig. 1). Crocodiles in sub-adult and adult size classes (ie >6') were counted during the day, and hatchlings and juveniles (<2' to 6') were primarily counted at night using spotlights.



Figure 1. Counts of crocodiles in narrow creeks has been conducted using small rowing boats since 1976.

Weather conditions (eg clear sunny days, low day and night temperatures, tides) were considered favourable, and 1768 crocodiles were counted: 593 hatchlings (33.5%); 367 yearlings (20.8%); 320 juveniles (18.1%); 152 sub-adults (8.6%); and, 336 adults (19.0%). There were 63 crocodiles estimated to be more than 16' (4.9 m) long (31 x 14-16', 22 x 16-18', 6 x 18-20', 4 x >20') (Figs. 2 and 3).



Figure 2. Large [>18' (5.5 m)] male *C. porosus* basking.

Most (N= 1404) crocodiles were sighted in Kanika Wildlife Range, which includes forest blocks and rivers starting from Khola to the Bhitarkanika-Pathasala confluence and beyond in Bramhani-Baitarani River systems, followed by 256 sightings in Rajnagar WL Range. Within the Mahanadi delta, 76 crocodiles were counted in Mahakalapada Wildlife Range, and 32 crocodiles in Gahirmatha Wildlife Range. The 2021 survey result was slightly higher than that reported in

January 2020 (1757 crocodiles). Bhitarkanika WS/NP holds the largest wild *C. porosus* population in all regional range states, and represents over 75% of the total Indian *C. porosus* population.



Figure 3. Large [~16' (4.9 m)] male *C. porosus* at water's edge.

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GHARIAL ECOLOGY PROJECT - UPDATE 2019-2021. The Gharial Ecology Project (GEP) is now in its 14th field season, since its initiation in 2008 following the mass die-off of Gharial (*Gavialis gangeticus*) in the winter of 2007-2008. Our research, supported by the international zoo community and private donations, is sanctioned under the NGO umbrella of the Madras Crocodile Bank Trust (MCBT). The GEP programs are facilitated by the State Forest Departments of Uttar Pradesh, Madhya Pradesh and Rajasthan, as well as the Ministry of Environment, Forest and Climate Change, Government of India. The GEP is the present day avatar of the Gharial Conservation Alliance, and our media presence has increased through an active Facebook page, YouTube Channel, and soon to be inaugurated new website, now under construction. What follows is a brief summary of recent activities, updating Lang *et al.* (2016, 2018).

The GEP has three main goals: 1) to develop a comprehensive assessment of Gharials in the National Chambal Sanctuary (NCS); 2) to identify and protect the species' critical riverine habitats; and, 3) to reduce threats and challenges to the species' continued survival. Gharials are Critically Endangered, with an estimated 650-700 mature adults globally (550+ of which are resident in NCS). Project activities are conducted by a small core staff (3-4) of Indian biologists/naturalists, with inputs from its Senior Scientific Advisor, Professor Jeff Lang.

Covid constraints. With the onset of pandemic restrictions in early 2020 on international travel, Prof. Lang's seasonal visits to the Chambal, usually three trips per year, were initially delayed, and then cancelled. From mid-March onward, he has stayed in touch with the field team via frequent phone and internet contacts. The GEP field crew, consisting of Jailabdeen A, Pankaj K., Anand K. and "Guddhu" K., plus Ashutosh T., have observed in-country lockdowns and precautions, worn masks, practiced social distancing, riding individually on motorbikes, and related precautions. Despite travel limitations, surveys have been possible for total population counts in the winter months, and for post-hatching nest/

hatchling counts at crèche sites before the annual monsoon in mid-summer. The outreach programs for capacity building, teacher-training and community development have been largely curtailed, but outside gatherings have allowed us to conduct a limited number of such programs, despite the pandemic conditions. As of April 2021, international travel has not resumed for most visitors to India, and we continue to plan and coordinate the GEP field activities remotely.

Comprehensive surveys. In early 2019, and again in 2020, the entire Gharial population within the NCS (bottom ~425 km, from Pali to Pachnada) was surveyed and estimated at ~1700 individuals (not including the annual crop of hatchlings). In the upper Chambal, there are an estimated 400+ Gharial, specifically 35 males, 285 females, 25 sub-adults, 48 juveniles and 23 yearlings. In the lower Chambal, 1274 Gharial were directly observed and tallied by static survey. These consisted of 66 males, 415 females 428 sub-adults, 261 juveniles and 104 yearlings. Adjusted for accuracy in size categories, these counts included 80 mature males (with ghara; Fig. 1) plus 59 “near-mature” males, 525 reproductive and “near-reproductive” females, 435 sub-adults, 295 juveniles and 151 yearlings.



Figure 1. Close-up of the ghara of a 5.3 m long Gharial (see Figures 5 and 6). The convoluted irregular shape of this ghara is distinctive, and each individual ghara is recognisable by its unique pattern of bulbous cartilage.

In January-March 2021, various surveys were conducted to make additional actual counts of Gharial in NCS, in the manner similar to those conducted in previous years. In the upper Chambal, there are an estimated ~380 Gharial, specifically 29 males, 210 females, 102 sub-adults, 26 juveniles and 21 yearlings. In the lower Chambal, ~1320 Gharial were directly observed and tallied by the static survey. These consisted of 73 males, 461 females, 399 sub-adults, 248 juveniles and 140 yearlings. Adjusted for accuracy in size categories, these counts included 71 mature males (with ghara) plus 31 “near-mature” males, 671 reproductive and “near reproductive” females, 501 sub-adults, 274 juveniles and 161 yearlings.

In 2019, we tallied 469 nests overall, with 185 in the upper stretch and 284 nests in the lower Chambal. Of these, at least 297 nests hatched, and 172 were lost, either to predation or

egg failure. In 2020, we counted 250 nests at 17 sites in the lower stretch of the Chambal, and 180 of these hatched at 16 sites. Overall, there were 401 nests counted in 2020, of which 297 hatched and 105 were lost.

The relative importance of the Chambal Gharial population is evident. With realistic estimates of all the other populations included, the global total number of adult Gharials is about 700 today. Consequently, the NCS population constitutes about 80-90% of the global total. Nesting in the NCS likely exceeds 90% of the global total annually. Today, the NCS population is the only remaining population residing in an open riverine, largely protected habitat. Importantly, it is self-sustaining, definitely stable, and appears in recent years to be on the increase. However, major threats loom large, including uncontrolled water extraction, rampant riverside sand mining, and ubiquitous illegal net fishing.

Drones deployed. We have been using DJI quadcopter drones to create 2D and 3D maps of riverine habitats, using geo-referenced JPEGs. Drone imagery facilitates species identification (Mugger versus Gharial), quantification of numbers present, as well as more accurate estimates of animal sizes. With regard to locating and counting nests, aerial methodology is reliable when colony size is mid-range - >5 but <20 nests. In general, drones are well tolerated by Gharials on land or in the water at >50 m height, but disturbances increase rapidly at lower altitudes. Within large crèches, counting hatchlings accurately is possible with drone-acquired imagery. Related software has allowed 3D imagery of nesting banks for detailed analyses of nest placement, relative to water levels and nearby nests (Fig. 2).



Figure 2. Pankaj K. and Jailabdeen A examine drone imagery of Gharial at a communal basking site, and use drone software to calculate the total length of individuals on the shore. They are working at our Garhaita downstream base, with walls behind them painted with Chambal fauna by our Outreach Director, Dr. Ashutosh Tripathi.

Gharial communication. Jailabdeen A has continued his PhD research on acoustic signaling amongst “big ghara” males. These signals consist of underwater “pops” in stereotypic patterns, primarily with “timing” variations, which are individually distinctive as well as context-dependent. At one site frequented by a breeding male, with few females (<10 in 2017) versus many (>30 in 2018), “recruiting” pops directed at females predominated in both years. In contrast, in 2018, when other males were present, the main acoustic signal

was a “challenging” pop. At this site, overall pop frequency almost doubled in 2018 (182 vs 101) relative to 2017. Then in 2019, frequency declined (120 vs 182), almost half as many as in 2018. Jai is also investigating chemical signaling via secretions produced in the gular and cloacal glands. Samples from wild Gharial of various sizes, ages, and sexes have yielded complex mixtures of distinctive chemical compounds (Fig. 3). Such secretions are presumably responsible for the noticeably strong, musky smell produced by large male Gharials during breeding.



Figure 3. Gular gland secretion samples are carefully collected by Jailabdeen A for chemical analysis at the Laboratory for Conservation of Endangered Species (LaCONES), Hyderabad, India. Material expelled from the gular gland along the underside of the restrained Gharial’s lower jaw is flash frozen in liquid nitrogen in the field.

Upstream base, downstream office. Our new upstream base at Katrinapur, a small riverside village, is located within a 15 minute walk to the Baroli sandbank on the Chambal River. It took shape in late-2019 as a stand-alone office-workroom with adjoining bath-toilet facilities, and was completed by late 2020. Its proximity to the two major breeding and nesting areas on the upper Chambal make it possible to conduct detailed behavioral observations every day, and this location also facilitates day trips to adjacent mainstream stretches, as well as tributary river habitats. Previously, this upstream location was a focal point for Gharial surveys and releases of captive-reared juveniles from Deori EcoCentre.

Downstream, we have established an Indian NGO called “Gharial Local and Global,” with a local Etawah office that serves as headquarters for our outreach programs. In Uttar Pradesh, India’s most populous state, the town of Etawah serves as a regional centre, and is located just 40 km from our riverside village base at Garhaita. Long-term plans involve sourcing in-country support for the GEP through this Chambal-based NGO, while continuing our affiliation with MCBT.

Tagging and tracking. In late 2019, and again in late 2020, our field tracking team joined forces with a trusted cadre of local fishermen to capture and tag Gharials with radio transmitters for tracking. In both years, we have conducted capture

operations in both downstream and upstream stretches of NCS, separated by about 250 km. In November-December 2019, we caught 27 Gharial, and radio-tagged 14, including one with an Iridium (satellite) tag (Fig. 4), and the rest with VHF transmitters in the downstream. In the upstream, in early December 2019, we tagged 10 large Gharial, including a 4.8 m “big ghara” male, and outfitted that animal and another female with satellite tags as well.



Figure 4. GEP field team attaching an Iridium Wildlink transmitter (GPS platform= black patch on top) just anterior to a conventional VHF transmitter. Both units are firmly attached to the dorsal surface at the base of the Gharial’s tail with Kevlar fishing line threaded beneath the skin and secured with metal swages (Advanced Telemetry Systems, Isanti, MN 55040, USA). left to right: Jailabdeen A, Deepu, Himani Shah and Prem Narian.

In November-December 2020, the field team caught and tagged 13 additional Gharial downstream and 13 upstream, including 8 Gharial with satellite tags. One of these was in the downstream, a female, and the remainder in the upstream, including 6 females and another “big ghara” male of 5.3 m TL (Figs. 5 and 6)



Figure 5. Nine team members work together, preparing to release a 5.3 m male Gharial after it had been tagged on the Nadigoan sandbank, near the GEP upstream base. Since 2009, an experienced group of local fishermen have worked closely with the GEP field team in 11 such capture-tag operations, culminating in another successful session in December 2020.



Figure 6. Jailabdeen A (left) points at the ghara of a 5.3 m long male Gharial during capture and radio-tagging in December 2020 at an upstream site. Additional GEP members (left to right) Himani Shah, Anand, Kishore and Prem Narian restrain the large animal prior to its release.

Altogether, as of end of March 2021, we are monitoring a total of 9 Iridium tagged Gharial, outfitted with GPS loggers. These units communicate daily location “fixes” of each animal several times a week via satellite link to the internet. A “kml” file is produced for each individual which can be visualized as map locations in Google Earth. To date, noteworthy new findings, using this methodology, have included:

1. Documentation of behavioural interactions among the multiple males resident at or near the upstream breeding groups;
2. discovery of multiple nests on an upstream tributary not previously known to be used by Chambal Gharial;
3. tracking a downstream resident female up into the mid-stretches of the NCS, where she subsequently bred and will most likely nest nearby in 2021 (Fig. 8); and,
4. recovery after 7 years, of a juvenile marked in 2013 with radio in the downstream. Now a sub-adult resident in the upstream, this female appears to have shifted its residency from downstream to upstream, over a total distance of 260 km. Such spatial findings are detailed on our Facebook page, as these seasonal movements occur.

Kuno connection. Discovery of the importance of Kuno National Park (KNP) as seasonal Gharial habitat (Fig. 7),

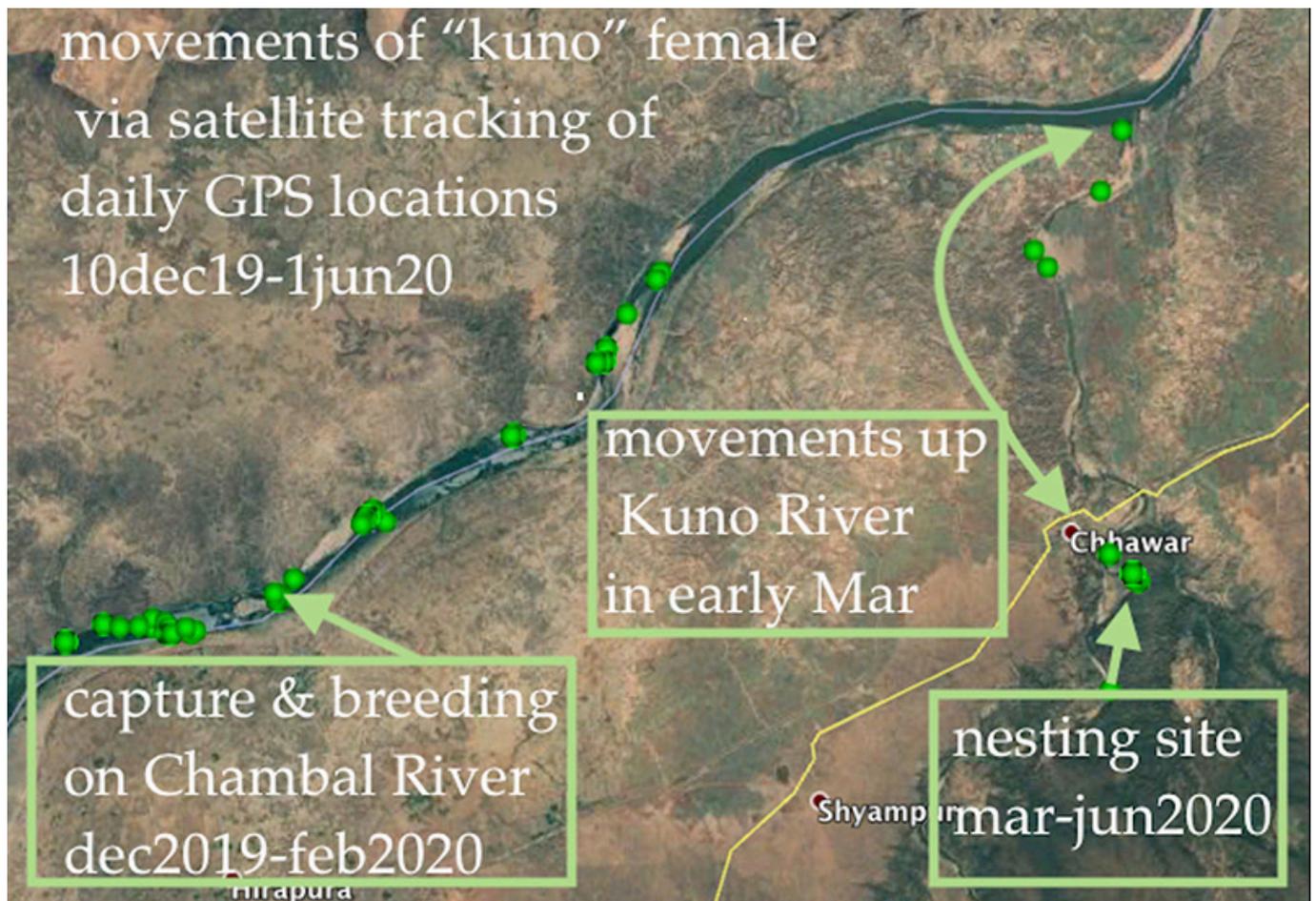


Figure 7. Satellite and radio-tracking, using frequent GPS locations acquired daily and transmitted via an Iridium link, produced “kml” files for visualization on Google Earth. Here, an adult female Gharial, tagged in the upstream Chambal near the GEP base in December 2019, moved downstream to the Kuno River, and then traveled up this tributary, where she nested in late March, along with 5 other nesting females. Following the hatch, she moved upstream in the Kuno during the monsoon, a further 40+ km.

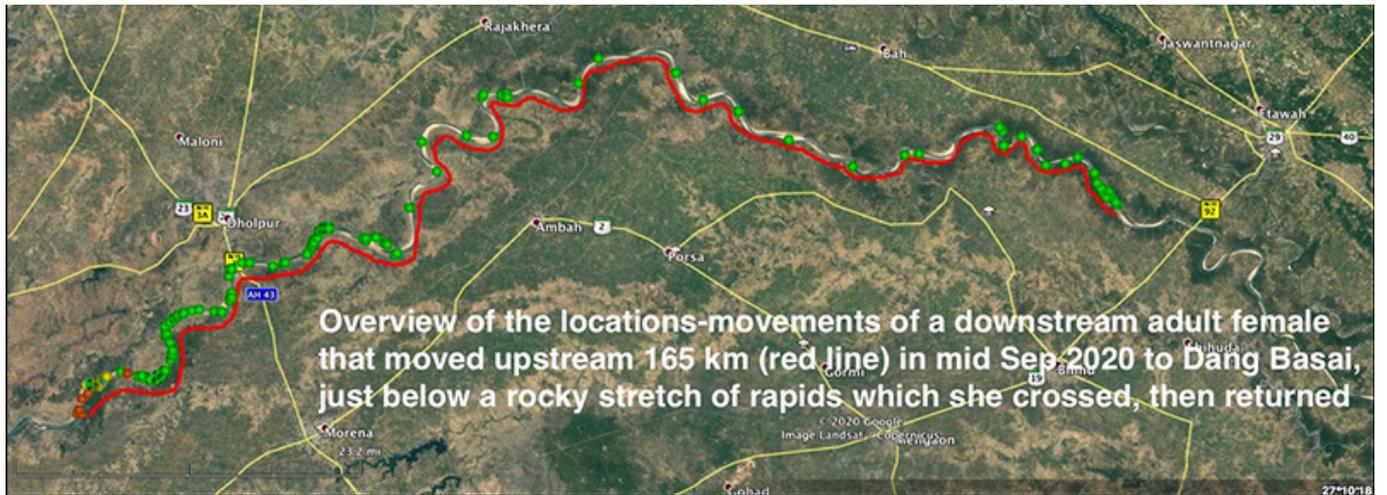


Figure 8. A downstream female Gharial, marked in November 2019, shifted upstream in 2020 after the monsoon, and joined a breeding group 170 km upstream from her earlier locations, then moved back downstream 60 km to her nesting site in 2021.

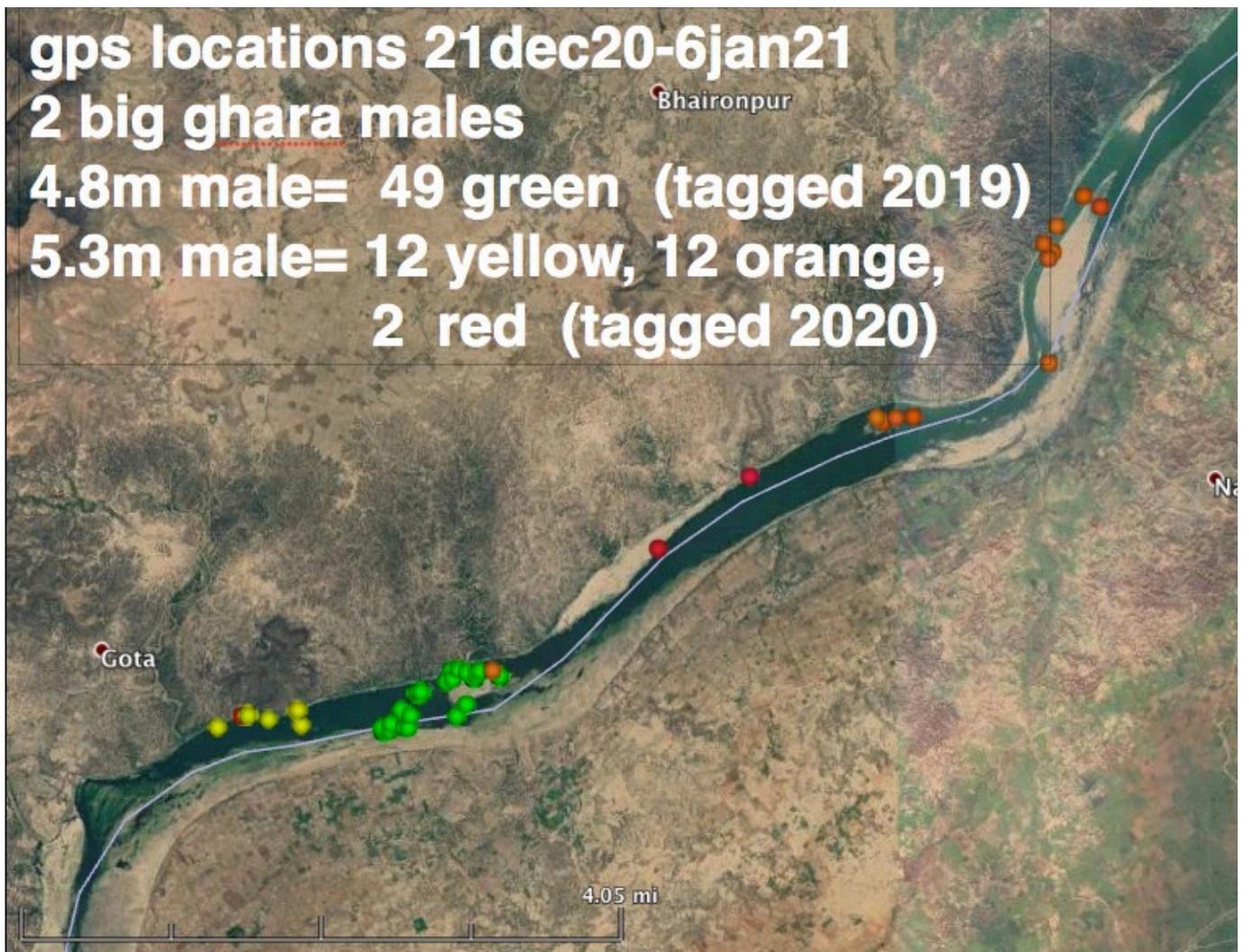


Figure 9. Spatial patterns of two “big-ghara” male Gharial residing near our upstream base on the mainstream Chambal. The smaller resident was tagged in 2019 (green dots), and he remained near his capture site throughout the year. The larger male, captured 10 km downstream in December 2020 (yellow, orange and red dots), moved upstream then back downstream near his capture site. Each of these males was the dominant breeding male in separate breeding groups located near the two locations.

through its connections with NCS, has spurred a new-found interest by the Madhya Pradesh Forest Department (MPFD) in Gharial conservation and protection in this specially designated and protected area. KNP is now being used as an

additional release site for “head-started” juvenile Gharial from the Deori EcoCentre rearing facility (Fig. 10). We have been able to partner with the MPFD, and radiotag a small cohort of these animals being released in this upstream tributary, and

in the mainstream Chambal nearby. In December 2020, we tagged 11 head-starts, 6 for release in KNP and 5 for release at the Baroli sandbank on the main Chambal. At the end of March 2021, all 11 of these juveniles are actively being tracked, with most remaining near their release sites. Also, none of the recently tagged Gharial from the mainstream Chambal have ventured into KNP for nesting this year.



Figure 10. Captive-raised Gharial is measured and radio-tagged at the Deori EcoCentre by GEP staff members Deepu (leg extended) and Jailabdeen A (back to camera), assisted by Madhya Pradesh Forest Department staff, Jyoti Prasad Dandofiya (left) and Sachin Baghel (right).

Water levels are markedly lower than in 2020, and trial nesting has not yet been observed along the Kuno River tributary this season.

Hatchling survival. Since 2018, we have been doing pilot studies with small groups of hatchlings during their first 6 months of life to get a better idea of how many of these survive as they grow, and learn more about how these young Gharial behave (Fig. 11). Small “back-pack” radios have facilitated locating tagged individuals within crèches, but so far none of these have been tracked through the actual monsoonal high water that peaks on the Chambal in mid-August. Recently, we outfitted 3-4-month-old young with backpack radios in the post-monsoon period (September-October) (Fig. 12). Survival of these young Gharial has been about 60% after 3 months, and appear to be lower than the 90% levels of survivorship we have documented for 9-12-month-old Gharials. In contrast, the first 4-6 weeks for a hatchling appear to be particularly perilous, and our observations of crèche size indicate that at least half of the crèche disappears, presumably directly through predation, before the onset of monsoonal high water.

Head-started versus wild juveniles. Starting in late 2018, we have been working in collaboration with the MPFD to track head-started 2-4-year-old juvenile Gharials, reared at the Deori EcoCentre facility (Fig. 10) near Morena in Madhya Pradesh. In comparisons of wild resident versus reared “head-starts”, matched for size/age, wild juveniles had higher rates of survival and showed well-defined and stable patterns of residence, with no residency shifts and/or long dispersals. In contrast, fewer “head-starts” survived,



Figure 11. Pankaj K. with his face masked, sits quietly at a colonial nest site on the Lower Chambal as hatching begins in late-May 2020. A large guardian male swims amongst the newly-hatched young that emerged from multiple nests on this sandbank. Craters from several opened nests are evident at the upper center and upper right of Pankaj’s position at the shoreline. Females have opened these nests, but the young have walked to the water unassisted, as evidenced by numerous small tracks to the water.



Figure 12. A 4-month-old Gharial remains motionless when approached in shallow water at night. In early October, post-monsoon, GEP trackers were able to hand capture and radiotag 14 of these young Gharial in the lower Chambal. Most of these Gharial were oblivious to close approach, while they were actively catching fish at the shoreline.

and were more likely to shift residences and/or move long distances. Furthermore, released captive-reared Gharial were more likely to be predated by sub-adult and adult Muggers, and showed atypical behaviours during the first few months following release in the wild.

Films, videos, media. The GEP has an active Facebook page, with frequent posts about recent events and activities. Selected GEP posts are now available in Hindi, and are being translated into other regional languages (eg Tamil) as well. These are freely downloadable on the GEP YouTube channel. Animal Logic produced a 7-minute video called “Boop the snoot” including GEP behavioural footage - an edited version

is on YouTube. A recent 3:30 min short on Chambal Gharial natural history appears on our Facebook and on the MCBT website, and is now available in English, Hindi, Nepali, Burmese, Sinhalese, Bengali, Malayalam, Tamil and Urdu, as well as Spanish, French, German, Czech, Norwegian, Dutch and Chinese. This video summarizes the major findings from GEP studies on the Chambal over the past decade and a half.

In April and June 2019, the GEP team worked collaboratively with “The Gaia People”, a Delhi production house, to produce an episode about Chambal Gharial natural history for the second season of “On the Brink”, an Indian TV series, co-produced by the Habitats Trust. The program is 26 minutes long, features Pankaj K. and Jailabdeen A (Fig. 13), and will be aired on Earth Day in April 2021, and throughout the Pacific Region simultaneously (<https://www.earthtouchtvsales.com/distribution/on-the-brink-season-2-gharial/>). The GEP has also been very fortunate to work closely with a talented Indian film maker, Kalyan Varma and associates, and currently is teaming up with these cinematographers to make a series of documentaries, focusing on resident Gharial in NCS.



Figure 13. On the Brink (Season 2) was filmed with our team in 2019, and features Pankaj Kumar, the main GEP field researcher and tracker. In this scene, Pankaj describes a newly constructed Gharial nest at a colonial nest site on the lower Chambal. Pankaj has worked with the GEP since its inception in March 2008.

Recent magazine articles that have featured stories about the GEP include a historical account of Gharial conservation at the MCBT by one of its founders, Zahida Whitaker (2020). In a three-part series in the Wall Street International travel magazine, Wijeyeratne (2020) highlighted findings of the telemetry tracking studies on Gharial, as well as Chambal River birds and related landscapes, and the challenges of conducting research in NCS.

Gharial elsewhere. Recent field work in Katerniaghat Wildlife Sanctuary, arguably the second most important Gharial population remaining, by Gaurav Vashistha and his colleagues has documented the tenuous nature of continued nesting by Gharial there (Vashistha *et al.* 2021a,b). In short, increased vegetation on riverside sandbanks has limited nesting opportunities in recent years. He relates the change to

a channel shift, resulting in less seasonal monsoonal flooding. To solve the problem, vegetation removal was attempted but proved largely unsuccessful, whereas sand addition to create new sandbanks resulted in increased nesting. Long-term prospects for Gharials living in such river-reservoir settings is not favourable, due to the unidirectional movements imposed by reservoir dams. At Katerniaghat, as well as at Corbett Tiger Reserve, juvenile recruitment remains the unresolved threat to the long-term sustainability of both “pocket” populations. On a brighter note, Gharial studies in Nepal have now documented a sixth breeding population for Gharial globally, with the discovery of nesting on the Babai River, on a protected stretch within the Bardiya National Park (Bashyal *et al.* 2021).

Future prospects. Hopefully, as Covid restrictions are relaxed, international travel will resume between India and the rest of the world, and our regular seasonal exchanges will be possible. In the interim, the GEP field team, headed by Jailabdeen A and Pankaj K., will continue to conduct field studies in both the upstream and downstream stretches of NCS, and develop strong ties with our upstream partners such as TigerWatch, based in Rajasthan.

Our focus in the near-term will be to document Gharial life history patterns of those residing in the upstream Chambal, for possible comparisons with our prior observations in the downstream Chambal, during the past decade.

We are extraordinarily fortunate to have the continued support of the City of Prague/Prague Zoo and the generous contributions of donors to CrocFest through the Gladys Porter Zoo. The Summer CrocFest (late June 2021) at Zoo Tampa promises to support the Gharial Ecology Project, and we gratefully acknowledge the invaluable support received to date, literally making Gharial conservation on the Chambal a reality.



Figure 14. In October 2020, a capacity building day-long program was presented at Pali by Dr. Ashutosh Tripathi and Dr. Hari Mohan Meena, GEP Outreach staff, for Rajasthan Forest Department staff, both frontline and higher officials working in the upstream section of the National Chambal Sanctuary.



Figure 15. As part of the GEP awareness programs, youngsters assume animal roles (eg Gharial, turtle, skimmers), and the roles of riverfolk (eg shepherd and net fishermen). Skits are presented about animal-people interactions on the Chambal River, such as hunting, net fishing, sand mining and riverside cultivation.



Figure 16. Village children at a community program organized by the GEP examine an awareness poster as part of the outreach meeting held at the confluence of the Yamuna and Chambal Rivers.

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## Pakistan

HABITAT DESTRUCTION AT SINDH SANTUARY THREATENS PAKISTAN'S MARSH CROCODILES. Habitat destruction at Deh Akro-II Desert Wildlife Sanctuary in Sindh Province, is threatening Pakistan's population of Mugger crocodiles (*Crocodylus palustris*), and officials and environmental experts are calling on authorities to implement conservation programs and ensure a steady supply of water to wetlands that are key to the survival of the species.

Declared a wildlife sanctuary by the Pakistan Government in 1988, and covering over 205 km<sup>2</sup>, the Deh Akro-II Desert Wildlife Sanctuary is a unique example of a desert wetland ecosystem that hosts a variety of rare and endangered wildlife species, including waterfowl, fish, otters and crocodiles. The sanctuary wetlands have been traditionally recharged through seepage of water from the Indus River-fed Nara Canal and rainwater - sources that are fast vanishing.

However, destruction and degradation of the wetland habitat due to unsustainable use and over-exploitation of natural resources by local communities, and water scarcity, are the major threats to the area according to the Global Nature Fund. In 1988 there were 45 wetlands, but today there are 32 - of which only 8 are active. The sanctuary is the largest for *C. palustris* in Pakistan, and the concerns are that continued shrinkage in area of habitat will lead to disappearance of the species in 8-10 years.

In the early 2000s, the Pakistani population of *C. palustris* was estimated to comprise about 600 individuals. A report from the University of Sindh stated that the population in the sanctuary has declined from around 2000 two decades ago, to 189 in 2012. The species is already extinct in Punjab Province.

## **East and Southeast Asia**

### **China**

CONTINUED REINTRODUCTION OF CAPTIVE-BRED CHINESE ALLIGATORS IN ANHUI NATIONAL CHINESE ALLIGATOR RESERVE, ANHUI PROVINCE, CHINA. The Chinese Alligator (*Alligator sinensis*) is regarded as the most critically endangered crocodylian in the world (Xing 2010). According to the latest survey conducted by the Anhui National Chinese Alligator Reserve (ANCAR) and Anhui Normal University, in 2018 there were fewer than 300 Chinese alligators surviving in the wild, and these occur in small populations at widely scattered locations. Sites occupied by wild Chinese alligators are typically small patches of marginal habitat embedded within an agricultural landscape (Thorbjarnarson and Wang 1999; Thorbjarnarson *et al.* 2002). Agricultural lands surrounding occupied habitats effectively isolate these populations, blocking dispersal, and precluding inter-population genetic exchange (Thorbjarnarson and Wang 2010). Moreover, the limited areal extent of occupied habitats prevents any significant increase in the size of wild alligator populations (Thorbjarnarson and Wang 2010).

In contrast to the tenuous conservation status of wild populations, *ex-situ* propagation has proven remarkably successful and thousands of Chinese alligators [28,000 in 2016 (Manolis *et al.* 2016)] are maintained in captivity in China, mainly at two government-operated conservation breeding centres (Thorbjarnarson and Wang 2010; Platt 2012; Manolis *et al.* 2016). An action plan prepared in 2001 strongly recommended that new wild populations be established by releasing captive-bred alligators into suitable, but currently unoccupied habitat (Jiang *et al.* 2006; Thorbjarnarson and Wang 2010). The Chinese alligator is an excellent candidate for reintroduction because wild populations are near extinction, alligators reproduce readily in captivity, and a burgeoning pool of captive animals is available for release (Thorbjarnarson and Wang 2010). Reintroduction of the Chinese alligator was accorded high priority by the Crocodile Specialist Group (Xing 2010) and forms the cornerstone of the conservation vision outlined by Thorbjarnarson and Wang (2010), which calls for establishing a network of relatively small wild populations managed together with the much larger captive population as a single “conservation metapopulation”. According to Thorbjarnarson and Wang (2010), the future of the Chinese alligator cannot be considered secure until at least 2500 free-living adults are established in the wild.

In accordance with recommendations of the action plan (Xing 2010), reintroductions of captive-bred alligators have been undertaken at three sites in ANCAR, one of which is Gaojingmiao Forest Reserve (GFR) in Langxi County of Anhui Province (Thorbjarnarson and Wang 2010; Wang *et*

*al.* 2011; Lu *et al.* 2014). GFR is characterized by low hills and undulating terrain largely devoted to the commercial production of pine trees and various hardwoods, and extensive agroforestry and tea plantations (Platt 2012). Initially, 500 ha of the forest reserve were set aside for alligator conservation and approximately 100 ponds, each about 1 ha with an island for nesting, were constructed within this area (Fig. 1).



Figure 1. Aerial view of Gaojingmiao Forest Reserve, showing man-made ponds for Chinese alligators set amidst tree plantations and patches of natural forest. Most ponds are inhabited by at least one reproductive female alligator.

Beginning in 2006, small numbers of captive-bred adult alligators from the Anhui Research Center for Chinese Alligator Reproduction (ARCCAR) were released into these ponds each year. By late 2018, 96 (1M:3F) adult alligators had been released into GFR. Most importantly, 8 nests (containing 158 eggs), and 80 hatchlings have subsequently been found in the ponds, indicating the reintroduced alligators are successfully reproducing in the wild.

Given the apparent success of these initial reintroduction efforts, officials from the Anhui Forestry Bureau (AFB) and ANCAR recognized that additional habitat was needed to accommodate the rapidly increasing alligator population at GFR. To this end, officials proposed to expand the existing alligator conservation area by acquiring an additional 100 ha of land from local farmers. This tract is now under a long-term (30 year) lease by GFR and consists of approximately 50 ha of abandoned rice fields and scattered woodlots, and an equal area of small ponds formerly used as irrigation reservoirs (Fig. 2). As an agricultural landscape, the tract required extensive modification to restore wetland habitats suitable for alligators. The AFB and ANCAR then invited Huangshan University and Wildlife Conservation Society-China Program to assist with developing a management plan and participate as a partner in this ongoing restoration effort.

Together with our government partners, we conducted an initial site visit to the proposed extension of GFR in November 2017. During our visit we found an alligator nest mound among bamboo and herbaceous vegetation adjacent to one of the existing irrigation reservoirs (Fig. 3). Eight eggshells were scattered about the mound, suggesting that hatchlings had successfully emerged from the nest. Based on the physical condition of the mound and eggshells, the nest appeared <6-months-old, and almost certainly was constructed during

the 2017 nesting season (June-August). The significance of our finding is that: 1) free-ranging alligators are dispersing from wetlands in GFR to adjacent lands; and, 2) at least one female alligator and her brood are probably already present in the proposed extension of the conservation area.



Figure 2. One of many abandoned rice fields (top) and irrigation reservoirs (bottom) on a 100-ha tract of farmland now leased from farmers by the Gaojingmiao Forest Reserve and incorporated into the existing Chinese Alligator Conservation Area.



Figure 3. Old alligator nest mound with 8 eggshells located in November 2017, beside an irrigation reservoir during an inspection of the tract acquired by GFR. It was most likely from the 2017 (June-August) season.

Habitat restoration within the newly acquired tract began in early 2018 and is to be conducted in successive stages during

the coming years. As part of the restoration process, wetlands are created by converting fallow rice fields into ponds of varying sizes (Fig. 4). Most ponds contain small islands, which appear to be the preferred nesting habitat of both wild and captive alligators (Thorbjarnarson and Wang 2010; Platt *et al.* 2016).



Figure 4. Abandoned rice fields are being converted to small ponds, revegetated and stocked with small prey. Note the small island in the newly constructed pond that will provide a secure nesting site for reintroduced female Chinese alligators.

After a pond is excavated, the banks and island are planted with vegetation to provide alligators with dense cover for concealment and nesting. Each pond is then “seeded” with several hundred kilograms of fish fingerlings, clams, snails, and crayfish as a first step towards establishing a diverse prey base for the reintroduced alligators. During the winter of 2018-19, the most recently excavated ponds were filled with water in the wake of abnormally heavy rainfall. Pond construction continued throughout 2019, only to be suspended when COVID-related health concerns became paramount as the pandemic emerged in early 2020. To date, more than 20 ha of wetlands suitable for alligators have been restored in the new conservation area of GFR.

In May 2019, health assessments of captive-bred alligators were carried out by veterinarians at ARCCAR. Health assessments are strongly recommended by the IUCN-SSC Reintroduction Specialist Group (IUCN 2013) prior to wildlife translocations, to: 1) ensure that only those individuals most likely to survive the rigors of reintroduction are selected for release; and, 2) reduce the likelihood of transferring infectious pathogens from captive to wild populations. Upon completion of the health assessments, 20 adult, captive-bred alligators were released into restored wetlands (20 ha) in the GRF extension (1 alligator/ha) on 3 June 2019 (Fig. 5). This initial release was followed shortly thereafter by the liberation of an additional 100 adult alligators into the same wetlands, increasing the density to 6 alligators/ha. Because VHF-transmitters were attached to few of the reintroduced alligators, post-release monitoring has proven difficult. However, the available data suggest that most of the released alligators remain alive, although many emigrated out of the restored wetlands and took up residence in long-established ponds elsewhere in GFR.

Additional alligator nests were found by GFR staff in 2019, but whether or not these were produced by the newly translocated alligators is uncertain. We attribute the emigration of most of the released alligators to a combination of two factors: 1) agonistic social interactions exacerbated by over-crowding in the limited area of habitat; and, 2) lack of an established resource base in the newly created wetlands.



Figure 5. Twenty captive-bred adult alligators were released in the newly constructed wetlands at GFR on 3 June 2020. This was followed by a second release of 100 captive-bred alligators later that month.

A follow-up survey planned for the spring of 2020 was cancelled owing to COVID-related restrictions, however, surveys might become possible in the coming year if the pandemic wanes in the face of widespread vaccination. In light of the uncertainty surrounding the emigration of alligators reintroduced into GFR, we recommend a temporary suspension of further releases in the newly restored wetlands until such time as a rigorous monitoring program can be designed and implemented.

#### Acknowledgements

We are indebted to the partnership and support provided by the Anhui Forestry Bureau, Anhui National Chinese Alligator Reserve, and Anqing Forestry Bureau. Funding for this project was provided by Ocean Park Conservation Foundation, Hong Kong. Comments by Thomas Rainwater and Lewis Medlock improved an early draft of this manuscript. We dedicate our efforts to the memory of Dr. John Thorbjarnarson (1957-2010). It remains our sincere hope that we can one day fulfill the conservation vision articulated by John and Dr. Wang Xiaoming and restore viable wild populations of Chinese alligators.

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## Recent Publications

Blackburn, D.G. and Stewart, J.R. (2021). Morphological research on amniote eggs and embryos: An introduction and historical retrospective. *Journal of Morphology* (<https://doi.org/10.1002/jmor.21320>).

**Abstract:** Evolution of the terrestrial egg of amniotes (reptiles, birds, and mammals) is often considered to be one of the most significant events in vertebrate history. Presence of an eggshell, fetal membranes, and a sizeable yolk allowed this egg to develop on land and hatch out well-developed, terrestrial offspring. For centuries, morphologically-based studies have provided valuable information about the eggs of amniotes and the embryos that develop from them. This review explores the history of such investigations, as a contribution to this special issue of *Journal of Morphology*, titled *Developmental Morphology and Evolution of Amniote Eggs and Embryos*. Anatomically-based investigations are surveyed from the ancient Greeks through the Scientific Revolution, followed by the 19th and early 20th centuries, with a focus on major findings of historical figures who have contributed significantly to our knowledge. Recent research on various aspects of amniote eggs is summarized, including gastrulation, egg shape and eggshell morphology, eggs of Mesozoic dinosaurs, sauropsid yolk sacs, squamate placentation, embryogenesis, and the phylotypic phase of embryonic development. As documented in this review, studies on amniote eggs and embryos have relied heavily on morphological approaches in order to answer functional and evolutionary questions.

Siroski, P.A. and Moleón, M.S.B. (2020). Review of the recent knowledge on the crocodylian immune system. *South American Journal of Herpetology* 18(1): 68-77.

**Abstract:** Despite the key position of reptiles in evolutionary history, reptilian immune responses have received relatively little attention. Like all jawed vertebrates, reptiles possess both an innate and adaptive immune system to recognize unknown foreign substances. Although diverse immunological mechanisms have been discovered, they seem not to be adequate to avoid the invasion of some microorganisms and stop some infections. All species of crocodylians show well-defined social behaviors, and hierarchical dominance attitudes can be observed in both males and females. This behavior generates conflicts that are expressed through aggression and combat with serious health consequences. These animals have evolved a very active immune mechanisms and components that provides a fast and effective line of defense. Science has focused on those mechanisms and components because crocodylians are an especially interesting group on which to perform evolutionary studies because they are one of the surviving archosaurs, which represents an important link within “higher” vertebrates. Based on those background, they are being observed and evaluated for their potential application in domestic and wild species. These findings will not only generate an increasing value as a therapeutic resource but also to the ecosystem, and to decode biological processes that could lead to phylogenetic (ancestral) cognition. In this review, many components of the crocodylian immune system are described that could lead to a more thorough understanding of how these animals select the most appropriate response to environmental challenges and antigen exposure and identify networks to study and interesting opportunities to the experts in the field.

Salazar-Pammo, A.C., Achá, D. and Miranda-Chumacero, G. (2021). Preferential liver accumulation of mercury explains low concentrations in muscle of *Caiman yacare* (Alligatoridae) in Upper Amazon. *Bulletin of Environmental Contamination and Toxicology*

(<https://doi.org/10.1007/s00128-020-03081-8>).

**Abstract:** *Caiman yacare* is considered one of the top predators in the Amazon basin, and understanding pollutant distribution within its tissues may help its sustainable management. As a top predator, *C. yacare* should have the highest mercury concentrations, but has lower Hg concentrations than carnivorous fish (Rivera *et al.* 2016), which are part of their diet. We compared total Hg among liver, kidney, fat, and muscle of *C. yacare*, and whether trends in the distribution of Hg among tissues were like other crocodylians, aquatic birds, omnivorous, and carnivorous fish. Fat had the lowest concentrations ( $0.025 \pm 0.03$  mg kg<sup>-1</sup>) followed by muscle ( $0.15 \pm 0.06$  mg kg<sup>-1</sup>), kidney ( $0.57 \pm 0.30$  mg kg<sup>-1</sup>) and liver ( $1.81 \pm 0.80$  mg kg<sup>-1</sup>). Such preferential accumulation makes *C. yacare* meat a safer alternative for human consumption than carnivorous fish. The relation between Hg accumulation in liver and muscle is highest in crocodylians, which has evolutive and environmental implications.

Aguilar-Olguin, S., Rivera-Rodriguez, M.C., Hernandez-Hurtado, H. and Ramirez-Martinez, M.M. (2021). Local knowledge on *Crocodylus acutus* (Reptilia: Crocodylia) in coastal zone of Colima, Mexico. *Caldasia* 43(1).

**Abstract:** Colima’s coastal zone local knowledge about crocodiles was studied utilizing semi-structured interviews. These interviews were divided into five sections: biological knowledge of the species, human-crocodile interaction, attacks by crocodiles, exploitation, as well as general perception. Information was analyzed using each section’s answers percentage. Thirty interviews were done, of which 25 participants were men and five were women. 40% of all participants were dedicated to fishing activities, 34% to touristic services, 10% trading, 7% mechanical workshop workers, 3% to fish farming, 3% were ranchers and 3% elementary school teachers. Although total participants know the crocodiles less than 50% have a biological knowledge of the species. Interest in utilizing the species as a tourist attractive by the locals was shown, which would help promote crocodile conservation in the area, and though participants’ opinion is positive, a sense of resource appropriation was not detected. We propose capacitation and awareness to groups that works or live around of the lagoons to establishing integrational conservation plans and management processes that help to conservation of crocodiles in the area.

Stockdale, M.T. and Benton, M.J. (2021). Environmental drivers of body size evolution in crocodile-line archosaurs. *Communications Biology* 4(1):38 (doi: [10.1038/s42003-020-01561-5](https://doi.org/10.1038/s42003-020-01561-5)).

**Abstract:** Ever since Darwin, biologists have debated the relative roles of external and internal drivers of large-scale evolution. The distributions and ecology of living crocodylians are controlled by environmental factors such as temperature. Crocodylians have a rich history, including amphibious, marine and terrestrial forms spanning the past 247 Myr. It is uncertain whether their evolution has been driven by extrinsic factors, such as climate change and mass extinctions, or intrinsic factors like sexual selection and competition. Using a new phylogeny of crocodylians and their relatives, we model evolutionary rates using phylogenetic comparative methods. We find that body size evolution follows a punctuated, variable rate model of evolution, consistent with environmental drivers of evolution, with periods of stability interrupted by periods of change. Regression analyses show warmer environmental temperatures are associated with high evolutionary rates and large body sizes. We confirm that environmental factors played a significant role in the evolution of crocodiles.

Brien, M., Taplin, L., Talmage, R., Booth, S., Bignell, C., Beri, P., Freeman, P. and Joyce, M. (2021). The suitability of digital video surveillance and multi-beam sonar to monitor Saltwater crocodiles. *Acoustics Australia* (<https://doi.org/10.1007/s40857-020-00216-z>).

**Abstract:** Despite intensive management, the increasing conflict between humans and saltwater crocodiles in places such as Queensland, Australia, has led to the investigation of alternative techniques to improve public safety. The reliability of digital video surveillance systems (DV) placed above water and multi-beam sonar (sonar) placed under water to detect and monitor saltwater crocodiles was tested in a seminatural freshwater environment over a 2 h period (1600-1800 h). A total of 29 crocodiles were detected within the study area using DV, and 28 with sonar. One was obscured by a section of bank, and thus not visible on sonar. Of the 28 crocodiles detected by both methods, sonar recorded both entry and exit for all, while DV recorded both entry and exit for 15 crocodiles. The length of time that crocodiles were detected was longer on average for sonar (4 min 27 s) compared with DV (2 min 50 s). This reflected the time spent above (detected by sonar and DV) or below water (not detected by DV), as only sonar was able to detect crocodiles underwater. The use of sonar may provide a valuable management tool for detecting and monitoring saltwater crocodiles in areas frequented by people (eg beaches, boat ramps, upper freshwater areas) where there is a high chance of a negative interaction.

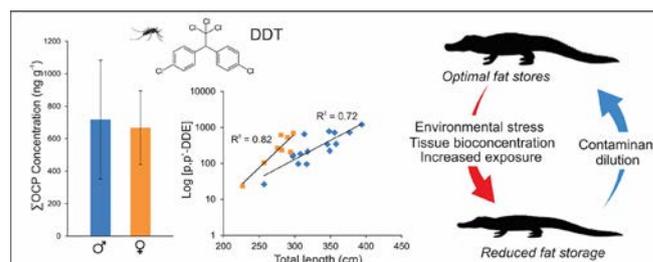
Flores-Escalona, C.I., Charruau, P., López-Luna, M.A., Zenteno-Ruiz, C.E., Rangel-Mendoza, J.A. and Peralta-Carreta, C. (2021). Population status and habitat preference of *Crocodylus moreletii* Duméril & Bibron, 1851 (Crocodylia: Crocodylidae) within the limits of two protected natural areas in southeastern Mexico. *Herpetology Notes* 14: 55-62.

**Abstract:** Morelet's crocodile (*Crocodylus moreletii*) has recovered from past overexploitation but it is necessary to continue monitoring its status in the context of the sustainable harvest (ranching) planned for the species in Mexico. We obtained new information on the population status of *C. moreletii* at the boundaries of two protected natural areas in southeastern Mexico that serve as the basis for long-term monitoring. From September 2014-March 2018 we carried out nocturnal sampling and captured crocodiles along four selected routes representing different water body types. For each crocodile observed we collected information on the localization, environment and the individual. We observed a mean of  $0.8 \pm 0.3$  crocodiles/km, with significant differences detected among routes. We captured 54 crocodiles (sex ratio: 1.7M: 1F). Except for subadults, crocodiles were more frequently associated with medium flooded forest than with other types of vegetation. Adults were observed at deeper sites than other age classes. Observation sites of yearlings have higher salinity than those of neonates, juveniles, and adults. The results show a dynamic population with all size classes in a suitable habitat for its growth.

Humphries, M.S., Myburgh, J.G., Campbell, R., Buah-Kwofie, A. and Combrink, X. (2021). 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* 753 (<https://doi.org/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.



Pooley, S., Bhatia, S. and Vasava, A. (2020). Rethinking the study of human-wildlife coexistence. *Conservation Biology* (<https://doi.org/10.1111/cobi.13653>)

**Abstract:** Although coexistence with wildlife is a key goal of conservation, little is known about it or how to study it. By coexistence we mean a sustainable though dynamic state in which humans and wildlife coadapt to sharing landscapes, where human interactions with wildlife are effectively governed to ensure wildlife populations persist in socially legitimate ways that ensure tolerable risk levels. Problems that arise from current conflict-oriented framing of human-wildlife interactions include reinforcing a human-nature dichotomy as fundamentally oppositional, suggesting coexistence requires the absence of conflict, and skewing research and management toward direct negative impacts over indirect impacts and positive aspects of living with wildlife. Human behavior toward wildlife is framed as rational calculus of costs and benefits, sidelining emotional and cultural dimensions of these interactions. Coexistence is less studied due to unfamiliarity with relevant methodologies, including qualitative methods, self-reflexivity and ethical rigor, and constraints on funding and time. These challenges are illustrated with examples from fieldwork in India and Africa. We recommend a basic approach to case studies aimed at expanding the scope of inquiries into human-wildlife relations beyond studies of rational behavior and quantification of costs and benefits of wildlife to humans.

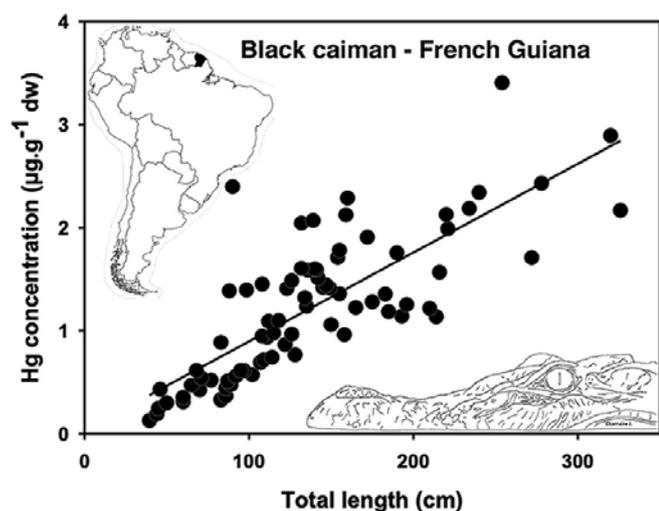
Rehman, M.N.U., Wang, Y., Pan, J., Han, Y., Yang, N., Wang, X., Fan, L., Yin, F., Wang, P., Zeng, W., Zheng, T., Zeng, J., Guo, G. and Zheng, J. (2021). Histological and molecular characterization of *Edwardsiella tarda* infection in Siamese crocodile (*Crocodylus siamensis*) hatchlings. *Aquaculture* (<https://doi.org/10.1016/j.aquaculture.2021.736367>).

**Abstract:** *Edwardsiellosis* is an important bacterial disease of fish, birds, reptiles and mammals. This study was conducted to describe the histopathology and etiology of the disease caused by *Edwardsiella tarda* in farmed hatchling Siamese crocodiles (*Crocodylus siamensis*) in Hainan, China. The main macroscopic lesions were congestion and hemorrhage of various internal organs, pericardial fluid and subcutaneous edema. Main histopathological lesions included necrotic hepatitis, hemorrhagic necrotizing nephritis, fibrinous pneumonia, and necrotic splenitis. *E. tarda* isolates

were isolated from blood and various internal organs. Genotyping showed that isolates were positive for 8 of 10 investigated virulence genes (80%) and 11 of 20 antibiotic-resistance genes (55%), which were largely correlated phenotypically, except for erythromycin resistance. Moreover, tetracycline resistance genes were detected after two years of oxytetracycline use on the farm, but only tetA-harboring strains yielded high resistance. All isolates formed biofilm that increased under low concentration tetracycline stress. Zebrafish experimental infections revealed that all isolates were virulent, and that the most virulent isolate formed the highest amount of biofilm, rather than harboring the highest number of virulence and resistance genes. This study is the first to demonstrate the histopathology of edwardsiellosis among hatchling Siamese crocodiles, and characterize virulence factors and tetracycline resistance in *E. tarda* isolates from a farm that employed long-term prophylactic use of oxytetracycline. Biofilm was suggested as a key virulent factor in the pathogenesis of *E. tarda*.

Lemaire, J., Bustamante, P., Marquis, O., Caut, S. and Brischox, F. (2021). Influence of sex, size and trophic level on blood Hg concentrations in Black caiman, *Melanosuchus niger* (Spix, 1825) in French Guiana. *Chemosphere* 262 (<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 ( $\delta^{13}\text{C}$ ) and nitrogen ( $\delta^{15}\text{N}$ ) 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  $\mu\text{g g}^{-1}\text{ dw}$  (mean  $\pm$  SD is  $1.284 \pm 0.672 \mu\text{g g}^{-1}\text{ dw}$ ) and was positively correlated to individual body size and trophic position ( $\delta^{15}\text{N}$ ). 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 as a major source of Hg variation and further suggest that it is essential to take trophic position ( $\delta^{15}\text{N}$ ) into account for future studies.



Mendyk, R.W. (2020). Heists, hoisters and herpetofauna: safeguarding zoological collections from thievery. *Der Zoologische Garten N.F.* 88: 91-111.

**Abstract:** As one of their many core responsibilities, zoological parks are entrusted with safeguarding their animal collections from a range of hazards and threats. Many zoos and related facilities have experienced thefts of collection animals over the past century, with reptiles and amphibians ranking among the most targeted animal groups. This article discusses general trends in reptile and amphibian thefts from zoos and related facilities and provides an historical overview of noteworthy thefts from these institutions dating back to the late 19th Century, with a particular focus on some of the more brazen and outlandish incidents primarily in English-speaking countries. Based on this review, I conclude with a discussion of how zoological parks can improve upon how they display and safeguard their herpetological collections from theft.

Whitfort, A. (2021). COVID-19 and wildlife farming in China: Legislating to protect wild animal health and welfare in the wake of a global pandemic. *Journal of Environmental Law* (<https://doi.org/10.1093/jel/eqaa030>).

**Abstract:** Coronavirus disease 2019 (COVID-19) has exposed serious deficiencies in the current legal framework to protect wild animal health, and consequently human health. As noted by the World Organisation for Animal Health (OIE), animal health and welfare are inextricably linked. However, there is no international agreement to promote animal welfare and neither the Convention on International Trade in Endangered Species of Wild Fauna and Flora nor the Convention on Biological Diversity, adequately address the welfare of the species they seek to conserve. While the OIE provides guidance on animal health and welfare standards for common agricultural species, it has provided limited guidance for the farming of wild species. China's wildlife farming industry has been linked with the spread of COVID-19 but, to date, China has introduced few national welfare controls to protect the health of wild animals bred for human consumption. In the wake of COVID-19, these omissions must be remedied to provide appropriate safeguards to ensure animal health and welfare and protect public health.

Sellés, A.G., Blanco, A., Vila, B., Marmi, J., López-Soriano, F.J., Llacer, S., Frigola, J., Canals, M. and Galobart, A. (2021). Author Correction: A small Cretaceous crocodyliform in a dinosaur nesting ground and the origin of sebecids. *Scientific Reports* 11: 1172.

Correction to: *Scientific Reports* (<https://doi.org/10.1038/s41598-020-71975-y>), published online 17 September 2020

Sellés *et al.* (2020), which was published electronically, does not include evidence of registration in ZooBank within the work itself, as required by Article 8.5.3 of the International Code of Zoological Nomenclature<sup>1</sup>. Therefore, the newly proposed genus-group name *Ogresuchus* and species-group name *Ogresuchus furatus* are not available from that work. This issue is addressed with this Correction.

Delfino, M., Luján, A.H., Abella, J., Alba, D.M., Böhme, M., Pérez-Ramos, A., Tschopp, E., Morales, J. and Montoya, P. (2021). Late Miocene remains from Venta del Moro (Iberian Peninsula) provide further insights on the dispersal of crocodiles across the late Miocene Tethys. *Journal of Paleontology* 95(1): 184-192.

**Abstract:** The dispersal of *Crocodylus* from Africa to Europe during the Miocene is not well understood. A small collection of cranial fragments and postcranial elements from the latest Miocene (6.2 Ma) site of Venta del Moro (Valencia, Spain) have previously been referred to *Crocodylus* cf. *C. checchiai* Maccagno, 1947 without accompanying descriptions. Here we describe and figure for the first time the crocodylian remains from Venta del Moro, which represent at least two individuals. Our comparisons indicate that this material clearly does not belong to *Diplocynodon* or *Tomistoma* - the only two other crocodylians described so far for the European late

Miocene. The material is only tentatively referred to cf. *Crocodylus* sp. because the apomorphies of this genus are not preserved and a referral to *C. checchiai* cannot be supported on a morphological basis. However, it is likely that this late Miocene species, originally described from Libya (As Sahabi) and later identified also in Kenya, could have dispersed across the Mediterranean Basin multiple times and colonized the southern areas of Mediterranean Europe, as evidenced by several *Crocodylus* or *Crocodylus*-like remains described during the past years.

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Reber, S.A., Oh, J., Janisch, J., Stevenson, C., Foggett, S. and Wilkinson, A. (2021). Early life differences in behavioral predispositions in two Alligatoridae species. *Animal Cognition* (doi: [10.1007/s10071-020-01461-5](https://doi.org/10.1007/s10071-020-01461-5)).

**Abstract:** Behavioral predispositions are innate tendencies of animals to behave in a given way without the input of learning. They increase survival chances and, due to environmental and ecological challenges, may vary substantially even between closely related taxa. These differences are likely to be especially pronounced in long-lived species like crocodylians. This order is particularly relevant for comparative cognition due to its phylogenetic proximity to birds. Here we compared early life behavioral predispositions in two Alligatoridae species. We exposed American alligator and spectacled caiman hatchlings to three different novel situations: a novel object, a novel environment that was open and a novel environment with a shelter. This was then repeated a week later. During exposure to the novel environments, alligators moved around more and explored a larger range of the arena than the caimans. When exposed to the novel object, the alligators reduced the mean distance to the novel object in the second phase, while the caimans further increased it, indicating diametrically opposite ontogenetic development in behavioral predispositions. Although all crocodylian hatchlings face comparable challenges, eg high predation pressure, the effectiveness of parental protection might explain the observed pattern. American alligators are apex predators capable of protecting their offspring against most dangers, whereas adult spectacled caimans are frequently predated themselves. Their distancing behavior might be related to increased predator avoidance and also explain the success of invasive spectacled caimans in the natural habitats of other crocodylians.

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Gabel, W., Frederick, P. and Zabala, J. (2021). Alligator presence influences colony site selection of long-legged wading birds through large scale facilitative nest protector relationship. *Scientific Reports* 11(1): 1019 (doi: [10.1038/s41598-020-80185-5](https://doi.org/10.1038/s41598-020-80185-5)).

**Abstract:** Positive ecological relationships, such as facilitation, are an important force in community organization. The effects of facilitative relationships can be strong enough to cause changes in the distributions of species and in many cases have evolved as a response to predation pressure, however, very little is known about this potential trend in vertebrate facilitative relationships. Predation is an important selective pressure that may strongly influence breeding site selection by nesting birds. The American Alligator (*Alligator mississippiensis*) facilitates a safer nesting location for wading birds (Ciconiiformes and Pelecaniformes) by deterring mammalian nest predators from breeding sites. However, alligators do not occur throughout the breeding range of most wading birds, and it is unclear whether alligator presence affects colony site selection. We predicted that nesting wading birds change colony site preferences when alligators are not present to serve as nest protectors. Within the northern fringe of alligator distribution we compared colony characteristics in locations where alligator presence was either likely or unlikely while controlling for availability of habitat. Wading birds preferred islands that were farther from the mainland and farther from landmasses >5 ha when alligator presence was unlikely compared to when alligators were likely. These findings indicate that wading birds are seeking nesting locations that are less accessible to mammalian predators when alligators are not present,

and that this requirement is relaxed when alligators are present. This study illustrates how a landscape-scale difference between realized and fundamental niche can result from a facilitative relationship in vertebrates.

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Cossette, A.P. (2021). A new species of *Bottosaurus* (Alligatoroidea: Caimaninae) from the Black Peaks Formation (Palaeocene) of Texas indicates an early radiation of North American caimanines. *Zoological Journal of the Linnean Society* 191(1): 276-301.

**Abstract:** Morphological and molecular data suggest a close relationship for alligators and caimans. The first fossil appearances combined with phylogenetic hypotheses suggest a divergence of the groups near the Cretaceous-Palaeogene boundary, but the early fossil record of Caimaninae is incomplete, and large gaps exist between the earliest representatives of the group. A new caimanine from lower Palaeocene (Tiffanian) deposits in the Black Peaks Formation of Brewster County, Texas is established upon two specimens of different size that bear similarities to *Bottosaurus harlani* from the uppermost Cretaceous and lowermost Palaeogene of New Jersey. The larger individual consists of a partial skull and lower jaw in addition to postcranial material. The smaller individual preserves a snout and posterior portions of the skull. Both specimens suggest an animal with a comparatively short, flat, broad snout. Species of *Bottosaurus* share diagnostic morphological character states but are differentiated in meaningful ways. Phylogenetic analysis shows that the new species is sister to *B. harlani*, indicates an early radiation of North American caimanines and elucidates a more complicated biogeographical history than previously hypothesized. A growing body of evidence suggests that Caimaninae may be diagnosed by ancestral characters, potentially drawing basal alligatoroids crownwards in phylogenetic trees.

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Zhang, X., Armani, A., Giusti, A., Wen, J., Fan, S. and Ying, X. (2021). Molecular authentication of crocodile dried food products (meat and feet) and skin sold on the Chinese market: Implication for the European market in the light of the new legislation on reptile meat. *Food Control* 124 (<https://doi.org/10.1016/j.foodcont.2021.107884>).

**Abstract:** A molecular approach (DNA barcoding and phylogenetic analysis) using mitochondrial COI and 16SrRNA genes was used to identify species in crocodile dried food products (meat and feet) and skin sold on the Chinese market and generically labelled as 鳄鱼 (crocodiles). All the 80 collected samples (100%) were identified at species level and five of them were also identified at sub-species level using the COI gene. Limits of the DNA barcoding approach related to the presence of sequences from misidentified specimens on official genetic databases (Genbank and BOLD) were encountered. The only DNA barcoding method was successfully applied for the species identification of 47 (58.7%) samples (42 using the COI and 5 using the 16SrRNA) while the support of the phylogenetic analysis was considered in 7 (8.7%) samples (performed using the 16SrRNA gene). For the remaining 26 samples (43.3%) the species identification was only achieved by phylogenetic analysis using the COI gene. Three species were overall detected: *Crocodylus siamensis* (n= 44; 55%), *C. porosus* (n= 29; 36.2%) and *Caiman crocodilus* (n= 7; 8.7%) with the sub-species *C. crocodilus crocodilus* in 5 out of the 7 cases. Although the traceability system of these products in China presented evident shortcomings, outcomes from this study appeared comforting since all the three species are among the most reared for meat production and can plausibly feed the market requests. Interestingly, only one of these species is included among those considered by the new EU legislation on reptile meat. Therefore, although Chinese crocodylian-based products are still not allowed to be imported in the EU market, a future law up-dating could not be excluded considering the relevance of the Chinese exports for the EU. Outcomes from this study, other than allowing to monitor products through the whole food value chain, contribute to enrich the scientific pool of data from which EU food imports legislation draw upon.

Capshaw, G., Willis, K.L., Han, D. and Bierman, H.S. (2021). Reptile sound production and perception. Pp. 101-118 (Chapter 7) in *Neuroendocrine Regulation of Animal Vocalization: Mechanisms and Anthropogenic Factors in Animal Communication*, ed. by C.S. Rosenfeld and F. Hoffmann. Elsevier.

**Abstract:** Although comprising a paraphyletic assemblage, tuatara, turtles, snakes, lizards, and crocodylians are colloquially grouped as reptiles. These groups all have at least some auditory capabilities but generally do not have very complex vocalizations. Most commonly, the sounds produced by reptiles are associated with defensive or aggressive behavior. Crocodylians and some lizards are the exception, using vocal communication to mediate group cohesion, parental care, courtship, and territoriality. Because of the diversity of acoustic signals and the variety of habitats in which these animals live, coupled with the relatively limited body of literature on reptile bioacoustics, reptiles represent a compelling subject for future studies on the evolution of vocalization.

Stocker, M.R., Brochu, C.A. and Kirk, E.C. (2021). A new caimanine alligatorid from the Middle Eocene of Southwest Texas and implications for spatial and temporal shifts in Paleogene crocodyliform diversity. *PeerJ* 9: e10665.

**Abstract:** Dramatic early Cenozoic climatic shifts resulted in faunal reorganization on a global scale. Among vertebrates, multiple groups of mammals (eg adapiform and omomyiform primates, mesonychids, taeniodonts, dichobunid artiodactyls) are well known from the Western Interior of North America in the warm, greenhouse conditions of the early Eocene, but a dramatic drop in the diversity of these groups, along with the introduction of more dry-tolerant taxa, occurred near the Eocene-Oligocene boundary. Crocodyliforms underwent a striking loss of diversity at this time as well. Pre-Uintan crocodyliform assemblages in the central Western Interior are characterized by multiple taxa, whereas Chadronian assemblages are depauperate with only *Alligator prenasalis* previously known. Crocodyliform diversity through the intervening Uintan and Duchesnean is not well understood. The middle Eocene Devil's Graveyard Formation (DGF) of southwest Texas provides new data from southern latitudes during that crucial period. A new specimen from the middle member of the DGF (late Uintan-Duchesnean) is the most complete cranial material of an alligatorid known from Paleogene deposits outside the Western Interior. We identify this specimen as a caimanine based on notched descending laminae of the pterygoids posterior to the choanae and long descending processes of the exoccipitals that are in contact with the basioccipital tubera. Unlike *Eocaiman cavernensis*, the anterior palatine process is rounded rather than quadrangular. The relationships and age of this new taxon support the hypothesis that the modern distribution of caimanines represents a contraction of a more expansive early Cenozoic distribution. We hypothesize that the range of caimanines tracked shifting warm, humid climatic conditions that contracted latitudinally toward the hothouse-icehouse transition later in the Eocene.

LaVere, A.A., Hamlin, H.J., Lowers, R.H., Parrott, B.B. and Ezenwa, V.O. (2021). Associations between testosterone and immune activity in alligators depend on bacteria species and temperature. *Functional Ecology* (<https://doi.org/10.1111/1365-2435.13756>).

**Abstract:** The immunocompetence handicap hypothesis (ICHH) postulates that testosterone supports the development of secondary sexual traits while simultaneously suppressing immune function, creating a trade-off between trait quality and pathogen vulnerability. The nature of interactions between testosterone and immunity are complex. Conflicting patterns from the literature suggest that testosterone-immunity relationships are variable across immune measures and may be modified by factors both intrinsic and extrinsic to the organism. In this study, we tested the ICHH in free-ranging American alligators (*Alligator mississippiensis*) and examined how

both intrinsic (steroid hormone levels) and extrinsic (temperature) factors modulate the relationship between testosterone and immunity. Specifically, we quantified the simultaneous effects of testosterone and dehydroepiandrosterone (DHEA) on microbial killing capacity of three bacteria species (*Escherichia coli*, *Salmonella typhimurium*, and *Klebsiella pneumoniae*) at two challenge temperatures (15°C and 30°C). We found that accounting for circulating levels of DHEA was important for predicting testosterone-mediated effects on microbial killing capacity. We also found that testosterone-mediated immunosuppression was dependent on temperature and bacteria species, with negative effects of testosterone present only for *S. typhimurium* at 15°C. Our results highlight the context dependency of interactions between testosterone and immunity, and illustrate the importance of evaluating the ICHH in natural systems to identify key intrinsic and extrinsic factors mediating testosterone-immunity trade-offs.

Padial, A.A., Lula Costa, A.P., Costa Bonecker, C., Gomes Nogueira, D., de Oliveira Roque, F., Message, H.J., Pereira Diniz, L., Lopes Cavalcante, L., Villegas Vallejos, M.A., Rúbia Ota, R. and Veiga Ludwig, T.A. (2021). Freshwater studies in the Atlantic Forest: General overview and prospects. Pp. 205-230 in *The Atlantic Forest*, ed. by M.C.M. Marques and C.E.V. Grelle. Springer: Cham.

**Abstract:** In this chapter, we reviewed the main studies on freshwater ecosystems of the Atlantic Forest, Brazil. We have firstly provided a list of the hydrographic basins that cross the Atlantic Forest and propose a classification of Atlantic Forest freshwaters based on a proposed wetland classification for Brazil. Anthropogenic disturbances and freshwater changes were discussed. We then made a panorama of studies on the main aquatic communities in the Atlantic Forest, ranging from vertebrates to microalgae. It is clear that basic research is still needed for many biological groups, although recent studies on aquatic biota deserve attention considering their theoretical advances in ecology. Common to studies on all biological groups are the concerns of anthropogenic actions, ranging from habitat alteration due to impoundments to water pollution, over- and illegal exploitation of vertebrates, and massive biological invasions. For many groups, such concerns are reflected in extinction risks of endemic species and biotic homogenization. We present prospects for future studies and urge for greater attention to preserve integrity of freshwaters in the Atlantic Forest.

Podani, J., Kalapos, T., Barta, B. and Schmera, D. (2021). Principal component analysis of incomplete data - a simple solution to an old problem. *Ecological Informatics* (<https://doi.org/10.1016/j.ecoinf.2021.101235>).

**Abstract:** A long-standing problem in biological data analysis is the unintentional absence of values for some observations or variables, preventing the use of standard multivariate exploratory methods, such as principal component analysis (PCA). Solutions include deleting parts of the data by which information is lost, data imputation, which is always arbitrary, and restriction of the analysis to either the variables or observations, thereby losing the advantages of biplot diagrams. We describe a minor modification of eigenanalysis-based PCA in which correlations or covariances are calculated using different numbers of observations for each pair of variables, and the resulting eigenvalues and eigenvectors are used to calculate component scores such that missing values are skipped. This procedure avoids artificial data imputation, exhausts all information from the data and allows the preparation of biplots for the simultaneous display of the ordination of variables and observations. The use of the modified PCA, called InDaPCA (PCA for Incomplete Data) is demonstrated on actual biological examples: leaf functional traits of plants, functional traits of invertebrates, cranial morphometry of crocodiles and fish hybridization data - with biologically meaningful results. Our study suggests that it is not the percentage of missing entries in the data matrix that matters; the success of InDaPCA is mostly affected by the minimum number of

observations available for comparing a given pair of variables. In the present study, interpretation of results in the space of the first two components was not hindered, however.

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Gonçalves, G.L., Medina, D.S., Grondona, K.E.B., Santos, A.L.Q. and Mahecha, G.A.B. (2021). Topographic relationships of the peritoneal canal of Testudines, Crocodylia, and Aves: Evolutionary implications. *South American Journal of Herpetology* 19(1): 54-75.

**Abstract:** Cloacae and peritoneal canals of species of Testudines, Crocodylia, and Aves were analyzed with the purpose of identifying and describing their morphology and investigating their possible relationship with other cloacal structures. Studies were conducted from dissections and routine histological preparations. The cloaca is located in the pelvic cavity and differs between Testudines and Crocodylia. In the former, the cloaca is divided into three compartments - the coprodeum, urodeum, and proctodeum - without folds separating them. In contrast, in Crocodylia the coprodeum, urodeum, and proctodeum are separated by discrete folds, the coprourodeal and uroproctodeal folds. The visceral layer of the peritoneum forms the peritoneal canal and also differs in Testudines and Crocodylia. In the former, the cranial opening of the peritoneal canal is lateral to the urogenital sinus and the canal is caudally projected into the phallus, laterally followed by the ejaculatory groove until the caudal end of the organ. In Crocodylia, the cranial opening of the peritoneal canal is lateral to the coprodeum and the canal extends caudally until reaching a papilla in the body of the phallus, where it terminates. Histologically, the mesothelium of the peritoneal canal has a simple pavement appearance. In Testudines, regions with a simple cubic epithelium were found, indicating intense cell activity. The lamina propria is characterized by a thickening of the connective tissue, moderately dense with a variable thickness and with a layer of bundles of smooth muscle arranged in different directions. In *Caiman yacare*, bundles of striated skeletal muscles were found on the loose connective tissue that involves the peritoneal canal. The cloacal and peritoneal fluids have a strong protein similarity. The peritoneal canal reflects functional characteristics related to reproduction. No peritoneal canals were found in birds.

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Marschang, R.E., Bogan, J., Pollock, C. and Gandar, F. (2021). What's new in the scientific literature? Infectious diseases of reptiles: Peer-reviewed publications, January-June 2020. *Journal of Herpetological Medicine and Surgery* 30(4): 185-193.

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Pooley, S., Siroski, P.A., Fernandez, L.F., Sideleau, B. and Ponce-Campos, P. (2021). Human-crocodilian interactions in Latin America and the Caribbean region. *Conservation Science and Practice* 2021: e351.

**Abstract:** Mitigating harmful interactions with wildlife requires an understanding of the interactions between predators, domesticated animals and humans. Large-scale transformations of crocodilian habitats across the Latin America and Caribbean region, alongside significant use of crocodilians as a resource, and retaliatory killing of crocodilians following (or to prevent) attacks on humans and their animals, are generating significant conservation challenges. This matters because this is the world's most biodiverse region for crocodilians. Because there is little information on specific situations across this vast and complex region, in 2018 we initiated a biannual questionnaire survey to establish a reporting network. In this article, we summarize the findings of surveys conducted in 2018 and 2020. We triangulate this feedback with croc attack data, and consultation with regional experts, to produce this very preliminary overview. We identify trends in negative human-crocodilian interactions at country level, the most reported causes of these, and identify the key species and regions of concern. We surveyed attitudes to management policies and responses to negative interactions including direct action and outreach activities. We acknowledge (and clarify) knowledge gaps, and motivate for improved regional cooperation

with regard to policies and management (notably monitoring and evaluation) and data collection and sharing.

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Rozada, L., Allain, R., Vullo, R., Goedert, J., Augier, D., Jean, A., Marchal, J., Peyre de Fabrègues, C., Qvarnström, M. and Royo-Torres, R. (2021). A Lower Cretaceous Lagerstätte from France: A taphonomic overview of the Angeac-Charente vertebrate assemblage. *Lethaia* (<https://doi.org/10.1111/let.12394>).

**Abstract:** Terrestrial ecosystems from the Lower Cretaceous of Europe and bonebeds formed in swampy environments are poorly known. The Berriasian-early Valanginian Angeac-Charente site in France represents an example of both. Nine field campaigns have yielded thousands of fossils of over a hundred taxa, including 16 taxa from vertebrate macroremains with numerous trample and crocodile bite marks; 22 taxa from the abundant vertebrate microremains; >10 vertebrate coprolite morphotypes with plant and vertebrate inclusions; abundant sauropod and stegosaur tracks including some preserved in '4-D'; termite coprolites; mollusc moulds; ostracods and plants, including coniferous wood, cones, leaves and cuticle fragments, charophytes and pollen. The richness, diversity and preservation of the fossils qualify the site as a *fossil-Lagerstätte*. The site represents a 'snapshot' into a Lower Cretaceous ecosystem. This is supported by REE analyses of biogenic apatite and sediment samples, the fossils being found in a single stratigraphical interval and the record of sedimentological and taphonomic 'frozen scenes'. The Angeac-Charente bonebed is highly diverse, dominated by an ornithomimosaur taxon, and contains both macro- and microfossils. This indicates a complex formation, likely primarily influenced by ecological and biologic processes, but also significant physical processes. These include crocodyliform predation and/or scavenging on turtles, ornithomimosaur and fishes; probable mass mortality occurrence of an ornithomimosaur herd; possible social behaviour of stegosaurs; limited hydraulic transport of most sauropod bones and intense dinoturbation.

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Schmidt, E., Kulendran, K., Green, D. and Chong, H.I. (2021). Penetrating skull injuries from a crocodile bite: General surgery in Far North Queensland. *ANZ Journal of Surgery* ([doi: 10.1111/ans.16607](https://doi.org/10.1111/ans.16607)).

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Visaya, V. Jr. (2021). Typhoons, floods linked to drop in crocodile population in Isabela. *Philippine Daily Inquirer*, 8 January 2021, p. A8.

**Excerpt:** The typhoons and floods that hit Isabela Province late last year might have caused the population of crocodiles in four sanctuaries to dwindle, a conservation group said on Wednesday. Marites Balbas, executive officer of Mabuwaya Foundation Inc., said only 10 of the 32 crocodiles recorded in these sites last September were sighted by December. "We received no records of crocodile killing in 2020, so we hoped and presumed that some might have been staying in safe areas, like creeks and lakes," she told the Inquirer.

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Hoffmann-Sommergruber, K. (2021). Rare food allergens. *Allergologie Select* 5: 29-32.

**Abstract:** In food allergy, only a restricted number of protein families have been identified to contain allergenic proteins. These can be further grouped into major allergens, responsible for inducing allergic reactions in the majority of patients allergic to the food source, as compared to minor allergens only affecting a small number of food allergic patients. In addition, rare allergens have only been described for single cases so far. Rare allergens can derive from novel foods, including exotic varieties and foods not yet frequently consumed in certain regions. Also, new or modified processing strategies could induce a higher allergenicity in certain

dietary proteins. And finally, low abundance and/or low allergenic activity may also account for some rare allergens. For allergenic risk assessment, cross-reactivity of novel allergens with already known allergens is in place and facilitates the identification of potential new allergens, while *de novo* sensitization to yet undefined allergens can only be described retrospectively. This review presents some examples of recently identified rare allergens.

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Velit, A., Elías Piperis, R., Montes Iturrizaga, D. and Saldarriaga, F. (2020). Valores hematológicos de cocodrilo de Tumbes *Crocodylus acutus* (Cuvier, 1807) mantenidos en cautiverio en Puerto Pizarro, Tumbes, Perú. *Salud y Tecnología Veterinaria* 8(2): 35-39.

**Abstract:** The objective was to determine the hematological values of the Tumbes crocodile (*Crocodylus acutus*), a species categorized as in critical endangered of extinction by the Peruvian Government. Blood samples were collected by puncture of the venous sinus located in the postoccipital cervical region of male individuals separated into two age groups (15 juveniles and 15 sub-adult individuals) apparently healthy from the Tuna Carranza Aquaculture Center, Puerto Pizarro in Tumbes, Peru. After collecting the blood in tubes with lithium heparin, hemogram smears were made and microcapillaries were filled for the determination of hematocrit. The samples were sent and processed in the Laboratory of Clinical Pathology of the Faculty of Veterinary Medicine and Zootechnics of the Universidad Peruana Cayetano Heredia. The average values found were: 23.56%  $\pm$  3.23 of hematocrit, 8.48 g/dL  $\pm$  2.13 of hemoglobine, 0.988  $10^6/\mu\text{L}$   $\pm$  4.54 of red blood cells y 5.90  $\pm$  4.27  $10^3/\mu\text{L}$  of white blood cells: 2.68  $10^3/\mu\text{L}$   $\pm$  1.51 of heterophils, 1.58  $10^3/\mu\text{L}$   $\pm$  1.4 of lymphocytes, 2.35  $10^3/\mu\text{L}$   $\pm$  2.4 of eosinophils, 1.45  $10^3/\mu\text{L}$   $\pm$  1.71 of basophils and 0.50  $10^3/\mu\text{L}$   $\pm$  0.85 of monocytes. No statistically significant differences were observed between age groups

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Abellán, N., Jiménez-García, B., Aznarte, J., Baquedano, E. and Domínguez-Rodrigo, M. (2021). Deep learning classification of tooth scores made by different carnivores: achieving high accuracy when comparing African carnivore taxa and testing the hominin shift in the balance of power. *Archaeological and Anthropological Sciences* 13(31).

**Abstract:** The balance of power (that is the dominance on the predation arena between carnivore competitors and hominins) remains controversial. One reflection of this is the carnivore modification of hominin bones. During human evolution, hominins were first prey and then predators of other animals, including carnivores. Modifications reported on some hominin bones could result from primary predators feeding on them or post-depositional modifications by scavengers. Determining carnivore agency would be crucial to interpret such information. Here, a series of computer vision models based on convolutional neural networks is presented, comparing five different types of carnivores jointly and then pairwise. It is shown how such models contain different heuristics regarding specific carnivore taxa, which regarding tooth marks made by lions and spotted hyenas can be accurately classified by as much as 92% of the testing set. The present study also shows the potential of transfer knowledge in building accurate classification of images and for taphonomic interpretation. The application to tooth marking on a 500 ka hominin femoral shaft indicates that by that time, carnivore modifications of human remains may have resulted from post-depositional scavenging rather than by predation.

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Herndon, C., Astley, H.C., Owerkowicz, T. and Fenton, F.H. (2021). Defibrillate you later, alligator; Q10 scaling and refractoriness keeps alligators from fibrillation. *Integrative Organismal Biology* (<https://doi.org/10.1093/iob/obaa047>).

**Abstract:** Effective cardiac contraction during each heartbeat relies on the coordination of an electrical wave of excitation

propagating across the heart. Dynamically induced heterogeneous wave propagation may fracture and initiate reentry-based cardiac arrhythmias, during which fast rotating electrical waves lead to repeated self-excitation that compromises cardiac function and potentially results in sudden cardiac death. Species which function effectively over a large range of heart temperatures must balance the many interacting, temperature-sensitive biochemical processes to maintain normal wave propagation at all temperatures. To investigate how these species avoid dangerous states across temperatures, we optically mapped the electrical activity across the surfaces of alligator (*Alligator mississippiensis*) hearts at 23°C and 38°C over a range of physiological heart rates and compare them with that of rabbits (*Oryctolagus cuniculus*). We find that unlike rabbits, alligators show minimal changes in wave parameters (action potential duration and conduction velocity) which complement each other to retain similar electrophysiological wavelengths across temperatures and pacing frequencies. The cardiac electrophysiology of rabbits accommodates the high heart rates necessary to sustain an active and endothermic metabolism at the cost of increased risk of cardiac arrhythmia and critical vulnerability to temperature changes, whereas that of alligators allows for effective function over a range of heart temperatures without risk of cardiac electrical arrhythmias such as fibrillation, but is restricted to low heart rates.

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Ekpraeng, J. and Chavolit, A. (2020). An analytical study of costs and returns of crocodile farming to increase efficiency production: A case study of Yang Sisu. *Journal of Liberal Arts and Management Science* Kasetsart University 7(2): 88-97.

**Abstract:** This research aimed to study on the costs and returns of the crocodile farming. This was the comparison study between costs and returns from the crocodile farming in Yang-Srisurach district, Mahasarakram province. The study group was the three pond crocodile farming agriculturalists in Yang-Srisurach district, Mahasarakram province. The researcher adopted the interview questions to collect the data and conducted data analysis via descriptive statistics and financial tools for the estimation of returns which were the Payback period and returns of investment. It was found that the capital and costs of single pond crocodile farming consisted of the cost of crocodile pond construction, cost of equipment purchasing and cost of crocodile farming implementation. It took three years to get incomes and returns. If conducting the analysis on the payback period from the single pond crocodile farming during B.E. 2012 until 2014, the payback period was 4 months and 4 days; while from B.E. 2017 until 2017, the payback period would be 2 months and 2 days. The ratio from the returns of investment was in the level that can be invested with the return rate from the high investment during B.E. 2012 to B.E. 2014 that lower than B.E. 2015 to B.E. 2017. Thus, this was since the higher amount of investment for 2,507,500 baht accounted to be the returns from investment at 225.24 percent. During B.E. 2015 to B.E. 2017, the amount of investment was at 1,810,700 baht or being accounted for 367.10% from the return of investment.

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Rivera, B.I. (2020). Difference in Heavy Metal Concentrations in the American Crocodile (*Crocodylus acutus*) in National Park Coiba Island and the Montijo Gulf, Panama. MSc thesis, Texas Tech University, Texas, USA.

**Abstract:** Environmental sources for possible metal contamination could be from: industry, agriculture, pharmaceutical, and mining smelters, among others. Heavy metals produced as a result of these processes become bioavailable and can have toxic effects on organisms when they surpass Threshold Limit Values. Therefore, is important to establish a direct connection of these disruptive contaminants in marine coastal environments and their impacts on ecosystems. This relationship can be addressed using a bioindicator, such as an apex predator like the American crocodile (*Crocodylus acutus*). The objective of this project was to identify and characterize possible transition metal pollution that is affecting the area. This

study was done at two study sites in Panama, Coiba Island National Park, and the Gulf of Montijo. Data were collected for over a two-year period, the information collected included: season (rainy and dry), sex, and age group. American crocodiles were captured, and morphological measurements were taken along with scute cuttings as well as determination of both the animal's sex and habitat from which the individual was captured. Scute samples were collected and analyzed using the ICP-MS instrument to determine heavy metal concentrations. I examined heavy metal concentrations of 12 metals vanadium(V), chromium (Cr), cobalt (Co), nickel (Ni), copper (Cu), arsenic (As), selenium (Se), strontium (Sr), cadmium (Cd), tin (Sn), antimony (Sb) and lead (Pb). Significant differences were found in concentrations of several metals within study sites at both Coiba Island and The Gulf of Montijo ( $p = 0.005$ ). The included: V ( $p = 0.016$ ), Ni ( $p = 0.022$ ), Cu ( $p < 0.001$ ), and Sr ( $p = 0.044$ ). Between the study sites there were higher concentrations of metals in the Gulf of Montijo and then at the Coiba Island site. Among age groups, seven metal concentrations showed significant differences: Cr ( $p = 0.040$ ), Ni ( $p = 0.054$ ), Cu ( $p = 0.004$ ), Se ( $p = 0.054$ ), Sr ( $p = 0.003$ ), Sn ( $p = 0.003$ ) and As ( $p = 0.056$ ). In general, juveniles presented higher metal concentrations followed by sub-adult and adults. The data showed that the concentrations of Cr, Cu, As, Sr, Cd, Sn, Sb and Pb decrease with an increase in size. However, Se, Co, Ni and V showed a positive relationship between size and metal concentration. Nonetheless, the only metals that showed a significant difference in multiple linear regression were Cu ( $p = 0.001$ ) and Sr ( $p = 0.001$ ). This is the first study that uses an apex predator like the American crocodile to study heavy metal bioconcentration utilizing a non-invasive method, measuring concentrations in caudal scutes. Moreover, is important to highlight that the information gather for this project, is the first to use measurements from multiple years, age classes and different sites in Panama. This project generated a clear view of pollutants in the study area that directly affect coastal environment and health conservation strategies for the populations of *Crocodylus acutus*, and it will ultimately contribute to the development of future strategies for fisheries and other activities that affect the marine coastal environment.

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Weems, R.E., Bachman, J.M., Rayburn, W.T. and McCloud, Jr., J.R. (2021). A vertebrate ichnofauna from the Late Pleistocene (Sangamon interglacial) Tabb Formation at Stratford Hall Plantation, Westmoreland County, Virginia USA. *New Mexico Museum of Natural History and Science Bulletin* 82: 505-512.

**Abstract:** Five types of vertebrate footprints have been discovered along the estuarine Potomac River beach front at Stratford Hall Plantation, on a bedding plane that tops a clay-silt bed within the late Pleistocene (Sangamon interglacial) Tabb Formation. These ichnotaxa and their likely trackmakers are: *Crocodylopodus* isp., made by an alligator (*Alligator mississippiensis*); *Glyptodontichnus* isp., likely made by a glyptodont (*Glyptotherium floridanum*); aff. *Palaeotheripus* isp., likely made by a tapir (*Tapirus veroensis*); *Lamaichnum guanicoe*, likely made by a lamine camelid (*Palaeolam mirifica*); and *Pecoripeda* isp., likely made by an elk (*Cervus canadensis*). This is the first report of late Pleistocene vertebrate footprints in the interglacial deposits of the Atlantic Coastal Plain of the eastern United States.

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Bestwick, J., Unwin D.M., Henderson, D.M. and Purnell, M.A. (2021). Dental microwear texture analysis along reptile tooth rows: complex variation with non-dietary variables. *Royal Society Open Science* 7: 201754.

**Abstract:** Dental microwear texture analysis (DMTA) is a powerful technique for reconstructing the diets of extant and extinct taxa. Few studies have investigated intraspecific microwear differences along with tooth rows and the influence of endogenous non-dietary variables on texture characteristics. Sampling teeth that are minimally affected by non-dietary variables is vital for robust dietary reconstructions, especially for taxa with non-occlusal

(non-chewing) dentitions as no standardized sampling strategies currently exist. Here, we apply DMTA to 13 species of extant reptile (crocodilians and monitor lizards) to investigate intraspecific microwear differences along with tooth rows and to explore the influence of three non-dietary variables on exhibited differences: (i) tooth position, (ii) mechanical advantage, and (iii) tooth aspect ratio. Five species exhibited intraspecific microwear differences. In several crocodilians, the distally positioned teeth exhibited the 'roughest' textures, and texture characteristics correlated with all non-dietary variables. By contrast, the mesial teeth of the roughneck monitor (*Varanus rudicollis*) exhibited the 'roughest' textures, and texture characteristics did not correlate with aspect ratio. These results are somewhat consistent with how reptiles preferentially use their teeth during feeding. We argue that DMTA has the potential to track mechanical and behavioural differences in tooth use which should be taken into consideration in future dietary reconstructions.

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Cornejo, A., Gómez-Hernández, Y., Gómez-Álvarez, G., González-Rebeles, C., Ulloa-Arvizu, R. and Villegas, A. (2021). Percepción y conocimiento popular sobre los cocodrilos en el "Área de Protección de Flora y Fauna Manglares de Nichupté", Quintana Roo, México. *Acta Zoologica Mexicana* 37(1): 1-14.

**Abstract:** The success of crocodile conservation programs highly depends on local people's views, perceptions, and knowledge regarding these reptiles. The present study assessed these variables across the Nichupté lagoon through semi-structured interviews. Answers were grouped into three categories: thoughts regarding the presence of crocodiles in the area, locals' perception on crocodiles, and local knowledge on crocodiles. Most of the 221 people interviewed showed no aversion to crocodiles, 93.2% knew about the presence of crocodiles in the lagoon, and 98.1% mentioned that it is essential to conserve these reptiles. On the other hand, 77.5% (men) and 70.5% (women) agreed that "it is fine" to share the lagoon with crocodiles. Concerning people's perceptions about crocodiles, "Quiet", "Indispensable" and "Interesting" were the most frequent answers. Regarding the local knowledge, we found a positive, statistically significant correlation between this variable and education, with those having high school degrees mentioning "Habitat" and those with college degrees mentioning "Reptile" more frequently. Conservation policies should be redesigned to include continuous environmental education programs that promote positive attitudes towards crocodile species. They should also include measures to guarantee the dissemination of necessary information to protect human and crocodile lives, is essential to consolidate conservation programs.

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Takasaki, R. and Kobayashi, Y. (2020). Stomach histology of *Crocodylus siamensis* and *Gavialis gangeticus* reveals analogy of archosaur "gizzards", with implication on crocodylian gastroliths function. *Acta Herpetologica* 15(2): 111-118.

**Abstract:** Two groups of extant Archosauria, Crocodylia and Neornithes, have two-chambered stomachs and store gastroliths inside their "gizzards". Morphological similarities of the "gizzards" lead some previous studies to assume that the presence of this structure, organ "gizzard" is synapomorphic to Archosauria. However, the homology of archosaur "gizzards" had never been tested. This study provides general histological descriptions of stomachs of two crocodylian taxa, *Crocodylus siamensis* and *Gavialis gangeticus*, to determine the homology of crocodylian and neornithine "gizzards". Our study demonstrates that both *Crocodylus siamensis* and *Gavialis gangeticus* have longer, more complex glands in the fundic stomach (crocodylian "gizzard") than in the pyloric stomach. Additionally, we found that compound glands are present in the fundic stomach of *Crocodylus siamensis*. Therefore, crocodylian stomach histomorphological structures are concordant with those of other non-avian reptiles, despite the unique gross morphology. The pyloric regions of non-avian reptile stomachs are known to be homologous with the pyloric regions of

mammalian stomachs as well as neornithine ventriculus (neornithine gizzard). Therefore, crocodylian and neornithine “gizzards” are morphologically analogous but not homologous. The presence of PAS-positive layer in the pyloric stomach of *Gavialis gangeticus*, which resembles the koilin layer of neornithine ventriculus, further supports this interpretation. At the same time, however, the similarity in gastroliths mass/body mass ratio and the correlations between gastroliths occurrence and diet types suggest that crocodylian gastroliths might have contributed to the digestion of ingesta, even though crocodylian and neornithine “gizzards” are not homologous.

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Wu, Y., Liu, J., Zhou, L., Zeng, X., Xiao, H. and Zhao, X. (2021). Potential mechanism of different gelation properties of white and red muscle fibre from crocodile (*Crocodylus siamensis*) meat: Study of myofibrillar protein. LWT (<https://doi.org/10.1016/j.lwt.2021.111045>).

**Abstract:** The present study was performed to investigate the effects of myofibrillar proteins (MPs) extracted from crocodile (tail, legs, torso) on gel formation mechanism and gel characteristics. The results showed that protein compositions and ratios were different in the three body parts. The tail MPs had a higher surface hydrophobicity than the legs and torso MPs, while the leg MPs had more reactive sulfhydryl groups than the tail and torso MPs ( $P < 0.05$ ). According to the Raman spectroscopy results, before heating, the leg MPs'  $\beta$ -sheet content was significantly higher than that of tail MPs ( $P < 0.05$ ). Heating significantly reduced the contents of  $\alpha$ -helices between the legs and torso, and there were significant differences in  $\beta$ -sheet content between the legs and tail ( $P < 0.05$ ). Moreover, with increasing myosin content, a denser microstructure of the tail gel was observed by scanning electron microscopy, leading to its gel strength and water-holding capacity being significantly higher than those of other parts. The tail MPs revealed a higher storage modulus ( $G'$ ) and spin-spin relaxation time ( $T_{21}$ ) than those in the other two parts. In conclusion, the tail of crocodile (white muscle) has stronger protein gelation properties than other parts (red muscle), which is conducive to producing gel products.

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Manafzadeh, A.R., Kambic, R.E. and Gatesy, S.M. (2021). A new role for joint mobility in reconstructing vertebrate locomotor evolution. Proceedings of the National Academy of Science USA 118(7): e2023513118 (doi: 10.1073/pnas.2023513118).

**Abstract:** Reconstructions of movement in extinct animals are critical to our understanding of major transformations in vertebrate locomotor evolution. Estimates of joint range of motion (ROM) have long been used to exclude anatomically impossible joint poses from hypothesized gait cycles. Here we demonstrate how comparative ROM data can be harnessed in a different way to better constrain locomotor reconstructions. As a case study, we measured nearly 600,000 poses from the hindlimb joints of the Helmeted Guineafowl and American alligator, which represent an extant phylogenetic bracket for the archosaurian ancestor and its pseudosuchian (crocodylian line) and ornithodiran (bird line) descendants. We then used joint mobility mapping to search for a consistent relationship between full potential joint mobility and the subset of joint poses used during locomotion. We found that walking and running poses are predictably located within full mobility, revealing additional constraints for reconstructions of extinct archosaurs. The inferential framework that we develop here can be expanded to identify ROM-based constraints for other animals and, in turn, will help to unravel the history of vertebrate locomotor evolution.

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Deem, V.R., Letter, A.W., Woodward, A.R., Ford, R.M. and Moore, B.C. (2021). Alligators and a new record total length and weight. Southeastern Naturalist 20(1): N7-N14 (<https://doi.org/10.1656/058.020.0109>).

**Abstract:** We reviewed past accounts of large female *Alligator*

*mississippiensis* (American alligator) from throughout their range and report on 2 exceptionally large female alligators ( $\geq 320$  cm total length) harvested in Florida. Both individuals exceeded the previous record total length for a female American alligator (309.9 cm [10 ft, 2.00 in]), and the larger of the 2 now holds the Florida state record for total length and weight at 322.0 cm (10 ft, 6.75 in) and 170 kg (375 lbs), which also makes it the largest officially measured free-ranging female American alligator. Standardized morphometric measurements were taken by trained biologists, and we examined the reproductive tracts to verify the sex of the individuals. In one alligator, the reproductive tract was found to be abnormal and immature. A partial reproductive tract of the other alligator appeared normal.

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Sideleau, B., Sitorus, T., Suryana, D. and Britton, A. (2021). Saltwater crocodile (*Crocodylus porosus*) attacks in East Nusa Tenggara, Indonesia. Marine and Freshwater Research (<https://doi.org/10.1071/MF20237>).

**Abstract:** Saltwater crocodiles (*Crocodylus porosus*) are extensively distributed throughout Southeast Asia, including the Indonesian province of East Nusa Tenggara (ENT), and they account for hundreds of attacks on people annually. Recorded incidents not only tell us where crocodiles are found (useful when survey data are limited), but importantly can improve our understanding of causal factors to better address risk. We compiled public attack records for ENT on humans from 2009 to 2018 using an online database of incidents (CrocBITE), then worked closely with government representatives to visit human-crocodile conflict (HCC) hot spots, where some unreported attack records were collected, and local attitudes towards crocodiles could be assessed. Of the 100 attacks we compiled, 60% were fatal incidents. Most victims were male (84%) and most attacks (75%) occurred during fishing. West Timor had the highest proportion of attacks (70%). Cultural attitudes towards crocodiles were found to be generally positive throughout ENT, similar to neighbouring Timor-Leste, although recent media stories appear to have introduced some negative beliefs and fears. We recommend that resources and training are made available to improve local crocodile knowledge, including habitat surveys in proximity to conflict areas, plus community-based education where the risk of crocodile attack is high.

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Odetti, L.M., Paravani, E.V., Simoniello, M.F. and Poletta, G.L. (2021). Identification and evaluation of antioxidant and reference genes for quantitative real-time PCR in blood of *Caiman latirostris*. Heliyon 7(2): e06253.

**Abstract:** The quantitative real-time polymerase chain reaction (qPCR) has been one of the most promising approaches to perform rapid and accurate quantification of DNA in various biological systems. The aim of this study was to standardize the qPCR technique for the analysis of important genes involved in the main routes of antioxidant defense against reactive oxygen species (catalase: *cat* and superoxide dismutase: *sod*) and evaluate the stability of different reference genes in blood of *Caiman latirostris* hatchlings. The stability of the reference genes,  $\beta$ -actin, glyceraldehyde 3-phosphate dehydrogenase (*gapdh*) and ribosomal protein L8 (*rpl8*) was determined using the comparative  $\Delta$ Ct, NormFinder, geNorm, BestKeeper and RefFinder. Then, *cat* and *sod* genes were normalized with each reference gene and their mRNA abundances were determined through the qPCR. Stability of genes was ranked through the different methods in the following order:  $\beta$ -actin, *rpl8* and *gapdh*, under normal physiological conditions. The results reveal that *cat* and *sod* genes present a similar relative mRNA abundance with  $\beta$ -actin and *rpl8*. This is the first report of the analysis of antioxidant mRNA as potential biomarkers of oxidative stress in blood for all crocodylian species. Besides, we determined the stability of different reference genes that can be used for normalization of mRNA abundance patterns in blood of *C. latirostris*, without the need to sacrifice the animals.

Johnston, S.D., Lever, J., McLeod, R., Qualischefski, E., Madrigal-Valverde, M. and Nixon, B. (2021). Assisted breeding technology in the saltwater crocodile *Crocodylus porosus*: A review and look to the future. *Reproduction, Fertility and Development* (doi: [10.1071/RD20217](https://doi.org/10.1071/RD20217)).

**Abstract:** This review reports the current status of artificial breeding technology in the Crocodylia and the future requirements for the establishment of AI in the saltwater crocodile. Although there are challenges regarding safe restraint and immobilisation, semen collection of the saltwater crocodile by manual stimulation has proven effective in yielding sufficient volume and sperm concentrations for empirical and molecular analyses of sperm preservation and physiology. Nevertheless, there is still much to learn with respect to fundamental anatomy, physiology and behaviour in both sexes, but particularly in the female. Although lessons can be learned from successful AI in the alligator, the details of this research are not readily accessible. Future research needs to focus on the proximate factors of seasonality and the underlying control of the female's annual reproductive cycle; this will require novel and innovative ways to collect blood samples without causing stress or injury, and ideally a dedicated crocodile research breeding colony. Because the saltwater crocodile is a farmed species, there is likely to be sufficient impetus for the application of assisted breeding technology to drive future productivity in the industry. These developments will also have benefits for the genetic and reproductive management of endangered captive populations.

Paravani, E.V., Odetti, L.M., Simoniello, M.F. and Poletta, G.L. (2021). Molecular analysis and bioinformatic characterization of cooper, zinc-superoxide dismutase (Cu/Zn-sod) gene of *Caiman latirostris*. *Molecular Biology Reports* (<https://doi.org/10.1007/s11033-020-05937-y>).

**Abstract:** Superoxide dismutase (SOD) is an antioxidant enzyme that acts as a component of first-line defense system against reactive oxygen species (ROS). Copper/Zinc superoxide dismutase (Cu/Zn-SOD) is one of the isoforms of SOD enzyme and is sensitive to the exposure of different environmental factors, in different species and tissues. *Caiman latirostris* is one of the two crocodylian species living in Argentina and no information is available on the molecular and biochemical characteristics of the Cu/Zn-sod gene in this species. In the present work, we reported the presence of the Cu/Zn-sod gene in *C. latirostris*, the nucleotide and amino acid sequences, the modelled protein structure, evolutionary distance among species and tissue specific expression patterns. Cu/Zn-sod gene was 620 bp open reading frame in length and encoded 178 amino acids. The nucleotide sequences of *C. latirostris* shared high similarity with the Cu/Zn-sod genes of other crocodylian species, so it showed to be highly conserved. PCR analysis showed that Cu/Zn-sod gene was expressed in all the tissues examined (liver, gonads, spleen, heart, and whole blood), suggesting a constitutively expressed gene in these tissues. This study allows further investigation into the structure-activity relationship and the mechanism of action of Cu/Zn-SOD, besides exploring the functional breadth and possible alteration factors, including xenobiotics.

Gao, H., Lin, J., Jia, X., Zhao, Y., Wang, S., Bai, H. and Ma, Q. (2021). Real-time authentication of animal species origin of leather products using rapid evaporative ionization mass spectrometry and chemometric analysis. *Talanta* (doi: [10.1016/j.talanta.2020.122069](https://doi.org/10.1016/j.talanta.2020.122069)).

**Abstract:** Increasing accounts of fraud and persistent labeling problems have brought the authenticity of leather products into question. In this study, we developed an extremely simplified workflow for real-time, *in situ*, and unambiguous authentication of leather samples using rapid evaporative ionization mass spectrometry (REIMS) coupled with an electric soldering iron. Initially, authentic leather samples from cattle, sheep, pig, deer, ostrich, crocodile, and snake were used to create a chemometric model based on principal

component analysis and linear discriminant analysis algorithms. The validated multivariate statistical model was then used to analyze and generate live classifications of commercial leather samples. In addition to REIMS analysis, the microstructures of leathers were characterized by scanning electron microscopy to provide complementary information. The current study is expected to provide a high-throughput tool with superior efficiency and accuracy for authenticating the identity of leathers and other consumer products of biogenic origin.

Velasco, A., Hernández, O., Babarro, R. and De Sola, R. (2020). Status of the Orinoco crocodile (*Crocodylus intermedius*) in Venezuela. *Boletín de la Academia de Ciencias Físicas, Matemáticas y Naturales* 80(2): 1-17.

**Abstract:** The abundance, density, and size class structure of Orinoco crocodile are determined by means of surveys in high-priority conservation areas and in zones where its presence has been widely reported in the past. The surveys were conducted in 14 localities, some of which were divided into smaller areas (transects) resulting in 38 sublocalities. More than 1000 km of both river and creeks banks were reconnoitered. The census data reported here were taken in 512.4 km of linear habitat where 260 Orinoco crocodiles were observed. They were classified by size class as follows: 33 (Class II), 36 (Class III), 35 (Class IV), and 83 (Class V). Two important discoveries were made. One is the finding of a third reproductive population in Santa Rosa ranch located in the Wildlife Reserve Estero de Camaguán in the state of Guárico. The other is the increased number of nests in the Capanaparo River.

Rummy, P. and Rummy, J.T. (2021). Pursuing the significance of crocodile conservation in Malaysia: An illustration of scientific, sociocultural and education awareness. SSRN (<https://ssrn.com/abstract=3777891>).

**Abstract:** A fundamental scientific and sociocultural apprehension of the exact nature of crocodiles, combined with the awareness through education for these magnificent reptiles could provide a crucial opportunity to enhance the wildlife conservation efforts in Malaysia. In this review article, we emphasised that there is a necessity to safeguard wildlife, especially the estuarine crocodiles (*Crocodylus porosus*) and the Malayan gharials (*Tomistoma schlegelii*) in the local ecosystem. More so, we aim to propose sustainable protection standards for these reptiles. Hence, by integrating an interdisciplinary research collaboration concept, we reviewed selected scientific studies and cultural beliefs related to crocodylians, and examined the linguistic constructions of this species in local media genre and international documentary. Our brief discourse and stylistic analysis suggested that crocodiles are being presented negatively in written and spoken text. We solidified the level of positive sociocultural conception of crocodiles as being mediocre in the community, and the exposure to crocodylian scientific knowledge is believed to be rare as compared to other wildlife. We argue that the erosion of knowledge, understanding and awareness will have adverse impacts on conservation efforts due to the loss of deep-rooted intrinsic values for crocodiles. The discussion also highlights the need to redress existing biodiversity policies and reduce knowledge gaps by foregrounding formal biodiversity curriculum and literacy for constructive nature ownership in Malaysian schools.

Binaday, J.W.B., Manalo, R.I., Bragais, M.A., Palao, L.K.M., Mojica, L.R.P., Nicopior, O.B.S. and Baltazar, P.C. (2020). Determining habitat suitability for the identification of Priority Conservation Sites for Indo-Pacific crocodile (*Crocodylus porosus* Schneider, 1801) in the Philippines. *Philippine Journal of Science* 150(S1): 333-344.

**Abstract:** This study examined the suitability of habitat occupied by the Indo-Pacific crocodile (*Crocodylus porosus*) in the Philippines

using data on the presence of populations from 2011-2020, geospatial technologies, and species distribution models (SDM). Habitat suitability was mapped using an ensemble model based on Biomod2 package in R software. Results showed that slope, temperature, and precipitation were strong predictors of suitable habitat for Indo-Pacific crocodiles. Thirty-five percent (35%) of the total habitats (1,137,351 ha) that were considered suitable for *C. porosus* in the Philippines are currently protected under national legislation. The provinces of Palawan, Agusan Del Sur, Surigao, Ligawasan Marsh, and Sulu Archipelago contain the largest areas of suitable habitats and should be considered a priority for conservation and protection.

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Chroust, M., Mazuch, M., Ivanov, M., Ekrt, B. and Luján, A.H. (2021). First remains of *Diplocynodon* cf. *ratelii* from the early Miocene sites of Ahníkov (Most Basin, Czech Republic). *Bulletin of Geosciences* 96(2): 123-138.

**Abstract:** Fossil crocodylians from the early Miocene (Eggenburgian, MN3a) sites of Ahníkov (Most Basin, Czech Republic) are described in this paper. The new material presented here includes over 200 remains (bones, teeth and osteoderms), and therefore constitutes the largest crocodylian sample known from the fossil record of the Czech Republic. Assignment of the specimens to the fossil alligatoroid taxon *Diplocynodon* cf. *ratelii* Pomel, 1847 (family Diplocynodontidae) is justified by the presence of several cranial and postcranial features. In the Czech Republic, this species has been previously reported only from the Tušimice site (MN3, Most Basin, Ohře/Eger Graben). The majority of the material reported from Ahníkov is composed of disarticulated juvenile individuals. Both sites are most likely attributable to the specific environment of swampy areas, where crocodile hatchlings would hide from predators. The presence of the genus *Diplocynodon* supports the assumption of rather warm climatic conditions in Central Europe during the early to middle Miocene, as well as a swampy depositional environment previously inferred for Ahníkov. However, some squamate taxa suggest the existence of additional, surrounding palaeoenvironment characterised by a more open landscape with slightly drier conditions.

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Filogonio, R., Dubansky, B.D., Dubansky, B.H., Wang, T., Elsey, R.M., Leite, C.A.C. and Crossley II, D.A. (2021). Arterial wall thickening normalizes arterial wall tension with growth in American alligators, *Alligator mississippiensis*. *Journal of Comparative Physiology B* (<https://doi.org/10.1007/s00360-021-01353-1>).

**Abstract:** Arterial wall tension increases with luminal radius and arterial pressure. Hence, as body mass ( $M_b$ ) increases, associated increases in radius induces larger tension. Thus, it could be predicted that high tension would increase the potential for rupture of the arterial wall. Studies on mammals have focused on systemic arteries and have shown that arterial wall thickness increases with  $M_b$  and normalizes tension. Reptiles are good models to study scaling because some species exhibit large body size range associated with growth, thus, allowing for ontogenetic comparisons. We used post-hatch American alligators, *Alligator mississippiensis*, ranging from 0.12 to 6.80 kg (~60-fold) to investigate how both the right aortic arch (RAo) and the left pulmonary artery (LPA) change with  $M_b$ . We tested two possibilities: (i) wall thickness increases with  $M_b$  and normalizes wall tension, such that stress (stress=tension/thickness) remains unchanged; (ii) collagen content scales with  $M_b$  and increases arterial strength. We measured heart rate and systolic and mean pressures from both systemic and pulmonary circulations in anesthetized animals. Once stabilized alligators were injected with adrenaline to induce a physiologically relevant increase in pressure. Heart rate decreased and systemic pressures increased with  $M_b$ ; pulmonary pressures remained unchanged. Both the RAo and LPA were fixed under physiological hydrostatic pressures and displayed larger radius, wall tension and thickness as  $M_b$  increased, thus, stress was independent from  $M_b$ ; relative collagen content was unchanged. We conclude that increased wall thickness normalizes tension and reduces the chances of arterial walls rupturing in large alligators.

González-Desales, G.A., Tello-Sahagún, L.A., Cadena-Ramírez, C.P., López-Luna, M.A., Buenrostro-Silva, A., García-Grajales, J., González-Ramón, M.C., Morales-Mavil, J.E., Charruau, P., Sigler, P., Rubio-Delgado, A., Zarco-González, M.M. and Monroy-Vilchis, O. (2020). Egg predation and vertebrates associated with wild crocodylian nests in Mexico determined using camera-traps. *Journal of Natural History* 54(29-30): 1813-1826.

**Abstract:** Interactions between species and individuals can determine their survival in the wild. Most of the time these relationships are difficult to study *in situ* by direct observation. However, technology can help collect these data with minimal impact on animals' behaviour. Egg stage is certainly the most vulnerable life stage in crocodylians, but few studies have focused on animal species visiting crocodylian nests and associated egg predation. Herein, we use camera-traps in four Mexican states (Chiapas, Oaxaca, Jalisco, Tabasco) to determine vertebrate species and egg predators associated with wild nests of *Caiman crocodilus chiapasius*, *Crocodylus acutus* and *C. moreletii*. We recorded 72 species of vertebrates at nesting sites and obtained the first photographic evidence of crocodylian egg predation by *Caracara cheriway*, *Cuniculus paca*, *Didelphis virginiana* and *Procyon lotor*. We also identified commensalism, cooperation, and predation as types of interactions within observed nesting areas, which indicates the importance of crocodylian nesting areas for other wild vertebrates. Finally, we found that crocodylian egg predation depends on species richness present in the area of study, as well as crocodylian size.

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Vashistha, G., Mungi, N.A., Lang, J.W., Ranjan, V., Dhakate, P.M., Khudsar, F.A. and Kothamasi, D. (2021). Gharial nesting in a reservoir is limited by reduced river flow and by increased bank vegetation. *Scientific Reports* 11(1): 4805.

**Abstract:** The gharial (*Gavialis gangeticus* Gmelin) is a fish-eating specialist crocodylian, endemic to south Asia, and critically endangered in its few remaining wild localities. A secondary gharial population resides in riverine-reservoir habitat adjacent to the Nepal border, within the Katarniaghat Wildlife Sanctuary (KWS), and nests along a 10 km riverbank of the Girwa River. A natural channel shift in the mainstream Karnali River (upstream in Nepal) has reduced seasonal flow in the Girwa stretch where gharials nest, coincident with a gradual loss of nest sites, which in turn was related to an overall shift to woody vegetation at these sites. To understand how these changes in riparian vegetation on riverbanks were related to gharial nesting, we sampled vegetation at these sites from 2017 to 2019, and derived an Enhanced Vegetation Index (EVI) from LANDSAT 8 satellite data to quantify riverside vegetation from 1988 through 2019. We found that sampled sites transitioned to woody cover, the number of nesting sites declined, and the number of nests were reduced by >40%. At these sites, after the channel shift, woody vegetation replaced open sites that predominated prior to the channel shift. Our findings indicate that the lack of open riverbanks and the increase in woody vegetation at potential nesting sites threatens the reproductive success of the KWS gharial population. This population persists today in a regulated river ecosystem, and nests in an altered riparian habitat which appears to be increasingly unsuitable for the continued successful recruitment of breeding adults. This second-ranking, critically endangered remnant population may have incurred an "extinction debt" by living in a reservoir that will lead to its eventual extirpation.

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Nixon, B., Anderson, A.L., Bromfield, E.G., Martin, J.H., Cafe, S.L., Skerrett-Byrne, D.A., Dun, M.D., Eamens, A.L., De Iuliis, G.N. and Johnston, S.D. (2021). Post-testicular sperm maturation in the saltwater crocodile *Crocodylus porosus*: Assessing the temporal acquisition of sperm motility. *Reproduction, Fertility and Development* (doi: 10.1071/RD20204).

**Abstract:** Conservation efforts to secure the long-term survival of crocodylian species would benefit from the establishment of a

frozen sperm bank in concert with artificial breeding technologies to maintain genetic diversity among captive assurance populations. Working towards this goal, our research has focused on the saltwater crocodile *Crocodylus porosus* as a tractable model for understanding crocodylian sperm physiology. In extending our systematic characterisation of saltwater crocodile spermatozoa, in this study we examined the development of motility during sperm transport through the excurrent duct system of the male crocodile. The results show that approximately 20% of crocodile testicular spermatozoa are immediately motile but experience a gradient of increasing motility (percentage motile and rate of movement) as they transit the male reproductive tract (epididymis). Moreover, we confirmed that, as in ejaculated crocodile spermatozoa, increased intracellular cAMP levels promoted a significant and sustained enhancement of sperm motility regardless of whether the cells were isolated from the testis or epididymis. Along with the development of artificial reproductive technologies, this research paves the way for the opportunistic recovery, storage and potential utilisation of post-mortem spermatozoa from genetically valuable animals.

McWhorter, A., Owens, J., Valcanis, M., Olds, L., Myers, C., Smith, I., Trott, D. and McLelland, D. (2021). *In vitro* invasiveness and antimicrobial resistance of *Salmonella enterica* subspecies isolated from wild and captive reptiles. *Zoonoses Public Health* (doi:10.1111/zph.12820).

**Abstract:** Reptiles are carriers of *Salmonella* and can intermittently shed bacteria in their faeces. Contact with snakes and lizards is a source of human salmonellosis. Here, two populations of reptiles, wild and captive were surveyed for *Salmonella*. One hundred thirty wild-caught reptiles were sampled for *Salmonella* including 2 turtle, 9 snake and 31 lizard species. Fifty-two of 130 (40%) animals were *Salmonella* positive: one of 5 (20%) turtles, 7 of 14 (50%) snakes and 44 of 111 (39.6%) lizards. One hundred twenty-two reptiles were sampled from a zoo collection including 1 turtle, 6 tortoise, 9 lizard, 14 snake and 1 crocodile species. Forty-two of 122 (34.4%) captive reptiles sampled were *Salmonella* positive. *Salmonella* was most commonly isolated from lizards and snakes. Fifteen serotypes were identified from zoo and 19 from wild-caught reptiles and most were members of subspecies *enterica* (I), *salamae* (II), *arizonae* (IIIa) or *diarizonae* (IIIb). Antimicrobial susceptibility testing was conducted on all *Salmonella* isolates; only two exhibited resistance, a *Salmonella* subsp. (II) ser. 21:z10 :z6 (Wandsbek) isolate cultured from a wild-caught reptile and a *Salmonella typhimurium* DT120 isolated from a captive snake. The invasive capacity of reptile-associated *Salmonella* strains into cultured human intestinal epithelial (Caco2) and mouse macrophages cell lines (J774A.1) was also investigated. All isolates were invasive into both cell lines. Significant ( $P \leq 0.001$ ) variability in invasiveness into polarized Caco2 cells was observed. *Salmonella eastbourne* exhibited the highest invasiveness into Caco2 cells and *Salmonella chester* the lowest, with mean per cent recoveries of  $19.99 \pm 0.32$  and  $1.23 \pm 0.30$ , respectively. Invasion into J774A.1 macrophages was also variable but was not significant. *Salmonella* subsp. II ser. 17:g,t:- (bleadon) exhibited the highest invasiveness into J774A.1 with a mean per cent recovery of  $10.19 \pm 0.19$ . Thus, reptile-associated *Salmonellae* are likely to have different capacities to cause disease in humans.

Zhang, X., Li, Y., Wu, X., Song, Y., Luan, F., Xue, X. and Jin, Z. (2021). Multi-isotope analysis on the Yangtze Alligator osteoderm unearthed from Yellow River Valley during the Longshan Period. *Acta Anthropologica Sinica* 40(1): 75-86.

**Abstract:** Chinese alligators (*Alligator sinensis*) nowadays inhabit the downstream Yangtze River, but the alligator remains were found at several archaeological sites in Yellow river region during the Longshan period (5000~4000 BP cal). To determine whether these Yangtze alligators were indigenous or were part of long-distance trading from Yellow river region, we conducted Sr, C and O isotopic

analysis of seven alligator osteoderms samples from Qingliangsi, Dinggong and Yinjiacheng sites dating from the Late Longshan Period. The  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios of these alligator osteoderms in three sites fall into the local bioavailable  $^{87}\text{Sr}/^{86}\text{Sr}$  ranges, and the  $\delta^{18}\text{O}$  ratio of Shandong samples was higher than Shanxi samples, which was consistent with the trend of  $\delta^{18}\text{O}$  increasing from the inland to coastal, indicating that these remains are mainly indigenous. The  $\delta^{13}\text{C}$  of Chinese alligator osteoderm were significantly higher than the rest of the world's inland freshwater systems crocodile, showing complex diet characteristics. The result of isotopes that is better to understand the geographical distribution change of Yangtze alligators in different periods, which is of great significance for reconstructing the paleo-environment of North China more than 4000 years ago. It also raised new questions about the relationship between the ancestors of Longshan and the Chinese alligator.

Spennemann, D.H.R. (2020). Cruising the currents: Observations of extra-limital saltwater crocodiles (*Crocodylus porosus* Schneider, 1801) in the Pacific region. *Pacific Science* 74(3): 211-227.

**Abstract:** Saltwater crocodiles (*Crocodylus porosus*) are known to leave their home range and to visit and eventually colonize offshore islands. Being good swimmers, coupled with an ability to go for a prolonged period without food, allows saltwater crocodiles to cover long open water voyages of 2000 km and more. Drawing on modern observations, historic data, and oral traditions, this paper compiles and critically examines all available evidence for vagrant crocodiles in the Pacific Ocean area. The modes of dispersal, as well as potential dispersal success, are discussed.

Saragih, G.S., Kayat, Hidayatullah, M. and Hadi, D.S. (2021). A preliminary study on the population and habitat of saltwater crocodile (*Crocodylus porosus*) in Timor Island, East Nusa Tenggara. In Proceedings of the the 7th Symposium of JAPAN-ASEAN Science Technology Innovation Platform (JASTIP). IOP Conf. Series: Earth and Environmental Science (doi:10.1088/1755-1315/591/1/012044).

**Abstract:** The information on the population size and habitat condition of the Saltwater crocodile (*Crocodylus porosus*) in East Nusa Tenggara is unavailable. The present paper discusses preliminary data on population and habitat characteristics of the Saltwater crocodile in three conservation areas in Timor island, namely Teluk Kupang Marine Nature Tourism Park, Menipo Nature Tourism Park, and Maubesi Mangrove Forest Nature Reserve. Spotlight surveys and vegetation analyses were carried out in each location. The crocodile encounter rate was calculated as individuals detected per km surveyed. The encounter rates in Teluk Kupang, Menipo, and Maubesi were 0.3 crocodiles/km, 0.4 crocodiles/km, and 0.6 crocodiles/km, respectively. Hatchlings, juveniles, and adult saltwater crocodiles were found in Maubesi, and only hatchlings were found in Menipo. Hatchlings were found in paddy fields, and adults were found in mangroves, estuaries, and rivers. Mangrove densities in Teluk Kupang, Menipo, and Maubesi were 127 trees/ha, 124 trees/ha, and 186 trees/ha, respectively. These are the first systematic surveys in the areas studied, and additional work is needed to characterize the population and habitat of the saltwater crocodile in East Nusa Tenggara.

Webb, E.C., Veldsman, D.M., Myburgh, J.G. and Swan, G.E. (2021). Effects of stocking density on growth and skin quality of grower Nile crocodiles (*Crocodylus niloticus*). *South African Journal of Animal Science* 51(2): 142-150.

**Abstract:** Intensive Nile crocodile (*Crocodylus niloticus*) farming operates with considerable variation in housing and stocking density. In this study, current commercial stocking densities for crocodylians were investigated using 261 grower-phase crocodiles (15 months old, average total body length 94.5 cm, and average weight 2.7 kg).

Low (2.60 m<sup>2</sup> per crocodile), medium (1.24 m<sup>2</sup> per crocodile), and high (0.41 m<sup>2</sup> per crocodile) stocking densities were tested. Growth, morphometric measures, Fulton's condition scores and skin qualities were assessed over a six-month (May–November 2017) period. High stocking density had no adverse effects on the growth of grower Nile crocodiles. Crocodiles stocked at medium and high densities outperformed those that were stocked at low density in Fulton's body condition scores, change in body condition from the start to the end of the trial, and feed conversion efficiencies. However, the high and, to a lesser extent, the medium stocking densities resulted in lower skin quality scores compared with those in the low-density treatment because of teeth marks from more aggressive behaviour. The results indicated that the medium pen density treatment is closer to the ideal than either the high or low stocking density groups. Stocking densities that provide 0.41 m<sup>2</sup> per crocodile or less should be avoided because of lower skin quality scores, which weigh more heavily than growth and feed efficiency responses in the financial viability of commercial crocodile farming in typical South African production systems.

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Hernández, O., Velasco, A., Núñez, R. and Babarro, R. (2021). Population reinforcement for the recovery of the Orinoco crocodile in Venezuela. Pp. 87–92 in *Global Conservation Translocation Perspectives*, ed. by P.S. Soorae. IUCN: Gland, Switzerland.

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Piazza, M.V., Fernández, M.S., Leiva, P.M.L., Piña, C.I. and Simoncini, M.S. (2021). "Intracascaral space" an eggshell structure of *Caiman latirostris* eggs. *Scientific Reports* 11: 5579.

**Abstract:** In recent decades, eggshells of eggs from large-bodied reptiles have been studied by many researchers, to describe the eggshell, to compare them to extinct lineages that once inhabited our planet and also to understand how the egg provides the embryo specific conditions during incubation. In previous studies we described and characterized normal and pathologic *Caiman latirostris* eggshells; we also evaluated how the eggshell changes during incubation. In a study relating temperature variation and eggshell structures of successful eggs, we observed empty structures not previously described that we termed "intracascaral space". The aim of this study is to describe this structure of *C. latirostris* eggshells. We hypothesize about the possible functions which it would perform during incubation and for development of the embryos.

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Cedillo-Leal, C., Simoncini, M.S., Leiva, P.M.L., Larriera, A., Lang, J.W. and Piña, C.I. (2021). Eggshell structure in *Caiman latirostris* eggs improves embryo survival during nest inundation. *Proceedings of the Royal Society B* 284: 20162675.

**Abstract:** Egg inundation often results in poor hatching success in crocodylians. However, how tolerant eggs are to submergence, and/or how eggshell ultrastructure may affect embryo survival when inundated, are not well understood. In this study, our objective was to determine if embryo survival in *Caiman latirostris* is affected by eggshell surface roughness, when eggs are submerged under water. Tolerance to inundation was tested early (day 30) versus late (day 60) in development, using eight clutches (four per time treatments), subdivided into four groups: (N= 9 per clutch per treatment; 9 x 4= 36 eggs per group). 'Rough' eggshell represented the natural, unmodified eggshell surface structure. 'Smooth' eggshell surface structure was created by mechanically sanding the natural rough surface to remove surface columnar elements and secondary layer features, e.g. irregularities that result in 'roughness'. When inundated by submerging eggs under water for 10 h at day 30, 'smooth' eggshell structure resulted in more than twice as many dead embryos (16 versus 6, smooth versus rough; N= 36), and fewer than half as many healthy embryos (6 versus 13, smooth versus rough, respectively; N= 36). By contrast, at day 60, inundation resulted in very low hatching success, regardless of eggshell surface structure. Only two hatchlings survived the inundation, notably in the

untreated group with intact, rough eggshells. Inundation produced a high rate of malformations (58% at day 30), but did not affect hatchling size. Our results indicate that eggshell roughness enhances embryo survival when eggs are inundated early in development, but not late in development. Apparently, the natural surface 'roughness' entraps air bubbles at the eggshell surface during inundation, thereby facilitating gas exchange through the eggshell even when the egg is submerged under water.

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Iijima, M., Takai, M., Nishioka, Y., Thaug-Htike, Zin-Maung-Maung-Thein, Egi, N., Kusuhashi, N., Tsubamoto, T., Kono, R.T. and Hirayama, R. (2021). Taxonomic overview of Neogene crocodylians in Myanmar. *Journal of Vertebrate Paleontology* (<https://doi.org/10.1080/02724634.2021.1879100>).

**Abstract:** Although Neogene crocodylians were well documented from Indo-Pakistan, few fossils were known from Southeast Asia, precluding the understanding of their evolutionary and biogeographic history. Here, we describe crocodylians from the Neogene Irrawaddy Formation of central Myanmar and evaluate their taxonomic status. Tebingan, SE of Magway (lower Upper Miocene) yields *Gavialis* and *Crocodylus* that differ from the previously known species of each genus, and the Gwebin area, SW of Bagan (Upper Pliocene) produces *Crocodylus* cf. *palaieindicus*. Taking into account the materials without provenance data, Neogene crocodylians from Myanmar include at least three gavialids and two *Crocodylus* that are characterized by different craniomandibular and postcranial features. The body length estimates for the gavialines from Tebingan and an unknown locality in central Myanmar are 7.5 m and 8.6 m, respectively, which exceed the maximum size limit of extant *Gavialis gangeticus*. Together with the previously reported large taxa, gavialids repeatedly evolved large body sizes in the Neogene of Asia. *Gavialis* from the Miocene of Myanmar is one of the oldest records of the genus, and its unraised orbital rim suggests that the "telescoped" eyes derived later during the genus evolution. *Crocodylus* cf. *palaieindicus* from the Pliocene of Myanmar indicates the species range was extended from western India to Myanmar during the Neogene. The absence of *Crocodylus siamensis* in the Neogene of India and central Myanmar implies the species originated east of central Myanmar.

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Valverde, A., Castro-Morales, O., Madrigal-Valverde, M., Camacho, M., Barquero, V., Soler, C. and Roldan, E.R.S. (2021). Sperm kinematic subpopulations of the American crocodile (*Crocodylus acutus*). *PLoS ONE* 16(3): e0248270.

**Abstract:** There has been very limited use of computer assisted semen analysis (CASA) to evaluate reptile sperm. The aim of this study was to examine sperm kinematic variables in American crocodile (*Crocodylus acutus*) semen samples and to assess whether sperm subpopulations could be characterized. Eight ejaculates (two ejaculates/male) from four sexually mature captive crocodiles were obtained. An ISAS@v1 CASA-Mot system, with an image acquisition rate of 50 Hz, and ISAS@D4C20 counting chambers were used for sperm analyses. The percentages of motile and progressively motile spermatozoa did not differ among animals (P>0.05) but there was a significant animal effect with regards to kinematic variables (P<0.05). Principal component (PC) analysis revealed that kinematic variables grouped into three components: PC1, related to velocity; PC2 to progressiveness and PC3 to oscillation. Subpopulation structure analysis identified four groups (P<0.05), which represented, on average, 9.8%, 32.1%, 26.8%, and 31.3% of the total sperm population. Males differed in the proportion of sperm in each of the kinematic subpopulations. This new approach for the analysis of reptile sperm kinematic subpopulations, reflecting quantifiable parameters generated by CASA system technology, opens up possibilities for future assessments of crocodile sperm and will be useful in the future development of assisted reproduction for these species.

Roy, M., Mufunda, F., Slawski, D., Mutswiri, C., Mvere, I., Slawski, K., Kelly, P., Piras, I., Bezuidenhout, A., Hanyire, T. and Markey, B. (2021). West Nile virus in crocodiles and mosquitoes in Zimbabwe. *bioRxiv* (<https://doi.org/10.1101/2021.02.19.431612>).

**Abstract:** We detected, for the first time, West Nile virus lineages 1 and 2 in Zimbabwe in mosquitoes and crocodile tissue samples, including fluid from egg waste. Our results provide evidence of WNV circulation in Zimbabwe, suggesting that an evaluation of the risk to humans and susceptible animals should be considered.

Young, B.A., Adams, J., Beary, J.M., Mardal, K.-A., Schneider, R. and Kondrashova, T. (2021). Variations in the cerebrospinal fluid dynamics of the American alligator (*Alligator mississippiensis*). *Fluids and Barriers of the CNS* 18(1) (doi: [10.1186/s12987-021-00248-1](https://doi.org/10.1186/s12987-021-00248-1)).

**Abstract:** Background: Studies of mammalian CSF dynamics have been focused on three things: paravascular flow, pressure and pulsatility, and “bulk” flow; and three (respective) potential motive forces have been identified: vasomotor, cardiac, and ventilatory. There are unresolved questions in each area, and few links between the different areas. The American alligator (*Alligator mississippiensis*) has pronounced plasticity in its ventilatory and cardiovascular systems. This study was designed to test the hypothesis that the greater cardiovascular and ventilatory plasticity of *A. mississippiensis* would result in more variation within the CSF dynamics of this species. Pressure transducers were surgically implanted into the cranial subarachnoid space of 12 sub-adult alligators; CSF pressure and pulsatility were monitored along with EKG and the exhalatory gases. In four of the alligators a second pressure transducer was implanted into the spinal subarachnoid space. In five of the alligators the CSF was labeled with artificial microspheres and Doppler ultrasonography used to quantify aspects of the spinal CSF flow. Both temporal and frequency analyses of the CSF pulsations showed highly variable contributions of both the cardiac and ventilatory cycles. Unlike the mammalian condition, the CSF pressure pulsations in the alligator are often of long (~3 s) duration, and similar duration CSF unidirectional flow pulses were recorded along the spinal cord. Reduction of the duration of the CSF pulsations, as during tachycardia, can lead to a “summation” of the pulsations. There appears to be a minimum duration (~1 s) of isolated CSF pulsations. Simultaneous recordings of cranial and spinal CSF pressures reveal a 200 ms delay in the propagation of the pressure pulse from the cranium to the vertebral canal. Most of the CSF flow dynamics recorded from the alligators, are similar to what has been reported from studies of the human CSF. It is hypothesized that the link between ventilatory mechanics and CSF pulsations in the alligator is mediated by displacement of the spinal dura. The results of the study suggest that understanding the CSF dynamics of *Alligator* may provide unique insights into the evolutionary origins and functional regulation of the human CSF dynamics.

Stankova, H., Janovcova, M., Peleskova, S., Sedlackova, K., Landova, E. and Frynta, D. (2021). The ultimate list of the most frightening and disgusting animals: Negative emotions elicited by animals in central European respondents. *Animals* 11: 747.

**Abstract:** Animals have always played an important role in our everyday life. They are given more attention than inanimate objects, which have been adaptive during the evolution of mankind, with some animal species still presenting a real threat to us. In this study, we focused on the species usually evaluated as the scariest and most disgusting in the animal kingdom. We analyzed which characteristics (eg weight, potential threat for humans) influence their evaluation in a nonclinical Central European WEIRD population (Western, educated, industrialized, rich, and democratic). The tested animals were divided into two separated sets containing 34 standardized photos evoking predominantly one negative emotion, fear or disgust. The pictures were ranked according to their emotional

intensity by 160 adult respondents with high inter-rater agreement. The most fear-eliciting species are mostly large vertebrates (eg carnivorans, ungulates, sharks, crocodiles), whereas smaller fear-evoking vertebrates are represented by snakes and invertebrates are represented by arachnids. The most disgust-evoking animals are human endo- and ectoparasites or animals visually resembling them. Humans emotionally react to fear-evoking animals that represent a real threat; however, identifying truly dangerous disgust-evoking animals might be harder. The results also support a somewhat special position of snakes and spiders.

Sharma, S.P., Ghazi, M.G., Katdare, S., Dasgupta, N., Mondol, S., Gupta, S.K. and Hussain, S.A. (2021). Microsatellite analysis reveals low genetic diversity in managed populations of the critically endangered gharial (*Gavialis gangeticus*) in India. *Scientific Reports* 11: 5627.

**Abstract:** The gharial (*Gavialis gangeticus*) is a critically endangered crocodylian, endemic to the Indian subcontinent. The species has experienced severe population decline during the twentieth century owing to habitat loss, poaching, and mortalities in passive fishing. Its extant populations have largely recovered through translocation programmes initiated in 1975. Understanding the genetic status of these populations is crucial for evaluating the effectiveness of the ongoing conservation efforts. This study assessed the genetic diversity, population structure, and evidence of genetic bottlenecks of the two managed populations inhabiting the Chambal and Girwa Rivers, which hold nearly 80% of the global gharial populations. We used seven polymorphic nuclear microsatellite loci and a 520 bp partial fragment of the mitochondrial control region (CR). The overall mean allelic richness ( $A_r$ ) was  $2.80 \pm 0.40$ , and the observed ( $H_o$ ) and expected ( $H_e$ ) heterozygosities were  $0.40 \pm 0.05$  and  $0.39 \pm 0.05$ , respectively. We observed low levels of genetic differentiation between populations ( $F_{ST} = 0.039$ ,  $P < 0.05$ ;  $G'_{ST} = 0.058$ ,  $P < 0.05$ ; Jost's  $D = 0.016$ ,  $P < 0.05$ ). The bottleneck analysis using the  $M$  ratio (Chambal =  $0.31 \pm 0.06$ ; Girwa =  $0.41 \pm 0.12$ ) suggested the presence of a genetic bottleneck in both populations. The mitochondrial CR also showed a low level of variation, with two haplotypes observed in the Girwa population. This study highlights the low level of genetic diversity in the two largest managed gharial populations in the wild. Hence, it is recommended to assess the genetic status of extant wild and captive gharial populations for planning future translocation programmes to ensure long-term survival in the wild.

Al Qiram, T., Effendi, R. and Hairiyadi. (2021). Pandangan masyarakat terhadap pengobatan dengan bantuan buaya mistik di desa Kuala Pembuang Kecamatan Seruyan Hilir Kabupaten Seruyan. *Prabayaksa: Journal of History Education* 1(1): 8-14.

**Abstract:** At the beginning of the 21st century, the people of Kuala Pembuang still believed in the existence of intermediaries who gave offerings to mystical crocodiles in the midst of the rise of science and technology, one of which was health. The purpose of this study was to determine the public's view of treatment with the help of crocodiles (mystical). The initial stage of this research is data collection through literature study and field studies. Literature study is used to obtain written data in the form of books or obtain primary data directly. Furthermore, after the data is collected the data is again considered to see the validity of the source. The next stage of interpretation is to describe the sources that have been considered. Finally, the historiography part is processing the data into written form. The results showed that the treatment through the ritual of giving offerings to the crocodile care family (mystical) was carried out through several stages and the community's view of the ritual procession still believed and some did not believe in the treatment process through the procession. The ritual of giving offerings. The conclusion from the research results is that the ritual of giving offerings to crocodiles (mystical) in order to cure the disease can only be done if the sick person has blood ties with the owner of the mystical crocodile and this ritual is only done if there is a family

affected by the disease and it is believed that they cannot recover. in a way obstructed through the help of a doctor. In this case, people also have different opinions in dealing with treatment through these rituals.

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Marshall, B.M., Freed, P., Vitt, L.J., Bernardo, P., Vogel, G., Lotzkat, S., Franzen, M., Hallermann, J., Sage, R.D., Bush, B., Duarte, M.R., Avila, L.J., Jandzik, D., Klusmeyer, B., Maryan, B., Hosek, J. and Uetz, P. (2020). An inventory of online reptile images. *Zootaxa* 4896(2): 251-264.

**Abstract:** No central online repository exists for the collection of animal images; hence it remains unclear how extensively species have been illustrated in the published literature or online. Here we compiled a list of more than 8000 reptile species (out of 11,341) that have photos in one of six popular online repositories, namely iNaturalist (6349 species), the Reptile Database (5144), Flickr (4386), CalPhotos (3071), Wikimedia (2952), and Herpmapper (2571). These sites have compiled over one million reptile photos, with some species represented by tens of thousands of images. Despite the number of images, many species have only one or a few images. This suggests that a considerable fraction of morphological and geographic variation is under documented or difficult to access. We highlight prominent gaps in amphisbaenians, lizards, and snakes, with geographic hotspots for species without images in Central Africa, Pacific Islands, and the Andes Mountains. We present a list of ~3000 species without photos in any of the six databases and ask the community to fill the gaps by depositing images on one of these sites (preferably with minimal copyright restrictions).

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Makaba, S., Tingginehe, R.M. and Ruru, Y. (2021). The effectiveness of crocodile oil extract ointment on the treatment of burns in mice (*Mus musculus*). *Medico-legal Update* 21(2): 1114-1121.

**Abstract:** The purpose of this study was to determine the effectiveness of the crocodile oil extract ointment in the treatment of burns in mice (*Mus musculus*). The research found that the ointment of crocodile oil extract has an effect in the healing of burns in mice, with the best concentration of 30% of the crocodile oil extract ointment dose. Moreover, the ointment met the standard on the basis of organoleptic and homogeneity tests. The ointment of crocodile oil extract with concentrations of 30% and 50% has the healing activity degree II-A burns in mice. The best percentage of reductions in average burns in mice was the ointment with a concentration of 30%. Further study needs to be done in the healing of wound in human skin.

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Wiseman, A.L.A., Bishop, P.J., Demuth, O.E., Cuff, A.R., Michel, K.B. and Hutchinson, J.R. (2021). Musculoskeletal modelling of the Nile crocodile (*Crocodylus niloticus*) hindlimb: Effects of limb posture on leverage during terrestrial locomotion. *Journal of Anatomy* (doi: 10.1111/joa.13431).

**Abstract:** We developed a three-dimensional, computational biomechanical model of a juvenile Nile crocodile (*Crocodylus niloticus*) pelvis and hindlimb, composed of 47 pelvic limb muscles, to investigate muscle function. We tested whether crocodiles, which are known to use a variety of limb postures during movement, use limb orientations (joint angles) that optimise the moment arms (leverages) or moment-generating capacities of their muscles during different limb postures ranging from a high walk to a sprawling motion. We also describe the three-dimensional (3D) kinematics of the crocodylian hindlimb during terrestrial locomotion across an instrumented walkway and a treadmill captured via X-ray Reconstruction of Moving Morphology (biplanar fluoroscopy; 'XRMM'). We reconstructed the 3D positions and orientations of each of the hindlimb bones and used dissection data for muscle lines of action to reconstruct a focal, subject-specific 3D musculoskeletal model. Motion data for different styles of walking (a high, crouched, bended and two types of sprawling motion) were fed into the 3D

model to identify whether any joints adopted near-optimal poses for leverage across each of the behaviours. We found that (1) the hip adductors and knee extensors had their largest leverages during sprawling postures and (2) more erect postures typically involved greater peak moment arms about the hip (flexion-extension), knee (flexion) and metatarsophalangeal (flexion) joints. The results did not fully support the hypothesis that optimal poses are present during different locomotory behaviours because the peak capacities were not always reached around mid-stance phase. Furthermore, we obtained few clear trends for isometric moment-generating capacities. Therefore, perhaps peak muscular leverage in Nile crocodiles is instead reached either in early/late stance or possibly during swing phase or other locomotory behaviours that were not studied here, such as non-terrestrial movement. Alternatively, our findings could reflect a trade-off between having to execute different postures, meaning that hindlimb muscle leverage is not optimised for any singular posture or behaviour. Our model, however, provides a comprehensive set of 3D estimates of muscle actions in extant crocodiles which can form a basis for investigating muscle function in extinct archosaurs.

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Nixon, B., Anderson, A.L., Bromfield, E.G., Martin, J.H., Lord, T., Cafe, S.L., Roman, S.D., Skerrett-Byrne, D.A., Eamens, A.L., De Iuliis, G.N. and Johnston, S.D. (2021). Gross and microanatomy of the male reproductive duct system of the saltwater crocodile *Crocodylus porosus*. *Reproduction, Fertility and Development* (doi: 10.1071/RD20303).

**Abstract:** Information on the morphology and histology of the male reproductive system of the Crocodylia species is necessary to determine the role of these tissues in the production of functional spermatozoa. Accordingly, in this study we examined the gross morphology and microanatomy of the testis and the male excurrent duct system through which spermatozoa pass before ejaculation. The data demonstrate that the reproductive system in male saltwater crocodiles comprises paired testes, which convey spermatozoa distally via the rete testis into an excurrent duct system comprising ductuli efferentes, ductuli epididymides, ductus epididymidis and ductus deferens. The epithelium delineating the male tract was dominated by non-ciliated and ciliated cells structured into a simple columnar lining of the ductuli efferentes and ductuli epididymides, through to the high pseudostratified columnar epithelium of the ductus epididymidis and ductus deferens. The morphology and histochemical staining of these ducts suggest their involvement in seminal fluid production and/or its modification, which likely contributes to the nourishment, protection and/or storage of crocodile spermatozoa. As a reflection of their common Archosaurs ancestry, the overall structural characteristics we describe for the crocodile male excurrent duct system share closer similarities to those of the Aves than other clades within the Reptilia class or Mammalia.

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Riley, A., Terry, M., Freeman, H., Alba, A.C., Soltis, J. and Leeds, A. (2021). Evaluating the effect of visitor presence on Nile crocodile (*Crocodylus niloticus*) behavior. *Journal of Zoological and Botanic Gardens* 2: 115-129.

**Abstract:** Visitor presence has been shown to affect the behavior of animals in zoos. However, studies to date have not included a wide range of taxonomic groupings, and thus, the effect is poorly understood for many species. Here, we compared the behavior of Nile crocodiles (*Crocodylus niloticus*) in the presence and absence of visitors for the first time. Data were collected at Disney's Animal Kingdom® over two months during normal operating conditions and during the same two months the following year when the park was closed due to the COVID-19 pandemic, totaling 158 observation hours. Significant differences in crocodile behavior were observed between park operating conditions; however, the direction of change varied by behavior and average differences were generally small. In addition, we found that time of day, temperature and month significantly affected behavior, often with greater magnitude than

visitor presence. This highlights the importance of accounting for environmental variables when evaluating and interpreting the behavior, and ultimately welfare, of reptiles in zoos. Collectively, the data suggest the overall effect of visitors on crocodile behavior was small and neutral from a welfare perspective. This study highlights the importance of taxonomic diversity in studying the visitor effect.

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Joanen, T., Merchant, M., Griffith, R., Linscombe, J. and Guidry, A. (2021). Evaluation of effects of harvest on alligator populations in Louisiana. *The Journal of Wildlife Management* (<https://doi.org/10.1002/jwmg.22028>).

**Abstract:** Biologists with the Louisiana Department of Wildlife and Fisheries, Louisiana, USA, have managed statewide annual harvest of alligators (*Alligator mississippiensis*) for 35 years (1981-present). We collected and analyzed harvest data for Louisiana alligators to determine the effects of harvest on the population structure, focusing on the larger size classes ( $\geq 274$  cm) of this slow-growing species. Linear regression analyses revealed that body size-class structure, based on overall average size and the percentage of animals harvested in the larger size classes was relatively stable. Annual aerial alligator nest counts indicated a continual growth of the population, and over time harvested alligators maintained a constant average size. Analyses of population size (based on number of nests and population modeling) indicated that the current annual harvest represents approximately 3% of the population. Linear regression analysis showed that annual hunter success declined only slightly during the study period, and the scheduling of the hunt season after the hatch period and recommended hunting in areas not frequented by breeding females provides economic opportunities for hunters to participate in a sustainable harvest that preserves the larger size classes of alligators in the population. Strict enforcement of existing laws was a key factor responsible for the success of this harvest program. Comparison of alligator population size and number of harvest-related citations indicated that illegal harvest did not have a negative effect on population size, and linear regression analyses revealed that the rate of increase in citations was lower than the increase in populations over the study period. The results of this harvest program indicated that alligators can be hunted in a sustainable manner if hunting is conducted after the hatch period and occurs in areas that primarily exclude the harvest of adult females, and strict law enforcement curbs illegal activities that negatively affect populations.

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Lin, J.Q., Yu, J., Sun, L. and Fang, S.G. (2021). Genome-wide DNA methylation and transcriptome analyses reveal epigenetic and genetic mechanisms underlying sex maintenance of adult Chinese alligator. *Frontiers in Genetics* (<https://doi.org/10.3389/fgene.2021.655900>).

**Abstract:** The sexes of Chinese alligators are determined during embryonic development and remain fixed thereafter. In this study, we investigated the genetic and epigenetic mechanisms underlying sex maintenance in Chinese alligators through RNA sequencing and bisulfite sequencing data analyses of the adult gonads. We identified the genes and pathways (eg DMRT1-SOX9-AMH pathway for males and oocyte meiotic maturation pathway for females) involved in male and female sex maintenance and gonadal development of adult Chinese alligators. In contrast to their expression patterns in the embryo, both DMRT1 and the steroid hormone biosynthesis related genes showed a male-biased expression in adult gonads. The overall DNA methylation density and level were higher in testes than in ovaries. Hypermethylation in the gene bodies enhanced the expression of male-biased genes (such as DMRT1-SOX9-AMH and steroid hormone biosynthesis related genes) in the testis, as opposed to the normalization of gene expression. Our results provide insights into the genetic and epigenetic mechanisms underlying sex maintenance in adult Chinese alligators, and are expected to contribute to the development of scientific programs for the successful conservation of this endangered species.

Cavalier, R., Serenari, C. and Konur, D. (2021). Mapping micro-level decision-making for alligator management in North Carolina. *Frontiers in Conservation Science* (<https://doi.org/10.3389/fcosc.2021.650339>).

**Abstract:** Human-carnivore interactions represent a grand challenge to conservation decision-making and legitimacy across all levels of governance. Human populations continue to encroach upon and devastate carnivore habitats and populations, intensifying interactions between a variety of biodiversity interests and beneficiaries. As a result, carnivores most intensely impact those living in their midst, demanding increased attention by local decision makers, who are often best suited to catering to the needs of communities most affected. Their views and desires can serve as a forerunner of public trust and acceptance of policies created. However, due to the complexity of decisions about carnivores, these actors are often overlooked in the formal decision process. To address this need, we applied multi-criteria decision analysis (MCDA) to a case study of American alligator (*Alligator mississippiensis*) conservation in 10 coastal North Carolina counties to identify and postulate legitimate outcomes. We surveyed 25 local decision makers who are or may be responsible for management decisions concerning the American alligator and asked them to evaluate and indicate the level of importance of salient alligator management elements. Results indicate that decision makers strongly favored the wildlife and social factors when making alligator management decisions, as well as the criteria human well-being, attitudes toward alligators, education programs, and storm mitigation. Respondents favored highly managed and balanced management alternatives to maximize preferred criteria and achieve legitimate alligator management at the local level. These results demonstrate that local decision makers are capable of identifying what is important to alligator management decisions, and can provide an insightful look at trade-offs that need to or could be made to achieve optimal alligator outcomes. We conclude that local decision makers should become more involved in shaping carnivore outcomes to enhance legitimacy of alligator policy and help achieve conservation targets. Future research will need to further expand understandings of local decision makers' decision-making process in other carnivore contexts. Researchers will want to consider using and refining decision analysis to cut through the complexity of carnivore conservation decision-making that exists across wide geopolitical expanses.

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Stubbs, T.L., Pierce, S.E., Elsler, A., Anderson, P.S.L., Rayfield, E.J. and Benton, M.J. (2021). Ecological opportunity and the rise and fall of crocodylomorph evolutionary innovation. *Proceedings of the Royal Society B: Biological Sciences* 288(1947): 20210069 ([doi: 10.1098/rspb.2021.0069](https://doi.org/10.1098/rspb.2021.0069)).

**Abstract:** Understanding the origin, expansion and loss of biodiversity is fundamental to evolutionary biology. The approximately 26 living species of crocodylomorphs (crocodiles, caimans, alligators and gharials) represent just a snapshot of the group's rich 230-million-year history, whereas the fossil record reveals a hidden past of great diversity and innovation, including ocean and land-dwelling forms, herbivores, omnivores and apex predators. In this macroevolutionary study of skull and jaw shape disparity, we show that crocodylomorph ecomorphological variation peaked in the Cretaceous, before declining in the Cenozoic, and the rise and fall of disparity was associated with great heterogeneity in evolutionary rates. Taxonomically diverse and ecologically divergent Mesozoic crocodylomorphs, like marine thalattosuchians and terrestrial notosuchians, rapidly evolved novel skull and jaw morphologies to fill specialized adaptive zones. Disparity in semi-aquatic predatory crocodylians, the only living crocodylomorph representatives, accumulated steadily, and they evolved more slowly for most of the last 80 million years, but despite their conservatism there is no evidence for long-term evolutionary stagnation. These complex evolutionary dynamics reflect ecological opportunities, that were readily exploited by some Mesozoic crocodylomorphs but more limited in Cenozoic crocodylians.

Levin, D., Raab, N., Pinto, Y., Rothschild, D., Zanir, G., Godneva, A., Mellul, N., Futorian, D., Gal, D., Leviatan, S., Zeevi, D., Bachelet, I. and Segal, E. (2021). Diversity and functional landscapes in the microbiota of animals in the wild. *Science* (doi: [10.1126/science.abb5352](https://doi.org/10.1126/science.abb5352)).

**Abstract:** Animals in the wild are able to subsist on pathogen-infected and poisonous food and show immunity to various diseases. These may be due to their microbiota, yet we have a poor understanding of animal microbial diversity and function. We used metagenomics to analyze the gut microbiota of over 180 species in the wild, covering diverse classes, feeding behaviors, geographies, and traits. Using de novo metagenome assembly, we constructed and functionally annotated a database of over 5000 genomes, comprising 1209 bacterial species of which 75% are unknown. The microbial composition, diversity, and functional content exhibit associations with animal taxonomy, diet, activity, social structure and lifespan. We identify the gut microbiota of wild animals as a largely untapped resource for the discovery of therapeutics and biotechnology applications.

Thilakarathna, A. and Godage, W.M.C.P. (2021). From conflict to coexistence: A critical look at issues related to human-wildlife interactions in Sri Lanka. *Asian Journal of Law and Governance* 3(1): 47-59.

**Abstract:** Sri Lanka is appreciated for its natural beauty and its biodiversity as being one of the hot spots in the world. Its picturesque environments are a great asset to its people and the abundance of wildlife resources it has is second to non-other. However, due to the increase in the struggle between the wildlife and human beings, this escalating conflict has resulted in violent interactions between the two, where both the parties have made the ultimate sacrifice with their lives. In particular, the Human-Elephant and Human-Crocodile conflict has created much controversy from socio, economic and political aspects in the country. Therefore, this research is focused on suggesting methods of turning this conflict between human beings and the wildlife in to one of coexistence with a critical review of literature and the study reports that have been produced both locally and internationally by using a qualitative method. The results reveal that, the conflict is more diverse than one might think as the conflict has now become human-wildlife-human conflict, where there is a conflict between who are trying to save the wildlife from the humans and the others who are trying to save their lives and crops from the wildlife. This tripartite conflict has made matters very complicated and therefore, it is suggested that the existing laws and regulations be amended and be made more realistic in order to protect both the wildlife and the human beings of the country, where the existing rules and regulations of the British Era has taken a more biocentre approach which seems unworkable in the modern times.

Ikpeze, O.O and Ngenegbo, U.C. (2020). Mapping of gastropods associated with urogenital schistosomiasis transmission in Agulu Lake area of Anambra State, Nigeria. *The Biomedical Diagnostics* 4(4): 117-135.

**Abstract:** Urogenital Schistosomiasis had been diagnosed among pupils in Agulu Lake areas of Anambra State, Nigeria. The causative parasite, *Schistosoma haematobium*, and the snail intermediate hosts have been identified. Some water parameters of Agulu Lake that influenced gastropod abundance around the lake were also determined. Recent crocodile infestation of the lake has limited human-water contact activities in the lake but there has been an increase in market-gardening at the Nri-axis of the lake, which may expose women and children to increased risk of urinary schistosomiasis and soil-transmitted helminth infections in the area.

Bautista, N.M., Malte, H., Natarajan, C., Wang, T., Storz, J.F. and Fago, A. (2021). New insights into the allosteric effects of CO<sub>2</sub>

and bicarbonate on crocodilian hemoglobin. *bioRxiv* (doi: <https://doi.org/10.1101/2021.03.22.436447>).

**Abstract:** Crocodilians are unique among vertebrates in that their hemoglobin (Hb) O<sub>2</sub> binding is allosterically regulated by bicarbonate, which forms in the red blood cell upon hydration of CO<sub>2</sub>. Although known for decades, this remarkable mode of allosteric control has not yet been experimentally verified with direct evidence of bicarbonate binding to crocodilian Hb, probably because of confounding CO<sub>2</sub>-mediated effects. Here we provide the first quantitative analysis of the separate allosteric effects of CO<sub>2</sub> and bicarbonate on Hb of the spectacled caiman (*Caiman crocodilus*). Using thin-layer gas diffusion chamber and Tucker chamber techniques, we demonstrate that both CO<sub>2</sub> and bicarbonate bind to Hb with high affinity and strongly decrease Hb-O<sub>2</sub> saturation, and propose that both effectors bind to an unidentified positively charged site containing a reactive amino group in the low-O<sub>2</sub> affinity T conformation of the Hb. These results provide the first experimental evidence that bicarbonate binds directly to crocodilian Hb and promotes O<sub>2</sub> delivery independently of CO<sub>2</sub>. Using the gas-diffusion chamber, we observed similar effects in the Hbs of a phylogenetically diverse set of other caiman, alligator, and crocodile species, suggesting that the unique mode of allosteric regulation by CO<sub>2</sub> and bicarbonate evolved >80-100 million years ago in the common ancestor of crocodilians. Taken together, our results show a tight and unusual linkage between O<sub>2</sub> and CO<sub>2</sub> transport in the blood of crocodilians, where build-up of blood CO<sub>2</sub> and bicarbonate ions during breath-hold diving or digestion facilitates O<sub>2</sub> delivery, while Hb desaturation facilitates CO<sub>2</sub> transport as protein-bound CO<sub>2</sub> and bicarbonate.

Lopes, A.G., Monteiro, D.A. and Kalinin, A.L. (2021). Effects of change in temperature on the cardiac contractility of broad-snouted caiman (*Caiman latirostris*) during digestion. *Journal of Experimental Zoology A. Ecology and Integrative Physiology* (doi: [10.1002/jez.2457](https://doi.org/10.1002/jez.2457)).

**Abstract:** In many reptiles, digestion has been associated with the selection of higher body temperatures, the so-called post-prandial thermophilic response. This study aimed to investigate the excitation-contraction (E-C) coupling in postprandial broad-snouted caimans (*Caiman latirostris*) in response to acute warming within a preferred body temperature range of crocodiles. Isometric preparations subjected to a temperature transition from 25°C to 30°C were used to investigate myocardial contractility of postprandial caimans, that is, 48 h after the animals ingested a rodent meal corresponding to 15% of body mass. The caiman heart exhibits a negative force-frequency relationship that is independent of the temperature. At 25°C, cardiac muscle was able to maintain a constant force up to 36 bpm, above which it decreased significantly, reaching minimum values at the highest frequency of 84 bpm. Moreover, E-C coupling is predominantly dependent on transsarcolemmal Ca<sup>2+</sup> transport denoted by the lack of significant ryanodine effects on force generation. On the contrary, ventricular strips at 30°C were able to sustain the cardiac contractility at higher pacing frequencies (from 12 to 144 bpm) due to an important role of Na<sup>+</sup>/Ca<sup>2+</sup> exchanger in Ca<sup>2+</sup> cycling, as indicated by the decay of the post-rest contraction, and a significant contribution of the sarcoplasmic reticulum above 72 bpm. Our results demonstrated that the myocardium of postprandial caimans exhibits a significant degree of thermal plasticity of E-C coupling during acute warming. Therefore, myocardial contractility can be maximized when postprandial broad-snouted caimans select higher body temperatures (preferred temperature zone) following feeding.

Helm, C.W. and Lockley, M.G. (2021). Pleistocene reptile swim traces confirmed from South Africa's Cape south coast. *South African Journal of Science* 117(3/4): 8830 (<https://doi.org/10.17159/sajs.2021/8830>).

**Abstract:** Large Pleistocene reptile tracks and traces were described from the Cape south coast of South Africa in 2020, including 'probable swim traces'. These trace fossils were found on loose slabs and blocks of the Klein Brak Formation. Subsequently, another surface has become exposed on this coastline, also on a loose slab. It exhibits more definitive evidence of swim traces in epirelief, probably made by the Nile crocodile (*Crocodylus niloticus*) or water monitor (*Varanus niloticus*), although a chelonian origin cannot be excluded. Length of a possible crocodylian trackmaker was estimated from measurements of interdigital distance in the swim traces. These provide a compelling example of reptile swim traces from Africa.

**Significance:** Pleistocene reptile swim traces have now been confidently confirmed from the Cape south coast of South Africa; the findings complement the suite of recently identified large reptile tracks; trackmaker size can be estimated from the dimensions of reptile swim traces; and, these are the first compelling non-dinosaurian reptile swim traces to be described from Africa.

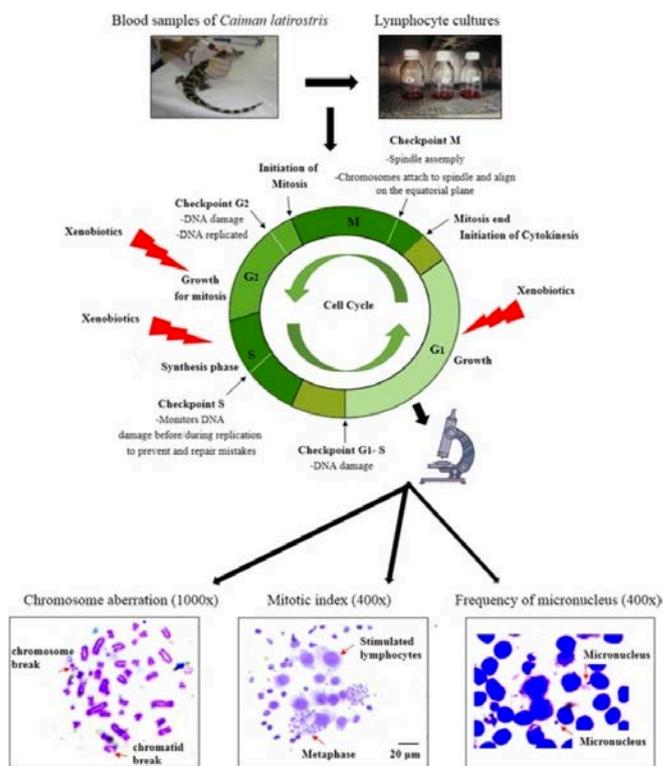
Booth, H., Arias, M., Brittain, S., Challender, D.W.S., Khanyari, M., Kuiper, T., Li, Y., Olmedo, A., Oyanedel, R., Pienkowski, T. and Milner-Gulland, E.J. (2021). "Saving lives, protecting livelihoods, and safeguarding nature": Risk-based wildlife trade policy for sustainable development outcomes post-COVID-19. *Frontiers in Ecology and Evolution* 9: 639216 (doi: 10.3389/fevo.2021.639216).

**Abstract:** The COVID-19 pandemic has caused huge loss of life, and immense social and economic harm. Wildlife trade has become central to discourse on COVID-19, zoonotic pandemics, and related policy responses, which must focus on "saving lives, protecting livelihoods, and safeguarding nature." Proposed policy responses have included extreme measures such as banning all use and trade of wildlife, or blanket measures for entire Classes. However, different trades pose varying degrees of risk for zoonotic pandemics, while some trades also play critical roles in delivering other key aspects of sustainable development, particularly related to poverty and hunger alleviation, decent work, responsible consumption and production, and life on land and below water. Here we describe how wildlife trade contributes to the UN Sustainable Development Goals (SDGs) in diverse ways, with synergies and trade-offs within and between the SDGs. In doing so, we show that prohibitions could result in severe trade-offs against some SDGs, with limited benefits for public health via pandemic prevention. This complexity necessitates context-specific policies, with multi-sector decision-making that goes beyond simple top-down solutions. We encourage decision-makers to adopt a risk-based approach to wildlife trade policy post-COVID-19, with policies formulated via participatory, evidence-based approaches, which explicitly acknowledge uncertainty, complexity, and conflicting values across different components of the SDGs. This should help to ensure that future use and trade of

wildlife is safe, environmentally sustainable and socially just.

Chacón, C.F., López González, E.C. and Poletta, G.L. (2021). Biomarkers of geno- and cytotoxicity in the native broad-snouted caiman (*Caiman latirostris*): chromosomal aberrations and mitotic index. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis* (<https://doi.org/10.1016/j.mrgentox.2021.503353>).

**Abstract:** We evaluated the sensitivity of the chromosomal aberration (CA) and mitotic index (MI) assays on peripheral blood lymphocytes (PBLs) of *Caiman latirostris*, following ex vivo exposure to the alkylating agent, MMS. Two concentrations of MMS were tested in cultured peripheral blood. Relative to controls, MMS exposure reduced the number of metaphases observed, but both the numbers of cells with MN and the percentages of aberrant metaphases increased. The types of CA identified were chromosome and chromatid breaks, chromosomal rearrangements, monosomies, and nullisomies, with significantly higher values in the MMS-exposed groups. The incorporation of the MI and CA tests in *C. latirostris* can provide information on damage caused by xenobiotic exposures.



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