

# CROCODILE SPECIALIST GROUP NEWSLETTER

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# CROCODILE

# SPECIALIST

# GROUP

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VOLUME 39 Number 4  
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IUCN - Species Survival Commission

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COVER PHOTOGRAPH: Feeding time for juvenile Gharial (*Gavialis gangeticus*) at the Gharial Conservation Breeding Center (GCBC), Chitwan National Park, Nepal (see pages 19-21). Photograph: Bed Kadka.

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

## CSG Newsletter

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

The CSG Newsletter provides information on the conservation, status, news and current events concerning crocodilians, and on the activities of the CSG. It is available as a free electronic, downloadable copy from "<http://www.iucncsg.org/pages/Publications.html>".

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Frank Robb, Florida, USA.  
Zoo Atlanta, Georgia, USA.

## Editorial

The Covid-19 situation seems to be taking 3 steps forward and 2 steps back, with variable patterns in different countries, and is clearly affecting CSG members in many different ways. Here's hoping that the vaccine solution is effective, but no doubt there will be many challenging moments yet to come. Some CSG members have been infected and recovered, but it was with deep sadness that we learned that long-time CSG member Dr. Widodo Ramono (75 y) from Indonesia, succumbed to the virus and passed away on 24 December 2020.

Widodo was a friend and colleague, with whom I worked closely, starting in early 1991 when Widodo accompanied a team reviewing crocodylian management in Indonesia (Webb and Jenkins 1991), and later as Indonesia was developing and implementing its crocodile management program. Widodo was involved with preliminary surveys, under CSG guidance, for *Tomistoma schlegelii* and *Crocodylus siamensis* in East Kalimantan and Sumatra in the mid-1990s (Muin and Ramono 1994), and more recently he participated in the CSG's 2014 review of crocodylian management in Indonesia (Brien *et al.* 2014). From 1969, Widodo held various Government posts, until his retirement in 2005. He is considered one of the most influential figures in Indonesia's efforts to conserve Indonesian rhinoceros, and in 2015 was awarded the Sir Peter Scott Award for Conservation Merit by the SSC in recognition of his work to save the Javan and Sumatran rhinos from extinction. We extend our sincerest condolences to Widodo's family and friends.



Dr. Widodo Sukohadi Ramono, 1945-2020.

The second wave of Covid-19 infection in Mexico remains serious, and so the decision to postpone the 26th CSG Working Meeting was a wise one. The new proposed dates are 21-27 November 2021, but organisers will continue to monitor the Covid-19 situation, and depending on what happens in Mexico and globally, will confirm the dates around the beginning of May 2021.

Elements of the Working Meeting have nonetheless been advanced through virtual meetings/seminars, which have been welcomed by many CSG members. The Latin America and the Caribbean office in Argentina conducted a Conference Cycle on Crocodylians [see CSG Newsletter 39(2): 4-5], and the CSG Drone Working Group has organised four live virtual workshops, in September, October, November and December 2020.

The IUCN World Conservation Congress, which was also deferred from 2020, is now planned for 3-11 September 2021, in Marseille, France. Both the Members' Assembly and Forum components of the IUCN Congress will be held together on the new dates, with the IUCN Programme and Financial Plan 2021-24 voted upon electronically in earlier 2021. Again, the viability of these dates will be intimately linked to progress made fighting the Covid-19 pandemic.

The IUCN-SSC is currently moving to the 2021-2024 Quadrennium, and the CSG is currently in the process of developing a 2021-2024 Strategic Plan, and reviewing the CSG membership. All memberships to the IUCN are automatically terminated at the end of a quadrennium, and members will need to be re-appointed for the new quadrennium. The Executive Officer will soon be contacting CSG members regarding their re-appointment to the IUCN-SSC and the process that they will need to follow. Of the current listing on the CSG's database, 121 people have yet to log into the IUCN portal and complete their profiles, and thus have not been formally recognised as CSG members by the IUCN.

On 13 October 2020, a US Federal Judge ruled on the appeal against the proposed law to ban the sale of crocodile and alligator goods in the state of California. The judge ruled that California had erred and could not unilaterally block the import and sale of alligator and crocodile leather and leather goods. This allows trade to continue within California, and consumers can continue to legally purchase crocodylian goods in California. However, the matter will need to be reassessed in California, so the problem has not been resolved in the long-term.

The Crocodylia Brasil Group (CrocBR), headed by Luis Bassetti and Ronis Da Silveira, has been launched in Brazil. The CrocBR is a network of researchers, technicians, and professionals involved in crocodylian conservation initiatives. The CrocBR expect to advise, promote and develop scientific research, extension, teaching and learning activities, supporting the preservation, conservation, and management of the crocodylian species in Brazil (see pages 13-14).

We welcome Jhon Caldron, from Colombia, as a member of the CSG Steering Committee, through his appointment as joint Regional Vice Chair for Latin America and the Caribbean, where he joins Sergio Balaguera-Reina. Jhon was a close associate of late CSG member Sergio Medrano.

The issue of “traceability” arose within CITES in response to concerns about the python and varanid lizard skin trade in 2010, where controls were not as robust as those implemented long ago with crocodilians. Traceability has also become a bigger commercial issue in the leather trade generally, as part of their general commitment to sustainability and stock control along supply chains. During the Californian deliberations, the possibility of increased “traceability” for crocodilians in trade became an issue, and CSG expertise was limited. The CSG Executive Committee decided that CSG members needed to get better a better understanding of what traceability was about, theoretically and practically, and to investigate competing traceability systems. Dr. Dan Natusch, who has a long track record of dealing with traceability in pythons and varanids, was engaged to prepare a review report, a draft of which is now being considered by the Executive Committee and by various CSG members with a specific interest in this issue. Of prime concern to the CSG is the conservation consequences of compliance. CSG deliberations and Dan’s report are in the final stages of editing, and will soon be available on the CSG website.

“Conservation Genetics of New World Crocodilians”, edited by Rodrigo Zucoloto, Patricia Amavet, Luciano Verdade and Izeni Farias has recently been published. This is a comprehensive review of the literature on the conservation genetics of New World crocodilians, and addresses the biological and demographical aspects of the living species, and the application of molecular techniques for conservation purposes (see pages 4-5).

We received exciting news of the repatriation of two adult pure-bred Philippine crocodiles (*C. mindorensis*) from Cologne Zoo, Germany, to Crocodylus Porosus Philippine Inc. (CPPI), Philippines, for building up a pure colony in the Philippines for reintroductions into the wild (see pages 16-18).

And more exciting news was recently provided from the Philippines. Seven years after the release of 36 juvenile Philippine crocodiles into Paghungawan Marsh, Siargao Island, in November 2020 two nests were discovered, one containing eggs (see pages 18-19).

Professor Grahame Webb, *CSG Chair*.

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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 again, 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)*.

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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 three students in the October-December 2020 quarter. One further application is currently under review.

1. Marcos Cigarroa (Mexico): Population estimation and dynamics of *Caiman crocodilus* in waterbodies of Ejido la Polka, Tonalá Municipality, Chiapas.
2. Mariano Aloupke (Benin): Conservation of threatened crocodile species in the agropastoral dams of Benin (Western Africa).
3. Tank Rawal (Nepal): Assessing human-crocodile conflict, people’s perceptions, and raising awareness for the conservation of Muggers in Ghodaghodi.

In all, 23 SRAS grants were awarded in 2020, bringing the total number of grants awarded since 2009 to 198.

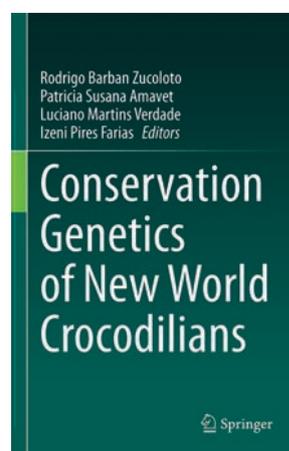
Tom Dacey, *CSG Executive Officer (csg@wmi.com.au)*.

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### Books

“Conservation Genetics of New World Crocodilians” is a comprehensive review of literature on the conservation genetics of the New World crocodilians, from the biological and demographical aspects of the living species to the application of molecular techniques for conservation purposes.

The editors have successfully brought together an important diversity of worldwide specialists, who present an overview with perspectives for the past, present and future of research in conservation genetics of New World crocodilians, highlighting the importance of developing integrative work through the complementation of multidisciplinary researchers. It also emphasizes the importance of the research networks established and favoured by CSG activities.



The book covers the current knowledge about molecular genetics applied to phylogenetics, phylogeography, diversity, kinship and mating systems, and hybridization, as well the implications for decision-making with regards to the conservation of these species at academic and governmental levels. It can be used as a guide for graduate and undergraduate students to understand how conservation genetics techniques are carried out and how they can help preserve not only crocodylians but also other living species.

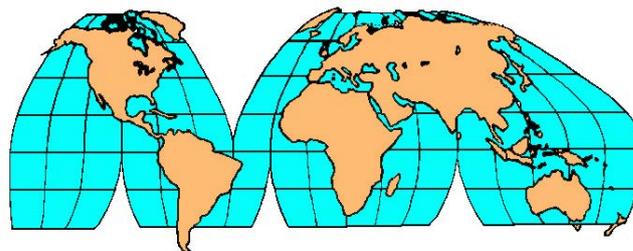
Abstracts for each chapter are on pages 29-31.

1. Geographic distribution, habitat, reproduction, and conservation status of crocodylians in the Americas (Francisco Villamarín, Armando H. Escobedo-Galván, Pablo Siroski and William E. Magnusson).
2. Molecular markers applied to conservation genetics of American crocodylians (Rodrigo Barban Zucoloto, Izeni Pires Farias and Patricia S. Amavet).
3. Molecular phylogenetics of the New-World Crocodylia (Llewellyn D. Densmore III and Tomas Hrbek).
4. Biogeography and comparative phylogeography of New-World crocodylians (Fábio de Lima Muniz, Pedro Senna Bittencourt, Sandra M. Hernández-Rangel, Igor Joventino Roberto, Izeni Pires Farias and Tomas Hrbek).
5. Genetic diversity of New World crocodylians (Patricia S. Amavet, Rodrigo Barban Zucoloto, Tomas Hrbek and Izeni Pires Farias).
6. Crocodylians are promiscuous but not to the benefit of heterozygosity (Sally R. Isberg).
7. Hybridization and speciation among New-World crocodylian species (Gualberto Pacheco-Sierra and Patricia S. Amavet)
8. Crocodylian genome advances (Katherine Brittain, David A. Ray and Jaime Gongora)
9. How genetic tools can help crocodylians' management and governance (Luciano M. Verdade, Carlos I. Piña, Melina Simoncini and Karina L. Silva-Brandão)
10. Perspectives and final considerations about the molecular ecology of New-World crocodylians (Patricia S. Amavet and Rodrigo Barban Zucoloto)

**Citation:** Zucoloto, R.B., Amavet, P.S., Verdade, L.M. and Farias, I.P. (Eds.) (2021). Conservation Genetics of New World Crocodylians. Springer: Cham.

Pablo Siroski, *CSG Regional Chair for Latin America and the Caribbean.*

## Regional Reports



### Latin America and the Caribbean

#### Cuba

**CUBAN CROCODILES ON THE ISLA DE LA JUVENTUD: AN OVERVIEW.** The Isla de la Juventud (named “Isle of Pines” until 1978) is the second largest island in the Cuban archipelago, with an area of 2419 km<sup>2</sup> and a population of 84,000 inhabitants (in 2017) (Fig. 1). Located approximately 60 km from the southwestern portion of mainland Cuba, Isla de la Juventud is surrounded by more than 600 keys and islets that make up the Canarreos Archipelago.



Figure 1. Study area (red circle) and Cayo Potrero Farm (red dot) on the Isla de la Juventud.

Lanier Swamp is a small wetland, 37 km in length and approximately 100 km<sup>2</sup> in area, situated on a west-east axis, from coast to coast across the central portion of Isla de la Juventud. The swamp is divided into two zones, eastern and western, well differentiated from geological and landscape points of view. These two areas are linked by a calcareous bridge, known as Cayo Piedra, situated midway between each coast. The freshwater surface is very small, and is fragmented into lagoons and sawgrass swamps that appear unevenly distributed over a dry limestone surface, and covered by natural shrub and forest vegetation. This is the third most important wetland in Cuba, after Zapata and Birama Swamps.

Lanier Swamp was declared a Ramsar site in 1971, and a wildlife refuge in 1990. It is important to highlight that Lanier Swamp divides the island into two drastically different territories - “North” (1312 km<sup>2</sup>) and “South” (850 km<sup>2</sup>). The North is densely populated, and is characterized

by a variegated landscape of very old soils, with a relief of undulating plains, savannas and valleys with agricultural, industrial and livestock activities. The landscape includes several groups of hills, with a maximum height of 303 m, large areas of extensive semi-deciduous and pine forests, rivers, estuaries, 13 large reservoirs and towns. The “South” consists of a flat karst platform, made of Neogene rocks, and is extensively covered by semi-deciduous Caribbean forest. There is only one small town on its southern coast, where sandy beaches, small estuarine streams and lagoons predominate.

Today, three species of crocodylian are found on the Isla de la Juventud, of which two are endemic: the American crocodile *Crocodylus acutus* and the Cuban crocodile *Crocodylus rhombifer*, the latter probably the relict of an endemic population plus the remnants of a reintroduction program initiated in 1994 (Rodríguez-Soberón 1996). The third species, the Brown caiman (*Caiman crocodilus fuscus*), resulted from the release of a small number of specimens imported from Colombia in 1959 (Varona 1976).

Currently in Cuba, it is a generalized belief that the natural geographical distribution of *C. rhombifer*, as far as historical memory reaches, is restricted to Zapata Swamp on mainland Cuba, and Lanier Swamp on the Isla de la Juventud (Ramos 1994). Historical reports document the presence of the species on the Isle of Pines from the end of the 17th century to the first two decades of the 20th century (Dampier 1699; Humboldt 1807; Gundlach 1866; Barbour and Ramsden 1919). Nevertheless, despite the existence of numerous testimonies and scientific reports issued over a long period of time that report the presence of *C. rhombifer* on the Isla de la Juventud, there is still some uncertainty, due to the lack of physical evidence. It must be noted that up to now, no specimen of *C. rhombifer* from this locality has been reported by any museum or study collection (Varona, unpublished; Thorbjarnarson, pers. comm.).

The earlier report of the presence of two species of crocodiles in Cuba was given by the British explorer, adventurer and pirate, William Dampier (1699). The historical account of Dampier provides tantalizing evidence that two different types of crocodiles, which could be none other than *C. acutus* and *C. rhombifer*, were seen by Europeans on the Cayman Islands as well as on the Isla de la Juventud (Ramos 2013).

Humboldt (1840) believed that *C. rhombifer* was distributed along the southern coast, from Jagua (Cienfuegos Province) to the coastal town of Surgidero de Batabanó (on the southern coast of Mayabeque Province), and on the Isla de la Juventud. Nuñez-Jiménez (1976), based on family testimonies, comments on the presence of two different species of crocodile on the Isla de la Juventud during the last three decades of the 19th century. One of these species is described as a non-aggressive dweller of brackish and saltwater habitats, and the other as a very aggressive dweller of freshwater bodies in forested inland areas. These descriptions fit with the general characteristics of *C. acutus* and *C. rhombifer*, respectively.

The population of *C. rhombifer* on the Isla de la Juventud was formerly more widespread, and its range included the northern coastal region [Hornaday (1904) in Ross (1998)]. By 1930, *C. rhombifer* were reported to have become rare in the Lanier Swamp, and restricted to the most inaccessible regions (De Sola 1930). Pablo de la Torriente Brau (1969) in his book “Presidio Modelo” narrates the presence, in the course of the Simon River (also called “El Cocodrilo”, one of the small streams of the northern territory of the Isla de la Juventud), of *biajacas* (*Nadopsis tetracanthus*), imported largemouth bass (*Micropterus salmoides*) and “hidden among the reeds that populate the ponds, crocodiles”. The two species of fish, and southern cattail (*Typha domingensis*), only inhabit fresh water, which suggests the possibility that the mentioned crocodiles were *C. rhombifer*. Furthermore, a photograph exhibited in the Museum of the former Model Prison of the Isla de la Juventud shows a group of prisoners capturing a crocodile, in which, despite the imperfections of the old photograph, the characteristics of *C. rhombifer* can be identified (Rodríguez-Soberón *et al.* 1996).

Interviews with old residents of the Isla de la Juventud confirm that *C. rhombifer* was once abundant in the eastern portion of Lanier Swamp and that it was intensely hunted during the first half of the last century. These informants reported that by 1950 the population was already virtually extinct. Presumably this process of population decline was aided by two major fires that occurred in 1926 and 1944, which destroyed most of the vegetation in the southern part of the island, and which, according to local informants, “allowed the hunters to follow the crocodile trails through the ashes to their most remote shelters”. It has been suggested that in addition to fire and commercial hunting, a severe drought could have added to these negative factors (Rodríguez-Soberón *et al.* 2000).

Further evidence demonstrates the early presence of *C. rhombifer* in that territory. A juvenile *C. rhombifer* was found in the stomach of an adult *Caiman crocodilus* (Varona 1983). Pedro Regalado, who worked as a forest ranger in the southern territory of the Isla de la Juventud in the 1970s, generously shared with us the following important information and documentation. He personally gave Luis Varona a set of photographs taken by himself in 1970, of a group of young crocodiles that were held by a local rancher in an enclosure at his ranch, near Rincón del Guanál, on the southern portion of the Isla de la Juventud. According to the rancher, he captured these crocodiles, some in freshwater ponds near Lanier Swamp, and others in a saltwater location on the southwest coast. Varona identified one of the animals shown in the photographs as *C. rhombifer*. Later, in a new group of photographs of the same origin, showing four crocodiles, Varona identified two adult *C. rhombifer* - a female and a male (Fig. 2). These two specimens had been captured in Laguna Villares, a freshwater pond located on the southwest portion of Lanier Swamp, which extends to Siguanea Bay, the same place where the introduction of *Caiman c. fuscus* had occurred almost two decades ago. The other two specimens identified by Varona in these photographs were an adult female *C. acutus* (2.50 m TL) captured in salt water, and an atypical adult male or “mixturado” (as those atypical, possible hybrids

of Cuban and American crocodile are commonly called in Cuba), also captured in salt water, near the community of Cocodrilo (formerly, Jacksonville) on the southwestern coast of the island.



Figure 2. Cuban crocodile captured May 1977 in southwest Isla de la Juventud. Photograph: Pedro Regalado.

Subsequently, a 2.16 m long female, also captured in the Isla de la Juventud (Fig. 2B), was carried to Havana by Pedro Regalado, to be examined by Varona. Having examined carefully the external characters (color of body, scale pattern) and cranial characteristics, Varona could not find any differences between this individual from the Isla de la Juventud and the typical *C. rhombifer* from the Cuban mainland. Varona regrettably did not publish his article, which was titled “*Crocodylus rhombifer*: Rediscovery in Isle of Pines, 1977”. It is noteworthy that while old inhabitants gave information about the abundance of *C. rhombifer* on the east side of the island, the specimens identified by Varona were all captured at the far southwestern end.

With the aim of recovering the historical distribution of the species, a restocking program for *C. rhombifer* was initiated at the Isla de la Juventud in 1987, under the leadership of the National Crocodile Program, a collegiate effort among various Cuban official institutions, led by the Department of Flora and Fauna (Ministry of Agriculture). The program was developed according to the criteria established by the “IUCN Position Statement on Translocation of Living Organisms: Introductions, Re-introductions and Re-stocking” (IUCN 1987).

The program was based on the establishment of a small crocodile farm inside Lanier Swamp. The farm was named after the place where it was built: “Cayo Potrero” (Rodríguez-Soberón *et al.* 1996). The founding stock of *C. rhombifer* for this farm came from Havana Zoo and the Zapata Swamp crocodile farm. The individuals were selected according to the phenotype of *C. rhombifer*, and no animal with atypical characteristics was taken to the Isla de la Juventud. A total of 777 specimens was transferred to the crocodile farm at Cayo Potrero: 52 adults ( $\geq 180$  cm TL), 75 sub-adults (175-195 cm TL) and 650 juveniles (90-120 cm TL). Another 16 *C. rhombifer* from the Zapata Swamp farm were added in 2008 (Rodríguez-Soberón, pers. comm.).

Restocking activities into the wild started in 1994, with the release of 200 individuals of both sexes and a size structure that imitated a natural distribution of sizes, from juvenile ( $\leq 90$

cm TL) to sub-adult (120-180 cm TL). The group of animals was diverse in relation to origin, with the intention of avoiding genetic bottlenecks. Restocking was repeated in 1995, and more than 600 farm-bred *C. rhombifer* have been released in Lanier Swamp since then. All the animals were uniquely scute-clipped. Information on the identification number, sex and size of every animal was recorded on release. At least 200 individuals of different ages had escaped from the farm prior to the initial release, particularly during events of severe flooding that occurred in 1993 and 1994 (Rodríguez-Soberón *et al.* 1996).

Monitoring of the reintroduced crocodile population began in 1996, and continued in 1997, 1999 and 2002, with the support of the American Zoo and Aquarium Association (AZA), Havana Zoo and Wildlife Conservation Society (WCS), and with the participation of William McMahan, Perran Ross and John Thorbjarnarson, along with Cuban specialists and other personnel. This study was conducted in the eastern sector of Lanier Swamp, located within a radius of 14 km south and southeast of the Cayo Potrero crocodile farm.



Figure 3. Cuban crocodile captured and measured in April 2002 in SW Isla de la Juventud. Photograph: John Thorbjarnarson.

Resuming the results of the monitoring conducted between 1996 and 2002, 32 *C. rhombifer* were captured and measured (Fig. 3) during daylight reconnaissance (quantitative spotlight surveys are not practicable in this heavily vegetated habitat), which represent approximately 5% of the total number of released animals (N= 600). The age distribution comprised 11 (23.1%) hatchlings, 4 juveniles (12.5%), 7 sub-adults (21.9%) and 10 adults (31.3%).

The sex ratio of captured animals  $< 180$  cm TL (N= 15) was 0.73 (expressed as proportion of females). For adults ( $\geq 180$  cm TL; N= 10), the sex ratio (0.70) was also biased towards females. The sex of 7 crocodiles  $< 60$  cm TL was not determined. Mean TL was  $129.8 \pm 61.2$  cm (range 40-228 cm; N= 32). For adults, mean TL was  $195.5 \pm 20$  cm (N= 10): females  $188.0 \pm 13.7$  cm (N= 7) and males  $213 \pm 24.3$  cm (N= 3).

Systematic monitoring of the reintroduced population showed important indicators of success. The crocodiles had dispersed

1-11 km from the release site in Cayo Potrero, and the majority of the animals were captured within 4-5 km. Some of these animals were known to be successfully reproducing (Fig. 4). In 1999, 9 *C. rhombifer* mound nests were located, and based on the distribution of groups of hatchlings, it is believed that there were other nests, which were not found (Rodríguez-Soberón, pers. comm). Three skulls and one carcass of *C. rhombifer* illegally killed were found. The estimated total length of these four specimens was estimated as 1.5 to 2.0 m.



Figure 4. Mound nest (left) and unmarked juvenile Cuban crocodile (right) located in April 2002 in SW Isla de la Juventud. Photograph: John Thorbjarnarson.

Although the local *C. acutus* population prefers brackish and saltwater habitats such as mangrove swamps, coastal lagoons and estuarine watercourses, individuals occasionally venture deep into the freshwater habitats of Lanier Swamp, enabling hybridization with *C. rhombifer* (Ramos *et al.* 2010). Ramos, Rodríguez-Soberón and McMahan (pers. obs.) report the capture in 1997 of an 1.72 m long unmarked, sub-adult male, showing atypical external characteristics, closer to *C. rhombifer* than to *C. acutus* (Fig. 5), probably a wild-born hybrid prior to the restocking program.



Figure 5. Hybrid (top) and Cuban crocodile (bottom) captured in 1997. Photograph: William McMahan.

We estimated that this individual was between 7 and 10 years of age, based to the annual growth rates obtained in Zapata Swamp from wild and farm-raised *C. rhombifer*. Accordingly, the specimen had hatched between 1987 and 1990, thereby demonstrating the existence of wild *C. rhombifer* on the island prior to the restocking program. It could not be confirmed whether *C. rhombifer* persisted in remote refuges of this locality after the 1950s.

Monitoring of the reintroduced population between 1994 and 2002 showed that the released crocodiles had established and reproduced successfully, despite the strong pressure of illegal hunting, aimed at obtaining meat for local consumption.

Old residents, who in the past hunted crocodiles in the eastern section of Lanier Swamp, and employees of the crocodile farm, who have been monitoring the area since 1990, wouldn't confirm that endemic *C. rhombifer* persist in the wild in this area. Subsequent monitoring expeditions to Lanier Swamp carried out by the crocodile farm personnel do not report any more sightings, nor any other trace of *C. rhombifer* since 2010 (Gavino, pers. comm.). In May 2019 they explored the surroundings of the crocodile farm and Punta Frances, on the southwestern corner of the island, without spotting any *C. rhombifer*; instead, they reported the ubiquitous presence of *Caiman crocodilus* and their nests. *Caiman crocodilus* is very common in Lanier Swamp and the lakes scattered around it, but it is not clear what ecological impacts the presence of so many caimans might exert on efforts to establish a wild *C. rhombifer* population. Apart from Varona's finding of one juvenile *C. rhombifer* in the stomach of an adult *C. crocodilus* on the Isla de la Juventud, no other evidence of negative impacts on *C. rhombifer* by caimans has been reported (Rodríguez-Soberón 2000; Varona 1983). Analysis of more than 1000 caiman stomachs (1995-1998) provided no evidence that they regularly prey on crocodiles (Rodríguez-Soberón, pers. comm.).

The conclusions of the Population and Habitat Viability Analysis (PHVA) carried out for *C. rhombifer* 20 years ago (Rodríguez-Soberón *et al.* 2000), showed that a removal of 30-40 sub-adult and adult crocodiles per year, over the next 20 years, would result negative population growth, and that if continued, it would eventually lead to extinction (although this would not become apparent in the next 40 years). However, these predictions underestimated the degree of illegal hunting. In less than 8 years since the workshop, no *C. rhombifer* have been reported in Lanier Swamp, although it must be recognized that after 2002 no regular population monitoring of the area has been carried out.

We conclude that illegal hunting activities have been the leading cause of the apparent extinction of the reintroduced *C. rhombifer* population in Lanier Swamp. This place is by far the best habitat available to establish another wild *C. rhombifer* population, but successfully achieving this requires the implementation of effective mechanisms to control illegal hunting, along with community education and programs that include community participation in conservation activity and sustainable use. Systematic and replicable surveys need to be conducted regularly, to determine the status of crocodilian populations on the island and plan management alternatives such as a new reintroduction of Cuban crocodiles.

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## Mexico

ACTIONS FOR SOCIAL AND ECOLOGICAL STRENGTHENING AND PREVENTION OF HUMAN-CROCODILE INTERACTIONS IN AN INDIGENOUS PARADISE ON THE COAST OF OAXACA, MEXICO. In Mexico, we find indigenous groups living throughout the country, but one of the largest representations is in the state of Oaxaca, with 15 native groups and also the Afro-mestizo group that is strongly represented on the coast of Oaxaca. Oaxaca, together with the states of Veracruz, Guerrero, Michoacán and Chiapas, have a great biological diversity, this as a result of the mountainous relief which also results in different vegetation profiles and a variety of climates. The binomial formed by native peoples and nature comprise the biocultural heritage.

Despite this cultural and natural richness in Oaxaca, the state has one of the highest levels of poverty by entity according to the National Council for the Evaluation of Social Development policy (CONEVAL 2019), and which is aggravated by natural phenomena that strike from time to time, such as earthquakes (most recent in 2017) and hurricanes (Paulina in 1997; Stan in 2005), and more recently the situation caused by the COVID-19 pandemic this year.

Man's relationship with nature, in addition to natural phenomena, also becomes negative when it is threatened or at permanent risk by some natural species with which it coexists in certain spaces. In the case of the Oaxaca coast, we find the American crocodile (*Crocodylus acutus*), which mainly occupies lagoons, rivers, estuaries and mangroves - wetlands that are also occupied by man for activities such as artisanal fishing and diving as forms of subsistence. The margins of these habitats are used for activities such as livestock and agriculture, and in many cases the construction of houses. It is in these areas that man and crocodile carry out their usual activities and the scene of encounters.

The problem of human-crocodile interaction means that *C. acutus* is perceived negatively, and as a constant threat by communities. However, we found some projects have managed to make crocodiles a tourist attraction, as well as the habitats in which they occur. (Fig. 1). For example, the community of La Ventanilla, municipality of Santa María Tonameca, Oaxaca, has had as a core point the conservation of *C. acutus*, that is a source of income through responsible tourism and non-extractive use by the Sociedad Cooperativa de Servicios Ecoturísticos de la Ventanilla SC by R.L. de C.V. (“the Cooperative”). Over a period of two decades, the Cooperative has achieved a local economy that has assisted members and their families, and has also significantly permeated the economy of all families in the community,

bringing as a palpable result the conservation of habitat and species. For these activities, in 2017 the Cooperative was awarded a distinction by the National Commission for the Development of Indigenous Peoples [now “National Institute of Indigenous Peoples” (INPI)] - calling it an “Indigenous Paradise” which highlights its commitment as a community and company with social and environmental responsibility, as well as the total of the coast of the state of Oaxaca.



Figure 1. *Crocodylus acutus* nesting and tourist activities area in La Ventanilla, Oaxaca. Photograph: Marco Antonio López Luna.

Taking into account the aforementioned and developing education, it is proposed as objectives and functions “to explore analytically, together with other disciplines, the relationships between human societies and nature to convert the results into a formative process that link with higher levels of understanding of the humans towards their ecosystem environments” (Reyes 2017).

Starting in 2016, the authors began to develop a proposal outside of documents published by governmental bodies such as the Secretary of the Environment and Natural Resources (SEMARNAT), the National Commission for Protected Natural Areas (CONANP) and the National Commission for the Use and Knowledge of Biodiversity (CONABIO) [eg Monitoring Program of the Swamp Crocodile (*Crocodylus moreletii*); Action Program for the Conservation of Species (PACE Crocodylia) (*Crocodylus acutus*, *Crocodylus moreletii* and *Caiman crocodilus chiapasius*) (SEMARNAT 2018a); Protocol for Attention to Human-Crocodylian Contingencies (SEMARNAT 2018b); Ranching Protocol for *Crocodylus moreletii*]. Currently, these documents form the basis and knowledge for the conservation and sustainable use of crocodiles on the coast of Oaxaca in a multisectoral manner, and specify an opportunity for social inclusion.

#### Work Development

With members of the Cooperative and the community, dialogue was established between technical-scientific knowledge. In addition to the increase in ecotourism activities, actions were initiated for the protection of crocodiles, such as search, surveillance and cleaning in nesting areas (Figs. 2-4). Wild hatchling *C. acutus* were collected and raised in captivity for a year, for subsequent release back to the wild (head-starting), in order to reduce mortality rates and increase the rate of population growth. A scientific collection permit was



Figure 2. Nest search by Cooperative members. Photograph: Gabriel Cruz.



Figure 3. Nest data collection. Photograph: Atanacio Martínez.



Figure 4. Nest data collection (distance from water). Photograph: Francisco Arango.

obtained from SEMARNAT through the General Directorate of Wildlife (SGPA/DGVS/002578/16) to carry out these activities.

So far, we have recorded 18, 20, 21 and 22 nests in 2016, 2017, 2018 and 2019, respectively, with an average of 35 eggs per nest. Cedillo-Leal (2012) reported 6 nests at this same

locality, indicates that the work carried out by the community has supported a significant increase in the number of mature female *C. acutus* in the population.

The Culture and Biodiversity Value Component of the Crocodylia Species Action and Conservation Program (PACE), carried out by CONANP, mentions carrying out “actions that promote education, communication and dissemination about the importance of the conservation of crocodilians, as well as the valuation of the goods and services obtained of the conservation of species and their habitats”, and as crocodiles are part of the “cosmovision” of the people of Oaxaca, some artists such as the teacher Francisco Toledo (RIP) have represented crocodiles in their paintings and sculptures.

Another example on the coast of Oaxaca is “Nahualism” (“spiritual and ancestral cosmic thought fought upon the arrival of the conquerors”) as a form of man’s relationship with species of nature, in this case the crocodile. Therefore, we not only take into account the presence of the crocodile in natural habitats but also the symbolism it represents in Oaxacan art and culture, encompassing it from a biocultural heritage perspective. We require new teachers who influence environmental education, mainly for two reasons; one that has to do with society, and the other with the environment. At the same time that we generate the need to know the problem from a new perspective that is art. This third reason allows us to work with our imagination and creativity with the purpose of seeing, rethinking, remodeling and improving our life, that is, concrete artistic actions that improve people’s living conditions, stimulating reflection and sustainable use.

Based on the above, in an inclusive, participatory and dynamic way, events were planned, organized and carried out in 2016 and 2018 (proposed 2020 activities were impacted by the pandemic). With “Children’s Encounter of Art, Environmental Education and Interculturality” (Figs. 5-9), the crocodile was the image and the main actor, emphasizing the importance of its natural space (ie mangroves in La Ventanilla), highlighting biological cycles and the biodiversity comprising it, and also addressing the negative human-crocodile interaction that occurs in the region.

Each event had a capacity for 150 children, and were aimed at young people aged 10-12 years, from different communities on the Oaxacan coast. They featured various activities such as work tables (Fig. 8), dialogue with specialists, tours, conferences and concerts of traditional music. Visual artists, musicians, biologists, sociologists, photographers, veterinarians, engineers, surfers, etc., from 12 states of the Mexican Republic, participated in these activities. These events were held thanks to several sponsors who know, follow and support the Cooperative’s project, as well as the financing of the Cooperative’s members.

In the same way, the National Protocol of Attention to Human-Crocodile Interactions of Mexico (HCI) (SEMARNAT 2018c) was published in 2018. And based on one of its objectives, the coast of the state of Oaxaca has a long history of multisectoral



Figure 5. Dr. Armando Escobedo, member of Scientific Committee, in La Ventanilla, Oaxaca. Photograph: Douglas Brandon.



Figure 6. Inauguration of the 2nd Children’s Encounter of Art, Environmental Education and Interculturality, October 2018. Photograph: Douglas Brandon.



Figure 7. Bonifacio Cortés (Cooperative member) talking about the importance of mangroves as crocodile habitat. Photograph: Douglas Brandon.



Figure 8. Work table with music and verse themes about crocodiles. Photograph: Douglas Brandon.



Figure 9. Participants of the Children's Encounter of Art, Environmental Education and Interculturality. Photograph: Douglas Brandon.

and multidisciplinary participation in negative interactions due to the different human activities that take place in their habitat (Grajales and Buenrostro 2018).

In November 2019, a Conference on Accidents with snakes and Human-Crocodile Interaction was organized with different institutions, companies and civil groups, with the main objective of making a general review of this published document (Fig. 10). During this conference, the characteristics of potential injuries and how they can be managed were emphasized. These sessions were held in Huatulco, Oaxaca, in the Hotel Dreams for the theoretical part and in the facilities of the Cooperativa en Ventanilla for the practical part. Participants were firefighters, lifeguards, tourism service providers, as well as people from some communities on the Oaxaca coast. It is worth mentioning that the Cooperative has a committee for prevention and response to emergencies that is made up of Guillermo Gil Alarcón and Hamblet Torija Morales, who are specialist Emergency Medical Technicians.



Figure 10. Participants in the conference on Accidents with snakes and Human-Crocodile Interaction in La Ventanilla, Oaxaca. Photograph: Francisco Arango Méndez.

## Reflections and Conclusions

The work from Environmental Education provides us with a range of opportunities to carry out comprehensive actions by adding different positions such as traditional knowledge, scientific knowledge and art are put into dialogue in their different expressions, not only in terms of knowledge of the crocodile, but of the entire ecosystem by making the natural

space a stage to consolidate a local economy. The above becomes a study laboratory where knowledge of the ecology of crocodiles is implemented, as well as a space used as a living classroom that invites the meeting of different ways of seeing and interpreting nature and especially crocodiles considered a threat, inviting permanent reflection on the crocodile, the main objective being that it becomes an ally and companion.

Taking into account the complexity of the human-crocodile relationship on the coast of Oaxaca, addressing the challenges in a comprehensive manner requires the intervention of actors from different perspectives and with different disciplines, resulting in the development of interdisciplinary and multidisciplinary work.

The "Ranching Protocol for the Swamp Crocodile (*Crocodylus moreletii*) in Mexico" (Barrios and Cremieux 2018) provides the basis for ranching of wild eggs, and reflects an opportunity for local economic development of *C. acutus*, not only in La Ventanilla, but for the entire coastal region of Oaxaca. Sustainable use of crocodiles for community development can also provide incentives for conservation of the species and its habitats.

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## Brazil

CROCODYLIA BRAZIL GROUP (CrocBr): A REFERENCE NETWORK IN THE RESEARCH AND CONSERVATION OF BRAZILIAN CROCODILIANS. Brazil is a megadiverse country harboring at least 20% of the world's biological diversity. The conservation of this immense biodiversity is a challenge, and requires the integration of different activities and strategies, in agreement with the number of biomes and the country's size, including environmental and legislative approaches. Historically, the natural-resource use has been an important component of the Brazilian socio-cultural context, and crocodilians are exploited at local, regional, and international levels, resulting in complicated conservation status for Brazilian crocodilians.

Brazil has six crocodilian species, all alligatorids. In light of innumerable threats, the six species have different conservation status, and some of them are economically explored in legal and sustainable scenarios. The joining of efforts by Brazilian researchers to provide relevant information for the management of Brazilian crocodilians has become fundamental to integrate conservation strategies and strengthen the union with local environmental agencies. The integrated articulation between biologists, veterinarians and managers has resulted in Brazilian caiman species being managed effectively and used sustainably. The effectiveness of these actions is internationally recognized, including by the CSG.

Integration and strengthening conservation actions were the

goals of a group of enthusiastic crocodilian specialists who launched the Crocodylia Brasil Group (CrocBR), a reference Brazilian team in crocodilian issues. CrocBR was officially constituted on 29 October 2020, and the founder members have solid expertise on research and conservation of the Brazilian crocodilians. Most of the founder members are also members of the CSG, and they implemented internal guidelines to guarantee a participatory decision-making process based on science.

CrocBR is a network of researchers, technicians, and other professionals involved in crocodilian conservation initiatives. Currently, the Group has 16 members. Its goal is to strengthen a Brazilian network, including other members representing crocodilian species, their habitats, ecosystems and biomes, offering support and an appropriate scientific advice for students, technicians, government officers, press, and the public in general, concerned about crocodilians conservation.

CrocBR expects to advise, promote and develop scientific research, extension, teaching and learning activities to promote conservation and management of the crocodilian species in Brazil, including foreign species, species in their natural habitats or zoos, other *ex-situ* conservation and commercial initiatives, according to environmental legislation.

The initial workgroup structure is:

General Coordinators: Dr. Luis Bassetti, Prof. Ronis Da Silveira

Scientific Advisory Committee: Dr. William Magnusson, Dr. Zilca Campos, Robinson Botero-Arias

Species Officers:

- *Caiman crocodilus*: Dr. Igor Joventino Roberto
- *Caiman latirostris*: Dr. Thiago Portelinha
- *Caiman yacare*: Dr. Guilherme Mourão
- *Melanosuchus niger*: Prof. Ronis Da Silveira
- *Paleosuchus trigonatus*: Dr. Boris Marioni
- *Paleosuchus palpebrosus*: Dr. Fábio Muniz

Veterinary Science Committee: Dr. Augusto Kluzklovski Júnior, Dr. Luis Bassetti

Extension and Education Committee: Dr. Thiago Portelinha, Eduardo Conde de Moura

Media and Communication Committee: Dr. Fabio Maffei, Paulo Braga Mascarenhas Júnior, Diogo Dutra Araújo

Advisory Board: Dr. Luciano Martins Verdade, Dr. Guilherme Mourão, Dr. Pablo Siroski, Alejandro Larriera

To learn more about and to contribute to CrocBR, follow us on Instagram and on Facebook (Crocodylia Brazil), or write for us ([crocodyliabrasil@gmail.com](mailto:crocodyliabrasil@gmail.com)). We look forward to hearing from you soon.

Luis Bassetti<sup>1</sup>, Ronis Da Silveira<sup>2</sup>, Robinson Botero-

Arias<sup>3,4</sup>, Zilca Campos<sup>5</sup>, William Magnusson<sup>6</sup>, Luciano Martins Verdade<sup>1</sup>, Thiago Costa Gonçalves Portelina<sup>7</sup>, Igor Joventino Roberto<sup>8</sup>, Augusto Kluczkovski-Junior<sup>9</sup>, Boris Marioni<sup>10</sup>, Paulo Braga Mascarenhas-Junior<sup>11</sup>, Fábio Muniz<sup>8</sup>, Fábio Maffei<sup>12</sup>, Diogo Dutra Araújo<sup>13</sup> and Eduardo Conde Moura<sup>14</sup>; <sup>1</sup>*Centro de Energia Nuclear na Agricultura (CENA), da Universidade de São Paulo, Piracicaba-SP, Brazil;* <sup>2</sup>*Laboratório de Manejo de Faunas, Instituto de Ciências Biológicas, Universidade Federal do Amazonas, Manaus-AM, Brazil;* <sup>3</sup>*Department of Wildlife Ecology and Conservation, Institute of Food and Agricultural Sciences, University of Florida, Gainesville-FL, USA;* <sup>4</sup>*Tropical Conservation and Development Program, Center for Latin American Studies, University of Florida, Gainesville-FL, USA;* <sup>5</sup>*Laboratório de Vida Selvagem, Embrapa Pantanal, Corumbá-MS, Brazil;* <sup>6</sup>*Coordenação de Biodiversidade, Instituto Nacional de Pesquisas da Amazônia, Manaus-AM, Brazil;* <sup>7</sup>*Universidade Federal do Tocantins, Curso de Engenharia Ambiental, Palmas-TO, Brazil;* <sup>8</sup>*Laboratório de Evolução e Genética Animal, Universidade Federal do Amazonas, Manaus-AM, Brazil;* <sup>9</sup>*Fundação de Vigilância em Saúde do Amazonas (Amazonas Health Department), Manaus-AM, Brazil;* <sup>10</sup>*Pós-Graduação em Biologia de Água Doce e Pesca Interior, Instituto Nacional de Pesquisas da Amazônia, Manaus-AM, Brazil;* <sup>11</sup>*Pós-Graduação em Biologia Animal, Universidade Federal de Pernambuco, Recife-PE, Brazil;* <sup>12</sup>*Universidade Estadual Paulista, Faculdade de Ciências de Bauru, Bauru-SP, Brazil;* <sup>13</sup>*Khamai Gestão de Recursos Naturais, Brazil;* <sup>14</sup>*Agência de Defesa Agropecuária e Florestal do Estado do Amazonas, Manaus-AM, Brazil.*

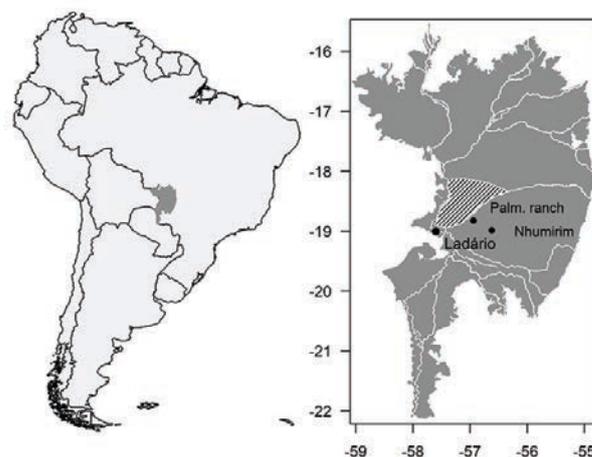


Figure 1. Location of the Pantanal wetland (right), Palmeirinha Ranch, Nhumirim (Embrapa's Field Station), and Ladário City, where measurements of the water level of the Paraguay River have been taken daily since 1900. The shaded area indicates the Taquari Fan, an area that flooded during most part of each year during the last decades.

**DROUGHT DRASTICALLY REDUCES SUITABLE HABITAT FOR YACARE CAIMAN.** The Pantanal wetlands is a Neotropical floodplain of about 165,000 km<sup>2</sup> area located in the middle of South America (Fig. 1). It is regulated by an annual flood pulse, with dry (April-September) and wet (October-March) periods (Junk and Da Silva 2000; Junk and Cunha 20005), which favors populations of aquatic and

semiaquatic species such as the Yacare caiman (*Caiman yacare*). Besides the annual flood pulse, the Pantanal is also subject to a largely unpredictable multiyear variation in flood intensity. For example, from 1964 to 1974 there was an unusually long dry period, in which the level of the Paraguay River stayed well below its historic mean level. However, for the next four decades its water level tended to be at high or average levels during the floods (Fig. 2).

Since the mid-1970s, the Yacare caiman, with its early reproduction capability and fast-growth rate, took advantage of the expansion and diversification of permanent or semi-permanent aquatic habitats in the Pantanal to rapidly become one of the most abundant of the crocodylians (eg Coutinho and Campos 1996; Mourão *et al.* 2000). Such population density was impressive, especially since the species was intensively

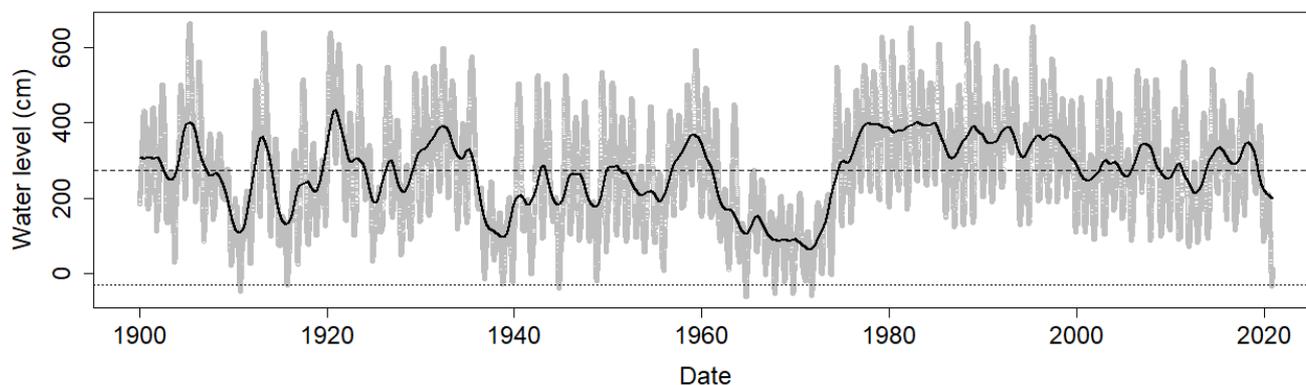


Figure 2. Daily water level (grey dots) of the Paraguay River, measured at the municipality of Ladário, MS, Brazil, from 1 January 1900 to 24 November 2020. The black line was obtained by a LOWESS smoother, which uses locally-weighted polynomial regression (Cleveland 1979). The dashed horizontal line indicates the historical water level average (272.5 cm) and the dotted line indicates the minimum value measured in November 2020 (-30 cm). Measurements of the Paraguay River level at Ladário are convenient to index the history of flood-pulse of the Pantanal, because the Paraguay River drains most of the water that flows through the tributaries and plains across the Pantanal and because it is by far the longest series of hydrological data available for the Pantanal.



Figure 3. Yacare caiman concentrated in ponds at Palmeirinha Ranch, November 2020.



Figure 4. Another pond “jammed” with cattle, caimans and capybaras, 2 km from the first ponds with many caimans on Palmeirinha Ranch, November 2020.



Figure 5. Yacare caiman at Palmeirinha Ranch, after water was supplied by a semi-artesian well, December 2020.

poached during the 1980s (Mourão *et al.* 1996). The poaching was largely controlled during the first years of the 1990s. However, we are now experiencing a drought comparable to the dry years from the mid-1960s to mid-1970s, and the effects on the Yacare caiman populations could be dramatic.

The reduction of water level in the Paraguay River was precipitous during the last two years (Fig. 2), but since 2006

rainfall was decreasing every year in the Pantanal, reducing the availability of water bodies (Araújo *et al.* 2018) suitable for caimans. The cumulative rainfall for the hydrologic year of 2019-2020 at Embrapa’s field station in the Pantanal was just 715 mm, well below from the historic mean of 1077 mm. The yacare caiman has some behavioral responses to periods of water scarcity (Campos and Mourão 2020), including aestivation in mud for several months or seeking refuge within forest patches, and sheltering under the litter, to avoid desiccation.

However, rainfall in 2019 and 2020 was extremely low for those caimans living in habitats other than perennial rivers. At Embrapa’s Field Station (Nhumirim), which is far from the rivers and where flooding is caused by local rain, most of the almost 100 shallow lakes that used to be “perennial” and were habitat for thousands of Yacare caiman a few decades ago, became dry or almost dry during the dry season from the mid-1990s to now (Mourão *et al.* 2013). At this site, increased caiman mortality and emigration, and reduction in the number of nests were processes diluted in time (Mourão *et al.* 2013; Campos *et al.* 2015). However, in sites located close to the intricate net of channels that form the Taquari River fan, the water only became limiting during the dry period of this year. For example, Palmerinha Ranch (18°49’29.40” S 56°56’25.11” W) used to have a large part of its area of one 100 km<sup>2</sup> flooded year-round. However, on 20 November, 2020, we found about 4000 Yacare caimans crowded in the mud of a waterhole made for cattle (Fig. 3).

Of the 8 waterholes originally on Palmeirinha Ranch, only two still have mud or a few centimetres of water (Fig. 4), and probably even the cattle will suffer from lack of water. It seems that most or all of the caiman in the mud will, if heavy rains do not start soon. Some of them could find refuge in the forest, within the litter or underground holes, but there they will be more exposed to fire, that has increased severely in the last two years (Einhorn *et al.* 2020).

At the time we are writing this note we learned that the owner of the ranch managed to drill a semi-artesian well to supply water to that waterhole (Fig. 5). Of course, we feel relieved with this news, but we do not know how effective this will be to reduce caiman mortality. There are probably hundreds of mud puddles like that one with crowded with caimans spread over the Pantanal. Therefore, we must realize that action was meritorious, but unlikely to be followed for other ranchowners. We know that the Pantanal suffered from severe and long droughts in the past, and Yacare caiman, as well as other semi-aquatic species such as giant otters and capybaras, survived somehow to re-expand their distribution when conditions became favorable. What is new and worrying is the expectation that climate changes will push the conditions to levels beyond the capacity of adaptation for many species.

#### Acknowledgements

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## Europe

### Germany

REPATRIATION OF PHILIPPINE CROCODILES FROM COLOGNE ZOO TO THE PHILIPPINES. The Philippine crocodile (*Crocodylus mindorensis*) is endemic to the Philippines, and the wild population is considered to comprise around 100 individuals, making it one of the rarest crocodilians in the world. Its status means that it is listed as Critically Endangered by both Department of Environment and Natural Resources (DENR) (DAO 2019-09) and the International Union for Conservation of Nature (IUCN), and listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The CSG has recommended *ex-situ* management, (eg conservation breeding in zoos) as an action to improve the status of the species in the wild.

International captive breeding programs have been executed under Memoranda of Agreement by the Philippine Government under DENR with the zoos in the USA, Australia, and Europe. In Europe, 15 hatchling *C. mindorensis* were transferred in 2006 from the DENR-Palawan Wildlife Rescue & Conservation Center (PWRCC) based on a Memorandum of Agreement between DENR, Protected Areas & Wildlife Bureau (PAWB; now Biodiversity Management Bureau), Government of the Philippines, and the Danish Crocodile Zoo. In 2009, 10 of the 15 hatchlings were transferred to other European zoos based on Wildlife Transfer Certificates issued by PAWB.

The first Philippine crocodile captive breeding program in Europe was officially initiated in April 2012, when the European Studbook (ESB) was established by the European Association of Zoos and Aquaria (EAZA), and administered by Cologne Zoo, Germany. The goal of the ESB was to build up a captive assurance/reserve colony in Europe for the critically endangered species.

Breeding first occurred at Cologne Zoo in July 2013, and further breeding successes occurred at Protivin Crocodile Zoo (Czech Republic), ZSL London Zoo (UK) and Krokodille Zoo (Denmark). Mainly due to these recent breeding successes, the number of *C. mindorensis* within the ESB has increased from the original 15 individuals to 52 individuals distributed among 12 institutions.

Genetic screening of the *C. mindorensis* held in Europe was undertaken in cooperation with Omaha's Henry Doorly Zoo (USA) and the Zoological Institute of the Technical University of Braunschweig (Germany) seven years ago. These and further tests conducted in 2015 were necessary,

to demonstrate the purity of the ESB individuals, as molecular studies had revealed the existence of phenetically indistinguishable hybrids (*C. mindorensis* x *C. porosus*) among farms in the Philippines.

In early 2016, Cologne Zoo informed BMB of these developments and that a possible restocking of pure *C. mindorensis* could be undertaken in the near future. Recent field research conducted by Crocodylus Porosus Philippines Inc. (CPPI), resulted in the discovery of a new *C. mindorensis* population in the southern Philippines. To support the few remaining natural populations, CPPI was on the search for purebred, captive surplus individuals. CPPI is a member of DENR's National Crocodile Conservation Committee, and is committed to the sustainable use of commercially-farmed saltwater crocodiles (*C. porosus*) and research and conservation of the two crocodile species (*C. porosus*, *C. mindorensis*) in the Philippines.

In June 2019 CPPI's Vicente Mercado and Rainier Manalo visited Cologne Zoo for preliminary talks on the repatriation of *C. mindorensis* progeny from the ESB, and to inspect potential individuals for repatriation (Fig. 1). For the first repatriation, CPPI selected "Hulky" and "Dodong", which had hatched in Cologne Zoo in July 2015 (Fig. 2).



Figure 1. Meeting at Cologne Zoo, June 2019: From left: Vicente Mercado (President, CPPI), Rainier Manalo (Program Director, CPPI), Prof. Theo Pagel (CEO and Cologne Zoo Director), Prof. Dr. Thomas Ziegler (Philippine crocodile ESB keeper, Cologne Zoo). Photograph: Anna Rauhaus.

They were produced from an induced natural breeding event, which allowed Cologne Zoo's Philippine crocodile team around section keeper Anna Rauhaus to observe and document parental care and breeding behaviour (mouth transfer, nest guarding) of this elusive species. Dodong and Hulky grew up under the care of their mother for the first weeks, and were thus considered well socialized and suited for repatriation.

After agreement between the German Federal Agency for Nature Conservation and the Philippines Biodiversity Management Bureau, Department of Environment and



Figure 2. Hulky and Dodong with mother (Mindong) at Cologne Zoo. Photograph: Anna Rauhaus.

Natural Resources, Quezon City, the transfer was organized and facilitated by Cologne Zoo's animal transfer coordinator Bernd Marcordes (Fig. 3), with Sandra Wedel from the animal travel agency "Gradlyn Petshipping", a company specializing in the transfer of exotic animals, at Frankfurt Airport.



Figure 3. Philippine crocodile team at Cologne Zoo (left), with Cologne Zoo's transfer coordinator Bernd Marcordes (outermost right) and transport crates for Dodong and Hulky. Photograph: J. Nicolaudius.

Initially, Hulky and Dodong were due to depart from Cologne Zoo on 17 March 2020. However, the outbreak of the Covid-19 pandemic thwarted the plan. A few days before the proposed transfer, Metro Manila in the Philippines was under community quarantine, and the flight was cancelled. It took 9 months to find a new transfer option.

Finally, Hulky and Dodong departed from Cologne Zoo on 14 December 2020, and arrived at the Department of Environment and Natural Resources (DENR) Biodiversity Management Bureau - National Wildlife Research and Rescue Center, Ninoy Aquino Parks and Wildlife Center, Diliman, Quezon City, Metro Manila, Philippines, the following day (Fig. 4). After acclimation, Hulky and Dodong will build up a pure colony in the Philippines for subsequent reintroduction into the wild.

Dr. Thomas Ziegler, CSG Regional Chair for Europe, stressed



Figure 4. Cordial welcome with poster for “Dodong” and “Hulky” at Manila Airport. Photograph: CPPI.

the importance of this transfer: “This is an excellent and positive example how *ex-situ* measures such as conservation breeding projects, coordinated by modern, scientifically led zoos, can help to actively support the *in-situ* conservation measures in the country of origin”. Cologne Zoo’s Director Professor Theo Pagel, who is also President of the World Association of Zoos and Aquariums (WAZA) summarized: “This is another successful example of the “One Plan Approach”, which is supported by the IUCN and aims to develop integrative strategies to combine *in-situ* and *ex-situ* measures with groups of experts for species conservation”.

If all works out as was planned, DENR-BMB in collaboration with CPPI has plans for further repatriation of offspring from the European captive-breeding program to the Philippines.

Assistant Secretary for Climate Change and concurrent Director of BMB, For. Ricardo Calderon welcomed the repatriation of the captive-bred Philippine crocodiles, with high hopes that these purebred Philippine crocodiles will contribute to the enhancement of the species’ wild population. “We need to step up our efforts to help recover the decimated population of the Philippine crocodile, including the protection of their wetland habitats, not only for the crocodiles but also to secure ecosystems services for the welfare of communities”, Calderon exclaimed.

Rainier Manalo<sup>1</sup>, Vicente Mercado<sup>1</sup>, Anson Tagtag<sup>2</sup>, Anna Rauhaus<sup>3</sup> and Thomas Ziegler<sup>3</sup>: <sup>1</sup>*Crocodylus Porosus Philippines Inc., Makati City, Philippines*; <sup>2</sup>*Biodiversity Management Bureau, Department of Environment and Natural Resources, Manila, Philippines*; <sup>3</sup>*Cologne Zoo/ESB Keeper, Köln, Germany (ziegler@koelnerzoo.de)*.

## **East and Southeast Asia**

### **Philippines**

#### **FIRST NESTING OF INTRODUCED PHILIPPINE**

**CROCODILES (*CROCODYLUS MINDORENSIS*) IN PAGHUNGAWAN MARSH, SIARGAO ISLAND, SOUTHERN PHILIPPINES.** Seven years after the first introduction of Philippine crocodiles (*Crocodylus mindorensis*) in Paghungawan Marsh in March 2013, nesting in the wild was observed for the first time. On 8 November 2020, two *C. mindorensis* nests were discovered by citizen scientist Fredo Magallanes, while he was conducting a monitoring activity in the marsh.

One of the nests contained 9 eggs, while the other was a false nest associated with the latter. The nest containing eggs was located in a shaded area (9°53.582’ N, 126°4.774’ E), approximately 34 m from the water’s edge. It had a circumference of 5 m and a height of 0.64 m (Fig. 1).

The eggs were estimated to have been laid in late October 2020, which is outside the reported laying period of March to July in Mindanao (Cruz *et al.* 2012). Wild Philippine crocodiles were observed nesting in April-May in Luzon. The same months have been observed for captive crocodiles in Negros (Alcala *et al.* 1987), and February-October for captive crocodiles in Palawan (van Weerd 2010).

This first record of nesting marks the beginning of a successful introduction program for *C. mindorensis* in the Philippines, and ongoing monitoring by Crocodylus Porosus Philippines Inc. (CPPI) and the citizen scientist community continues to increase biological knowledge on the species (Diesmos *et al.* 2012). Details on egg fertility in the nest are still pending, and will be reported in due course.

Since the first release of juvenile *C. mindorensis* in the marsh, continuous monitoring has been undertaken to assess the condition of the introduced crocodiles. Interestingly, individual *C. mindorensis* have been observed utilizing elevated limestone crevices and caverns on steep slopes adjacent to their aquatic habitats (Binaday *et al.* 2020), and recently initiated radio-telemetry study may provide more details on this interesting behaviour.

#### **Acknowledgements**

We extend our warmest appreciation to the continued support of the Jaboy Ecotourism and Conservation Organization (JECO), the local government unit of Pilar, and other concerned stakeholders that has resulted to this milestone in the Philippine crocodile conservation project in Paghungawan Marsh, Siargao Island Protected Landscape and Seascape.

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Figure 1. Philippine crocodile nest (left) with citizen scientist (middle), and members of the People's Organization and technical staff of the Pilar Municipal Tourism (right) in Paghungawan Marsh, Siargao Island, Mindanao, Philippines.

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## South Asia and Iran

### Nepal

GHARIAL CONSERVATION BREEDING CENTER IN CHITWAN NATIONAL PARK: CONTRIBUTION, CHALLENGES AND OPPORTUNITIES. In 1975, Scottish researcher H.R. Austurn came to Chitwan National Park (CNP), Nepal, to study Gharials (*Gavialis gangeticus*), and took some Gharial eggs to Odissa, India, for artificial incubation. Inspired by that event, then CNP Conservation Officer Mr. Rampreet Yadav started to incubate Gharial eggs in CNP, by putting eggs in dug-out sand pits. A few years later, the Gharial Conservation Breeding Center (GCBC) was formally established in CNP under the leadership of Mr.

Yadav.

The GCBC is an *ex-situ* facility for breeding and rearing Gharials, located at Kasara in CNP. It was established in 1978 with the aim of reinforcing the plummeting population of wild Gharials and maintain a viable wild population (Maskey 1989; Khadka 2013). Since its establishment, the GCBC has been collecting Gharial eggs from the Rapti and Narayani Rivers, incubating them in its facilities and rearing hatchlings until they attain a total length of at least 1.5 m, for eventual release into the wild (Maskey 1989; Khadka 2014). The GCBC has a satellite facility - the Gharial Monitoring Center (GMC) located on an island in the Narayani River, some 45 km southwest of the GCBC (Khadka 2010).

The main objectives of the GCBC are to:

- a. maintain viable populations of Gharials *in-situ*;
- b. act as a research center facilitating and coordinating scientific studies on crocodylians and wildlife in general; and,
- c. function as recreation and awareness center.

Major contributions and achievements of the GCBC include:

- a. Reinforcement of wild Gharial population: By the 1980s, only 57 Gharials were estimated to be in CNP, and no more than 200 Gharials across their range in the wild (Khadka 2011). Between 1978 and December 2020, the GCBC released 1565 Gharials into various Nepalese rivers [Narayani (399), Rapti (885), Kali Gandaki (35), SaptaKosi (95), Karnali (41), Babai (110)], and the population in CNP is estimated as 230 Gharials as of February 2020.
- b. Telemetry study: For an ongoing telemetry study on Gharials in Nepal, led by Phoebe Griffith, 20 Gharials were randomly caught in the Rapti River in 2019, all of which were found to be Gharials originating from the GCBC. This suggests that captive-released Gharials make up a significant proportion of the Gharial population in the Rapti River.

c. Reinforcement of Gharial population in the Gandak River, India: It is believed that a high proportion of Gharials released from the GCBC travel downstream towards India (Khadka 2020; Griffith *et al.* 2020), and contribute to the Gharial population in the Gandak River there. Two radio-tagged Gharials released from the GCBC were captured in the Ganga River in Patna, India, in 1984. Since “Made in USA” was on the transmitters, the humor spread that the USA had released spies in India (Ramprit Yadav, pers. comm. 2020). Technical and financial cooperation between India and Nepal will be crucial to effective Gharial breeding and rearing in the GCBC.



Figure 1. Juvenile Gharial at the GCBC.

d. Transfers: Since its establishment, the GCBC has gifted 32 Gharials, 631 Gharial eggs and 20 Mugger eggs to zoos and captive facilities in the USA, France, India, Japan and Bhutan.

e. Awareness for crocodylian conservation: The GCBC is open to visitors, where they can see Gharials and learn about them. Currently, the GCBC houses 600 Gharials and 5 turtle species (3 aquatic, 2 terrestrial), and serves as a visitor information center, with ‘Crocodile’ café and turtle display enclosures within the GCBC perimeter. Footage of Gharial and Mugger nesting, turtle behaviour and other wildlife is shown to visitors, students and local stakeholders. On average, over 40,000 visitors (including foreigners) visit the GCBC annually.

Issues and challenges include:

a. Infertile eggs: Gharial eggs collected from the Narayani and Rapti Rivers, and brought to the GCBC, generally hatch on time.

Table 1. Hatching data for Gharial nests at GCBC, 2014-2020. \* = 30 late-term embryonic deaths recorded.

Year	Nests	Eggs	Hatching (%)	Infertile Nests	Live Hatchlings
Jun '14	4	124	4.0	3	5
Jun '15	8	220	0.0	8	0
Jun '16	7	308	17.2	2	53 *
Jun '17	9	343	1.5	6	5
Jun '18	6	-	-	-	47
Jun '19	8	371	3.2	6	12
Jun '20	5	229	0.0	5	0

But eggs laid by captive females at GCBC are mostly infertile (Table 1). In 2020, the GCBC male seemed to be active during the mating period (February), but all eggs produced were infertile. The Department of National Parks and Wildlife Conservation has acknowledged the problem in its strategic plan.

b. Funding: Annual operating costs for the GCBC are \$75,000 on average, including expenses for fish, Gharial keepers, and renovation and maintenance of ponds. The GCBC collects \$30,000 annually from visitor fees, but Covid-19 has impacted significantly on this income stream.

#### Future Plan

The future plan is to establish the GCBC as a research center to provide a platform for research and collaboration between Nepalese and international students, researchers and scientists. Where researchers from Nepal and elsewhere can come to learn about crocodylians and herpetofauna in general, conduct research and gain firsthand experience in techniques in handling and rearing Gharials as well as release protocols.

#### Funders and Collaborators

The GCBC is fully managed by Chitwan National Park, Government of Nepal, with partial funding and support from the Frankfurt Zoological Society, Atagawa Alligator Garden, National Trust For Nature Conservation, WWF Nepal, Smithsonian Institution, International Trust for Nature Conservation, ARCO-Nepal, Lacoste, Fonds De Dotation Pour la Biodiversite, Save Your Logo and the Zoological Society of London.

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## **Recent Publications**

Labarre, D., Charruau, P., Parsons, W.F.J., Larocque-Desroches, S. and Gallardo-Cruz, J.A. (2020). Major hurricanes affect body condition of American crocodile *Crocodylus acutus* inhabiting Mexican Caribbean islands. *Marine Ecology Progress Series* 651: 145-162.

**Abstract:** Recent models suggest that anthropogenic global warming will lead to an increase in the number of major hurricanes, which have strong effects on ecosystems and may modify animal population characteristics. The goal of this study was to assess the body condition of American crocodiles *Crocodylus acutus* of Cozumel and Banco Chinchorro islands, Mexico, and use it as a tool to better understand short- and long-term effects of hurricanes on crocodylian populations. Changes in body condition (Fulton's K) of 392 crocodiles, captured between 2003 and 2015, were assessed and analyzed in response to a major hurricane through different environmental factors. Differences among populations and size classes, and between sexes, together with seasonal variation, were also evaluated. The body condition of crocodiles was generally good, with better condition for Banco Chinchorro, suggesting that these populations and the ecosystems they inhabit are healthy. Body condition for hatchlings and adults was higher than for other classes, with adults exhibiting the best condition. Body condition of Banco Chinchorro individuals varied seasonally, responding to reproductive events and environmental parameter fluctuations. We also found that *C. acutus* body condition is sensitive to the passage of tropical cyclones, most likely through their effects on salinity, temperature, and prey availability. Tropical cyclones have a 2-fold effect on populations. In the short-term, crocodile health is negatively affected by disturbance, while the species seems to maintain and improve its body condition over the longer term. An increase in strong tropical cyclone frequency could impede the recovery of populations, while causing a continual decrease in crocodile body condition.

Bell, P.R. and Hendrickx, C. (2020). Crocodile-like sensory scales in a Late Jurassic theropod dinosaur. *Current Biology* 30(19): R1068-R1070 (doi: 10.1016/j.cub.2020.08.066).

**Abstract:** Early in amniote evolution, epidermal scales evolved in stem reptiles as an efficient barrier against water loss and ultraviolet radiation, making them a key development in the transition to a fully terrestrial existence. Accordingly, epidermal scales are not simple inert structures but highly-evolved organs suited to perform a broad suite of functions. Here, we provide new data on the epidermal complexity of a non-avian theropod, *Juravenator starki*, from the Torleite Formation (upper Kimmeridgian), Bavaria, Germany. Although epidermal scales have been noted previously on the tail of *Juravenator*, we report a unique scale type with distinctive circular nodes that we identify as integumentary sense organs, analogous to those in modern crocodylians. The surprising presence of such structures suggests the tail had a sensory function, which is nevertheless congruent with the inferred ecology of *Juravenator* and the evolution of integumentary sense organs among archosaurs.

Beal, E.R. and Rosenblatt, A.E. (2020). Alligators in the big city: Spatial ecology of American alligators (*Alligator mississippiensis*) at multiple scales across an urban landscape. *Scientific Reports* 10(1): 16575. (doi: 10.1038/s41598-020-73685-x).

**Abstract:** Urbanization impacts wildlife, yet research has been limited to few taxa. American alligators (*Alligator mississippiensis*) are apex predators that have received minimal attention within urban areas. We investigated potential effects of urban land use on alligators through surveys of relative alligator abundance in 9 tributaries of the lower St. Johns River within Jacksonville, FL. We then explored the potential effects of urban development on alligator spatial distribution and habitat selection at coarse and fine scales. At the coarse scale, we found no correlation between percent developed land and alligator abundance across tributaries; instead, salinity was the primary driver. However, at the fine scale alligators preferred habitats with more open water and vegetated shorelines and avoided anthropogenic structure. Surprisingly, only one of 93 sighted individuals was an adult. Hunting and nuisance alligator data suggests that adults are relatively rare in Jacksonville because they have been targeted for removal. Thus, smaller alligators still occupy urban habitats because they are not targeted and face no competition from adults. Increasing urbanization and human activity may further degrade alligator habitats and limit the distribution of breeding adults, potentially leading to local population declines.

Piskovská, A. (2019). Clinical Cardiology of Reptiles. Diploma thesis, University of Veterinary and Pharmaceutical Sciences Brno, Brno, Czech Republic.

Usman, J. and Yusuf, Y.Q. (2020). The dehumanizing metaphors in the culture of Acehnese in Indonesia. *Indonesian Journal of Applied Linguistics* 10(2) (<https://doi.org/10.17509/ijal.v10i2.28611>).

**Abstract:** This study investigated dehumanizing metaphors used in the daily life and collective memory of Acehnese people in Indonesia and how male and female persons are presented. The interviews were held with 20 people from six districts in Aceh province, Indonesia. Data were collected from elders aged 60 and above, and Acehnese is spoken as their mother tongue. Since they did not travel much (except for occasional holidays with families and Hajj pilgrimage), they are deemed untainted native speakers of Acehnese. For analysis, grounded by the Conceptual Metaphor Theory, this study found that the metaphorical expressions in the Acehnese culture that dehumanize people mostly use animals' concepts, and the rests are of the inanimate entity, and plants. The negative meanings present human as animals are such as *agam buya* (crocodile man), *kamèng keudèe* (goat in the market), *manok agam* (cock), among others, and the positive ones that present human as plants are *boh lam ôn* (a leaf-covered fruit) and *padé jum* (wet rice). They negatively or positively describe a person's behavior where the negative ones are commonly associated with a person's corrupt behavior and the positive ones for good behavior. Most of the dehumanizing metaphors are genderless; only a few are gender-based. Acehnese is a genderless language that has no distinctions of grammatical gender. These metaphors inform the conceptual system or belief of the Acehnese society through language use.

Papet, L., Raymond, M., Boyer, N., Mathevon, N. and Grimault, N. (2020). Crocodiles use both interaural level differences and interaural time differences to locate a sound source. *Journal of the Acoustical Society of America* 148(4). (<https://doi.org/10.1121/10.0001979>).

**Abstract:** To explore how crocodylians locate a sound source, two Nile crocodiles (*Crocodylus niloticus*) were trained to swim towards an acoustic target. Using filtered versions of synthesized stimuli, the respective roles of interaural level differences (ILDs) and interaural time differences (ITDs), which are the two main cues providing information on sound source position, were tested. This study shows

that crocodiles rely on both ILDs and ITDs to locate the spatial direction of a sound source and that their performance is lower when one of the cues is lacking.

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Alibardi, L. (2020). Review: Development, structure, and protein composition of reptilian claws and hypotheses of their evolution. *The Anatomical Record* (<https://doi.org/10.1002/ar.24515>).

**Abstract:** Here, we review the development, morphology, genes, and proteins of claws in reptiles. Claws likely form owing to the inductive influence of phalangeal mesenchyme on the apical epidermis of developing digits, resulting in hyper-proliferation and intense protein synthesis in the dorsal epidermis, which forms the unguis. The tip of claws results from prevalent cell proliferation and distal movement along most of the ungueal epidermis in comparison to the ventral surface forming the sub-unguis. Asymmetrical growth between the unguis and sub-unguis forces beta-cells from the unguis to rotate into the apical part of the sub-unguis, sharpening the claw tip. Further sharpening occurs by scratching and mechanical wearing. Ungueal keratinocytes elongate, form an intricate perimeter and cementing junctions, and remain united impeding desquamation. In contrast, thin keratinocytes in the sub-unguis form a smooth perimeter, accumulate less corneous beta proteins and cysteine-poor intermediate filament (IF)-keratins, and desquamate. In addition to prevalent glycine-cysteine-tyrosine rich corneous beta proteins, special cysteine-rich IF-keratins are also synthesized in the claw, generating numerous -S-S- bonds that harden the thick and compact corneous material. Desquamation and mechanical wear at the tip ensure that the unguis curvature remains approximately stable over time. Reptilian claws are likely very ancient in evolution, although the unguis differentiated like the outer scale surface of scales, while the sub-unguis might have derived from the inner scale surface. The few hair-like IF-keratins synthesized in reptilian claws indicate that ancestors of sauropsids and mammals shared cysteine-rich IF-keratins. However, the number of these keratins remained low in reptiles, while new types of corneous beta proteins function to strengthen claws.

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Lin, H.-Y., Cooke, S.J., Wolter, C., Young, N. and Bennett, J.R. (2020). On the conservation value of historic canals for aquatic ecosystems. *Biological Conservation* 251 (<https://doi.org/10.1016/j.biocon.2020.108764>).

**Abstract:** While fragmentation and habitat loss due to water infrastructure threaten freshwater biodiversity worldwide, historic canals have the potential to contribute to both cultural heritage and biodiversity conservation. Shifting management objectives regarding historic canals from development to recreation and conservation offer opportunities for achieving conservation targets in these anthropogenic systems. However, managing historic canals often involves multiple objectives (eg nature conservation vs historic preservation). We reviewed ecological studies in various types of canal systems, examined the potential of historic canals to contribute to biodiversity conservation, and provided suggestions to promote biodiversity conservation given the opportunities and challenges in canal management. Canal characteristics (eg size, main use, surrounding environment, physical and hydrological properties) can be used to qualify or quantify their potential conservation value and risk. Changing management regimes to mimic natural flow, enhance habitat complexity, and modify connectivity could improve ecosystem functions and services in canals. To achieve conservation potential of historic canals, studies are required to fill knowledge gaps and to understand trade-offs among often competing objectives. The use of decision analysis such as structured decision making allows managers to incorporate multiple objectives, evaluate trade-offs, and address uncertainties in historic canal management.

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Padilla, S.E., González-Jáuregui, M., Rendón Von Osten, J., Valdespino, C., López Luna, M.A., Barrios Quiróz, G. and Barão-

Nóbrega, J.A.L. (2020). Using regression tree analysis to determine size class intervals and sexual dimorphism in the Morelet's crocodile *Crocodylus moreletii*. *Wildlife Biology* 2020: wlb.00707.

**Abstract:** Assignment of Morelet's crocodile *Crocodylus moreletii* individuals into size groups or classes based on ecological and morphological similarities has not yet been associated with species-specific ontogeny related changes. Age or size of first reproductive behavior is not precisely known for *C. moreletii*, but differences in allometric patterns and relative cranial size between juveniles and adults might be used as an indicator of sexual maturity. In this study, a regression tree analysis was used to investigate the relationship between age and body size in 1266 crocodiles by using both simple and generalized linear models, with gender and origin (captive or wild) as factors. Total length (TL), snout-vent length (SVL) and cranial length (CL) were used as predictor variables and the logarithm of body mass as the response variable. Four length intervals with well-defined thresholds (514, 899 and 1497 mm of TL) were established using all three predictors (TL, SVL and CL). Relationship between SVL and TL was described, and a strong positive relationship ( $r^2=0.98$ ), unaffected by crocodile gender, was observed. The observed CL-TL and CL-SVL relationships were also positive but significantly different between males and females ( $p<0.001$ ) and length interval classes ( $p=0.01$ ). These results suggest that our estimated size thresholds seem to correspond to important ontogenetic changes in *C. moreletii* and that sexual maturity is closely related to size in this species, where sexual dimorphism in body length occurs, particularly in large individuals (size group IV).

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Bock, S.L., Hale, M.D., Leri, F.M., Wilkinson, P.M., Rainwater, T.R. and Parrott, B.B. (2020). Post-transcriptional mechanisms respond rapidly to ecologically relevant thermal fluctuations during temperature-dependent sex determination. *Integrative Organismal Biology* (<https://doi.org/10.1093/iob/obaa033>).

**Abstract:** An organism's ability to integrate transient environmental cues experienced during development into molecular and physiological responses forms the basis for adaptive shifts in phenotypic trajectories. During temperature-dependent sex determination (TSD), thermal cues during discrete periods in development coordinate molecular changes that ultimately dictate sexual fate and contribute to patterns of inter- and intra-sexual variation. How these mechanisms interface with dynamic thermal environments in nature remains largely unknown. By deploying thermal loggers in wild nests of the American alligator (*Alligator mississippiensis*) over two consecutive breeding seasons, we observed that 80% of nests exhibit both male- and female-promoting thermal cues during the thermosensitive period, and of these nests, all exhibited both male- and female-promoting temperatures within the span of a single day. These observations raise a critical question - How are opposing environmental cues integrated into sexually dimorphic transcriptional programs across short temporal scales? To address this question, alligator embryos were exposed to fluctuating temperatures based on nest thermal profiles and sampled over the course of a daily thermal fluctuation. We examined the expression dynamics of upstream genes in the temperature-sensing pathway and find that post-transcriptional alternative splicing and transcript abundance of epigenetic modifier genes JARID2 and KDM6B respond rapidly to thermal fluctuations while transcriptional changes of downstream effector genes, SOX9 and DMRT1, occur on a delayed timescale. Our findings reveal how the basic mechanisms of TSD operate in an ecologically relevant context. We present a hypothetical hierarchical model based on our findings as well as previous studies, in which temperature-sensitive alternative splicing incrementally influences the epigenetic landscape to affect the transcriptional activity of key sex-determining genes.

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Kvasilova, A., Olejnickova, V., Jensen, B., Christoffels, V.M., Kolesova, H., Sedmera, D. and Gregorovicova, M. (2020). The formation of the atrioventricular conduction axis is linked in

development to ventricular septation. *Journal of Experimental Biology* 223(19) (doi: 10.1242/jeb.229278).

**Abstract:** During development, the ventricles of mammals and birds acquire a specialized pattern of electrical activation with the formation of the atrioventricular conduction system (AVCS), which coincides with the completion of ventricular septation. We investigated whether AVCS formation coincides with ventricular septation in developing Siamese crocodiles (*Crocodylus siamensis*). Comparisons were made with Amazon toadhead turtle (*Mesoclemmys heliostemma*) with a partial septum only and no AVCS (negative control) and with chicken (*Gallus gallus*) (septum and AVCS, positive control). Optical mapping of the electrical impulse in the crocodile and chicken showed a similar developmental specialization that coincided with full ventricular septation, whereas in the turtle the ventricular activation remained primitive. Co-localization of neural marker human natural killer-1 (HNK-1) and cardiomyocyte marker anti-myosin heavy chain (MF20) identified the AVCS on top of the ventricular septum in the crocodile and chicken only. AVCS formation is correlated with ventricular septation in both evolution and development.

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

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

Rainwater, T.R., Griess, J., Murphy, T.M., Boylan, S.M., Parrott, B.B., Kohno, S., Rainwater, K.A.E., Richards, S.M., Guillette, M., Mills, T., Platt, S.G., Wilkinson, P.M. and Guillette Jr., L.J. (2020). Leucistic American alligator hatchlings in coastal South Carolina. *Southeastern Naturalist* 19: N62-N72.

**Abstract:** Leucism (white skin, dark eyes) is a rare color disorder occurring in a range of invertebrates and vertebrates, and as a result, relatively few reports exist of leucistic individuals in the wild. In March 2014, we found 6 leucistic *Alligator mississippiensis* (American Alligator) hatchlings in coastal South Carolina. All individuals were basking under cool, cloudy conditions within ~15 m of the den, appeared moderately emaciated, and were somewhat lethargic upon capture. The animals were removed from the field and treated for malnutrition under veterinary supervision. Three

alligators died within 6 days of collection, and the remaining 3 individuals were transferred to different institutions for long-term care and display. These animals also eventually died after surviving in captivity for ~4.5-45 months. Leucistic alligators are known to suffer from a variety of health problems, and the mortalities and associated causes of death in the animals we describe here were consistent with previous reports of other leucistic alligators. The incidence of leucism among wild crocodilians is very low, and disease, increased susceptibility to predation, and collection by humans further exacerbate its rarity.

Behangana, M., Magala, R., Katumba, R., Ochanda, D., Kigoolo, S., Mutebi, S., Dendi, D., Luiselli, L. and Hughes, D.F. (2020). Ontogenetic habitat use and seasonal activity of Nile crocodiles (*Crocodylus niloticus*) in the Lake Albert delta, East Africa. *Journal of Great Lakes Research* (https://doi.org/10.1016/j.jglr.2020.09.010).

**Abstract:** Crocodiles play important roles in many ecosystems, but their populations worldwide are threatened by human exploitation and habitat destruction. We studied ontogenetic changes in habitat use and seasonal activity patterns in a population of Nile crocodiles (*Crocodylus niloticus*) inhabiting the Lake Albert Delta Wetland System, a Ramsar Site of international importance in Murchison Falls National Park of western Uganda. A total of 186 crocodile observations were made from monthly surveys of five transects during October 2017 to September 2018. Crocodiles exhibited a marginally bi-modal seasonal pattern, with the fewest observations from July to August and October to November, and the highest observations from January to February and April to May. Crocodiles were most frequently encountered along the north shore of the delta, especially on riverbanks with woody vegetation, followed by *Cyperus papyrus-Vossia* dominated habitats, while crocodiles were infrequently observed on islands and muddy banks. Habitat niche breadth was narrowest in hatchlings and widest in sub-adults, with juveniles and large adults exhibiting intermediate values. Overlap in habitat resource use across size classes was generally high, with the lowest overlap between hatchlings and juveniles, and the highest between large and sub-adult crocodiles. Our study on Nile crocodiles in the Lake Albert delta provides insights into habitat partitioning among different demographic segments of this population that can be utilized to improve its management in one of Africa's Great Lakes by spatially and temporally focusing conservation efforts on the most used habitats and seasonal aggregations, respectively.

Marsh, A.D., Smith, M.E., Parker, W.G., Irmis, R.B. and Kligman, B.T. (2020). Skeletal anatomy of *Acaenasuchus geoffreyi* Long and Murry, 1995 (Archosauria: Pseudosuchia) and its implications for the origin of the aetosaurian carapace. *Journal of Vertebrate Paleontology* (https://doi.org/10.1080/02724634.2020.1794885).

**Abstract:** *Acaenasuchus geoffreyi* is a diminutive armored archosaur from the Upper Triassic Chinle Formation of northern Arizona, USA, with uncertain evolutionary relationships and skeletal maturity. Known only from osteoderms, the taxon has been considered a valid taxon of aetosaur, juvenile specimens synonymous with the aetosaur *Desmatosuchus spurensis*, or a non-aetosaurian pseudosuchian archosaur. Here, we describe new fossils of *Acaenasuchus geoffreyi* that represent cranial, vertebral, and appendicular elements as well as previously unknown variations in the dorsal carapace and ventral shield. The skull bones are ornamented with the same anastomosing complex of ridges and grooves found on the paramedian and lateral osteoderms, and the appendicular skeleton resembles that of *Revueletosaurus callenderi*, *Euscolosuchus olseni*, aetosaurs, and other armored archosaurs such as erpetosuchids. Histology of osteoderms from the hypodigm of *Acaenasuchus geoffreyi* shows multiple growth lines, laminar tissue, and low vascularity, evidence that the individuals were close to skeletal maturity and not young juveniles. A revised phylogenetic analysis of early archosaurs recovers *Acaenasuchus geoffreyi* and *Euscolosuchus olseni* as sister taxa and members of a new clade that is the sister taxon of

Aetosauria. This new phylogeny depicts a broader distribution of osteoderm character states previously thought to only occur in aetosaurs, demonstrating the danger of using only armor character states in aetosaur taxonomy and phylogeny. *Acaenasuchus geoffreyi* is also a good example of how new fossils can stabilize 'wild card' taxa in phylogenetic analyses and contributes to our understanding of the evolution of the aetosaur carapace.

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Starck, J.M. (2020). Morphology of the avian yolk sac. *Journal of Morphology* (doi: 10.1002/jmor.21262).

**Abstract:** The avian yolk sac is a multifunctional extraembryonic organ that serves not only as a site of nutrient (yolk) absorption, but also for early hemopoiesis, and formation of blood vessels. Although the yolk sac membrane being specialized to function as an extraembryonic absorptive organ, it is neither morphologically nor functionally part of the embryonic gut. Yolk absorption is by the phagocytic activity of the extraembryonic endoderm. I used cryohistology and resin embedding histology of complete developmental series of Japanese quail to document the development of the avian yolk sac and changes of the microscopic anatomy throughout development. This material is complemented by complete series of MRT-scans of live ostrich embryos from beginning of incubation through hatching. Considerable changes of size and shape of the yolk mass are documented and discussed as resulting from water flux from albumen to yolk associated with the biochemical activation of yolk sac proteins. During embryogenesis, the yolk sac endoderm forms villi that increase the absorptive surface and reach into the yolk ball. The histology of the absorptive epithelium is specialized for phagocytic absorption of yolk. During early developmental stages, the extraembryonic endoderm is single layered, but it eventually becomes several layers thick during later stages. The extraembryonic mesoderm forms an extensive layer of hematopoietic tissue; deep in this tissue lie the yolk sac vessels. During late stages of development, the erythropoietic tissue disappears, blood vessels are obliterated, and the yolk sac epithelium becomes apoptotic. Results are discussed in the light of the evolutionary history and phylogeny of the amniote egg.

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

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

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Bishop, P.J., Bates, K.T., Allen, V.R., Henderson, D.M., Randau, M. and Hutchinson, J.R. (2020). Relationships of mass properties and body proportions to locomotor habit in terrestrial Archosauria. *Paleobiology* (doi: <https://doi.org/10.1017/pab.2020.47>).

**Abstract:** Throughout their 250 Myr history, archosaurian reptiles have exhibited a wide array of body sizes, shapes, and locomotor habits, especially in regard to terrestriality. These features make Archosauria a useful clade with which to study the interplay between body size, shape, and locomotor behavior, and how this interplay may have influenced locomotor evolution. Here, digital volumetric models of 80 taxa are used to explore how mass properties and body proportions relate to each other and locomotor posture in archosaurs. One-way, nonparametric, multivariate analysis of variance, based on the results of principal components analysis, shows that bipedal and quadrupedal archosaurs are largely distinguished from each other on the basis of just four anatomical parameters ( $p < 0.001$ ): mass, center of mass position, and relative forelimb and hindlimb lengths. This facilitates the development of a quantitative predictive framework that can help assess gross locomotor posture in understudied or controversial taxa, such as the crocodile-line *Batrachotomus* (predicted quadruped) and *Postosuchus* (predicted biped). Compared with quadrupedal archosaurs, bipedal species tend to have relatively longer hindlimbs and a more caudally positioned whole-body center of mass, and collectively exhibit greater variance in forelimb lengths. These patterns are interpreted to reflect differing biomechanical constraints acting on the archosaurian Bauplan in bipedal versus quadrupedal groups, which may have shaped the evolutionary histories of their respective members.

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Andrei, M.A. (2020). *Nature's Mirror: How Taxidermists Shaped America's Natural History Museums and Saved Endangered Species*. University of Chicago Press: Chicago, USA.

**Abstract:** It may be surprising to us now, but the taxidermists who filled the museums, zoos, and aquaria of the 20th century were also among the first to become aware of the devastating effects of careless human interaction with the natural world. Witnessing firsthand the decimation caused by hide hunters, commercial feather collectors, whalers, big game hunters, and poachers, these museum taxidermists recognized the existential threat to critically endangered species and the urgent need to protect them. The compelling exhibits they created - as well as the scientific field work, popular writing, and lobbying they undertook - established a vital leadership role in the early conservation movement for American museums that persists to this day. Through their individual research expeditions and collective efforts to arouse demand for environmental protections, this remarkable cohort - including William T. Hornaday, Carl E. Akeley, and several lesser-known colleagues - created our popular understanding of the animal world and its fragile habitats. For generations of museum visitors, they turned the glass of an exhibition case into a window on nature - and a mirror in which to reflect on our responsibility for its conservation.

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Martín D. Ezcurra, M.D., Montefeltro, F.C., Pinheiro, F.L., Jimena Trotteyn, M., Gentil, A.R., Lehmann, O.E.R. and Pradelli, L.A. (2020). The stem-archosaur evolutionary radiation in South America. *Journal of South American Earth Sciences* (<https://doi.org/10.1016/j.jsames.2020.102935>).

**Abstract:** The oldest archosauromorphs (dinosaurs, birds, crocodiles, and their stem-taxa) are recorded in middle-upper Permian rocks, but it was not after the Permo-Triassic mass extinction that the group shows a substantially high taxonomic richness and ecomorphological disparity. The early evolutionary history of the Archosauromorpha during the Early and Middle Triassic is mainly based on fossils recovered from rocks in southern Africa, Europe and Asia, whereas South America possesses a more complete fossil record of the group only in the Late Triassic. Here we revisit, discuss, and reanalyse the non-archosaurian archosauromorph fossil record of the current-day South America. The Early Triassic archosauromorph record in this continent is still scarce, but it documents the early evolution of the group in western Pangaea and is crucial to understand more globally the biotic recovery after the Permo-Triassic mass extinction. The Middle Triassic record is extremely scarce, but the Late Triassic

archosauromorph assemblage of South America is among the most diverse and abundant worldwide. The last decade has witnessed a considerable improvement in our knowledge of the record, taxonomy, phylogeny, and macroevolution of the group with the input from the South American fossils. Nevertheless, a considerable amount of research is needed and ideally should be focused on some particular aspects of the Triassic evolutionary radiation of Archosauromorpha. Among them, the Early Triassic record should be expanded, more numerous and more complete Middle Triassic archosauromorph specimens are crucial to have a more complete picture of the evolution of the group, and the taxonomy of groups like proterochampsids and hyperodapedontine rhynchosaurs should be clarified through detailed anatomical work.

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Warodell, J. (2020). Three Hundred Fifty Animal Species in Melville's Fiction. *Leviathan* 22(3): 68-74.

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Young, B.A., Adams, J., Beary, J.M., Mardal, K-A., Schneider, R. and Kondrashova, T. (2020). The myodural bridge of the American alligator (*Alligator mississippiensis*) alters CSF flow. *Journal of Experimental Biology* (doi: 10.1242/jeb.230896).

**Abstract:** Disorders of the volume, pressure, or circulation of the cerebrospinal fluid (CSF) lead to disease states in both newborns and adults; despite this significance, there is uncertainty regarding the basic mechanics of the CSF. The suboccipital muscles connect to the dura surrounding the spinal cord, forming a complex termed the "myodural bridge;" this study tests the hypothesis that the myodural bridge functions to alter the CSF circulation. The suboccipital muscles of American alligators were surgically exposed and electrically stimulated simultaneous with direct recordings of CSF pressure and flow. Contraction of the suboccipital muscles significantly changed both CSF flow and pressure. By demonstrating another influence on CSF circulation and pulsatility, the present study increases our understanding of the mechanics underlying the movement of the CSF.

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Barboza, R.S.L., Correia, J.M.S. and Dos Santos, E.M. (2020). Solid waste in the nest composition of Broad-snouted caiman *Caiman latirostris* (Daudin 1802). *Herpetology Notes* 13: 891-894.

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Szabo, B., Noble, D.W.A. and Whiting, M.J. (2020). Learning in non-avian reptiles 40 years on: advances and promising new directions. *Biological Reviews* (<https://doi.org/10.1111/brv.12658>).

**Abstract:** Recently, there has been a surge in cognition research using non-avian reptile systems. As a diverse group of animals, non-avian reptiles [turtles, the tuatara, crocodylians, and squamates (lizards, snakes and amphisbaenids)] are good model systems for answering questions related to cognitive ecology, from the role of the environment on the brain, behaviour and learning, to how social and life-history factors correlate with learning ability. Furthermore, given their variable social structure and degree of sociality, studies on reptiles have shown that group living is not a pre-condition for social learning. Past research has demonstrated that non-avian reptiles are capable of more than just instinctive reactions and basic cognition. Despite their ability to provide answers to fundamental questions in cognitive ecology, and a growing literature, there have been no recent systematic syntheses of research in this group. Here, we systematically, and comprehensively review studies on reptile learning. We identify 92 new studies investigating learning in reptiles not included in previous reviews on this topic - affording a unique opportunity to provide a more in-depth synthesis of existing work, its taxonomic distribution, the types of cognitive domains tested and methodologies that have been used. Our review therefore provides a major update on our current state of knowledge and ties the collective evidence together under nine umbrella research areas: (i) habituation of behaviour, (ii) animal training through conditioning,

(iii) avoiding aversive stimuli, (iv) spatial learning and memory, (v) learning during foraging, (vi) quality and quantity discrimination, (vii) responding to change, (viii) solving novel problems, and (ix) social learning. Importantly, we identify knowledge gaps and propose themes which offer important future research opportunities including how cognitive ability might influence fitness and survival, testing cognition in ecologically relevant situations, comparing cognition in invasive and non-invasive populations of species, and social learning. To move the field forward, it will be immensely important to build upon the descriptive approach of testing whether a species can learn a task with experimental studies elucidating causal reasons for cognitive variation within and among species. With the appropriate methodology, this young but rapidly growing field of research should advance greatly in the coming years providing significant opportunities for addressing general questions in cognitive ecology and beyond.

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Stout, J.B. (2020). New early Pleistocene *Alligator* (Eusuchia: Crocodylia) from Florida bridges a gap in *Alligator* evolution. *Zootaxa* 4868(1) (doi: <https://doi.org/10.11646/zootaxa.4868.1.3>).

**Abstract:** The American Alligator (*Alligator mississippiensis*) is one of two species of *Alligator* in the modern world. It is only distantly related to the other extant species (*A. sinensis*), with much closer relatives known from the geologic past of North America. A disparity exists, though, in the fossil record between *A. mississippiensis* and its close relative, the late Miocene (?) - early Pliocene *A. mefferdi*. While *A. mississippiensis* is known from the mid-Pleistocene and later, few *Alligator* remains were known from the earliest Pleistocene of North America until the discovery of the Haile 7C and 7G early Pleistocene (Blancan Land Mammal Age) sites from Alachua County, Florida. The Haile alligators exhibit a suite of characters from both *A. mississippiensis* and *A. mefferdi*, displaying intermediate morphology in time. The Haile alligators are distinct from either of the aforementioned taxa, and a new species, *Alligator hailensis* is suggested, bridging an important gap in the evolution of the American alligator.

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Aymen, J., Lamglait, B., Wong, E., Carmel, E.N., Lair, S. and Maccolini, E. (2020) Ovarian carcinoma with skeletal metastasis in a Yacare caiman (*Caiman yacare*). *Journal of Herpetological Medicine and Surgery* 30(3): 123-128.

**Abstract:** A 39-yr-old intact adult female Yacare caiman (*Caiman yacare*) presented with hindlimb paresis. Magnetic resonance imaging and computed tomography studies revealed a compressive vertebral mass in the lumbar spine associated with a large left pelvic osseous mass and multiple extensive osteolytic lesions in both the axial and appendicular skeletons. Because of the severity and extension of the osseous lesions, euthanasia was elected. Gross necropsy findings included bilateral, hardened, irregular ovaries and multifocal pale, thickened bone marrow. Histopathologic findings were consistent with an ovarian carcinoma with metastasis to the pelvis, vertebrae, and femurs. Reproductive neoplasms with skeletal metastasis should be added to the differential diagnoses for nonspecific progressive and chronic wasting or lameness in intact aging crocodylians.

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Lessner, E.J. and Holliday, C.M. (2020). A 3D ontogenetic atlas of *Alligator mississippiensis* cranial nerves and their significance for comparative neurology of reptiles. *The Anatomical Record* (<https://doi.org/10.1002/ar.24550>).

**Abstract:** Cranial nerves are key features of the nervous system and vertebrate body plan. However, little is known about the anatomical relationships and ontogeny of cranial nerves in crocodylians and other reptiles, hampering understanding of adaptations, evolution, and development of special senses, somatosensation, and motor control of cranial organs. Here we share three dimensional

(3D) models of the cranial nerves and cranial nerve targets of embryonic, juvenile, and adult American alligators (*Alligator mississippiensis*) derived from iodine-contrast CT imaging, for the first time, exploring anatomical patterns of cranial nerves across ontogeny. These data reveal the tradeoffs of using contrast-enhanced CT data as well as patterns in growth and development of the alligator cranial nervous system. Though contrast-enhanced CT scanning allows for reconstruction of numerous tissue types in a non-destructive manner, it is still limited by size and resolution. The position of alligator cranial nerves varies little with respect to other cranial structures yet grow at different rates as the skull elongates. These data constrain timing of trigeminal and sympathetic ganglion fusion and reveal morphometric differences in nerve size and path during growth. As demonstrated by these data, alligator cranial nerve morphology is useful in understanding patterns of neurological diversity and distribution, evolution of sensory and muscular innervation, and developmental homology of cranial regions, which in turn, lead to inferences of physiology and behavior.

Moore, B.C., Brennan, P.L.R., Francis, R., Penland, S., Shiavone, K., Wayne, K., Woodward, A.R., Does, M.D., Kim, D.K. and Kelly, D.A. (2020). Glans inflation morphology and female cloaca copulatory interactions of the male American alligator phallus. *Biology of Reproduction* (doi: 10.1093/biolre/iaaa197).

**Abstract:** The phallic glans of the American alligator (*Alligator mississippiensis*) is the distal termination of the semen-conducting sulcus spermaticus and during copulation has the closest, most intimate mechanical interactions with the female urodeum, the middle cloacal chamber that contains the opening to the vaginal passages and oviducts. However, the details of this interface leading to insemination and gamete uptake are unclear. Here we: 1) Histologically characterize the underlying tissue types and morphologically quantify the shape changes associated with glans inflation into the copulatory conformation, 2) Digitally reconstruct from MRI the 3D shape of functional tissue compartments, and 3) diceCT image the copulatory fit between male phallus and female cloaca. We discuss these results in relation to tissue type material properties, the transfer on intromittent forces, establishing potential copulatory lock, inflated glans volume scaling with body mass/length, the mechanics of semen targeting and insemination, and potential female cryptic choice impacting multiple clutch paternity. In part, this study further clarifies the phallic morphological variation observed among crocodylians and begins to investigate the role(s) these divergent male forms play during copulation interacting with female cloacal forms to increase reproductive success.

Fukuda, Y., Webb, G., Edwards, G., Saalfeld, K. and Whitehead, P. (2020). Harvesting predators: Simulation of population recovery and controlled harvest of saltwater crocodiles *Crocodylus porosus*. *Wildlife Research* (<https://doi.org/10.1071/WR20033>).

**Abstract:** The population of saltwater crocodiles *Crocodylus porosus* in the Northern Territory, Australia has been recovering from a period of intensive, unregulated harvest (1945 to 1971) since protection in 1971. Consequently, the management goal is shifting from restoring a seriously depleted population to managing an abundant population through controlled harvests for both commercial purposes and public safety. We conducted this study to 1) examine whether the controlled harvest of eggs and adults since protection has had an adverse effect on population size and structure, and 2) explore the effect of future harvest scenarios on population size and structure by adjusting harvest levels of both eggs and adults. On the basis of 40 years population monitoring data and knowledge of population attributes from previous research, we developed density-dependent, structured matrix population models to explore our aims. The models supported that the depleted population recovered rapidly under protection and that the harvest rates since protection were benign. The model estimated the 2017 harvested population, 46 years after protection, to be approximately 102,000 non-hatchlings

(>0.6 m crocodiles), of which 42.2% are large (>2.1 m total length) individuals. This is similar to the estimated population prior to the period of intensive, unregulated harvest. Like other crocodylians, the harvest simulations showed the viability of the population is highly sensitive to adult survival rates. The estimated population should be able to sustain an annual harvest of up to 135,500 eggs if the harvest of large crocodiles remain small (<500 per year). While egg harvest has little impact on population size and structure, population size is sensitive to adult harvest. Crocodile populations are highly sensitive to adult survival, which needs to be taken into account when considering future harvest scenarios.

Velasco, B., A. (2020). Individual identification of *Crocodylus intermedius* (Orinoco crocodile) using tail spot patterns. *UNED Research Journal* 12(2): e3140.

**Abstract:** The Conservation Action Plan of the Orinoco crocodile (*Crocodylus intermedius*) includes the release of captive-bred specimens back into the wild. By monitoring these specimens in their natural habitat their adaptability is examined. However, an accurate identification system is necessary to recognize the individuals when they are recaptured. The objective was to determine if Swanepoel or Boucher, Tellez and Anderson crocodile identification methods are useful for the Orinoco crocodile. A total of 543 Orinoco crocodiles were photographed and each photo was vectorized by drawing dark spots greater than 25% for each scute, in the first 10 lines of double caudal scales of the tail on the right side. Two system codes were evaluated, one is a numeric code described by Swanepoel and the other is an additive code described by Boucher, Tellez and Anderson. A total of 464 Swanepoel codes and 537 Boucher, Tellez and Anderson codes based on the dark spot pattern of the scales on the right side of the tails were generated for the 543 specimens. Both methods yielded high code values, however, the one developed by Boucher, Tellez and Anderson, with a 98.90% differentiation of the analyzed specimens, worked better. The study confirms that using the method of spots in the tail of crocodiles is an effective tool for identifying individual crocodiles.

Nesbitt, S.J., Zawiskie, J.M. and Dawley, R.M. (2020). The osteology and phylogenetic position of the loricatan (Archosauria: Pseudosuchia) *Heptasuchus clarki*, from the ?Mid-Upper Triassic, southeastern Big Horn Mountains, Central Wyoming (USA). *PeerJ* 8: e10101.

**Abstract:** Loricatan pseudosuchians (known as “rauisuchians”) typically consist of poorly understood fragmentary remains known worldwide from the Middle Triassic to the end of the Triassic Period. Renewed interest and the discovery of more complete specimens recently revolutionized our understanding of the relationships of archosaurs, the origin of Crocodylomorpha, and the paleobiology of these animals. However, there are still few loricatans known from the Middle to early portion of the Late Triassic and the forms that occur during this time are largely known from southern Pangea or Europe. *Heptasuchus clarki* was the first formally recognized North American “rauisuchian” and was collected from a poorly sampled and disparately fossiliferous sequence of Triassic strata in North America. Exposed along the trend of the Casper Arch flanking the southeastern Big Horn Mountains, the type locality of *H. clarki* occurs within a sequence of red beds above the Alcova Limestone and Crow Mountain formations within the Chugwater Group. The age of the type locality is poorly constrained to the Middle-early Late Triassic and is likely similar to or just older than that of the Popo Agie Formation assemblage from the western portion of Wyoming. The holotype consists of associated cranial elements found *in situ*, and the referred specimens consist of crania and postcrania. Thus, about 30% of the osteology of the taxon is preserved. All of the pseudosuchian elements collected at the locality appear to belong to *H. clarki* and the taxon is not a chimera as previously hypothesized. *Heptasuchus clarki* is distinct from all other archosaurs by the presence of large, posteriorly directed flanges on the

parabasisphenoid and a distinct, orbit-overhanging postfrontal. Our phylogenetic hypothesis posits a sister-taxon relationship between *H. clarki* and the Ladinian-aged *Batrachotomus kupferzellensis* from current-day Germany within Loricata. These two taxa share a number of apomorphies from across the skull and their phylogenetic position further supports 'rauisuchian' paraphyly. A minimum of three individuals of *Heptasuchus* are present at the type locality suggesting that a group of individuals died together, similar to other aggregations of loricatans (eg *Heptasuchus*, *Batrachotomus*, *Decuriasuchus*, *Postosuchus*).

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Paravani, E.V., Odetti, L.M., Simoniello, M.F. and Poletta, G.L. (2020). Molecular analysis and bioinformatic characterization of copper, 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.

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Barrios-de Pedro, S., Osuna, A. and Buscalioni, A.D. (2020). Helminth eggs from early cretaceous faeces. *Scientific Reports* 10: 18747.

**Abstract:** The exceptional fossil site of Las Hoyas (upper Barremian, Cuenca, Spain) yields abundant small to medium vertebrate coprolites, hindering the search for parasites. We studied the contents of 29 coprolites that were previously classified into distinct morphotypes. Several parasitic eggs were retrieved from two of these coprolites, confirming the second record of digenea trematode eggs and nematode (ascaridid) eggs from an Early Cretaceous locality. The cylindrical coprolite containing anisakid eggs was likely produced by a crocodylomorph as the parasite host, whereas the bump-headed lace coprolite indicates the role of a fish as an intermediary or definitive host of the trematodes and ascaridids. These trace and body fossils show that the Las Hoyas 126-129 Ma lacustrine ecosystem documents the early connection between basal Gonorynchiformes fish and digenetic trematodes.

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Godoy, P.L. and Turner, A.H. (2020). Body size evolution in crocodylians and their extinct relatives. *eLS* (<https://doi.org/10.1002/9780470015902.a0029089>).

**Abstract:** Crocodylians are currently facing evolutionary decline. This is evinced by the rich fossil record of their extinct relatives, crocodylomorphs, which show not only significantly higher levels of biodiversity in the past but also remarkable morphological disparity and higher ecological diversity. In terms of body size, crocodylians are mostly large animals (>2m), especially when compared to other

extant reptiles. In contrast, extinct crocodylomorphs exhibited a 10-fold range in body sizes, with early terrestrial forms often quite small. Recent research has shed new light on the tempo and mode of crocodylomorph body size evolution, demonstrating a close relationship with ecology, in which physiological constraints contribute to the larger sizes of marine species. Abiotic environmental factors can also play an important role within individual subgroups. Crocodylians, for instance, have been experiencing an average size increase during Cenozoic, which seems to be related to a long-term process of global cooling.

#### Key Concept:

- Although Crocodylia is currently a depauperate group, the fossil record of its closest extinct relatives, crocodylomorphs, can provide important evidence to answer major evolutionary questions, such as on extinction and diversity loss.
- Crocodylomorph body size has varied significantly over time, as well as between subgroups, ranging from relatively small (<1 m) to gigantic (>10 m) species.
- Crocodylomorph body size evolution is not consistent with an overall trend towards large or smaller sizes through time; instead, multiple shifts to different evolutionary regimes can explain the observed body size values.
- Climate alone cannot explain the evolution of body size in all crocodylomorphs, but some environmental factors had stronger influence on individual subgroups.
- The usually larger sizes of aquatic and marine crocodylomorphs can be explained by physiological constraints associated with thermoregulation and lung capacity when under the water.
- A strong correlation between temperature and body size found for members of the crown-group (Crocodylia) indicates that species became larger on average as the world became cooler during the Cenozoic.

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Papet, L., Raymond, M., Boyer, N., Mathevon, N. and Grimault, N. (2020). Crocodiles use both interaural level differences and interaural time differences to locate a sound source. *Journal of the Acoustical Society of America* 148(4):EL307 (doi: 10.1121/10.0001979).

**Abstract:** To explore how crocodylians locate a sound source, two Nile crocodiles (*Crocodylus niloticus*) were trained to swim towards an acoustic target. Using filtered versions of synthesized stimuli, the respective roles of interaural level differences (ILDs) and interaural time differences (ITDs), which are the two main cues providing information on sound source position, were tested. This study shows that crocodiles rely on both ILDs and ITDs to locate the spatial direction of a sound source and that their performance is lower when one of the cues is lacking.

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Abreu, D., Sales Viana, M.S., De Oliveira, P.V., Fernandes Viana, G. and Borges-Nojosa, D.M. (2020). First record of an amniotic egg from the Romualdo Formation (Lower Cretaceous, Araripe Basin, Brazil). *Revista Brasileira de Paleontologia* 23(3): 185-193.

**Abstract:** Fossil amniotic eggs have great informative potential, especially regarding reproductive and evolutionary aspects of vertebrates. However, there are only few intact specimens or with fossilized embryos within, and the rare reported cases are mostly related to dinosaurs. In Brazil, the records of these ichnofossils are practically restricted to the Bauru Basin. This research aims to describe the first amniotic egg found in carbonate concretions in the Romualdo Formation, adding information to the study of these fossils and to the paleontological context of the basin. The specimen was collected at the Sítio Pé da Serra do Félix, in the Municipality of Simões, Piauí State, Brazil. The methodology employed was based on Scanning Electron Microscopy, Energy Dispersive Spectroscopy and Optical Microscopy techniques, as well as computed tomography analyses. The morphological and microstructural characteristics of the shell suggests the identification of the fossil as a crocodylomorph

egg. This specimen differs from other fossil eggs assigned to the aforementioned group by its small size and considerably thick shell. The tomographic sections revealed possible basic structures of an embryo inside the egg, suggesting that this is the first fossilized egg with a crocodylomorph embryonic trace found in the world.

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Dwinarendra, A., Rahardjo, P. and Bela, P.A. (2020). Strategi meningkatkan jumlah pengunjung Wisata Taman Buaya Tanjung Pasir. *Jurnal Sains, Teknologi, Urban, Perancangan, Arsitektur (Stupa)* 2(2): 2483-2492.

**Abstract:** Crocodile Tourism Park has a land area of 5 hectares. This crocodile park is located in Tanjung Pasir tourist area, as a tourist destination in and around Kabupaten Tangerang. This crocodile park has been operating since 2005 owned by Lukman Arifin. This crocodile park is the only theme park of fauna and breeding, especially crocodile in Tangerang. This crocodile park is expected to be one of the new icons in Tanjung Pasir tourism area and become an educative amusement park. At the moment there are more than 400 crocodiles of new age hatch up to 70 years and in this crocodile park has a rare collection of albino crocodiles. In addition to seeing crocodiles in this crocodile park can also feed crocodiles. Once this crocodile park has various performances of crocodile, selling the knacks, but now stopped because of the visitors. This research aims to determine the potential and problems of the Tanjung Pasir Crocodile Park, which has an impact on visitors. Data collection is done by field survey, questionnaire scatter, interview, documentation and literature study. From analysis results conducted such as site and site analysis, benchmark analysis, visitor perception analysis and policy, resulted in strategy proposals such as from the start of physical repair, improvement of management, and proposed promotion of tourist parks. So visitors feel interested to visit.

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Del Roble Pensado-Leglise, M. and Rodríguez Quiroz, G. (2020). The challenge of the Science of Sustainability in protected natural areas: The case of the UMA “Wotoch Aayin” in the Ría Celestún Biosphere Reserve, Campeche. Pp. 441-46- in *Socio-ecological Studies in Natural Protected Areas*, ed. by A. Ortega-Rubio. Springer: Cham.

**Abstract:** This study analyzes the current challenges in the science of sustainability (SS) in protected natural areas, particularly the case of a Unit of Environmental Management (UMA - Unidad de Manejo Ambiental) of Morelet's crocodile in Ría Celestún, Campeche. SS is conceptualized as a holistic approach for identification and resolution of the main problems in sustainable systems with a global, social, and human scope. SS is not a basic or applied science; rather it distinguishes knowledge (scientific and non-scientific) to reach its objective to solve problems in the relationships between society and nature. The results of the analysis revealed intertwining of the activities of biodiversity conservation with sustainable practices in the territories parting from the approach of ecosystem services. This has been a key factor in obtaining advances in proper management of an intensive breeding farm associated with a scheme of productive diversification linked to development of both scientific-technological and social innovation, in which it is sought to conjugate scientific innovation with culture, traditional productive practices, and strengthening of local sociocultural identity of the mangroves to constitute a sustainable civil productive organization.

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Zimmerman, L.M. (2020). The reptilian perspective on vertebrate immunity: 10 years of progress. *Journal of Experimental Biology* (doi: 10.1242/jeb.214171).

**Abstract:** Ten years ago, ‘Understanding the vertebrate immune system: insights from the reptilian perspective’ was published. At the time, our understanding of the reptilian immune system lagged behind that of birds, mammals, fish and amphibians. Since then, great progress has been made in elucidating the mechanisms of

reptilian immunity. Here, I review recent discoveries associated with the recognition of pathogens, effector mechanisms and memory responses in reptiles. Moreover, I put forward key questions to drive the next 10 years of research, including how reptiles are able to balance robust innate mechanisms with avoiding self-damage, how B cells and antibodies are used in immune defense and whether innate mechanisms can display the hallmarks of memory. Finally, I briefly discuss the links between our mechanistic understanding of the reptilian immune system and the field of eco-immunology. Overall, the field of reptile immunology is poised to contribute greatly to our understanding of vertebrate immunity in the next 10 years.

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Michel, K.B., West, T.G., Daley, M.A., Allen, V.R. and Hutchinson, J.R. (2020). Appendicular muscle physiology and biomechanics in *Crocodylus niloticus*. *Integrative Organismal Biology* (<https://doi.org/10.1093/iob/obaa038>).

**Abstract:** Archosaurian reptiles (including living crocodiles and birds) had an explosive diversification of locomotor form and function since the Triassic ~250 million years ago. Their limb muscle physiology and biomechanics are pivotal to our understanding of how their diversity and evolution relate to locomotor function. Muscle contraction velocity, force and power in extinct archosaurs such as early crocodiles, pterosaurs or non-avian dinosaurs is not available from fossil material, but is needed for biomechanical modelling and simulation. However, an approximation or range of potential parameter values can be obtained by studying extant representatives of the archosaur lineage. Here, we study the physiological performance of three appendicular muscles in Nile crocodiles (*Crocodylus niloticus*). Nile crocodile musculature showed high power and velocity values - the flexor tibialis internus 4 muscle, a small “hamstring” hip extensor and knee flexor actively used for terrestrial locomotion, performed particularly well. Our findings demonstrate some physiological differences between muscles, potentially relating to differences in locomotor function and muscle fibre type composition. By considering these new data from a previously unstudied archosaurian species in light of existing data (eg from birds), we can now better bracket estimates of muscle parameters for extinct species and related extant species. Nonetheless, it will be important to consider the potential specialization and physiological variation among muscles, because some archosaurian muscles (such as those with terrestrial locomotor function) may well have close to double the muscle power and contraction velocity capacities of others.

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Wesson, J.P. (2020). Sunshinevirus in Australian Snakes: Investigating the Link with Disease. PhD thesis, Murdoch University, Perth, WA, Australia.

**Abstract:** This thesis describes experiments undertaken to investigate the link between sunshinevirus virus and disease. Sunshinevirus was first discovered in a collection of Australian pythons that were euthanased because of a neurorespiratory disease outbreak. Cases of sunshinevirus infection, including chronic asymptomatic infections, have subsequently been detected throughout Australia by PCR testing, and the virus has been found in most Australian python species. There has been a documented association between sunshinevirus and disease, but no causal link had been proven. To investigate this link, and to provide information on viral transmission and pathogenesis, controlled experimental infection studies were undertaken. Carpet pythons were directly inoculated with the virus and subsequently developed infection and neurorespiratory disease. The virus was reisolated from infected pythons. An uninfected python co-housed with an infected python also became infected and developed neurological signs of disease. This is consistent with natural transmission. Clinical signs and histopathology indicated a viral predilection for the central nervous system. Clinically, pythons showed evidence of disease in the cerebellum and/or brainstem and central vestibular system, as well as the spinal cord.

Histologically, there was a non-suppurative encephalomyelitis, with the most consistent finding being vacuolation and gliosis in the brain. Pathological changes were also found in a wide range of other tissues. Cytoplasmic inclusions were found in a range of predominantly epithelial tissues. Infected pythons shed virus and were viraemic for several months. Several possible routes of horizontal transmission were identified, including cloacal-oral, oral-oral and via the circulatory system. The experimental infection study proved a causal link between sunshinevirus and disease in carpet pythons. The dose of virus required to cause infection was not established and the python immune response to sunshinevirus infection remains unclear.

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Hilevski, S. and Siroski, P. (2020). A novel laxative method for crocodylians and digestibility of soybean (*Glycine max*) in broad-snouted caiman (*Caiman latirostris*). *Aquaculture* (<https://doi.org/10.1016/j.aquaculture.2020.736137>).

**Abstract:** The objectives of this study were to evaluate the laxative capacity of saline solution, vegetable oil, and a commercial drug on *Caiman latirostris* and determine digestibility of diets with plant derived protein sources as a supplement for this species. After a trial using three laxative treatments in different doses, caimans were treated with 1.5 mL of lactulose daily for two days. They were then force-fed their corresponding diet once per day for 7 days and then digesta residues were collected. Digestibility was determined through a dietary marker, acid digestion of digesta residues, and calculated with a standard equation. Digestion of diets were between 96 and 99%, exhibiting differences among these ( $P=0.0006$ ), with the control diet 2.45% lower than treatments diets ( $P=0.0050$ ). Digestibility of soybean meal was between 90 and 95%. There were differences according to the treatment diet ( $P=0.018$ ). The results of this study indicate that the use of lactulose as a laxative for *C. latirostris* is effective and does not affect health. Inclusion of soybean meal in the diet of *C. latirostris* at levels of 20-60% improved its digestibility and nutrients were efficiently digested. Deliberate ingestion of plant material by wild crocodylians may serve to aid digestion and absorption of dietary nutrients, and not act only as gastroliths. This information could be used to develop crocodylian diets and assist future research to determine optimum nutrient levels and ingredient combinations for farm-raised crocodylians fed compounded diets.

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Filippi, L.S. and Bellardini, F. (2020). Feeding traces on postcranial sauropod remains from Bajo de la Carpa Formation (Upper Cretaceous, Santonian), northern Neuquén Basin, Patagonia, Argentina. *Cretaceous Research* (<https://doi.org/10.1016/j.cretres.2020.104696>).

**Abstract:** Bite marks in non-avian dinosaur fossil records can constitute the best evidence of predator-prey interactions even if they are uncommon, ambiguous, or of uncertain origin. In this contribution, we present new evidence of feeding traces on an isolated sauropod element from Bajo de la Carpa Formation outcrops (Upper Cretaceous, Santonian), northern Neuquén province, Patagonia, Argentina. The specimen is composed of a partial dorsal vertebral centrum (MAU-Pv-CO-651; deposited at the Museo Municipal Argentino Urquiza, Rincón de los Sauces, Neuquén, Argentina). We tentatively refer it to an indeterminate titanosaur sauropod due to the presence of an opisthocealic articulation and an internal pneumatic camellate condition. Three kinds of marks are preserved on the lateroventral face of the centrum: large and deep parallel marks, small and shallow longitudinal marks, and deep oval holes that we tentatively consider as punctures. These fossil marks can be considered to be feeding traces produced by a large-bodied carnivore to deflesh the bone and/or to obtain bone nutrients, probably during a single scavenging event. The marks and the punctures on the vertebral centrum can be referred to a theropod dinosaur due to their pattern and distribution. *Viavenator exxoni* (Filippi *et al.* 2016) represents the most likely trace-maker candidate

among the several theropod and crocodile taxa present in the Bajo de la Carpa Formation fossil record. The fossil feeding traces reported here improve our knowledge about the feeding behaviour of large scavengers in the north of the Neuquén Basin, at least during the Santonian.

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Lin, J.Q., Yu, J., Jiang, H., Zhang Y., Wan, Q.H. and Fang, S.G. (2020). Multi-omics analysis reveals that natural hibernation is crucial for oocyte maturation in the female Chinese alligator. *BMC Genomics* (doi: 10.1186/s12864-020-07187-5).

**Abstract:** Hibernation in an appropriate environment not only is important for the survival of hibernators in winter, but also is crucial for breeding in the following season for many hibernating species. However, the genetic and epigenetic mechanism underlying this process remain unclear. In the current study, we performed an integrative multi-omics analysis of gonads collected from Chinese alligators that overwintered in wild cave and artificial warmroom to explore transcriptomic and epigenomic alternations in these organs. The data revealed that in the breeding season, female alligators were more strongly affected in terms of gene expression than males by non-hibernation because of overwintering in a warm room, especially for genes related to oocyte maturation, and this effect commenced in winter with the downregulation of STAR, which is the rate limiting factor of steroid biosynthesis. Further, miRNAs were found to play essential roles in this negative effect of overwintering in the warm room on hibernation. The upregulated miRNAs likely were responsible for the suppression of oocyte maturation in the breeding season. Finally, DNA methylome changes, especially hypomethylation, were found to play an important role in the alterations in ovarian function-related gene expression induced by non-hibernation. Our study revealed the crucial role of hibernation quality for oocyte maturation in the Chinese alligator and the underlying genetic and epigenetic mechanisms, and highlights the importance of habitat, and especially, the overwintering site, in the conservation of not only the Chinese alligator, but also other endangered hibernators.

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Villamarín, F., Escobedo-Galván, A.H., Siroski, P. and Magnusson, W.E. (2021). Geographic distribution, habitat, reproduction, and conservation status of crocodylians in the Americas. Pp. 1-30 *in* Conservation Genetics of New World Crocodylians, ed. by R.B. Zucoloto, P.S. Amavet, L.M. Verdade and I.P. Farias. Springer: Cham.

**Abstract:** The chapter gives an introductory overview on the biology of the 11 species of crocodylians inhabiting the Americas. Geographical distribution is broadly discussed in the light of biogeographical and evolutionary origins. As a broad generalization, crocodylians are morphologically, genetically, and ecologically conservative and show a high dispersal ability, which together complicate the delimitation of species boundaries. Furthermore, distinct clades of crocodylians are a result of environmental selection for different adaptive characteristics. Gene flow occurs between clades, but distinct morphological varieties are sometimes a result of environmental filters. Thus, many taxa of crocodylians can be considered ecological species. Reproductive characteristics, such as nest-site choice and female reproductive output, influence reproductive success and thus population trends, so we discuss reproductive and habitat characteristics in the light of conservation genetics. Finally, the status of crocodylians is discussed both in terms of past hunting pressure and current conservation and management initiatives. In general, crocodylians can look after themselves if they have sufficient habitat, but some species are critically endangered by hunting, even though much of their original habitat remains intact. Conservation actions must be applied locally, taking into account threats and dispersal between source and sink populations. Given the difficulty of studying the dispersal of crocodylians by direct observation in most places in Latin America, the definition of effective management units will depend on genetic studies that can

be linked to economic or conservation goals.

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Zucoloto, R.B., Farias, I.P. and Amavet, P.S. (2021). Molecular Markers applied to conservation genetics of American crocodylians. Pp. 31-78 *in* Conservation Genetics of New World Crocodylians, ed. by R.B. Zucoloto, P.S. Amavet, L.M. Verdade and I.P. Farias. Springer: Cham.

**Abstract:** The subject of this chapter is addressed seeking to establish a balanced relationship of deepening, trying to be interesting for those who are looking for information on molecular markers, while not intending to be too long in the descriptions of the techniques and providing an indication of application in molecular ecology of crocodylians that are best treated in other chapters of the book. Whenever possible, we use examples of the results of our own research with crocodylians, while mixing them with illustrative images of the techniques with the intention of making the reading interesting both for the public that wants to study other groups of living beings and for other researchers like us falling in love with crocodylians. The application of molecular markers in molecular ecology is presented in the next chapters: a discussion of the progress in phylogenetic studies is done in Chapter 3; the application of molecular markers to study phylogeography is presented in Chapter 4; a more accurate review of the molecular markers used to conservation genetics studies is done in Chapter 5; in Chapter 6 parentage and mating systems of crocodylians are reviewed in the light of molecular markers; and in Chapter 7, examples of hybridization detected with those markers were depicted. A review of the development of molecular markers for later use in the studies of molecular ecology of crocodylians in America is presented in this chapter, from the first studies with isoenzymes to the most current techniques.

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De Lima Muniz, F., Bittencourt, P.S., Hernández-Rangel, S.M., Roberto, I.J., Farias, I.P. and Hrbek, T. (2021). Pp. 95-122 *in* Conservation Genetics of New World Crocodylians, ed. by R.B. Zucoloto, P.S. Amavet, L.M. Verdade and I.P. Farias. Springer: Cham.

**Abstract:** Biogeography is an area of study dedicated to understanding the evolutionary processes that resulted in current organismal distribution patterns. In general, exclusively terrestrial and exclusively aquatic vertebrates have well-studied and defined biogeographic patterns in the New World, but the biogeography of semiaquatic organisms is still poorly understood. In this chapter we discuss the biogeographic patterns and processes of New-World crocodylians. Although dispersal was probably an important process for the diversification of the ancestors of this group, the species/lineages - especially those of the South Americans - have their geographic distributions delimited by natural geographical barriers such as watershed divides, waterfalls and rapids, and captured watersheds, but also ecological specialization and competitive exclusions. The species/lineages occupying these areas show nearly identical divergence times, pointing to common historical processes that drove the evolution and divergence of these species/lineages. Recent studies have shown that widely distributed species have diversified into a significant number of independent evolutionary lineages. Knowing the biogeographic patterns of this group is of fundamental importance for conservation, since in the Anthropocene the effects of changes caused by man are devastating, destroying in a short period of time what nature took thousands/millions of years to build.

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Amavet, P.S., Zucoloto, R.B., Hrbek, T. and Farias, I.P. (2021). Genetic diversity of New World crocodylians. Pp. 123-151 *in* Conservation Genetics of New World Crocodylians, ed. by R.B. Zucoloto, P.S. Amavet, L.M. Verdade and I.P. Farias. Springer: Cham.

**Abstract:** Genetic diversity is one of the most important attributes of any population; it is defined as the variation in the amount of genetic information within and among individuals of a population, species, assemblage, or community. It can be expressed as differences between individuals at different levels, such as morphological features, structure and chromosomal number, and polymorphisms of sequences of DNA or proteins. An assessment of genetic diversity is fundamental to population genetic studies and has extremely important applications in conservation biology and the development of management and sustainable use plans. This chapter discusses the main indices that allow analyzing genetic variability and population structure of New World crocodylian populations, the methodologies used to estimate these indices, and the principal population genetic data available for these species. The effective population size concept is also discussed, a fundamental parameter in the study of principally those crocodile populations that have been drastically reduced in size and/or suffered fragmentation of their environments.

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Brittain, K., Ray, D.A. and Gongora, J. (2020). Crocodylian genome advances. Pp. 185-202 *in* Conservation Genetics of New World Crocodylians, ed. by R.B. Zucoloto, P.S. Amavet, L.M. Verdade and I.P. Farias. Springer: Cham.

**Abstract:** Advancements in genomic techniques have greatly increased the scope of research into many aspects of crocodylian evolution and biology. As cold-blooded amniotes, crocodylians hold a unique evolutionary position for understanding all vertebrate lineages. Applying up-to-date genomic techniques to crocodylian genomes can have far-reaching implications for understanding whole-genome evolution, adaptation and veterinary medicine. The slow rates of genomic mutations in crocodylians also mean we can use them as a way to gain insights into ancient genomes. Currently, only a few complete crocodylian genomes are publicly available; however this is rapidly changing thanks to the work of several laboratories around the world. This chapter will outline the existing available genomic research into biological systems such as innate immunity and sensory perception, as well as disease susceptibility and possible applications in human medicine. We will also outline industry and conservation implications of having high-quality crocodylian genomes for complex trait analysis and identifying ancient hybridization events.

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Densmore III, L.D. and Hrbek, T. (2021). Molecular phylogenetics of the New-World Crocodylia. Pp. 79-93 *in* Conservation Genetics of New World Crocodylians, ed. by R.B. Zucoloto, P.S. Amavet, L.M. Verdade and I.P. Farias. Springer: Cham.

**Abstract:** During the late twentieth and early twenty-first centuries, there has been a revolution in evolutionary biology. Traditional methods that had been applied to understanding relationships and natural history for hundreds of years have been supplemented (and sometimes replaced) by biochemical and molecular techniques that now allow us to examine the entire genomes of non-model organisms. Herein we review the use of these new technologies as they apply to crocodylians in general and specifically to the New-World members of the Alligatoridae and Crocodylidae. While generally concordant with traditional analyses, in some cases they have permitted cryptic species to be recognized. In addition, they have allowed crocodylian biologists to detect hybridization events between species, both in captivity and in the wild, that would not have been possible before their use. Hybridization may lead to the formation of new species, but it may also allow a common species to "swamp out" a rarer one. Because there appears to be little hybrid dysgenesis between many of the potential hybridizing forms, hybridization is potentially a serious problem for several New-World species.

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Pacheco-Sierra, G. and Amavet, P.S. (2021). Hybridization and speciation among New-World crocodylian species. Pp. 171-183 *in* Conservation Genetics of New World Crocodylians, ed. by R.B.

Zucoloto, P.S. Amavet, L.M. Verdade and I.P. Farias. Springer: Cham.

**Abstract:** In this chapter is analyzed one characteristic of the reproductive behavior that is frequently found among crocodylian species: hybridization. Hybridization is defined as reproduction between members of genetically distinct populations, producing offspring of mixed ancestry. The phenomenon of hybridization and hybrid speciation has been a topic of extensive discussion because it questions the concept of biological species. These discussions include topics such as sexual compatibility between species, fertility or not of hybrid offspring, phenotypic or genotypic similarity of hybrids, hybrid vigor, and potential hybrid zones. Crocodiles are long-lived and ancient species, but their specimens are very promiscuous and sexually active in their reproduction seasons. In this context, hybridization was and is a significant force in evolution to crocodylians. In this chapter, the different mechanisms that influence hybridization processes, the effects of hybridization at different evolutionary levels, species boundaries in hybrid zones, methodologies for the study of this phenomenon, main results of hybridization studies, and the conservation status of parental and hybrid species in New-World crocodile species are discussed.

Isberg, S.R. (2021). Crocodylians are promiscuous but not to the benefit of heterozygosity. Pp. 153-170 in *Conservation Genetics of New World Crocodylians*, ed. by R.B. Zucoloto, P.S. Amavet, L.M. Verdade and I.P. Farias. Springer: Cham.

**Abstract:** Crocodylian mating systems are complex but molecular genetics is providing some of the tools necessary to begin their unravelling. The most significant unravelling has been the widespread occurrence of multiple paternity (more than one sire for a clutch of eggs) across the global crocodylian species. The advantages of this strategy are still being debated and may differ across the different species, being dependent on factors such as population density and habitat availability at the individual population level. This chapter reviews the available literature outlining the impact other complexities such as nest site selection, the potential for communal nesting and “alloprotection” (non-biological female exhibiting nest guarding of conspecific eggs) could have on defining the mating strategies of crocodylians. However, it is argued that any advantage of genetic gain, genetic variability or inbreeding avoidance that might be achieved by multiple paternity is overcome by low embryo and offspring survival leading to low recruitment rates into the adult breeding population. The limitations of experimental design are also discussed which may be leading to upwardly biased estimates of hypothetical sire numbers.

Verdade, L.M., Piña, C.I., Simoncini, M. and Silva-Brandão, K.L. (2021). How genetic tools can help crocodylians’ management and governance. Pp. 203-214 in *Conservation Genetics of New World Crocodylians*, ed. by R.B. Zucoloto, P.S. Amavet, L.M. Verdade and I.P. Farias. Springer: Cham.

**Abstract:** The applications of genetic tools for crocodylians’ management and governance can be done at two levels: intra- and interspecific. The following intraspecific processes can be investigated by the use of genetic tools: mating system, parental care, and dispersal pattern, potentially useful for biological conservation; identification of “problem” individuals involved in humans and livestock predation, potentially useful for control; and the identification of reproductive females in monitoring programs based on nest identification and counting. As management of endangered species implies in the necessity for the increase of depleted populations, two possible consequences should be considered: loss of genetic variability and a change on the selective pressures. The former has been usually monitored using genetic markers. However, the later has been systematically neglected. Whenever possible to collect DNA from the suspect “problem” animals at the “crime scene,” it is possible to confirm whether the guilty one has been

culled, based on molecular markers, which can avoid overkill. In sustainable use programs, genetic markers can determine the origin of the skin, meat, eggs, and hatchlings, avoiding illegal extraction from wild populations. Finally, in the future eDNA might be used to identify individuals, thus providing information about crocodylian populations. Future studies should prioritize the identification of adaptive genes to human-modified environments and to human management itself to mitigate the anthropic pressures crocodylians face in the Anthropocene, including an unintended domestication process, in which they might become dependent on humans to survive.

Amavet, P.S. and Zucoloto, R.B. (2021). Perspectives and final considerations about the molecular ecology of New-World crocodylians. Pp. 215-221 in *Conservation Genetics of New World Crocodylians*, ed. by R.B. Zucoloto, P.S. Amavet, L.M. Verdade and I.P. Farias. Springer: Cham.

**Abstract:** This final chapter summarizes the main concepts expressed in this book, condensing the main findings developed over many years through genetic research in crocodile populations of the New World. Since the development of new technologies, researchers from the New World have been applying them successfully in the species that concern us. In this way, a large amount of information has been collected over time, as displayed throughout the reading of this book, obtaining a body of knowledge that contributes to the conservation of its populations. Basic data have been obtained, such as population parameters of genetic diversity up to applied data, for example, determining the species or population of origin to which a commercial product belongs. A large part of the successful results was obtained thanks to the collaboration between working groups of crocodile specialists, which allows extending the sampling, and the genetic information or markers to be used or increase the depth of the analysis. The fundamental ideas developed in each of the previous chapters are organized here with the aim of elaborating on the final conclusions of this book.

La Grange, L.J. and Mukaratirwa, S. (2020). Experimental infection of tigerfish (*Hydrocynus vittatus*) and African sharp tooth catfish (*Clarias gariepinus*) with *Trichinella zimbabwensis*. *Onderstepoort J Vet Res* 87(1) (doi: 10.4102/ojvr.v87i1.1876).

**Abstract:** *Trichinella zimbabwensis* naturally infects a variety of reptilian and wild mammalian hosts in South Africa. Attempts have been made to experimentally infect piranha fish with *T. zimbabwensis* and *T. papuae* without success. Tigerfish (*Hydrocynus vittatus*) and African sharp tooth catfish (*Clarias gariepinus*) are accomplished predators cohabiting with Nile crocodiles (*Crocodylus niloticus*) and Nile monitor lizards (*Varanus niloticus*) in southern Africa and are natural hosts of *T. zimbabwensis*. To assess the infectivity of *T. zimbabwensis* to these two hosts, 24 African sharp tooth catfish (mean live weight 581.75 ± 249.71 g) randomly divided into 5 groups were experimentally infected with 1.0 ± 0.34 *T. zimbabwensis* larvae per gram (lpg) of fish. Forty-one tigerfish (mean live weight 298.6 ± 99.3 g) were randomly divided for three separate trials. An additional 7 tigerfish were assessed for the presence of natural infection as controls. Results showed no adult worms or larvae of *T. zimbabwensis* in the gastrointestinal tract and body cavities of catfish sacrificed at day 1, 2 and 7 post-infection (p.i.). Two tigerfish from one experimental group yielded 0.1 lpg and 0.02 lpg of muscle tissue at day 26 p.i. and 28 p.i., respectively. No adult worms or larvae were detected in the fish from the remaining groups sacrificed at day 7, 21, 28, 33 and 35 p.i. and from the control group. Results from this study suggest that tigerfish could sustain *T. zimbabwensis* under specific yet unknown circumstances.

Saragih, G.S., Kayat, Hidayatullah, M. and Hadi, D.S. (2020). A preliminary study on the population and habitat of saltwater crocodile (*Crocodylus porosus*) in Timor Island, East Nusa Tenggara. *IOP*

**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.

Riordan, C., Jacquet, J. and Franks, B. (2020). Investigating the welfare and conservation implications of alligator wrestling for American alligators (*Alligator mississippiensis*). PLoS ONE 15(11): e0242106.

**Abstract:** Wildlife tourism attractions (WTA) are popular in the United States, but they may be harmful to the individual animals involved and we question whether they provide benefits to environmental conservation. Most research on the welfare and environmental implications of WTAs focuses on charismatic mammals, with few studies investigating these issues for reptiles. Here we examine alligator wrestling, including its impact on animal welfare and environmental conservation. Using a sample of 94 relevant YouTube videos of alligator wrestling in Florida representing 16 different venues, we coded the environmental and behavioral characteristics evident in each video. We then performed a content analysis of wrestlers' narration in a subset of 51 videos to analyze the environmental awareness and educational components of alligator wrestling. Our results show systemic welfare harm: 11 venues housed adult alligators together with conspecifics, 96% of alligator wrestling performances facilitated direct contact in the form of physical restraint by one or more human wrestlers, and as many as 96% of the videos did not show a suitable water or waterside features for captive alligators. Furthermore, 12% of performances showed wrestlers flipping alligators onto their backs while 16% showed wrestlers tying alligators' jaws shut, both of which are known to be acute stressors. Finally, just under half of alligator wrestling commentary (49%) addressed environmental conservation topics, and much of this commentary included contradictory or misleading information that is not likely to benefit alligators in the wild. We argue that alligator wrestling serves no role in promoting positive relationships between humans, animals, and the environment, and instead furthers traditional notions of dominion that undermine welfare and conservation aims.

Venter, M., Kelly, A., Boffard, K., Pretorius, R. and Younus, A. (2020). African Nile crocodile bite of the forearm: A case report. East African Orthopaedic Journal 14(2): 102-107.

**Abstract:** African Nile crocodiles are the only species of crocodile consistently found across central and sub-Saharan Africa. A large and specifically aggressive species of the African Nile crocodile is solely responsible for almost all unprovoked attacks on humans, the exact incidence of which is unknown. The reported mortality rate of an African Nile crocodile attack is between 65-91% with up to 70% of surviving individuals with a bite of a limb ultimately requiring

amputation. We describe an adult male patient whom, during the course of performing his daily duties, slipped on a riverbank and fell into the water where he was immediately seized on the left forearm by an African Nile crocodile. Through fighting back the African Nile crocodile released its hold and he was able to survive the attack and reach our unit. Despite relatively benign looking wounds the initial surgical exploration revealed the true extent of the underlying muscle damage and within hours a flexor compartment syndrome developed needing surgical management. Through serial operating room visits and directed antibiotic therapy we were able to successfully treat the patient resulting in a favorable outcome.

Nagahama, Y., Chakraborty, T., Paul-Prasanth, B., Ohta, K. and Nakamura, M. (2020). Sex determination, gonadal sex differentiation and plasticity in vertebrate species. Physiological Reviews (https://doi.org/10.1152/physrev.00044.2019).

**Abstract:** A diverse array of sex determination (SD) mechanisms, encompassing environmental to genetic, have been found to exist among vertebrates, covering a spectrum from fixed SD mechanisms (mammals) to functional sex change in fishes (sequential hermaphroditic fishes). A major landmark in vertebrate SD was the discovery of the SRY gene in 1990. Since that time, many attempts to clone an SRY ortholog from non-mammalian vertebrates remained unsuccessful, until 2002, when DMY/DMRT1BY was discovered as the SD gene of a small fish, medaka. Surprisingly, however, DMY/DMRT1BY was found in only two species among more than 20 species of medaka, suggesting a large diversity of SD genes among vertebrates. Considerable progress has been made over the last 3 decades, such that it is now possible to formulate reasonable paradigms of how SD and gonadal sex differentiation may work in some model vertebrate species. This review outlines our current understanding of vertebrate SD and gonadal sex differentiation, with a focus on the molecular and cellular mechanisms involved. An impressive number of genes and factors have been discovered that play important roles in testicular and ovarian differentiation. An antagonism between the male and female pathway genes exists in gonads during both sex differentiation and, surprisingly, even as adults, suggesting that, in addition to sex-changing fishes, gonochoristic vertebrates including mice maintain some degree of gonadal sexual plasticity into adulthood. Importantly, reviewing various SD mechanisms among vertebrates suggest that this is the ideal biological event that can make us understand the evolutionary conundrums underlying speciation and species diversity.

Bossi, L., Falorni, P., Windsor, C., Zandonai, F., Bizzarini, F., Delfino, M., Giusberti, L., Bechtel, T., Chizh, M., Ivashov, S. and Capineri, L. (2020). The imaging of subsurface crocodile remains in a limestone slab using holographic radar. In Proceedings of the 18th International Conference on Ground Penetrating Radar, Golden, Colorado, USA, 14-19 June 2020 (https://doi.org/10.1190/gpr2020-003.1).

**Abstract:** RASCAN holographic radar has been used to observe a rostrum of an Upper Jurassic-Lower Cretaceous fossil crocodylomorph under the upper surface 21 mm thick limestone slab (Maiolica Formation). The specimen, recovered in the Altopiano di Asiago (Vicenza Province, Italy), is at present housed in the paleontological collections of the Rovereto Civic Museum (Trento Province, Italy). The holographic radar response correlates well with the actual fossil shape revealed on the reverse side of the slab. This study has been made using the RASCAN-4/7000 holographic radar which can penetrate through several centimeters of the limestone. It works by comparing the phase of a sinusoid electromagnetic wave reflected from the subsurface of the fossil with the internal reference of the transmitting antennae. The radar has receiving antennas with both cross and parallel polarizations relative to the transmitter. On a processed radar plan-view image, objects can often be identified directly by their shape and texture as was first demonstrated in a similar research field for dinosaurs' tracks investigation [1, 2]. This

is a great simplification compared with the processing needed using impulse radar [3]. The RASCAN method is suitable for portable and on-site applications due to its small size, light weight and low power consumption. The images generated can be used for diagnostic purposes similar to X-ray methods, but without the complications that the use of ionizing radiation entails. Another advantage is the possibility to make measurements from just one side of the object under investigation. Comparison of microwave holographic radar and the X-Ray images are used here to evaluate the proposed method.

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Udphuay, S., Thapchim, J., Ditbanjong, P., Yawichai, A. and Chanthasit, P. (2020). Ground-penetrating radar for fossil investigation, Phu Noi excavation site, Thailand. *In Proceedings of the 18th International Conference on Ground Penetrating Radar*, Golden, Colorado, USA, 14-19 June 2020 (<https://doi.org/10.1190/gpr2020-076.1>).

**Abstract:** In this study, ground penetrating radar (GPR) surveys were conducted to investigate subsurface fossil remains in Phu Noi excavation site located in Kalasin province, northeastern Thailand. The site was chosen due to the presence of dinosaur bones associated with a rich fauna of fish and crocodile, and petrified wood. It has been presumed that there are more of fossil remains to be found in the area. Therefore, this study aims to locate the distribution of shallow burial fossil remains at the site and to verify the resolution capability of the GPR technique in detecting fossils. The GPR surveys were conducted using 500 MHz shielded transducers of the PulseEKKO PRO GPR system. The surveyed area was divided into a few subareas depending on their accessible limitations. A grid system with equally spaced parallel GPR profiles was used in each subarea. Raw GPR data were processed using a standard procedure of EKKO\_Project software with an application of the envelope attribute analysis. GPR anomalies were created at various depths. These anomalies were suspected to be from the fossils. By comparing geophysical and paleontological data, we observed the effectiveness of GPR for detecting large size of fossil bones. Despite its relatively low penetration depth, the high resolution of the 500 MHz GPR makes this technique successful for shallow depth study. This case study can be applied in other areas of paleontological field study as GPR anomaly maps are very useful for field site paleontologists in guiding their excavation plan.

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Hale, M.D. and Parrott, B.B. (2020). Assessing the ability of developmentally precocious estrogen signaling to recapitulate ovarian transcriptomes and follicle dynamics in alligators from a contaminated lake. *Environ Health Perspect* 128(11) (doi: 10.1289/EHP6627).

**Abstract:** Concern has grown in recent decades over anthropogenic contaminants that interfere with the functioning of endocrine hormones. However, mechanisms connecting developmental processes to pathologies associated with endocrine-disrupting chemical (EDC) exposure are poorly understood in naturally exposed populations. We sought to a) characterize divergence in ovarian transcriptomic and follicular profiles between alligators originating from a historically EDC-contaminated site, Lake Apopka, and a reference site; b) test the ability of developmentally precocious estrogen exposure to recapitulate site-associated patterns of divergence; and c) test whether treatment with exogenous follicle-stimulating hormone (FSH) is capable of rescuing phenotypes associated with contaminant exposure and/or embryonic estrogen treatment. Alligators eggs were collected from a contaminated site and a reference site, and a subset of eggs from the reference site were treated with estradiol (E2) during embryonic development prior to gonadal differentiation. After hatching, alligators were raised under controlled laboratory settings for 5 months. Juveniles from both sites were divided and treated with exogenous FSH. Histological analyses and RNA-sequencing were conducted to characterize divergence in ovarian follicle dynamics and transcriptomes between sites, between

reference and E2-treated animals, and between FSH-treated and nontreated animals. We observed broad site-of-origin divergence in ovarian transcriptomes and reductions in ovarian follicle density between juvenile alligators from Lake Apopka and the reference site. Treating embryos from the reference site with E2 overwhelmingly recapitulated transcriptional and histological alterations observed in Lake Apopka juveniles. Ovarian phenotypes observed in Lake Apopka alligators or resulting from estrogen treatment were only partially rescued by treatment with exogenous FSH. Recapitulation of ovarian abnormalities by precocious E2 revealed a relatively simple mechanism underlying contaminant-induced pathologies in a historical example of environmental endocrine disruption. Findings reported here support a model where the developmental timing of estrogen signaling has the potential to permanently alter ovarian organization and function.

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Swain, S., Sahu, B.K., Pattanaik, S., Sahoo, R.K., Majhi, A., Satapathy, D.R., Panda, C.R., Roy, R. and Choudhury, S.B. (2020). Anthropogenic influence on the physico-chemical parameters of Dhamra estuary and adjoining coastal water of the Bay of Bengal. *Marine Pollution Bulletin* (<https://doi.org/10.1016/j.marpolbul.2020.111826>).

**Abstract:** Estuaries receive the anthropogenic pollutants of their watershed area. Dhamra estuary, on the east coast of India, is such an estuary that receives a huge amount of pollutants, and it will eventually pose a threat to the ecological sensitive areas in its vicinity. Therefore, a study was carried out on physico-chemical parameters and chlorophyll-*a* to delineate the sources of variation during pre-monsoon and post-monsoon seasons. Surface water sampling was carried out from 12 stations in the estuarine and coastal area. Factor analysis and cluster analysis were applied to seasonal data to understand the sources of variation. From the study, it was observed that the chemical parameters are severely affected by anthropogenic influences such as sediment dredging, aquaculture effluent, and waste from industry and sewage from upstream. In the long run, this will affect the nearby nesting ground of vulnerable Olive Ridley turtles, high bio-diverse mangrove forests, and saltwater crocodile habitat.

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Xu, C., Palade, J., Fisher, R.E., Smith, C.I., Clark, A.R., Sampson, S., Bourgeois, R., Rawls, A., Elsey, R.M., Wilson-Rawls, J. and Kusumi, K. (2020). Anatomical and histological analyses reveal that tail repair is coupled with regrowth in wild-caught, juvenile American alligators (*Alligator mississippiensis*). *Scientific Reports* 10: 20122.

**Abstract:** Reptiles are the only amniotes that maintain the capacity to regenerate appendages. This study presents the first anatomical and histological evidence of tail repair with regrowth in an archosaur, the American alligator. The regrown alligator tails constituted approximately 6-18% of the total body length and were morphologically distinct from original tail segments. Gross dissection, radiographs, and magnetic resonance imaging revealed that caudal vertebrae were replaced by a ventrally positioned, unsegmented endoskeleton. This contrasts with lepidosaurs, where the regenerated tail is radially organized around a central endoskeleton. Furthermore, the regrown alligator tail lacked skeletal muscle and instead consisted of fibrous connective tissue composed of type I and type III collagen fibers. The overproduction of connective tissue shares features with mammalian wound healing or fibrosis. The lack of skeletal muscle contrasts with lizards, but shares similarities with regenerated tails in the tuatara and regenerated limbs in *Xenopus* adult frogs, which have a cartilaginous endoskeleton surrounded by connective tissue, but lack skeletal muscle. Overall, this study of wild-caught, juvenile American alligator tails identifies a distinct pattern of wound repair in mammals while exhibiting features in common with regeneration in lepidosaurs and amphibia.

Lemaire, J., Olivier, M., Paco, B., Rosanna, M. and Francois, B. (2020). I got it from my mother: Inter-nest variation of mercury concentration in neonate Smooth-fronted Caiman (*Paleosuchus trigonatus*) suggests maternal transfer and possible phenotypical effects. *Environmental Research* (<https://doi.org/10.1016/j.envres.2020.110494>).

**Abstract:** The deleterious effects of mercury (Hg) contamination are well documented in humans and wildlife. Chronic exposure via diet and maternal transfer are two pathways which increase the toxicological risk for wild populations. However, few studies examined the physiological impact of Hg in crocodylians. We investigated the Hg contamination in neonate Smooth-fronted Caimans, *Paleosuchus trigonatus*, and the use of keratinized tissues and blood to evaluate maternal transfer. Between November 2017 and February 2020, we sampled 38 neonates from 4 distinct nests. Mercury concentration was measured in claws, scutes and total blood. Highest Hg concentrations were found in claws. Strong inter-nest variations (Hg ranging from  $0.17 \pm 0.02$  to  $0.66 \pm 0.07 \mu\text{g}\cdot\text{g}^{-1}$  dw) presumably reflect maternal transfer. Reduced body size in neonates characterized by elevated Hg concentrations suggests an influence of Hg during embryonic development. We emphasize the use of claws as an alternative to egg collection to investigate maternal transfer in crocodylians. Our results demonstrated the need of further investigation of the impact of Hg contamination in the first life stages of crocodylians.

Masés-García, C.A., Briones-Salas, M. and Sosa-Escalante, J.E. (2020). Assessment of wildlife crime in a high-biodiversity region of Mexico. *Journal for Nature Conservation* (<https://doi.org/10.1016/j.jnc.2020.125932>).

**Abstract:** Wildlife crime, including illegal harvesting, poaching, use, and trade, is a global issue. While studies on wildlife crimes have been performed on a global scale, it is also essential to assess their impact on native species at national scales. Investigating illegal activities involves analyzing law enforcement and seizure data, especially in areas with high biodiversity. In this study, we analyzed the effects of wildlife crime on native wild vertebrates of Oaxaca, southern Mexico, from 2004 to 2018. We used data from law enforcement by Mexican authorities on activities that affect vertebrates: trafficking, illegal possession, exploitation, breaking of hunting laws, permit breaches, and illegal scientific collecting. Oaxaca has a high incidence of wildlife crime, and illegal trading accounts for 38% of wildlife law violations (62% are other illegal activities). In addition, 8,047 specimens of 226 species were seized during the study period, of which 54% are considered endangered in Mexico or worldwide. Reptiles accounted for the highest number of individual specimens, while birds recorded the greatest range of species. The main species seized were green iguana (*Iguana iguana*), black iguana (*Ctenosaura pectinata*), Morelet's crocodile (*Crocodylus moreletii*), olive ridley turtle (*Lepidochelys olivacea*), orange-fronted parakeet (*Aratinga canicularis*), and white-tailed deer (*Odocoileus virginianus*). Many of these seizures were made close to roads. Our results support the understanding that illegal trade reports are underestimates. This study allows us to have a greater understanding of the real magnitude of the problem. We hope this research will inform policies and strategies to combat the illegal activities that affect wildlife in regions with high biodiversity.

Hart, L.J., Bell, P.R., Smith, E.T., Mitchell, D.R., Brougham, T. and Salisbury, S.W. (2020). A probable skeleton of *Isisfordia* (Crocodyliformes) and additional crocodyliform remains from the Griman Creek Formation (Cenomanian, New South Wales, Australia). *Journal of Paleontology* (doi: <https://doi.org/10.1017/jpa.2020.98>).

**Abstract:** The sparse record of Cretaceous crocodyliforms in Australia comprises only three species, all within the genus *Isisfordia*. *Isisfordia duncani* Salisbury *et al.*, 2006 is from the

Albian-Turonian Winton Formation of Queensland, and both *Isisfordia molnari* Hart *et al.*, 2019 and *Isisfordia selaslophensis* Etheridge, 1917 have been described from opalized material from the Cenomanian Griman Creek Formation of New South Wales. Here, we describe new cranial and postcranial material, including the most complete crocodyliform skeleton from the Cretaceous of New South Wales, which is assigned to *Isisfordia* cf. *I. selaslophensis*. We also reappraise previously described crocodyliform material from the same locality. We find that much of this material displays features that are consistent with *Isisfordia*.

Séon, N., Amiot, R. and Vincent, P. (2020). Thermophysiology des reptiles marins mésozoïques révélées par la composition isotopique de l'oxygène des tissus phosphatés. *Bulletin de l'Association paléontologique de Villers-sur-Mer* (mnhn-03016214).

**Abstract:** There are currently about a hundred species of marine reptiles (snakes, turtles, crocodile and Galapagos iguana). With the exception of some turtles, all of these organisms live in the intertropical zones where they absorb heat from their environment in order to increase their body temperature, mainly through behavioral regulation. During the Mesozoic (from -252 to -66 Million years), the specific diversity of marine reptiles was at least five times greater than today, with taxa such as Ichthyosauria, Plesiosauria, Mosasauroida but also Crocodylomorpha and Testudinata (turtles). Fossil remains of Plesiosauria and Ichthyosauria were found in strata deposited at low to subpolar paleolatitudes, suggesting they had a thermophysiology allowing them to live in cold waters. In addition, histological studies of long bone sections of Ichthyosauria, Plesiosauria and Crocodylomorpha have revealed rapid rates of bone growth followed by strong remodeling suggesting high metabolism. To study the thermophysiology of marine reptiles of the Mesozoic from another perspective, the isotopic oxygen composition of the hydroxyapatite constituting dental enamel and bone has been analyzed in order to estimate the body temperatures of these organisms. These temperatures have then been compared to those of poikilothermic ectotherms (Chondrichthyes and Osteichthyes) found in the same deposits. Body temperature estimates indicate that Ichthyosauria and Plesiosauria had high and constant temperatures, in contrast to those of Metriorhynchidae and Mosasauroida that appeared to vary with those of their living environment. Consequently, Ichthyosauria and Plesiosauria were supposed to be homeothermic endotherms while Metriorhynchidae and Mosasauroida were poikilothermic endotherms. Teleosauridae seem to have an ectothermic thermophysiology coupled with a behavioral regulation linked to their semi-aquatic ecology. The presence of endothermy involving temperature independence from the environment probably conferred a significant adaptive advantage for these organisms to colonize high-latitude environments and to survive cooling episodes of the Mesozoic.

Numbere, A.O. and Iwuji, C.B.W. (2020). Burrow distribution, size and chemical composition of the African Dwarf crocodile (*Osteolaemus tetraspis*) of the Niger Delta Nigeria. *London Journals Press* 20(10): 39-50.

**Abstract:** Studies on the African dwarf crocodile in the Niger Delta mangrove are limited because of lack of data. This study was a chance event which discovered some burrows in cleared mangrove forest. Based on the nocturnal life and the difficulty in tracking and capturing the crocodiles their burrows were studied to determine their numbers and size differences. Furthermore, distances of the burrow to the river and the burrow soil chemistry were investigated to determine the impact of anthropogenic activities on the nascent community. The diameter of the burrows and the distances of the burrow to water were measured and the soil samples collected from each burrow to determine the total hydrocarbon content (THC) and heavy metals. In all 105 burrows were counted along a 90 m transect and results reveals that more burrows were medium sized (n= 69; size range: 9-15 cm), followed by large (n= 24; size range:

16-23 cm) and small (n= 12; size range: 0-8 cm) sizes. The soil chemistry revealed that there was no significant difference between burrows in THC and heavy metal concentration ( $P>0.05$ ). However, burrows close to the river had higher chemical concentration than inner burrows. The order of chemical concentration is  $\text{THC}>\text{chromium}>\text{copper}>\text{cadmium}>\text{lead}$ . Again there was no correlation between distance from water and diameter of burrow ( $(F_{1,103} = 0.33, P = 0.56)$ ). The smaller burrows were the closest to the river ( $1.43 \pm 0.10$  m) followed by the large ( $1.59 \pm 0.11$  m) and the medium ( $1.59 \pm 0.11$ ) burrows. Proximity to the water provides quick access to the river for hunting and safety for predators.

Kean, K.J., Foffa, D., Johnson, M.M., Young, M.T., Greitens, G. and Brusatte, S.L. (2020). First and most northern occurrence of a thalattosuchian crocodylomorph from the Jurassic of the Isle of Skye, Scotland. *Scottish Journal of Geology* (<https://doi.org/10.1144/sjg2020-013>).

**Abstract:** The Jurassic was a key interval for the evolution of dinosaurs, crocodylomorphs, and many other vertebrate groups. In recent years, new vertebrate fossils have emerged from the Early-Middle Jurassic of the Isle of Skye, Scotland; however, much more is known about Skye's dinosaur fauna than its crocodylomorphs. Here we report new crocodylomorph material collected from Jurassic marine deposits at Prince Charlie's Cave on the north east coast of Skye. The specimen is a small cobble containing postcranial elements from an individual that is considerably larger in size than previous crocodylomorphs described from Skye. Based on features of the vertebrae and osteoderms, the specimen is assigned to Thalattosuchia, an extinct clade of semiaquatic/pelagic crocodylomorphs. Specifically, the sub-circular and bean-shaped pit ornamentation on the dorsal surface of the osteoderms in alternating rows suggest affinities with the semi-aquatic lineage Teleosauroidea. Although the ornamentation pattern on the osteoderms is most similar to *Macrospodylus* ("*Steneosaurus*") *bollensis*, we conservatively assign the specimen to Teleosauroidea indeterminate. Regardless of its precise affinities and fragmentary nature, the specimen is the first thalattosuchian discovered in Scotland and is the most northerly reported Jurassic thalattosuchian globally, adding to our understanding of the palaeobiogeography and evolution of this group.

Iijima, M. and Kubo, T. (2020). Vertebrae-based body length estimation in crocodylians and its implication for sexual maturity and the maximum sizes. *Integrative Organismal Biology* (<https://doi.org/10.1093/iob/obaa042>).

**Abstract:** Body size is fundamental to the physiology and ecology of organisms. Crocodylians are no exception, and several methods have been developed to estimate their absolute body sizes from bone measurements. However, species-specific sizes, such as sexually mature sizes and the maximum sizes were not taken into account due to the challenging maturity assessment of osteological specimens. Here, we provide a vertebrae-based method to estimate absolute and species-specific body lengths in crocodylians. Lengths of cervical to anterior caudal centra were measured and relations between the body lengths (snout-vent and total lengths) and lengths of either a single centrum or a series of centra were modeled for extant species. Additionally, states of neurocentral suture closure were recorded for the maturity assessment. Comparisons of total lengths and timings of neurocentral suture closure showed that most extant crocodylians reach sexual maturity before closure of precaudal neurocentral sutures. Centrum lengths of the smallest individuals with closed precaudal neurocentral sutures within species were correlated with the species maximum total lengths in extant taxa; therefore, the upper or lower limit of the species maximum sizes can be determined from centrum lengths and states of neurocentral suture closure. The application of the current method to non-crocodylian crocodylians requires similar numbers of precaudal vertebrae, body proportions, and timings of neurocentral suture closure as

compared to extant crocodylians.

Wibowo, A. (2020). In search of Makara, an extirpated freshwater crocodile *Crocodylus siamensis* (Schneider, 1801) of Java Island, using temple reliefs,  $\Psi$  AIC and habitat modeling. Preprints 2020, 2020110595 (doi: 10.20944/preprints202011.0595.v1).

**Abstract:** Ancient reliefs in temple can provide information of past ecosystem along with biodiversity including Makara relief representing crocodile figure. In here, this study aims to identify and model the population of freshwater *Crocodylus siamensis* as portrayed in reliefs in 6 temples. The result shows that the crocodile reliefs in temples were having similar pattern to the freshwater *C. siamensis* fossils in term of locality. The temples and the fossils were located in the inland and near the rivers. While the temple locality patterns were in contrast to the locations where extant saltwater *Crocodylus porosus* has occurred. These contradictions strengthen the possibility that the crocodile portrayed in reliefs was made based on the *C. siamensis* occurrences. Based on the analysis, it is estimated that *C. siamensis* once has occupied river and wetland in Java and its presence has been recorded in the reliefs. This occurrence at least happened from 1280 to 700 BC. From assessments of habitats near the temples using  $\Psi$  AIC, most surrounding habitats have high detection probability and occupancy for *C. siamensis* from  $\Psi$  0.500 (95%CI:0.058-0.941). to  $\Psi$  1.000 (95%CI:0.000-1.000).

Jumaryati, Poti, J. and Okparizan (2020). Implementasi kebijakan pengendalian populasi buaya oleh dinas Lingkungan hidup kabupaten lingga. *Student Online Journal* 1(2): 123-135.

**Abstract:** Wildlife in the form of a crocodile in Lingga Regency is one of the predators that often raises itself to the surface of rivers and swamps so that many people become victims of these wild animals. Crocodile in Lingga including estuarine crocodile type or often called the crocodile crocodile (*Crocodylus porosus*) where this is the largest type of crocodile in the world. The purpose of this study was to determine the implementation of the crocodile population control policy by the Lingga Regency Environmental Agency. The research method used is descriptive with a qualitative approach. The data analysis technique in this study uses triangulation techniques. In implementing this crocodile population control policy the researchers used 4 indicators from G. Shabbir Cheema and Dennis A. Rondinelli's theories. The results of this study with 9 informants indicated that the environmental conditions of the crocodile shelter were strategic because they were far from residential areas. Judging from the relationship between the organizations implementing the policy has been implemented well but communication to the community is still lacking. In terms of resources, the implementation of this program has been carried out but there is still a lack of experts in handling cases of crocodile population control. Judging from the characteristics and capabilities of the implementing agent, the policy implementers are indeed experts in dealing with crocodiles and there has been training given previously from the agency. The conclusion is that the implementation of the crocodile population control policy in Lingga Regency has not been maximized and there are still many technical and operational constraints faced by the implementers in the field or the implementers of the policies that have not yet fully benefited the community. At the end of this study, it is suggested that if tangible benefits have not been felt by the community, such a program should be reviewed so that it can be actualized properly and provide tangible benefits for the community.

Zhang, J., Cai R., Liang, J., Izaz, A., Shu, Y., Pan, T. and Wu, X. (2020). Molecular mechanism of Chinese alligator (*Alligator sinensis*) adapting to hibernation. *Journal of Experimental Zoology. Part B, Molecular and Developmental Evolution* (doi: 10.1002/jez.b.23013).

**Abstract:** Hibernation is a physiological state for Chinese alligators

to cope with cold weather. In mammals, gene expression changes during hibernation and their regulatory mechanisms have been extensively studied, however, these studies in reptiles are still rare. Here, integrated analysis of messenger RNA (mRNA), microRNA (miRNA), and long noncoding RNA (lncRNA) reveals the molecular mechanisms of the hypothalamus, liver, and skeletal muscle in hibernating and active individuals. During hibernation, the number of genes increased in the hypothalamus, liver, and skeletal muscle was 585, 282, and 297, while the number of genes decreased was 215, 561, and 627, respectively, as compared with active individuals. Through Gene Ontology and Kyoto Encyclopedia of Genes and Genomes enrichment analysis, the differentially expressed genes were mainly enriched in DNA damage repair, biological rhythm, energy metabolism, myoprotein degradation, and other related items and pathways. Besides, 4740 miRNAs were identified in three tissues. Through the comprehensive analysis of miRNA and mRNA abundance profiles, 12,291, 6997, and 8232 miRNA-mRNA pairs all showed a negative correlation in the hypothalamus, liver, and skeletal muscle, respectively. Some miRNA target genes were related to biological rhythm and energy metabolism, suggesting that miRNA may play an important role in the physiological metabolism of the hibernating adaptability of Chinese alligators. Moreover, 402, 230, and 130 differentially expressed lncRNAs were identified in the hypothalamus, liver, and skeletal muscle, respectively. The targeting relationship of four lncRNA-mRNA pairs were predicted, with the main function of target genes involved in the amino acid transportation. These results are helpful to further understand the molecular regulatory basis of the hibernation adaptation in Chinese alligators.

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Hussein, R., Kivitz, S., Poltiylova, E. and Granatosky, M.C. (2020). Crocodylia locomotion. *In* Encyclopedia of Animal Cognition and Behavior, ed. by J. Vonk and T.K. Shackelford. Springer Nature: Switzerland.

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Yesudas, R.R. and Young, B.A. (2020). Impact of nematodes on the gastric mucosa of the American alligator (*Alligator mississippiensis*). *The Journal of Advances in Parasitology* 7(2): 7-13.

**Abstract:** The intestinal tract represents an ideal habitat for a large number of parasites, as compared to stomach's acidic environment. The American alligator (*Alligator mississippiensis*, Daudin) has "typical" vertebrate gastric pits and glands in the stomach mucosa, with a corresponding acidic gastric environment. Crocodylians have a remarkably effective immune system, which enables them to combat microbial infections and allows relatively quick wound healing. We sought to explore how the alligator's immune system responded to parasites, rather than microbial, challenges. We examined the stomachs of 14 sub-adults, wild-caught, American alligators from the coastal region of Louisiana, and found that four (~29%) were infected with enteric helminthes. Two different nematodes were found: *Dujardinascaris waltoni* (Nematoda: Heterocheilidae) was found loose among the stomach contents, whereas *Ortleppascaris antipini* (Nematoda: Ascaridoidea) was associated with multifocal lesions in the gastric mucosa. These lesions were roughly 4 mm in diameter, housed multiple parasites, and formed an elevated node of mucosa and nematodes. As the parasites invaded the gastric mucosa, they induced a granulomatous inflammation near the lesion; the site of worm attachment was associated with a marked eosinophilic necrosis. This cellular response produced a penumbra around the invasive nodule that was clearly visible under light and electron microscopy. Embedded worms were surrounded by an eosinophilic exudation, presumably representing proliferating host mucosal tissue, which formed the elevated nodule. Mucosal burrows of the nematodes led to a loss of the gastric pits in the infected zone and a presumed decrease in digestive efficiency of the host alligator.

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Carl, N.J., Stewart, H.A. and Paul, J.S. (2020). Unprovoked mouth gaping behavior in extant Crocodylia. *Journal of Herpetology* 54(4):

418-426.

**Abstract:** Unprovoked mouth gaping behavior is ubiquitous throughout 24 extant members of Crocodylia, yet information on gaping is limited. Proposed hypotheses for gaping include thermoregulation and the evaluation of potential environmental conditions. To determine temperature effects, we tracked head surface (Tsh), body surface (Tsb), and ambient (Ta) temperatures with insulation utilization and positions. To evaluate potential environmental stimuli, we tested behavioral effects (ie open-eye frequency) and recorded conspecific presence, day and night events, and interaction with flies and fish. We included 24 extant species representatives, with detailed assessments of American alligators (*Alligator mississippiensis*), *Crocodylus siamensis*, *C. intermedius*, *C. rhombifer*, and *C. halli*. Observations occurred during a range of Ta (3.89-32.22°C) with mean Tsh consistently higher than both Tsb and Ta across all crocodylians. Differences in Tsh and Ta were most pronounced with head in the sun. However, no significant differences in Tsh and Tsb were detected for *A. mississippiensis* and *C. siamensis*. Conversely, *C. halli*, *C. intermedius*, and *C. rhombifer* demonstrated statistically higher Tsh. Gaping with open eyes was more common, yet modeling suggested a relationship with closed eyes and temperature. Anecdotal observations indicated weather changes may elicit mouth gaping, and we report the second nocturnal mouth gaping observation (the first for three species). Overall, mixed results indicated unprovoked mouth gaping is a complex behavior, making it difficult to draw clear cause and effect relationships. Future research may benefit from a focus on natural history and quantitative behavioral studies.

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Avila-Cervantes, J., Arias, C., Venegas-Anaya, M., Vargas, M., Larsson, H.C.E. and McMillan, O. (2020). Effect of the Central American Isthmus on gene flow and divergence of the American crocodile (*Crocodylus acutus*). *Evolution* (<https://doi.org/10.1111/evo.14139>).

**Abstract:** The final formation of the Central American Isthmus (CAI) about 3.5 Ma altered global ocean circulation, connected North and South America terrestrial biotas and established the Caribbean Sea. The nature of this event creates a natural scenario to test vicariance, divergence, and speciation by allopatry. Studies have shown the effect of the CAI on marine and terrestrial species, but none have examined a large-bodied amphibious taxon. We used RAD sequencing on populations of the American crocodile (*Crocodylus acutus*), to study the genomic variation of *C. acutus* on both sides of the CAI, infer its demographic history and measure the effect of the opening of the Panama Canal. Our results showed three genomic clusters: 1) Caribbean and the Panama Canal, 2) Pacific coast, and 3) Coiba island. The estimated divergence times between the Caribbean and Pacific populations are about 20 ka, which is younger than the formation of the CAI, coinciding with the Last Glacial Maximum. We hypothesize the glacial/interglacial cycles facilitated gene flow between the Caribbean and Pacific crocodile populations after the formation of the CAI, masking any genomic divergence the CAI may have caused. There is no evidence of gene flow associated with the opening of the Panama Canal.

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Heid, B. and Márquez-Ramos, L. (2020). Wildlife Trade Policy and the Decline of Wildlife. Munich Society for the Promotion of Economic Research: Munich.

**Abstract:** The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is the international agreement that regulates international trade in wildlife to prevent its decline. Little is known about the effectiveness of its trade restrictions and bans. Combining the largest available panel database on wildlife population sizes of vertebrates with the history of species' inclusion into CITES, we find that populations increase by 20% after their species' inclusion into CITES. This effect is driven by populations in countries with thorough enforcement. Outright trade bans increase

wildlife, but restrictions that incentivize sustainable use have more immediate positive effects.

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Hu, K., King, J.L., Romick, C.A., Dufeu, D.L., Witmer, L.M., Stubbs, T.L., Rayfield, E.J. and Benton, M.J. (2020). Ontogenetic endocranial shape change in alligators and ostriches and implications for the development of the non-avian dinosaur endocranium. *The Anatomical Record* (<https://doi.org/10.1002/ar.24579>).

**Abstract:** Birds and crocodiles show radically different patterns of brain development, and it is of interest to compare these to determine the pattern of brain growth expected in dinosaurs. Here we provide atlases of 3D brain (endocast) reconstructions for *Alligator mississippiensis* (alligator) and *Struthio camelus* (ostrich) through ontogeny, prepared as digital restorations from CT scans of stained head and dry skull specimens. Our morphometric analysis confirms that ostrich brains do not change significantly in shape during postnatal growth, whereas alligator brains unfold from a cramped bird-like shape in the hatchling to an elongate, straight structure in the adult. We confirm that birds exhibit paedomorphic dinosaur endocranial traits such as retaining an enlarged and compact brain shape in the adult, whereas crocodiles show peramorphic traits where the brain elongates with growth as the skull elongates. These atlases of ontogenetic stages of modern bird and crocodylian endocrania provide a basis for comparison of non-avian dinosaur endocasts and consideration of the divergence of the ‘avian’ and ‘crocodylian’ modes of brain development and heterochronic change on phylogenies.

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Santana, F.L., Estrada, K., Ortiz, E. and Corzoa, G. (2020). Reptilian  $\beta$ -defensins: Expanding the repertoire of known crocodylian peptides. *Peptides* (<https://doi.org/10.1016/j.peptides.2020.170473>).

**Abstract:** One of the major families of host defense peptides (HDPs) in vertebrates are  $\beta$ -defensins. They constitute important components of innate immunity and have remained an interesting topic of research for more than two decades. While many  $\beta$ -defensin sequences in mammals and birds have been identified and their properties and functions characterized,  $\beta$ -defensin peptides from other groups of vertebrates, particularly reptiles, are still largely unexplored. In this review, we focus on reptilian  $\beta$ -defensins and summarize different aspects of their biology, such as their genomic organization, evolution, structure, and biological activities. Reptilian  $\beta$ -defensin genes exhibit similar genomic organization to birds and their number and gene structure are variable among different species. During the evolution of reptiles, several gene duplication and deletion events have occurred and the functional diversification of  $\beta$ -defensins has been mainly driven by positive selection. These peptides display broad antimicrobial activity *in vitro*, but a deeper understanding of their mechanisms of action *in vivo*, including their role as immunomodulators, is still lacking. Reptilian  $\beta$ -defensins constitute unique polypeptide sequences to expand our current understanding of innate immunity in these animals and elucidate core biological functions of this family of HDPs across amniotes.

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Pereira de Souza-Filho, J., Guilherme, E., Mann de Toledo, P., De Souza Carvalho, I., Negri, F.R., Aparecida da Rocha Maciente, A., Cidade, G.M., Da Silva Lacerda, M.B. and Gomes de Souza, L. (2020). On a new *Melanosuchus* species (Alligatoroidea: Caimaninae) from Solimões Formation (Eocene-Pliocene), Northern Brazil, and evolution of Caimaninae. *Zootaxa* 4894(4) (<https://doi.org/10.11646/zootaxa.4894.4.5>).

**Abstract:** The Solimões Formation (Eocene-Pliocene) is a well-known geological unit due to the great diversity of crocodylian species. Here we describe a new species of *Melanosuchus*, *M. latrubessei* sp. nov., from the Talismã locality, state of Amazonas, from the Upper Miocene of the Solimões Formation (Solimões Basin, Brazil). A new phylogenetic inference focused on Caimaninae

is provided and the different evolutionary scenarios involving this new species are discussed. In addition, quantitative morphology studies are carried out and comments regarding the paleoecology aspects of this new species are made. *M. latrubessei* represents a medium-sized generalist predator, being proportional to the medium-sized *M. niger*. This new species inhabited the drainages of the Solimões Formation and was ecologically related to other taxa of crocodylians during the proto-Amazon Miocene. The evolutionary advantages of *Melanosuchus* genus are discussed to better understand the biogeographical occurrence of *M. niger* in South America, a species which survives to this day in contrast to several other species that became extinct during the Miocene-Pliocene periods. The extinction of the Miocene-Pliocene crocodylian taxa of the Solimões Formation, including *Melanosuchus latrubessei*, seems to be directly related with the uplift of the northern portions of the Andes, which generated significantly changes in drainages and Amazon paleoenvironments.

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Bueno de Souza, R.B., Gomes Bonfim, V.M., Passos Rios, V. and Klein, W. (2020). Allometric relations of respiratory variables in Amniota: Effects of phylogeny, form, and function. *Comparative Biochemistry and Physiology Part A* (<https://doi.org/10.1016/j.cbpa.2020.110845>).

**Abstract:** Biological variables are frequently described by analyzing scaling relationships of the variable against body mass ( $M_B$ ). Respiratory variables are no exception and allometric relations for oxygen consumption, pulmonary ventilation, tidal volume, breathing frequency, and lung volume have been described in the literature. While the allometric relations of respiratory variables given for mammals and birds are very consistent among different studies, scaling relationships for non-avian reptiles have only been scarcely described and show considerable variation between studies. Since no comprehensive study of allometric relations of respiratory variables has been carried out comparing the different groups of non-avian reptiles, we analyzed morphological and physiological variables of the respiratory system of crocodylians, chelonians, lizards, snakes, birds, and mammals, regarding the allometric relations of each variable from a phylogenetic perspective as well as related to lung morphology. Our results indicated that few respiratory variables possess significant phylogenetic signals and that tidal volume, breathing frequency (except mammals), and air convection requirement were independent of phylogeny. Contrary to the literature, lung volume of amniotes scaled isometrically to  $M_B$ , with the exception of lizards ( $M_B^{0.78}$ ). Air convection requirement scaled isometrically in mammals and birds, but was more variable among non-avian reptiles, from a taxonomic perspective and in regard to different lung structures. In conclusion, respiratory variables among non-avian reptiles scaled more variably than previously expected, both according to phylogeny and to lung type, warranting future studies to explore structure-function relations of the reptilian respiratory system, especially regarding snakes and crocodylians, since these groups had very few data available for analysis.

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Zin Than, K., Zaw, Z. and Hughes, A.C. (2020). Integrating local perspectives into conservation could facilitate human-crocodile coexistence in the Ayeyarwady Delta, Myanmar. *Oryx* (doi:10.1017/S003060532000037X).

**Abstract:** Conservation will always fail when it does not address the drivers of biodiversity loss, which in many cases involves understanding human behaviours and the attitudes that underlie them. The Saltwater crocodile *Crocodylus porosus* is a keystone species in mangrove wetlands but also a dangerous predator that affects people’s safety and livelihoods. Although Saltwater crocodiles are protected under the Myanmar Biodiversity and Protected Area Law, the Government has not integrated local people’s attitudes into conservation and management. As a consequence, Saltwater crocodiles, although categorized as Least Concern on the IUCN Red List, are restricted to a single protected area, Meinmahlakyun

Wildlife Sanctuary, in Myanmar. To examine local attitudes towards the species, we investigated local knowledge about the environment, crocodiles, habitats and threats, awareness of human-crocodile conflict, and perceptions of the benefits and impacts of saltwater crocodile conservation through questionnaires in 244 households in 17 villages. We found that people were highly knowledgeable about the local environment, saltwater crocodiles, and their habitats. People with seasonal livelihoods that rely on natural resources from Meinmahlakyun had negative attitudes towards crocodile conservation. People were likely to have negative attitudes if they perceived there were no benefits from conserving the species. Law enforcement through restricting resource access does not enhance conservation success and builds resentment towards the conservation of the species. Local people suggested that, as a basis for management, understanding risks posed by crocodiles was the best approach to facilitate human-crocodile coexistence in the Aeyarwady delta region.

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Bucol, A.A., Manalo, R.I., Alcala, A. and Aspilla, P.S. (2020). Crocodilians and fisheries in the Philippines: Revisiting Fittkau's hypothesis. *Philippine Journal of Systematic Biology* 14(2) (doi: 10.26757/pjsb2020b14004).

**Abstract:** Crocodilians have been assumed to influence aquatic primary productivity and fishery yield. However, strong empirical evidence to support such claims is lacking. The long-standing assumption first hypothesized by Fittkau (1970), is that local fisheries (secondary productivity) in areas inhabited by crocodilians would be expected to improve. We tested this hypothesis at two locations in the Philippines, inhabited by the Philippine Crocodile (*Crocodylus mindorensis*) in Paghungawan Marsh in Siargao Island Protected Landscape & Seascape (SIPLAS), Jaboy, Pilar, Surigao Del Norte, and the Indo-Pacific Crocodile (*Crocodylus porosus*) in the Rio Tuba River, Bataraza, southern Palawan Island. Water chemistry parameters, with emphasis on nutrient (nitrate and phosphate) levels, were determined using standard protocols. Catch-per-Unit Effort (CPUE) of gillnets in sites with crocodiles was compared with corresponding control sites without crocodiles. CPUE was higher in areas inhabited by crocodiles, but appeared not to be directly influenced by nutrient levels. Increased fish catches in areas inhabited by crocodiles might be attributed to several factors, such as reduced fishing pressure due to the presence of crocodiles which discouraged the local fishermen to fish intensively. Overall, while fish catch was higher in areas inhabited by crocodiles, it is too early to attribute this to the nutrient output from crocodiles due to several confounding factors.

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Lu, Y. and Fang, S. (2020). Expression profile of  $\beta$ -defensin genes and the effect of stocking density on them in Chinese alligator blood. *Journal of Zhejiang University (Agriculture and Life Sciences)* 46(5): 604-610.

**Abstract:** In order to investigate the expression profile of  $\beta$ -defensin genes in the blood of Chinese alligator and the effect of stocking density on them, reverse transcription quantitative polymerase chain reaction (RT-qPCR) was used to detect the expression levels of  $\beta$ -defensin genes in blood samples from 41 7-year-old Chinese alligators and study the defensin gene expression level differences between sexes and populations with different stocking densities. The results showed that only the AsBD5 and AsBD8 genes expressed in the blood of Chinese alligator, and there was a significantly positive correlation between their expression levels. There was no significant sex-biased difference of the defensin gene expression levels. However, their expression levels were significantly different between the two populations with different stocking densities. The defensin gene expression levels were significantly higher in the Chinese alligator population with higher stocking density, which indicating that the stocking density has some effect on the immune status of the captive Chinese alligator.

Zhang, H.B., Li, Y.S., Pan, T., Yan, P., Li, E., Xue, H. and Wu, X.B. (2021). Immunohistochemical localization of leptin and Leptin-Receptor Proteins in different tissues of Chinese alligator, *Alligator sinensis*. *Pakistan Journal of Zoology* (doi: <https://dx.doi.org/10.17582/journal.pjz/20200627060600>).

**Abstract:** Leptin is a multifunctional hormone encoded of the ob gene, plays an important role in food intake and energy homeostasis. Recent studies indicated that the role of leptin is much broader, such as the regulation of reproduction and hibernation. But so far the limited study of leptin and its receptor has investigated in Chinese alligator, *Alligator sinensis*. Therefore, we reported the presence and location of leptin and its receptor in different tissues of Chinese alligator by immunohistochemistry analysis. This study aims to access the possible effect of leptin in Chinese alligator. The results showed that immunoreactivity of leptin was observed in the adipocyte of white adipose tissue, the gastric gland of the stomach, the lamina propria of the intestine and the interstitial cell and seminiferous tubule of testis, leptin receptor staining was detected in the adipocyte of white adipose tissue, the gastric gland and submucosa of the stomach, the submucosa, muscular layer and intestine villi of the intestine, the granulose cell and follicular membrane cell of the ovary and the interstitial cell and seminiferous tubule of the testis. Moreover, we investigated seasonal changes of leptin in plasma of Chinese alligator by radioimmunoassay method. Our results demonstrated circulating leptin levels varied significantly over the season. Therefore, we hypothesize that leptin is involved in nutrient stores, absorption and utilization, and reproductive behavior of the Chinese alligator

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Izaz, A., Pan, T., Wang, L., Zhang, H., Duan, S., Li, E., Yan, P. and Wu, X. (2020). Molecular cloning, characterization, and gene expression behavior of glucocorticoid and mineralocorticoid receptors from the Chinese alligator (*Alligator sinensis*). *JEZ-B* (<https://doi.org/10.1002/jez.b.23015>).

**Abstract:** The Chinese alligator is an endemic crocodilian species in China. We isolated and obtained the glucocorticoid and mineralocorticoid receptor genes coding from the kidney of *Alligator sinensis* by nested polymerase chain reaction (PCR) and rapid amplification of cDNA ends (RACE). The glucocorticoid receptor (GR) gene has 2343 base pairs encoding 780 amino acids, while the mineralocorticoid receptor (MR) gene is 2958 bp in length encoding 985 amino acids. Quantitative real-time PCR was used to detect the distribution of messenger RNA (mRNA) levels. The maximum mRNA expressions were observed in the ovary and kidney, suggesting that these receptors may be involved in basic cellular functions or stress response of alligators. Besides this, RT-qPCR was performed to analyze the abundance of GR and MR mRNA transcripts in early embryonic development of the Chinese alligator in the kidney, liver, and heart. The mRNA levels of GR and MR at earlier stages in kidney, liver, and heart indicates that they might involve in the transcriptional regulation of early embryos and activate many precise developmental effects in fetal tissues. We also measured the protein expression in the liver embryonic developmental stages and found that the GR and MR proteins were restricted to both the nuclei and cytoplasm. The protein expression levels in the liver at different embryonic developmental stages have extremely prominent differences. Taken together, our results showed the full coding regions of GR and MR, their characteristics, and embryonic developmental mRNA and protein expressions of both genes in *A. sinensis*. This study could provide the necessary information for further investigating the diverse functions of GR and MR in *A. sinensis*.

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Schachner, E.R., Hedrick, B.P., Richbourg, H.A., Hutchinson, J.R. and Farmer, C.G. (2020). Anatomy, ontogeny, and evolution of the archosaurian respiratory system: A case study on *Alligator mississippiensis* and *Struthio camelus*. *Journal of Anatomy* (doi: 10.1111/joa.13358).

**Abstract:** The avian lung is highly specialized and is both functionally and morphologically distinct from that of their closest extant relatives, the crocodylians. It is highly partitioned, with a unidirectionally ventilated and immobilized gas-exchanging lung, and functionally decoupled, compliant, poorly vascularized ventilatory air-sacs. To understand the evolutionary history of the archosaurian respiratory system, it is essential to determine which anatomical characteristics are shared between birds and crocodylians and the role these shared traits play in their respective respiratory biology. To begin to address this larger question, we examined the anatomy of the lung and bronchial tree of 10 American alligators (*Alligator mississippiensis*) and 11 ostriches (*Struthio camelus*) across an ontogenetic series using traditional and micro-computed tomography ( $\mu$ CT), three-dimensional (3D) digital models, and morphometry. Intraspecific variation and left to right asymmetry were present in certain aspects of the bronchial tree of both taxa but was particularly evident in the cardiac (medial) region of the lungs of alligators and the caudal aspect of the bronchial tree in both species. The cross-sectional area of the primary bronchus at the level of the major secondary airways and cross-sectional area of ostia scaled either isometrically or negatively allometrically in alligators and isometrically or positively allometrically in ostriches with respect to body mass. Of 15 lung metrics, five were significantly different between the alligator and ostrich, suggesting that these aspects of the lung are more interspecifically plastic in archosaurs. One metric, the distances between the carina and each of the major secondary airways, had minimal intraspecific or ontogenetic variation in both alligators and ostriches, and thus may be a conserved trait in both taxa. In contrast to previous descriptions, the 3D digital models and CT scan data demonstrate that the pulmonary diverticula pneumatize the axial skeleton of the ostrich directly from the gas-exchanging pulmonary tissues instead of the air sacs. Global and specific comparisons between the bronchial topography of the alligator and ostrich reveal multiple possible homologies, suggesting that certain structural aspects of the bronchial tree are likely conserved across Archosauria, and may have been present in the ancestral archosaurian lung.

Wu, Y.F, Zhang, R.K, Dong, H.L., Liu, J., Liu M. and Xiao, H.M. (2020). Nutrient quality and processing characteristics of the crocodile meat from different breeding environments and different parts. *Science and Technology of Food Industry* 41(3): 302-307.

**Abstract:** This study shows the differences of nutrient quality and processing characteristics in different breeding environments and parts of the crocodile. Crocodile meat was taken as sample to analyze its nutrient value and processing characteristics by comparing with different breeding environments (indoor crocodile, outdoor crocodile) and parts (leg, tail, torso). The results showed that the highest protein content in the tail of outdoor breeding crocodiles was 20.88% in terms of nutritional quality. In addition, the highest ash content in trunk was 0.12%. The legs of outdoor crocodiles contained 0.88% of the lowest fat and 76.09% ( $P < 0.05$ ) of the highest moisture content. A total of 17 kinds of amino acids were detected in different parts of meat in different farming environments. The total amino acid content in the legs was the highest ( $P < 0.05$ ), and the content of total amino acids in the trunk and legs of outdoor crocodiles was lower than that in indoor crocodiles. As for processing characteristics, the  $L^*$  of the tail of crocodiles was the highest, the cooking loss was the lowest, the holding water power was the highest, and the pH value was the lowest. The gel quality of outdoor crocodile was better than that of indoor crocodile in water holding capacity, textural properties and rheological properties. Breeding environment and parts had a significant effect on the nutritional quality and processing characteristics of crocodile meat. The tail meat of outdoor breeding crocodiles had higher nutritional quality and processing characteristics.

Soopramanien, M., Khan, N.A. and Siddiqui, R. (2020). Gut microbiota of animals living in polluted environments are a potential

resource of anticancer molecules. *Journal of Applied Microbiology* (doi: 10.1111/jam.14981).

**Abstract:** Cancer is a prominent cause of morbidity and mortality worldwide, in spite of advances in therapeutic interventions and supportive care. In 2018 alone, there were 18.1 million new cancer cases and 9.6 million deaths indicating the need for novel anticancer agents. Plant-based products have often been linked with protective effects against communicable and non-communicable diseases. Recently, we have shown that animals such as crocodiles thrive in polluted environments and are often exposed to carcinogenic agents, but still benefit from prolonged lifespan. The protective mechanisms shielding them from cancer could be attributed to the immune system, and/or it is possible that their gut microbiota produce anticancer molecules. In support, several lines of evidence suggest that gut microbiota plays a critical role in the physiology of its host. Here, we reviewed the available literature to assess whether the gut microbiota of animals thriving in polluted environment possess anticancer molecules.

Barrios-de Pedro, S., Osuna, O. and Buscalioni, A.D. (2020). Helminth eggs from early cretaceous faeces. *Scientific Reports* 10(1) (doi:10.1038/s41598-020-75757-4).

**Abstract:** The exceptional fossil site of Las Hoyas (upper Barremian, Cuenca, Spain) yields abundant small to medium vertebrate coprolites, hindering the search for parasites. We studied the contents of 29 coprolites that were previously classified into distinct morphotypes. Several parasitic eggs were retrieved from two of these coprolites, confirming the second record of digenea trematode eggs and nematode (ascaridid) eggs from an Early Cretaceous locality. The cylindrical coprolite containing anisakid eggs was likely produced by a crocodylomorph as the parasite host, whereas the bump-headed lace coprolite indicates the role of a fish as an intermediary or definitive host of the trematodes and ascaridids. These trace and body fossils show that the Las Hoyas 126-129 Ma lacustrine ecosystem documents the early connection between basal Gonorynchiformes fish and digenetic trematodes.

Campos, Z., Magnusson, W.E. and Muniz, F. (2020). *Paleosuchus palpebrosus* (Cuvier's Dwarf Caiman) and *Paleosuchus trigonatus* (Schneider's Dwarf Caiman). *Epizoic algae. Herpetological Review* 51(4): 842-843.

Sales Oliveira, V.C., Ferreira Viana, P., Gross, M.C., Feldberg, E., Da Silveira, R., de Bello Cioffi, M., Carlos Bertollo, L.A. and Schneider, C.H. (2020). Looking for genetic effects of polluted anthropized environments on *Caiman crocodilus crocodilus* (Reptilia, Crocodylia): A comparative genotoxic and chromosomal analysis. *Exotoxicology and Environmental Safety* (<https://doi.org/10.1016/j.ecoenv.2020.111835>).

**Abstract:** The Amazon aquatic ecosystems have been modified by the human population growth, going through changes in their water bodies and aquatic biota. The spectacled alligator (*Caiman crocodilus crocodilus*) has a wide distribution and adaptability to several environments, even those polluted ones. This study aimed to investigate if a Caiman species living in urban streams of Manaus city (Amazonas State, Brazil) is affected by environmental pollution. For that, it was used classical and molecular cytogenetic procedures, in addition to micronucleus and comet assays. Although the karyotype macrostructure remains unaltered ( $2n = 42$  chromosomes;  $24t + 18m/sm$ ;  $NF = 60$ ), the genotoxic analysis and the cytogenetic mapping of repetitive DNA sequences demonstrated that polluted environments alter the genome of the specimens, affecting both the chromosomal organization and the genetic material.

Chima, U.D., Aleru, N.A. and Ijeomah, H.M. (2020). Seasonal

variations in species composition, abundance and diversity of wildfauna sold at Omagwa Bushmeat Market in Rivers State, Nigeria. *Applied Tropical Agriculture* 25(1): 76-84.

**Abstract:** Effects of seasons on species composition, abundance and diversity of wildfauna brought for sale at Omagwa bushmeat market in Rivers State, Nigeria, was studied in 2018 for a period of 7 months covering the Late Dry Season (January to February), Early Rainy Season (March to May) and the Peak Rainy Season (June to July). Enumerations of species of wildfauna brought for sale in the market were carried out twice in a month during this study. A total of 1888 individuals belonging to 15 species were enumerated during the period. *Thryonomys swinderianus* (Cane Rat) was the most abundant species in all the seasons while *Herpestes ichneumon* (Egyptian mongoose) was the second most abundant species during the Early and Peak Rainy Seasons, and *Cricetomys emini* (Emin's giant rat) the second most abundant during the Late Dry Season. The least abundant species was *Python regius* (Royal python) followed by *Vulpes vulpes* (fox), and *Crocodylus niloticus* (crocodile) respectively. The average monthly abundance of wildfauna was 5.19 % and 35.39 % higher during the Peak Rainy Season than during the Early Rainy Season and the Late Dry Season, respectively. Average monthly species diversity was generally low with the Late Dry Season having the highest index (Shannon H= 1.94) followed by Early Rainy Season (Shannon H= 1.87) and the Peak Rainy Season (Shannon H= 1.86). Average monthly species richness was 12, 12.67, and 13 species for the Late Dry Season, the Early Rainy Season, and the Peak Rainy Season, respectively. Similarity in species composition was high between months across seasons and ranged from 70% (February/June) to 96% (March/July and April/July). The seasonal effect on wildfauna brought to the market for sale was more distinct on species abundance than on species composition and diversity.

Spennemann, D.H.R. (2020). Matthäus Merian's crocodile in the *Historiae naturalis de quadrupetibus* - Supplemental data. Script & Print Supplements, pp. 1-42.

**Abstract:** This document provides supplementary data to the following paper: Spennemann, D.H.R. (2019)[2020]. Matthäus Merian's crocodile in Japan. A biblio-forensic examination of the origins and longevity of an illustration of a *Crocodylus niloticus* in Jan Jonston's *Historiae naturalis de quadrupetibus*. *Script & Print* 43(4): 201-239.

Khalil, H.M. (2020). Interpretation of the scenes of Amun in the tombs of Gebel El-Mawta at Siwa. *Journal of the Faculty of Tourism and Hotels (Alexandria University)* 17(2): 195-202.

**Abstract:** Two scenes appeared in the tombs of Gebel El-Matwa (one in the tomb of Si-Amun and the other in the tomb of the crocodile) representing a ram-headed figure holding a knife in his hand. This figure was interpreted by all the scholars who dealt with Siwa tombs as god Amun. This could be related to the fact that god Amun was the main deity in the Oasis. However, it is unusual to see god Amun holding knife in his hand. As long as no inscription survived that could decipher the figure, the researcher aims at pointing out that this figure could be a demonic gatekeeper of the netherworld. Those gatekeepers facilitate the deceased's passage through the gates of the Netherworld to reach the goal of joining Osiris. They were mentioned in the Book of the Dead and used to be represented on the walls of tombs. They were depicted as animal-headed figures, either sitting or standing and holding weapons in their hands, especially knives.

Lucas, S.G., Rinehart, L.F., Chesebrough, B., Chesebrough, R. and Chesebrough, S. (2021). A Late Jurassic crocodile from New Mexico. *Fossil Record* 7. New Mexico Museum of Natural History and Science Bulletin 82: 245-247.

**Abstract:** New Mexico has a relatively sparse record of Jurassic fossil vertebrates because the Middle Jurassic stratigraphic units in the state consist of eolian and evaporitic facies and relatively little exploration has been undertaken of the more promising Upper Jurassic facies (Morrison Formation). Thus, the only Middle Jurassic vertebrates from New Mexico are "holostean" fish from the Callovian Luciano Mesa Member of the Todilto Formation, whereas the Morrison Formation vertebrate-fossil record is dominated by fragmentary remains of sauropod dinosaurs. We add to this sparse record the first Jurassic crocodile fossil from New Mexico. This fossil is from the Brushy Basin Member of the Morrison Formation at NMMNH (New Mexico Museum of Natural History) locality 12333 in the Ojito Wilderness Area of Sandoval County. One of us (Ben C.) discovered this fossil in 2018, and it consists of part of the postero-dorsal skull roof of a goniopholidid crocodile catalogued as NMMNH P-81149. This fossil includes much of the parietal, fragments of the squamosals and frontals, the medial margins of both supratemporal fenestrae and part of a natural endocast. We cannot distinguish this fossil from *Eutretauranosuchus* or *Amphicotylus*, but it is so incomplete that we only identify it as Goniopholididae. Scaled to a complete skull of *Eutretauranosuchus*, NMMNH P-81149 had a skull with a total length of 26 cm and a total body length of about 1.5 m, which is a characteristic body size of an adult Morrison goniopholidid. This discovery of a Morrison Formation crocodile in New Mexico comes more than one century after the first discovery of dinosaur bones in the New Mexico Morrison. The discovery of the crocodile fossil, as well as the relatively recent discovery (early 2000s) of a Morrison turtle fossil in New Mexico, provide incentive to search further for relatively small, non-dinosaurian vertebrate fossils in the New Mexican Morrison Formation.

Pradupong, A., Srimangkornkaew, P., Siruntawinetti, J., Chaeychomsri, S. and Chaeychomsri, W. (2020). Acute oral toxicity of mixed *Crocodylus siamensis* oil and *Kaempferia parviflora* Wall. Ex. Baker in Wistar rats. *Bulletin of the Department of Medical Sciences* 62(4): 297-330.

**Abstract:** *Crocodylus siamensis* oil and *Kaempferia parviflora* (black ginger) have traditionally been used as folk medicine to promote health. A new formulation, consisting of *C. siamensis* oil and black ginger extract, is developed as an alternative health product. Toxicological studies of this formulation have not been evaluated. This study was to determine acute oral toxicity of mixed *C. siamensis* oil and black ginger in Wistar rats. Our study was conducted in a stepwise procedure according to OECD Guidelines for the testing of chemicals 423, Acute Oral Toxicity-Acute Toxic Class Method (2001). After oral administration with 300 and 2000 mg/kg body weight of mixed *C. siamensis* oil and black ginger, all animals were not shown any signs of toxic effects, moribund and mortality. The results indicated that mixed *C. siamensis* oil and black ginger was grouped in Globally Harmonized System of Classification and Labelling of Chemical as category 5 or unclassified and the LD50 is at 5000-∞ mg/kg body weight. Our study suggested that the mixture of *C. siamensis* oil and black ginger is safe for oral administration and support its use as food supplements or other industrial applications.

Nguyen, T.T.H. and Nguyen, N.T. (2020). Effects of chrome-tanning process on structural process on structural characteristics and physico-mechanical properties of *Crocodylus porosus* leather. *Industrial University of Ho Chi Minh City Journal of Science and Technology* 43B: 25-33.

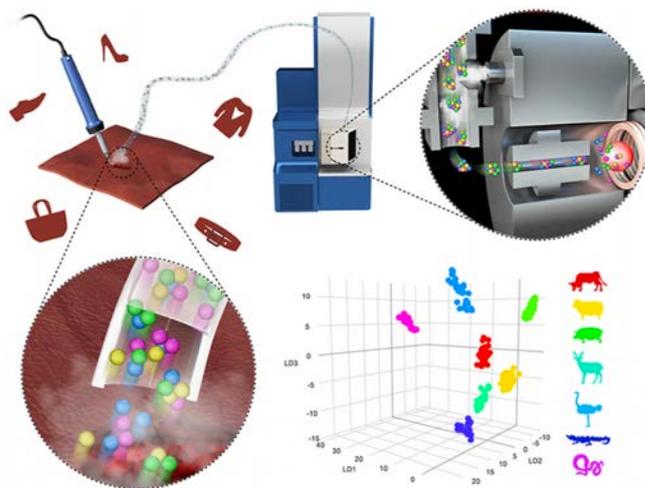
**Abstract:** Crocodile leather occupied about 80% of the crocodile's value, and has high economic value. Due to the different in the structure and texture of the crocodile leather, each fashion products made from it is highly unique. Because the crocodile leather could be easily damaged during the breeding, harvest and production process, the leather must be tanned to improve the durability and practicability of leather products and prevent putrefaction. This research will consider the change in color, surface patterns,

structures and physic-mechanical properties of the different leather parts. The leather part has been investigated before and after the tanning process with a chromium salt. In this research, 2-year-old *Crocodylus porosus* crocodile was studied.

Gao, H., Lin, J., Jia, X., Zhao, Y., Wang, S., Bai, H. and Ma, Q. (2020). Real-time authentication of animal species origin of leather products using rapid evaporative ionization mass spectrometry and chemometric analysis. *Talanta* (<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 complimentary 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.



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