# CROCODILE SPECIALIST GROUP NEWSLETTER

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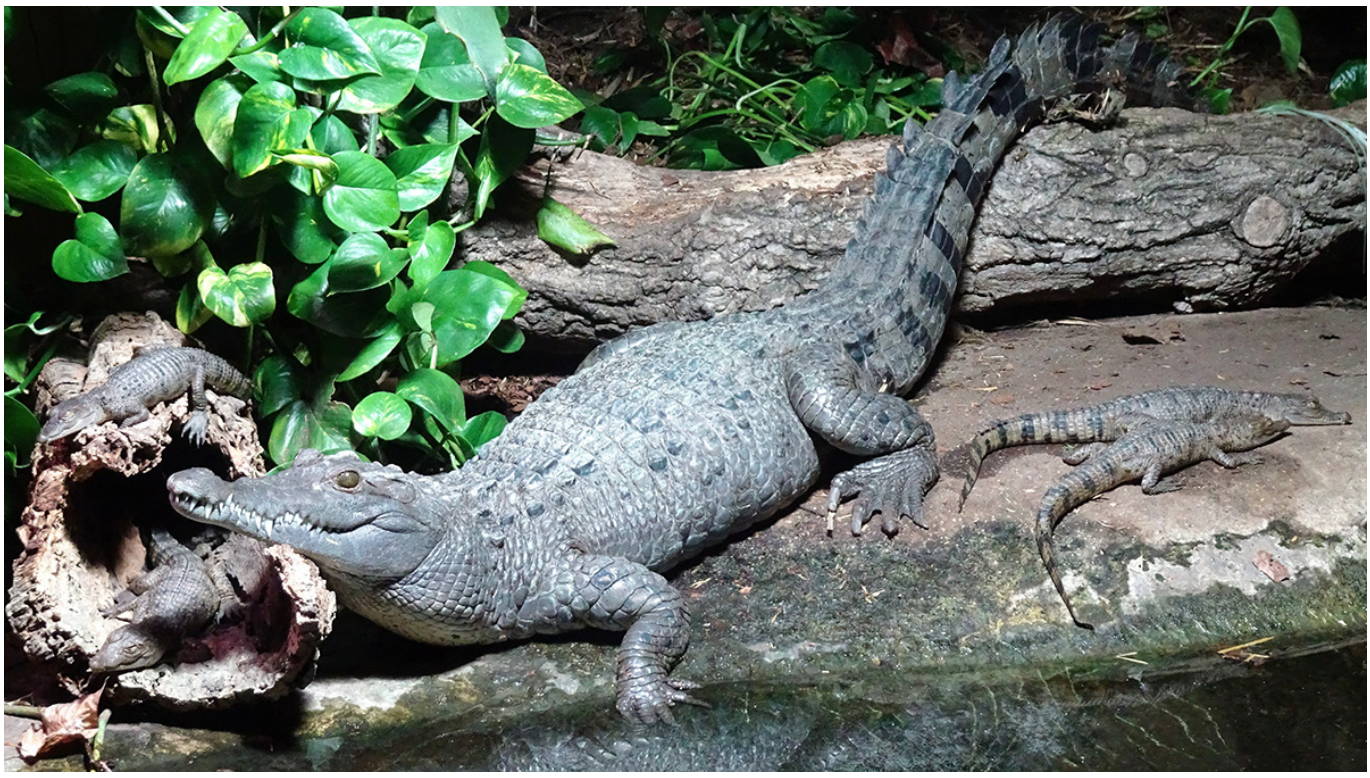

IUCN • Species Survival Commission

# CROCODILE

# SPECIALIST

# GROUP

# NEWSLETTER

VOLUME 40 Number 4
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IUCN - Species Survival Commission

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COVER PHOTOGRAPH: Adult Philippine crocodile (*Crocodylus mindorensis*), "Mindo", with her four 6-month-old hatchlings [Ligaya (luck), Mutya (jewel), Mayumi (gentle) and Tala (light star)], at Cologne Zoo, Germany, in December 2021. Photograph: Thomas Ziegler.

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## 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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## PATRONS

We thank all patrons who have donated to the CSG and its conservation program over many years, and especially to donors in 2020-2021 (listed below).

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# Editorial

It is with deep sorrow that I report that Uthai Youngprapakorn, a founding member of the CSG (1971), passed away on 5 October 2021, at 96 years of age. Uthai was a pioneer of crocodile farming, who established Samutprakan Crocodile Farm in 1950, which went on to become one of the largest crocodile farms and a popular tourist destination in the region (see page 4).

In December, the IUCN Species Survival Commission Chair Jon Paul Rodriguez awarded the CSG with the "SSC Chair's Citation of Excellence", for its outstanding contribution in delivering the 2017-2020 Species Strategic Plan (https://www.iucn.org/sites/dev/files/framework_iucn_species_strategic_plan_2021-2024.pdf) and the excellent work carried out by the group in 2020. According to the SSC Chair, these positive outcomes contributed to accomplishing the SSC vision of "*a just world that values and conserves nature through positive action to both prevent the loss and aid recovery of diversity of life on earth*".

To commemorate the significant milestone of the 50th anniversary of the first CSG Working Meeting (1971), a virtual presentation has been deferred to early February 2022. Details will be provided to the membership as soon a a final date has been finalised.

As indicated in the previous CSG Newsletter, the document on "Traceability in Crocodylian Conservation and Management" has been finalized, and is now available from the CSG website [http://www.iucncsg.org/content_images/attachments/Traceability%20(9.3MB).pdf].

The 19th meeting of the Conference of the Parties to CITES (CoP19) is scheduled to be held in Panama City, Panama, on 14-25 November 2022. Draft resolutions, draft decisions or other document submitted for consideration at CoP19 should be communicated to the CITES Secretariat at least 150 days before the meeting (ie by 17 June 2022). Amendment proposals pursuant to the Ranching Resolution [Resolution Conf. 11.16 (Rev. CoP15)] must have been submitted by 19 December 2021. Online registration is expected to be open to all participants in April 2022, with a deadline of 15 September 2022 (see www.cites.org/eng/cop19, www.cites.org/esp/cop19 or www.cites.org/fra/cop19).

The CSG Drone Working Group organised the 9th and 10th virtual workshops during the October-December quarter. On 1 December, Antonella Panebianco (INIBIOMA-CONICET) and Wade Sedgwick (Island Foundation) presented "Collaborative advances in the use of drones for conservation in Argentina", and on 15 December, Brinky Desai (PhD student, Ahmedabad University, Gujarat, India) presented "Development of an automated biometric system for individual identification of Mugger crocodile (*Crocodylus palustris*): A deep learning approach". [Youtube links are at https://youtu.be/ntcLJekGUF8 (9th workshop) and https://youtu.be/IopqWtKTZqk (10th workshop)]. Both workshops were well attended, and the Drone Working Group is commended for its ongoing work.

The "Zoo Species of the Year" campaign 2021, organised by the Zoological Society for the Conservation of Species and Populations (ZGAP), raised more than 150,000 euros within one year for the first time. These funds will go towards effective conservation actions for highly endangered crocodile species in Cuba, Philippines, Borneo and Nepal (see page 24).

Winter CrocFest 2021, held at Gatorland, Florida, on 11 December 2021, raised more than $US60,000 for conservation efforts on Orinoco crocodiles (*Crocodylus intermedius*) in Venezuela! This is the second-highest amount raised by a CrocFest fundraiser (see pages 10-11).

I can confirm that the 26th CSG Working Meeting will be held in Chetumal, Quintana Roo, Mexico, on 3-9 July 2022. Despite challenges that may still exist due to the COVID-19 pandemic, organisors have reiterated their commitment to a face-to-face meeting (see page 4 for details).

Professor Grahame Webb, *CSG Chair*.

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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 10 students in the October-December 2021 quarter, and two additional applications are under review.

1. Johannes le Roux (Namibia): The state of crocodiles on the Kunene River, Namibia: Population dynamics and socio-ecological interactions.

2. Rafael Barboza (Brazil): From reproductive ecology to local ecological knowledge of a crocodilian, the Broad-snouted caiman (*Caiman latirostris*).

3. Maryana de Souza (Brazil): Which environmental attributes does the Broad-snouted caiman (*Caiman latirostris*) select for nesting?

4. Sabina Shakya (Nepal): Human-Mugger crocodile conflict around the buffer zone of Chitwan National Park.

5. Srijana Timilsina (Nepal): Investigating winter habitat suitability of *Gavialis gangeticus* and human-crocodile conflict in Chitwan National Park, Nepal.

6. Andrew Park (USA): Population genetics and dispersal

modeling of crocodylians from Trinidad and Tobago.

7. Trinidad Cordero (Argentina): Identification and molecular characterization of the complement system of the Broad-snouted caiman (*Caiman latirostris*).

8. Yashendu Joshi (India): The crocodile conundrum of Charotar: Understanding crocodile behaviours and their socio-ecological connections with humans.

9. Jose Manon Gonzalez (Mexico): Ecological aspects of *Caiman crocodilus chiapasius* in Reserva de la Biosfera la Encrucijada, Chiapas, Mexico.

10. Alberto Castillo Contreras (Mexico): Determination of microplastics in stomach contents of four populations of Morelet's crocodile (*Crocodylus moreletii*) in the Yucatan Peninsula.

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

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## Obituary

Uthai Youngprapakorn (1925-2021)

Uthai Youngprapakorn, a founding member of the CSG, passed away on 5 October 2021, at 96 years of age. Uthai was a pioneer of crocodile farming, and established Samutprakan Crocodile Farm and Zoo in Bangkok, in 1950, which became one of the largest crocodile farms and a popular tourist destination in the region. Some of Uthai's children, and grandchildren, have followed in his footsteps, and were, and continue to be, involved in the crocodile industry.

Uthai participated in the first meeting of the Crocodile Specialist Group in 1971 [see Crocodile Specialist Group Newsletter 40(3): 4], at a time when the status of many species of crocodilian was very grim indeed. In 1994, Uthai and his family were involved in co-hosting the 12th CSG Working Meeting in Pattaya, Thailand. And in 2008, he participated in the CSG-Tomistoma Task Force Group workshop, that was also held in Thailand.

Figure 1. Uthai Youngprapakorn pictured with (seated, from left) John Breuggen, Kent Vliet, David Drysdale and (standing), son Uthen Youngprapakorn, in 2004.

## 26th CSG Working Meeting

The Government of Quintana Roo has reiterated its commitment to host the 26th CSG Working Meeting in Chetumal, Quintana Roo, Mexico, on 3-9 July 2022. It is anticipated that parts of the meeting will be "virtual" (eg via "Teams"), to allow the participation of people who are unable to travel and/or participate in person.

Organisors have advised that the meeting webpage (https://www.biodiversidad.gob.mx/planeta/csg2021/index.html) will be updated soon to reflect the latest information, including COVID-19 protocols and sanitary measures likely to be in place for the meeting.

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

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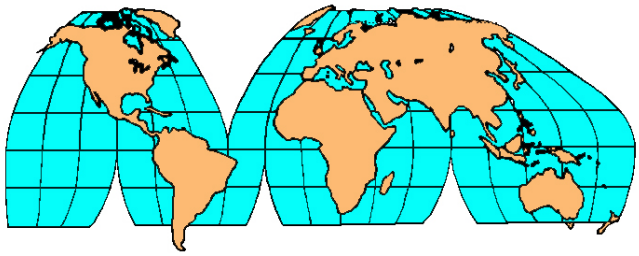
# Regional Reports



A BRIEF OVERVIEW OF CROCODILIAN ATTACKS WORLDWIDE FOR THE DECADE. Over the 10 years since we began collecting data for CrocBITE Worldwide Crocodilian Attack Database (www.crocodile-attack.info), the quantity and quality of crocodilian attack data have improved considerably. Extensive communication and cooperation with local authorities, as well as the contribution of data by authors of papers on regional human-crocodile conflict (HCC) (eg Cupul-Magana *et al*. 2010; Corvera *et al*. 2017; Balaguera-Reina *et al*. 2018; Van der Ploeg *et al*. 2019), have resulted in more comprehensive datasets from countries that were previously considered data deficient. Despite these improvements, there are still several countries where HCC is believed to be a major issue, yet data remain limited or nonexistent. In most of these countries we have no contacts from whom to collect attack data, so we rely solely on sporadic reports of attacks in the news media.

For the period 1 January 2011 to 31 December 2020, we recorded 3602 attacks on humans by crocodilians worldwide, resulting in 1716 deaths. These attacks occurred in 66 countries (see Tables 1-4) and involved 16 crocodilian species. Fatal attacks were recorded for 10 species, although only three species were responsible more than 100 deaths (Table 5).

Saltwater Crocodile (*Crocodylus porosus*)

Over half of reported *C. porosus* attacks came from Indonesia, and substantial numbers of attacks were reported from India, Malaysia, Solomon Islands and Timor-Leste. In

Indonesia, the highest numbers of attacks were reported from Bangka-Belitung, East Kalimantan, East Nusa Tenggara, and Riau Provinces. During the latter half of the decade, attacks increased significantly in Central Sulawesi, southeast Sulawesi (North and South Konawe regencies, as well as Buton Island) and Maluku (Taliabu Island and Tanimbar Islands). Outside of Indonesia there were notable increases in the Andaman Islands (India), Palawan (Philippines) and Sarawak (Malaysia). The number of attacks remained stable in Orissa (India) throughout the decade and decreased in Australia, following a peak in 2014.

Attacks likely went unreported in a number of areas throughout the range of *C. porosus*, likely to a substantial degree in areas where HCC is known to be an issue and no records of attacks are maintained (eg Papua New Guinea and the Indonesian Provinces of Papua and West Papua). From the limited amount of data that are available, most attacks in Papua New Guinea are reported from the Kikori, Purari and Turama River regions of Gulf Province, Bougainville and Manus Island. A report of a fatal attack and sightings from Sudest Island (11°30'07.3" S, 153°27'54.5" E) at the eastern edge of the Louisiade Archipelago confirms the presence of the species there. Furthermore, HCC surveys conducted in Tawi-Tawi Province of the Philippines by Crocodylus Porosus Philippines Incorporated (CPPI), and in the Solomon Islands (Van der Ploeg *et al*. 2019), revealed many previously unreported incidents.

Two non-fatal attacks were reported from Lombok Island (West Nusa Tenggara, Indonesia) in 2017 and 2019, where the species was believed to be extinct as recently as 2008 (Klock 2008). No attacks were reported from the Javan mainland during the decade, although a single fatal attack was reported from the Kangean Islands of East Java in 2011 and others are claimed to have occurred. Reports of crocodile sightings and captures around Java increased dramatically during this period. While some of these may have involved animals that escaped from captivity, in many areas it appears likely that these were wandering itinerants or representative of small resident populations. Sightings of crocodiles also increased in Peninsular Malaysia, where the species is believed to be rare (Webb *et al*. 2010), and four non-fatal attacks were reported from the eastern coast in the states of Johor, Kelantan and Pahang.

Nile Crocodile (*Crocodylus niloticus*)

The highest numbers of *C. niloticus* attacks were reported from Zambia and Zimbabwe, although it is possible that other countries within the range of the species experienced more attacks. Based on the limited information available, it is likely that dozens of people are killed annually in Mozambique and Uganda. In some countries (eg Ethiopia, Somalia, Sudan) only a very small amount of data exists, and in countries where a large number of attacks have been recorded (eg Angola, Kenya, Tanzania) it is likely that many attacks go unreported. The high fatality rate associated with *C. niloticus* could be due to a bias in which fatal attacks are more frequently reported than non-fatal attacks (Pooley 2015).

Despite this data deficiency, the available information has allowed us to identify many attack hotspots. Attacks were frequently reported from many of the Rift Valley lakes. Lake Victoria experienced high attack frequency in all countries along its shores. Reports of attacks were numerous from Lake Tanganyika and the adjacent rivers in the Democratic Republic of the Congo and Tanzania, yet reports were infrequent from the Zambian portion and nonexistent from Burundi. There were also numerous reports from Lake Malawi and the Shire River in Malawi, yet no reports from the Mozambican portion of the lake. Similar situations were found in Lake Albert, Lake Edward and Lake George, where there were frequent reports from the Ugandan portions of the lakes, but no reports from those in the Democratic Republic of the Congo. Attacks were also commonplace along much of the length of the Zambezi River, including Lake Kariba bordering Zambia and Zimbabwe. Other problem areas identified include Lake Bangweulu in Zambia, the Okavango River (mostly along the Angolan and Namibian portions of the river), and the Tana River in Kenya.

Mugger Crocodile (*Crocodylus palustris*)

Within the Indian subcontinent, *C. palustris* was responsible for the highest number of reported attacks. Most of these attacks were reported from India, followed by Sri Lanka and Nepal. Low numbers of attacks were also reported from Iran and Pakistan. It is likely that some attacks went unreported in every country within the range of the species. In Sri Lanka, many attacks were reported from Eastern Province, particularly from around Batticaloa Lagoon. Both *C. palustris* and *C. porosus* are present in this area and thus far we have been unable to determine which species were responsible for most of these incidents.

Attacks were reported in 15 Indian states, with Uttar Pradesh having the highest number of attacks, followed by Gujarat. Together, these two states accounted for nearly half of all *C. palustris* attacks reported in India. In Uttar Pradesh, known hotspots included the waterways in Bahraich District (particularly around Katarniaghat Wildlife Sanctuary) and in Pilibhit District (Khakra River). In Gujarat, attacks were frequently reported from around Vadodara, as well as from the Narmada River. Other hotspots were the Bagaha municipality in Bihar, the Ghataprabha River in Karnataka, the Kollidam River near Chidambaram in Tamil Nadu, the Krishna River in Maharashtra, and the Parwan River in Rajasthan. Attacks were frequently reported along the Chambal River in Madhya Pradesh, Rajasthan and Uttar Pradesh. In Nepal, most attacks were reported from the Rapti River, in and around Chitwan National Park.

American Crocodile *(Crocodylus acutus)*

The highest numbers of *C. acutus* attacks were reported from Mexico, mostly along the Pacific Coast, followed by Costa Rica, Panama and Colombia. The Mexican states with the highest numbers of reported attacks were Jalisco, Michoacan

and Oaxaca. Although only non-fatal 8 attacks were confirmed to have involved *C. acutus* in the Caribbean state of Quintana Roo, a further 13 attacks (including one death) were reported. These attacks could have involved either *C. acutus* or *C. moreletii* (or hybrids of the two species). Most of these attacks occurred around Cancun, where both species are present, and hybridization is known to occur (Cedeno-Vazquez *et al*. 2008). There was a noticeable increase in attacks reported from along the southern coast of Jamaica, including the first fatal attack reported in the country since 1999. Only a single incident, resulting in non-fatal injuries to two victims, was reported from southern Florida. This was the first confirmed attack on a human by *C. acutus* in the USA.

Several attack hotspots were identified, most of them in Mexico. In Jalisco, many attacks were reported from Puerto Vallarta, particularly from around the lower Ameca River, Boca Negra Estuary and the Marina Vallarta Golf Course. Crocodiles are known to have been fed by people in this area. Along the coast of Oaxaca, attacks were frequently reported from Pinotepa Nacional, Santa Maria Colotepec and Santa Maria Tonameca Municipalities. In Michoacan, most attacks were reported from near the city of Lazaro Cardenas, especially in Santa Ana Estuary.

All attacks reported from El Salvador occurred within the San Francisco Menendez Municipality near the border with Guatemala. Although no *C. acutus* attacks were reported from Guatemala, attacks by *C. moreletii* have occurred. The HCC situation in Honduras and Nicaragua remains unclear, and it is possible that attacks on humans are rare. Two attacks, including one fatality, were reported from Honduras. The fatal attack occurred in the remote Brus Laguna Municipality of Gracias a Dios. The single attack reported from Cuba involved an American biologist, and the incident does not appear to have been reported in the local news media. While it is unlikely that crocodile attacks are a major concern in the country, if attacks occurred, they likely went unreported.

Black Caiman (*Melanosuchus niger*)

In South America, most attacks are attributed to *M. niger*, which has the highest fatality rate of all New World crocodilians. It is possible that this is due to the underreporting of non-fatal attacks throughout its range. Most attacks occurred in Brazil, and mostly within Amazonas State. Attacks were also reported from Colombia, Ecuador, French Guiana, Guyana and Peru. The only fatal attack reported from outside of Brazil occurred in the Apaporis River of Colombia. In addition, a fatal attack on a child that could have involved either *M. niger* or *Caiman yacare* was reported from Bolivia. It is likely that some attacks go unreported throughout the *M. niger* range, especially in remote portions of the Amazon and in Guyana.

Morelet's Crocodile (*Crocodylus moreletii*)

Morelet's crocodile (*C. moreletii*) was responsible for attacks, including deaths, in Belize, Guatemala and Mexico. As with *C. acutus*, most attacks were reported from Mexico. The state of Tamaulipas was the site of the highest number of attacks, mostly from around Tampico in the southern portion of the state, which appears to be the range-wide "hotspot" for attack and bite incidents involving *C. moreletii*. Several incidents were also reported from around Vicente Guerrero Dam in central Tamaulipas and from the Tampaon River region in San Luis Potosi. In Belize, two fatal attacks were reported from Ladyville and Maypen, both in Belize district. In Guatemala, 9 attacks were reported, of which one was fatal. All of these incidents occurred within Peten Department.

Tomistoma (*Tomistoma schlegelii*)

Tomistoma (*Tomistoma schlegelii*) was considered the most likely culprit in 30 attacks, including 10 deaths. All of these reports came from Indonesia, where >95% of reported attacks involved *C. porosus*. The highest numbers of attacks were reported from the upper Batanghari River in Jambi and West Sumatra Provinces in Sumatra. These attacks occurred along the main river channel and tributaries (Alai River, Jujuhan River) in the Bungo, Dharmasraya, and Tebo regencies. Tomistoma was deemed the most likely culprit by local authorities as it is the only species confirmed to be present in the area and an exceptionally large individual believed to have been responsible for the attacks was killed. In addition, all photographs in the media of crocodilians sighted or captured in these regencies have shown *T. schlegelii*. Despite this, we cannot discount the possibility that *C. porosus* entered the area undetected. Although *T. schlegelii* is a shy and reclusive species, it can become accustomed to human presence (Rachmawan and Bend 2009). Videos and photographs of *T. schlegelii* displaying little fear of humans have been taken in Central Kalimantan and Jambi. The cause for this loss of fear and bold behavior is unclear, although some articles in the news media have claimed that habitat destruction and pollution may play a role.

Other Species

Seven fatal incidents were attributed to the American alligator (*Alligator mississippiensis*), all of them occurring during the latter half of the decade and prior to 2015 no fatal attacks had been reported since 2007. The Spectacled caiman (*Caiman crocodilus*) had the highest number of attacks reported of the smaller caiman species, including one fatal attack (involving an infant) and a handful of seemingly unprovoked incidents. Most of these incidents occurred in Colombia, with small numbers reported from Costa Rica and Mexico (Chiapas).

Two non-fatal attacks were attributed to the Siamese crocodile (*C. siamensis*) and one non-fatal incident to the Orinoco crocodile (*C. intermedius*). All three incidents appear to have been unintentionally provoked. No attacks involving the New Guinea freshwater crocodile (*C. novaeguineae*) or Halls crocodile (*C. halli*) or Cuban crocodile (*C. rhombifer*) were reported, although it is possible that attacks by these species may have occurred.

The West African crocodile (*C. suchus*) was the most likely culprit in 13 attacks (9 fatal). These incidents occurred in Burkina Faso, Ghana, Guinea, Guinea-Bissau, Mali and

Sierra Leone. In addition, a further 11 attacks (9 fatal) were reported from the Central African Republic, but it is unclear whether these incidents involved *C. suchus* or *C. niloticus*, as the distribution of both species within the country is unclear.

Table 1. Crocodilian attacks reported in Australia and Oceania, 2011-2021.

| Country | Fatal | Non-fatal | Total |
|---|---|---|---|
| Australia | 15 | 45 | 60 |
| Palau | - | 1 | 1 |
| Papua New Guinea | 43 | 23 | 66 |
| Solomon Islands | 47 | 83 | 130 |
| Totals | 105 | 152 | 257 |

Table 2. Crocodilian attacks reported in Africa, 2011-2021.

| Country | Fatal | Non-fatal | Total |
|---|---|---|---|
| Angola | 40 | 18 | 58 |
| Botswana | 10 | 9 | 19 |
| Burkina Faso | 3 | - | 3 |
| Central African Republic | 10 | 2 | 12 |
| Democratic Rep. Congo | 38 | 21 | 59 |
| Ethiopia | 5 | 5 | 10 |
| Ghana | 1 | 3 | 4 |
| Guinea | 1 | 3 | 4 |
| Guinea-Bissau | 2 | - | 2 |
| Kenya | 68 | 31 | 99 |
| Madagascar | 22 | 16 | 38 |
| Malawi | 76 | 21 | 97 |
| Mali | 1 | - | 1 |
| Mozambique | 59 | 24 | 83 |
| Namibia | 42 | 6 | 48 |
| Republic of Congo | - | 1 | 1 |
| Rwanda | 9 | 3 | 12 |
| Sierra Leone | 1 | - | 1 |
| Somalia | 3 | 1 | 4 |
| South Africa | 13 | 19 | 32 |
| South Sudan | 2 | - | 2 |
| Sudan | 5 | 1 | 6 |
| Swaziland | 3 | 8 | 11 |
| Tanzania | 56 | 16 | 72 |
| Uganda | 78 | 11 | 89 |
| Zambia | 100 | 56 | 156 |
| Zimbabwe | 87 | 50 | 137 |
| Totals | 735 | 325 | 1060 |

Table 3. Crocodilian attacks reported in the Americas, 2011-2021.

| Country | Fatal | Non-fatal | Total |
|---|---|---|---|
| Argentina | - | 3 | 3 |
| Belize | 2 | 13 | 15 |
| Bolivia | 1 | 5 | 6 |
| Brazil | 15 | 56 | 71 |
| Colombia | 3 | 24 | 27 |
| Costa Rica | 3 | 25 | 28 |
| Cuba | - | 1 | 1 |
| Ecuador | - | 3 | 3 |
| El Salvador | - | 3 | 3 |
| French Guiana | - | 2 | 2 |
| Guatemala | 1 | 8 | 9 |
| Guyana | 1 | 3 | 4 |
| Honduras | 1 | 1 | 2 |
| Jamaica | 1 | 8 | 9 |
| Mexico | 24 | 169 | 193 |
| Nicaragua | - | 2 | 2 |
| Panama | 2 | 8 | 10 |
| Paraguay | - | 1 | 1 |
| Peru | - | 6 | 6 |
| Suriname | - | 1 | 1 |
| USA | 7 | 124 | 131 |
| Venezuela | - | 2 | 2 |
| Total | 61 | 468 | 529 |

Table 4. Crocodilian attacks reported in Asia, 2011-2021.

| Country | Fatal | Non-fatal | Total |
|---|---|---|---|
| Bangladesh | 5 | 2 | 7 |
| Brunei | 4 | 3 | 7 |
| India | 216 | 318 | 534 |
| Indonesia | 350 | 428 | 778 |
| Iran | 1 | 6 | 7 |
| Malaysia | 99 | 67 | 166 |
| Myanmar | 11 | 7 | 18 |
| Nepal | 7 | 16 | 23 |
| Pakistan | 2 | 0 | 2 |
| Philippines | 14 | 38 | 52 |
| Sri Lanka | 56 | 31 | 87 |
| Thailand | 0 | 1 | 1 |
| Timor-Leste | 50 | 24 | 74 |
| Totals | 815 | 941 | 1756 |

Table 5. Crocodilian attacks by species, 2011-2021.

| Species | Fatal | Non-fatal | Total |
|---|---|---|---|
| *Crocodylus porosus* | 700 | 744 | 1444 |
| *Crocodylus niloticus* | 716 | 317 | 1033 |
| *Crocodylus palustris* | 195 | 302 | 497 |
| *Crocodylus acutus* | 23 | 154 | 177 |
| *Alligator mississippiensis* | 7 | 122 | 129 |
| *Crocodylus moreletii* | 11 | 76 | 87 |
| *Melanosuchus niger* | 17 | 50 | 67 |
| *Caiman crocodilus* | 1 | 30 | 31 |
| *Tomistoma schlegelii* | 10 | 20 | 30 |
| *Crocodylus johnstoni* | - | 16 | 16 |
| *Crocodylus suchus* | 9 | 6 | 15 |
| *Caiman yacare* | - | 11 | 11 |
| *Caiman latirostris* | - | 5 | 5 |
| *Crocodylus siamensis* | - | 2 | 2 |
| *Crocodylus intermedius* | - | 1 | 1 |
| *Paleosuchus palpebrosus* | - | 1 | 1 |
| Undetermined species | 27 | 29 | 56 |
| Total | 1716 | 1886 | 3602 |

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# North America

## USA

POSSIBLE HURRICANE MORTALITY OF *ALLIGATOR MISSISSIPPIENSIS*. The state of Louisiana was severely impacted by Hurricane Laura (a strong Category 4 storm), which made landfall on 27 August 2020 near Cameron, Louisiana. Sustained winds of up to 240 km/h (150 mph) and a massive storm surge of ~5 m (15 ft) inundated the coastal area of southwest Louisiana, and the intense winds caused massive damage well into central and north Louisiana. Hurricane Laura was one of the strongest storms on record to hit the USA, with some reports saying it was the worst hurricane in 150 years. The Louisiana Department of Wildlife and Fisheries' Rockefeller Wildlife Refuge (RWR) is about 40 km (25 miles) east of where Laura made landfall. Details on this hurricane were reported previously (Elsey 2020). Incredibly, about 6 weeks later, Hurricane Delta (Category 2) made landfall near Creole, Louisiana - just a few kilometres from where Hurricane Laura hit, and even closer to RWR.

Other major hurricanes have had adverse impacts on alligators and the region, including Hurricanes Audrey (Ensminger and Nichols 1957), Rita (Elsey *et al*. 2006; Lance *et al*. 2010) and Ike (Elsey and Aldrich 2009). Adverse effects to the habitat, high salinities, and wetlands losses may be long-lasting and with some potential permanent loss of habitat.

On 21 November 2020, a local citizen in Grand Chenier was doing some cleanup work around his residence, approximately 4 km east of the RWR headquarters, and noticed an alligator carcass suspended in an oak (*Quercus* sp.) tree (Fig. 1). We estimate the carcass to be approximately 2.0-2.5 m total length and located about 3-4 m off the ground, resting over a tree limb. This was the first time since the hurricanes that the observer noticed the alligator, however due to mandatory evacuation orders and curfews, as well as challenging logistics, site visits were opportunistic and infrequent. Follow up photographs were taken on 26 December 2020, at which

Figure 1. Alligator carcass resting in tree on 21 November 2020, cause of death likely hurricane related. Photograph: Joe Landry.

Figure 2. Same alligator carcass still suspended in tree, 26 December 2020. Photograph: Vida Landry.

point the carcass was still suspended in the tree (Fig. 2) but was starting to disarticulate, and the skull had fallen away; nuchal scutes were still present and attached to the carcass.

The cause of death to this alligator is unknown, but was almost certainly related to one of the hurricanes. The alligator may have suffered trauma if storm surge rushing waters threw it up against a tree or some other immobile obstacle, or it could have become wedged elsewhere and drowned, and came to rest across the tree limb as floodwaters receded. It also could have died from osmotic stress (Lance *et al*. 2010) or dehydration due to no access to fresh water after the hurricane(s).

It is too early to assess full impacts to alligators, but we anticipate this resilient species will recover quickly, as we saw after Hurricane Rita (Lance *et al*. 2010). Indeed, in the summer of 2021 our Louisiana coastal nest count survey estimated some 64,345 alligator nests were present, which was an increase from the 60,794 nests in 2020, and the second highest nest estimate since surveys began in 1970.

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WINTER CROCFEST 2021. "Winter CrocFest 2021" took place on 11 December 2021, at Gatorland in Orlando, Florida, USA, attracting 615 attendees and raising over $US60,000. These funds will support the release and satellite tracking of a group of head-started Orinoco crocodiles (*Crocodylus intermedius*), bred and hatched at Zoo Miami and Gladys Porter Zoo in the USA, and collected from wild stock in Venezuela.

Orinoco crocodiles were brought to near-extinction in the mid-1900s by unsustainable hunting for skins. Though large-scale hunting has been prohibited, their populations have never fully recovered. Conservation efforts to date include the establishment of a national park (Parque Nacional Santos Luzardo) and headstart/release programs for young crocodiles produced from wild eggs. Since late 2016, socio-economic crises in Venezuela have brought most conservation efforts to a standstill. Funds raised through CrocFest will provide much-needed resources to re-enable the headstart program based at Hato Masaguaral as well as track the program's long-term viability.

Figure 1. Project PI Alvaro Velasco samples Florida alligator meat.

Dallas World Aquarium is serving as the US advisor on this project, and will facilitate the export of the US-

Figure 2. Part of the Winter Crocfest 2021 crew. Standing, from left: Casey Grey (Gatorland), Chrissie Thompson (Gatorland), Scott Valenti (Gatorland), Curt Harbsmeier (CrocFest), Skylar Hairston (Gladys Porter Zoo), Ashley Lawrence (Zoo Miami), Colette Adams (CrocFest/Gladys Porter Zoo), Michael Malden (Zoo Miami), Ryan Martinez (Zoo Miami), Savi Serrott (Zoo Miami); Kneeling, from left: Oscar Hildago (Gatorland), Savannah Boan (Gatorland), Alvaro Velasco (Fauna Silvestre), Luis Sigler (Dallas World Aquarium).

Figure 3. Gator Jumparoo Competition.

produced animals. Alvaro Velasco Barbieri (Fig. 1), Chair of the Venezuelan Crocodile Specialist Group, will serve as Principal Investigator (PI) in Venezuela.

Program goals include:

1. Determining the mobilization, habitat use, home range and adaptability of two groups of headstarted/released *C. intermedius*;
2. Engaging the husbandry, logistical and financial support of 11 US zoological institutions in the conservation of *C. intermedius*; and,
3. Improving facilities for ongoing incubation/headstart/soft release/release of *C. intermedius* at Hato Masaguaral in central Venezuela.

CrocFest fundraisers are family-friendly events geared to increase awareness of and raise funds for international crocodilian conservation. Event-goers were granted complete access to Gatorland and were treated to a number of croc-centric activities, including feedings, training sessions and Gatorland's signature show, called "Jumparoo" (Fig. 3), pitting croc-handlers and social media personalities against each other in a fun competition!

After an all-you-can eat Sonny's BBQ meal, the evening wound up with a spirited live auction conducted by Joe Wasilewski and Phil Goss (President of USARK). Over 20 CSG members were in attendance!

CrocFest continues to be run entirely by volunteers (Fig. 2). Thanks to the generosity and commitment of the private sector, zoos, and corporate sponsors all working together, as of December 2021, CrocFest fundraisers have generated nearly $US700,000 for crocodilians in peril! All proceeds go directly to crocodilian projects, with event expenses covered by event organizers and sponsors.

Colette Adams, Curt Harbsmeier and Flavio Morrissiey, *Winter CrocFest 2021*.

INTERSEXUALITY IN A CHINESE ALLIGATOR (*ALLIGATOR SINENSIS*). Intersexuality, a condition in which individuals exhibit abnormal differentiation of the reproductive organs, has been reported in most major groups of reptiles, including lizards (Brown 2008; Mendyk 2018; Holmes *et al*. 2005), snakes (Maclean 1968; Hardy 1970; Sharp *et al*. 2013; Regnet *et al*. 2018), chelonians (Risley 1941; Hansen 1943; Limpus *et al*. 2009) and crocodilians (Forbes 1940; Webb and Smith 1984; Langer *et al*. 2014). The condition is presumed to be rare in reptiles, although it is likely that most cases go undetected due to the internalized reproductive anatomy of the group and the inability to observe such aberrations externally. In crocodilians, cases of intersexuality confirmed via gonadal histology have been documented in several species including the American alligator (*Alligator mississippiensis*) (Forbes 1940; Moore *et al*. 2010), Australian Freshwater crocodile (*Crocodylus johnstoni*) (Webb and Smith 1984) and African Dwarf crocodile (*Osteolaemus tetraspis*) (Langer *et al*. 2014). Here, we report a case of intersexuality in an additional species, the Chinese alligator (*A. sinensis*).

A 14-year-old captive-bred *A. sinensis,* originally hatched at the Bronx Zoo in 1986 (Gerety and Foster 1987), was acquired by Audubon Zoo in November 2000 for exhibition and breeding as recommended by the Association of Zoos and Aquarium's Species Survival Plan (SSP) for the species. This individual (AZ#100049) had been identified as a male by its previous institution, and attempts were made over several years to house it with a large adult female (AZ#R811) in Audubon Zoo's collection. From their first introduction in 2001 to the last time they were paired in 2005, aggression was observed in each animal, requiring frequent separation; in some cases, both individuals were observed attacking one another through a bamboo fence that separated their exhibits. Potential courtship behavior initiated by #100049 was observed once in 2003, but #R811 did not appear to be receptive and no subsequent courtship, copulation or oviposition ensued. In 2005, #100049 escaped from its enclosure into an adjacent enclosure housing a smaller female

(AZ#178), and immediately began to fight with it. No further pairings or introductions were attempted.

On 15 August 2010, at 24 years of age, the specimen was found deceased in its exhibit, with no signs of prior illness or injury. Its last recorded body weight, taken a few years earlier in 2006, was 12.5 kg. Upon necropsy, a 4-cm long penis was present within the cloaca and it was revealed that the individual had both male and female reproductive structures, with several large solid and cystic tumors attached to the ovaries, mesovarium and oviducts, that were likely attributed to the animal's death. Histopathological analysis confirmed the identities of these tissues and the intersexuality of the individual.

Without detailed information on the incubation and development of this individual, it is unclear what mechanisms may have been responsible for its intersexuality, although incubation temperature is likely to have played a contributing role since crocodilians exhibit temperature-dependent sex determination (TSD) (Lang and Andrews 1994). For an intersex *O. tetraspis*, Langer *et al*. (2014) suspected that its incubation environment during the critical thermal period of sexual differentiation must have been at the pivotal temperature that produces males and females. *Alligator sinensis* exhibits a female-male pattern of TSD, with all females produced at an incubation temperature of 29°C and all males at 34°C (Fang *et al*. 2015; Lin *et al*. 2018). Although it is not entirely clear from the published report describing the hatching of the species at the Bronx Zoo which would have included this individual (Gerety and Foster 1987), eggs appear to have been incubated at 32-34°C, which would place them more towards the male-production side of the temperature threshold for the species. With five siblings still living in zoological parks [Zoological Information Management System (ZIMS) 2021), it would be of much interest to determine whether additional individuals from the same clutch incubated at presumably the same temperature exhibit the same condition.

In addition to the intersexuality of this *A. sinensis*, a further noteworthy finding from the necropsy was the tumors present in this specimen, since documented cases of neoplasia are generally rare in crocodilians (Hill *et al*. 2016; Ahmad *et al*. 2017; Aymen *et al*. 2020). Based on histopathology results, the animal's malignancies appeared to be related to a spontaneous infectious event, with viral oncogenesis posited as a potential aetiology. Beyond establishing a cause for death, the post-mortem discovery of intersexuality in this *A. sinensis* and other reptiles in zoological parks (eg Langer *et al*. 2014; Mendyk 2018) highlights the importance of necropsy and histopathological analysis for identifying rare, internal anatomical and developmental abnormalities that would otherwise go undetected. Such procedures can also help facilitate and inform further research needed to determine just how common intersexuality is within crocodilians as well as the specific mechanisms behind its manifestation.

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# East and Southeast Asia

## Vietnam

A REVIEW OF THE HISTORIC DISTRIBUTION OF THE SALTWATER CROCODILE (*CROCODYLUS POROSUS*) IN VIETNAM. The Saltwater crocodile (*Crocodylus porosus*) is the widest ranging of all crocodilians (Sideleau *et al*. 2021), but this range was even wider in historical times. During antiquity the species' range extended from the Seychelles (Gerlach and Canning 1993) and Kerala, India (Rao 1990) in the west through to southeastern China (Jinzhong 1994), Palau and Vanuatu in the east. Today, the species is extinct in many of these areas, as well as from most of mainland Southeast Asia (Webb *et al*. 2012) (Fig. 1). It is well-known that *C. porosus* was historically found in the Mekong Delta region of southern Vietnam (Platt *et al*. 2014), extending at least as far inland to Tonle Sap Lake in Cambodia (Platt *et al*. 2006). The species was also known to be present on Phu Quoc Island and in the Con Dao Archipelago (Stuart *et al*. 2002). In addition, human-crocodile conflict records reveal that the species was also present in the lower Dong Nai River in Ho Chi Minh City and in Vung Tau to the north (CrocBITE 2021).


Figure 1. Approximate range (dark green), suspected historic range (orange) and possible current range (light green) for Saltwater crocodiles.

The historical occurrence of *C. porosus* in Vietnam north of Vung Tau is unconfirmed, though the historical presence of the species in southeastern China strongly suggests that it would have been present in the coastal portions of central and northern Vietnam. Chinese records of *C. porosus* exist for many areas, including the Nanliujiang River of Guangxi, which is around 100 km from the border with northern Vietnam, Hainan Island, the Pearl River delta, and as far north as Fuzhou and the Penghu Islands off the western coast of Taiwan (Jinzhong 1994). There would also have been suitable *C. porosus* habitat along the central and northern coasts of Vietnam, with mangrove forest extending from Ninh Thuan and Khanh Hoa Provinces (Nguyen *et al*. 2010) north to Nghe An, Thanh Hoa, and the Red River Delta (Nguyen *et al*. 2021). While extensive reforestation efforts have increased Vietnam's mangrove coverage from only 73,000 ha in the 1990s to 235,569 ha in 2019, most primary mangrove forest has been lost (Nguyen *et al*. 2010).

Although UNESCO erroneously states that *C. porosus* is currently present within the Red River Delta (UNESCO 2015), no reliable records of crocodiles exist for the coastal portions of central or northern Vietnam. In fact, there exists only a vague historical mention from the 13th Century involving the Minister of Justice Nguyen Thuyen, who in

1292 was said to have been tasked with driving crocodiles out of the Red River by casting a written spell/text into the river (Strasakova 2011). This lack of records may be due to historically distant extirpation and the fact that this part of Vietnam had been under Chinese rule at various points throughout history (Womack 2006). In China, *C. porosus* had reportedly become rare by the end of the Song Dynasty (over 700 years ago), but the species may have persisted into the 19th Century in portions of Guangxi, which borders northern Vietnam (Jinzhong 1994). This suggests that *C. porosus* may have been extirpated from central and northern Vietnam long ago.

This lack of knowledge of the historical distribution of *C. porosus* in Southeast Asia is not limited to Vietnam. Records from the early 20th Century of man-eating crocodiles along the Mekong and Srepok Rivers in Stung Treng Province, Cambodia (just south of the Laotian border, >600 km inland) (Guerin 2013) suggests that the species may have been found much further up the Mekong River historically than the current accepted distribution, or that Siamese crocodiles (*C. siamensis*) regularly preyed upon adult humans historically, though this seems unlikely. The same is true of Myanmar, where man-eating crocodiles were an issue along the Irrawaddy River in Thayet (≈450 km inland) during the late 19th Century (CrocBITE).

While we may never know the true historical distribution or time of extinction for *C. porosus* in central and northern Vietnam, a larger (but still limited) amount of information exists regarding the historical occurrence of the species in southern Vietnam. We compiled a list of historical records (Table 1) to gain a better understanding of the historical distribution of the species in southern Vietnam, as well as a better grasp on when the species may have been extirpated from the country.

Table 1. Historical records of *C. porosus* in southern Vietnam.

| Location | Province | Year | |
|---|---|---|---|
| Thu Dau Mot | Binh Duong | 1879 | Fatal attack |
| Nha-Be | Gia Dinh or Saigon | 1895 | Fatal attack |
| Long Hung | Dong Nai | 1925 | Fatal attack |
| Dinh River, Ba Ria | Vung Tau | 1929 | Fatal attack |
| Ong Keo River | Dong Nai | 1968 | Report |
| Rung Sac Special Zone | Ho Chi Minh City | 1969 | Report |
| Ly Nhon, Can Gio | Ho Chi Minh City | 1976 | Fatal attack |

Judging from the French Indochinese news media of the early 20th Century, human-saltwater crocodile conflict was still a common issue in southern Vietnam until at least the late 1920s (CrocBITE). A 70.7 cm *C. porosus* skull recovered from the Mekong Delta at An Bin, Can Tho Province, in 2010, suggests that very large individuals once inhabited the region (Ziegler *et al*. 2019). We were unable to find any records from World War II and there are no records of American troops being attacked by crocodiles during the Vietnam War, but anecdotal reports suggest that the species was indeed still present at that time, particularly within the Rung Sac Special Zone (modern-day Can Gio Biosphere). In a 1967 article in the Los Angeles Times, a Navy SEAL boatswain described a "frightening" encounter with a large crocodile in the Rung Sac Special Zone, which he claimed had charged at him, resulting in him discharging his weapon and giving away his position (Tuohy 1967).

Anecdotal reports also state that crocodiles were common in the Dong Tranh and adjacent Ong Keo River during the war (Voc 2012). There are also various reports of Vietnamese soldiers being attacked by crocodiles during the war, but these are mostly undated and lack enough locational detail to be used here. The only officially recorded sighting occurred in the Rung Sac Special Zone in 1969 when a "large crocodile" was encountered on the shore of a tributary during a survey to assess the effects of defoliation on the environment (Orians and Pfeiffer 1970). Joseph B. Mucelli, who was stationed in Lam Dong Province from 1965 to 1968, suggested that Saltwater crocodiles may have been present in this inland area, based on reports of two attacks on NVA soldiers (Mucelli 2005). Indeed, the Dong Nai River does enter Lam Dong Province around 200 km upstream. It is well known that breeding Saltwater crocodile populations can be found up to 1000 km inland along some rivers (Sideleau *et al*. 2021), so this is certainly possible.

The most recent record of a crocodile attack in Vietnam comes from just after the Vietnam War in 1976. That year, it is reported that attacks occurred (only one of which was detailed) around Ly Nhon in Can Gio. One woman was killed, and a 4 m *C. porosus* was hunted in retaliation in November of that year (Nong nghiep Vietnam 2015). The only record of a wild *C. porosus* in Vietnam since then is in the form of an anecdotal record of a crocodile being shot in the Can Gio Biosphere in 1990 (BirdLife International and the Forest Inventory and Planning Institute 2001), but no detailed information is available regarding this incident. This evidence aligns with previous surveys for *C. porosus* presence in Vietnam, where it had been determined that the species may have been extinct in the country since the 1970s or 1980s (Stuart *et al*. 2002). Today, the only known population of wild crocodiles in Vietnam consists of a reintroduced population of Siamese crocodiles in Bau Sau Lake, Cat Tien National Park (Ziegler *et al*. 2019). Crocodiles sighted elsewhere are typically assumed to be escapees from farms and are promptly captured or killed (Stuart *et al*. 2002). This makes the likelihood of the continued presence of a small, undetected population of a large and dangerous species like the Saltwater crocodile highly unlikely.

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# Latin America and the Caribbean

## Cuba

BODY CONDITION OF CROCODILES IN ZAPATA SWAMP, CUBA. Body condition indices are useful indicators of the health, nutrition and life history of individuals in a population, which in crocodiles have been related to individual characteristics such as body dimension, age, sex and also environmental factors such as water level, seasonal fluctuations in food availability and others that characterize the quality of the habitat. The objective of this study was to evaluate the body condition of crocodiles in the central southwestern region of Zapata Swamp (Fig. 1), through the application of the Scale Mass Index (SMI).

Two species are present, the Cuban crocodile (*Crocodylus rhombifer*) and American crocodile (*C. acutus*), as well as hybrids [called "mixturados" here)] of these two species. The criterion for differentiating the three "morphological entities" was based on external morphological characteristics. The proposed hypothesis was "if the three morphological entities sympatrically inhabit a habitat with the same ecological characteristics and food availability, the physical condition does not differ among them".

In the period 1994-2013 (excluding 2001 and 2006), 532 crocodiles were captured in the wet season: 329 *C. rhombifer*, 72 *C. acutus* and 131 mixturados. Total length and body weight were used to calculate the body index (SMI) of each individual. Sex was determined by examination of the

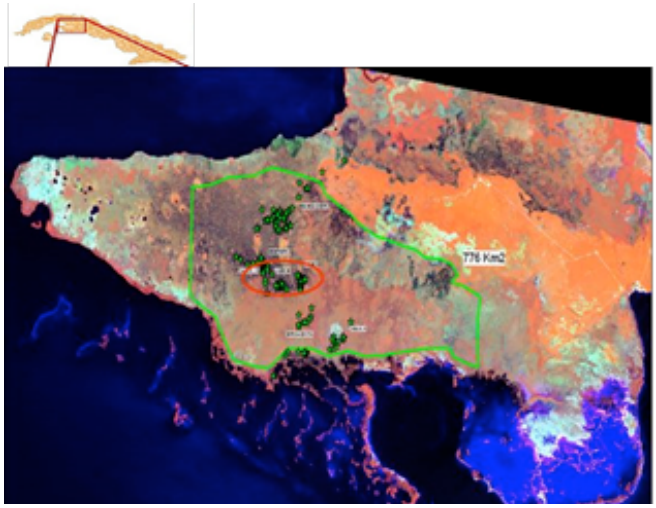

Figure 1. Locations of captures in Zapata Swamp, Cuba.

cliteropenis, and specimens were categorized into three size classes: Class I (juveniles, <150 cm TL), Class II (sub-adults, 150-179 cm TL) and Class III (adults, ≥180 cm TL). The SMI of each morphological entity was statistically characterized by sex and class size, as mean, standard deviation (SD), range and average coefficient of variation (CV).

The Spearman correlation coefficient (r), with a threshold of r<0.30, showed the independence of TL and BW with respect to SMI. No significant association between SMI was found with TL or with BW for the three morphological entities: *C. rhombifer* (TL: r= -0.12, p= 0.25; BW: r= -0.02, p= 0.72), *C. acutus* (TL: r= 0.09; p= 0.42; BW: r= 0.13, p= 0.27) and mixturado (TL: r= -0.11, p= 0.20; BW: r= 0.14, p= 0.10).

The morphological entities showed significant differences in SMI [Kruskal-Wallis test: H (2, N= 532)= 229.9985, p= 0.000] (Fig. 2). The Cuban crocodile showed the lowest mean SMI (10.66 ± 1.4, range 4.92 to 16.08, CV%= 13.1, N= 329) and the American crocodile the highest (14.49 ± 2.91, range 5.86 to 26.09, CV%= 20.06, N= 72), while the mixturados had an intermediate mean SMI (12.74 ± 1.84, range 8.34 to 19.33, CV%= 14.44, N= 131).

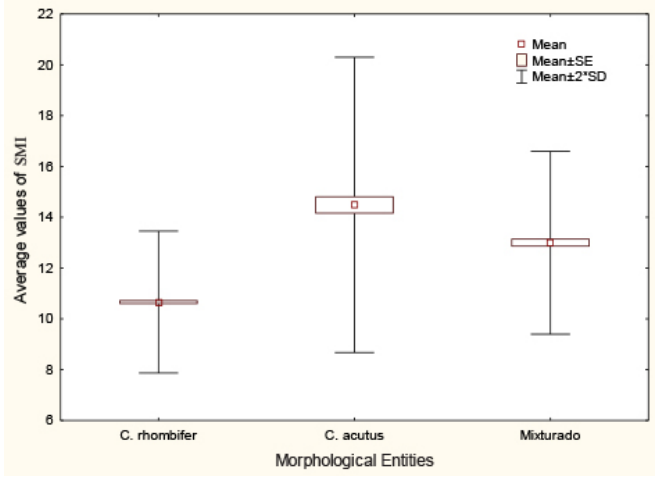

Figure 2. Mean Mass Scale Index (SMI) of *C. rhombifer*, *C. acutus* and mixturados, in Zapata Swamp.

The physical condition of *Alligator mississippiensis* is affected by a number of factors, including diet quantity and quality, prey density, crocodile density, water level and temperature (Zweig 2014; Fukisaki *et al*. 2009; Brandt *et al*. 2016). By not having previous and systematic studies of the biotic and abiotic factors that affect the body condition of the crocodiles in Zapata Swamp, it could be speculated that the lower average value of SMI presented by *C. rhombifer* could be due to the higher percentage of specimens and by the fact that its population is the most dense (Ramos 2013). The pattern of the physical condition for the three morphological entities in the southwestern region of the Zapata Swamp was inconsistent with the hypothesis that the mean values of SMI are similar between entities.

The Cuban and American crocodiles showed significant differences in SMI between classes [Kruskal-Wallis test: H (2, N= 329)= 21.078, p= 0.000 and H (2, N= 72)= 10.46, p= 0.0054, respectively], while no significant differences were found between SMI classes in the mixturados [Kruskal-Wallis test: H (2, N= 131)= 3.454432 p= 0.1778]. Class I in *C. rhombifer* and *C. acutus* presented the highest average values of physical condition (Table 1).

Table 1. Descriptive statistics of the Scale Mass Index (SMI) by morphological entity and size class in Zapata Swamp. SD= standard deviation; CV%= coefficient of variation; N= sample size.

| Class | N (%) | Mean | SD | Min. | Max. | CV% |
|---|---|---|---|---|---|---|
| *Crocodylus rhombifer* | | | | | | |
| Class I | 133 (40.4) | 10.96 | 1.63 | 4.92 | 14.58 | 14.83 |
| Class II | 122 (37.1) | 10.41 | 1.29 | 6.01 | 16.08 | 12.35 |
| Class III | 74 (22.5) | 10.53 | 0.97 | 8.74 | 12.82 | 9.24 |
| *Crocodylus acutus* | | | | | | |
| Class I | 24 (33.3) | 14.99 | 4.51 | 5.86 | 26.09 | 30.09 |
| Class II | 12 (16.7) | 12.84 | 1.06 | 11.63 | 14.65 | 8.25 |
| Class III | 36 (50.0) | 14.70 | 1.51 | 12.12 | 17.98 | 10.25 |
| Mixturados | | | | | | |
| Class I | 40 (30.5) | 13.17 | 1.87 | 10.39 | 17.99 | 14.21 |
| Class II | 45 (34.4) | 12.50 | 2.09 | 18.34 | 19.33 | 16.72 |
| Class III | 46 (35.1) | 12.56 | 1.49 | 9.96 | 16.23 | 11.82 |

Classes II and III in *C. rhombifer* did not show statistically significant differences between each other, while *C. acutus* revealed a significantly higher average value of SMI in Class I relative to Class II, and no significant difference with Class III. This class exhibited a significantly higher mean value of physical condition than Class II. When analyzing the categorization by size classes, the differences in SMI between them cannot be explained with precision until studies are carried out on availability, abundance and quality of the diet in each class.

The American crocodile did not present significant differences in mean SMI between sexes, while the male and mixed Cuban crocodile showed higher significant mean values of SMI than did females (Table 2). Crocodiles in Zapata Swamp

Table 2. Descriptive statistics of mean Scale Mass Index by sex for the three morphological entities in Zapata Swamp. SD= standard deviation; CV%= coefficient of variation; N= sample size; *= p<0.05.

| Entity | Males | | | | Females | | | | U-test |
|---|---|---|---|---|---|---|---|---|---|
| | Mean ± SD | Range | CV% | N | Mean ± SD | Range | CV% | N | |
| *C. rhombifer* | 10.7 ± 1.6 | 4.9-14.6 | 14.9 | 150 | 10.6 ± 1.2 | 8.6-16.1 | 11.3 | 179 | U= 11524.00 * |
| *C. acutus* | 14.5 ± 3.7 | 5.9-26.1 | 25.4 | 32 | 14.4 ± 2.1 | 9.4-20.5 | 14.8 | 40 | U= 580.50 |
| Mixturados | 13.1 ± 1.5 | 10.4-17.9 | 12.2 | 61 | 12.4 ± 2.0 | 8.3-19.3 | 16.0 | 70 | U= 1647.00 * |

Table 3. Number (and percentage) of crocodiles in each size class and physical condition (Bad, Good, Excellent) for each morphological entity in Zapata Swamp. TL= total length.

| Physical Condition | Class I (<150 cm TL) | Class II (150-179 cm TL) | Class III (≥180 cm TL) | Males | Females | All |
|---|---|---|---|---|---|---|
| *C. rhombifer* | 133 | 122 | 74 | 150 | 179 | 329 |
| Bad | 15 (11.3) | 9 (7.4) | 9 (12.2) | 17 (11.3) | 16 (8.9) | 33 (10.0) |
| Good | 101 (75.9) | 96 (78.7) | 52 (70.3) | 105 (70.0) | 104 (58.1) | 249 (75.7) |
| Excellent | 17 (12.8) | 17 (13.9) | 13 (17.6) | 28 (18.7) | 19 (10.6) | 47 (14.3) |
| *C. acutus* | 24 | 12 | 26 | 32 | 40 | 72 |
| Bad | 4 (16.7) | 2 (16.7) | 4 (11.1) | 5 (15.6) | 5 (12.5) | 10 (13.9) |
| Good | 17 (70.8) | 7 (58,3) | 25 (69.4) | 23 (71.9) | 26 (65) | 49 (68.0) |
| Excellent | 3 (1.5) | 3 (25.0) | 7 (19.4) | 4 (12.5) | 9 (22.5) | 13 (18.1) |
| Mixturados | 40 | 45 | 46 | 61 | 70 | 131 |
| Bad | 6 (15.0) | 6 (13.3) | 7 (15.2) | 6 (9.8) | 13 (18.6) | 19 (14.5) |
| Good | 29 (72.5) | 36 (80.0) | 30 (65.2) | 47 (77.0) | 48 (68.6) | 95 (72.5) |
| Excellent | 5 (12.5) | 3 (6.7) | 9 (19.6) | 8 (13.1) | 9 (12.9) | 17 (13.0) |

are generally sedentary (Ramos *et al*. 1994), and there are no studies available on the movement of crocodiles by sex in Cuba, so we cannot give an explanation of the difference in physical condition between the sexes in *C. rhombifer* and the mixturados, and *C. acutus* does not present any difference in SMI between sexes. Our criterion is that the nutritional value of the prey consumed can play an important role in explaining differences between the sexes, which coincides with what is indicated by González (2015).

Three categories were established to categorize the SMI: a) poor condition (individuals whose SMI value is less than the value of the arithmetic mean minus one standard deviation); b) good condition (individuals whose SMI value is equal to or greater than the previous value and less than or equal to the value obtained from the sum of the mean plus a standard deviation); and c) excellent condition (individuals whose SMI value is greater than the obtained value of the sum of the mean and a standard deviation). In addition, the number and percentage of crocodiles captured in the study were summarized by category of corporal condition and according to the size class and sex of each morphological entity (Table 3). The following values were established in the three established categories: *C. rhombifer*: bad (<9.26), good (12.06-12.80), excellent (>12.06); *C. acutus*: bad (<11.58), good (11.58-17.39), excellent (>17.39); and, mixturados: bad (<10.90), good (10.90-14.58), excellent (>14.58).

More than 68% of captured specimens were in the category of good condition, and more than 13% were in excellent condition (Table 3), similar to that found in other species (Labarre *et al*. 2020; Cedeño *et al*. 2011; González 2010), and is a reflection of the ability of crocodiles to assimilate and store fat, due to a balanced diet (Padilla-Paz 2008). The good health of crocodile populations in Zapata Swamp coincides with what was observed in previous studies, at least in *C. rhombifer*, showing that its population is healthy and vigorous (Ramos 2013).

In general, the three morphological entities presented 88.3% of specimens in the good and excellent condition categories (*C. rhombifer* 90%, *C. acutus* 86.1%, mixturados 85.5%). The Cuban crocodile had the lowest percentage of specimens in "bad" body condition, followed by *C. acutus* and the mixturados showing the highest percentage. In this category, *C. rhombifer* presented the highest percentage of crocodiles in Class I, *C. acutus* in Classes I and II, and mixturados in Class III. In the categories of good and excellent as a whole, *C. rhombifer* showed 90% of specimens, with the highest percentage of specimens in Class II (93%). The American crocodile presented 86% of specimens, with the highest percentage of individuals in Class III (89%), and mixturados showed 86%, with the highest frequency in Class II (87%).

The results indicate many gaps in the knowledge of physical

condition, and a more accurate and reliable analysis of the health of the morphological entities present in Zapata Swamp is needed. Additional studies should be performed to evaluate the physical condition of Zapata Swamp crocodiles in relation to hydrology, habitat and temperature, among others, and to provide applied data as a reference point for population and ecosystem monitoring.

In addition, other health parameters should be considered: parasite load, blood biochemistry, the composition of the diet of each entity by class; the influence of illegal crocodile hunting on the composition of species, sizes, and sexes; the illegal hunting of the main available prey such as hutias, hicotea (*Trachemys decussata*) and feral pigs (*Sus scrofa*); and the effect of the introduction of invasive species such as the fish *Claria* sp. and *Tilapia* sp. on the physical condition of crocodiles in this area.

The monitoring of body index should be considered in future studies in order to evaluate its relationship with biotic and abiotic variables, enhance its application to the improvement of crocodile conservation strategies and management of the ecosystems of Zapata Swamp, and provide a measure of habitat quality. The results can provide a baseline for monitoring the health of crocodile populations to support their conservation and the ecosystem, not only in Zapata Swamp, but also throughout the country.

Acknowledgments

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## Mexico

FIRST RECORD OF THE AMERICAN CROCODILE (*CROCODYLUS ACUTUS*) IN BAJA CALIFORNIA. The American crocodile (*Crocodylus acutus*) has the most extensive range of New World crocodiles, occurring from Mexico and the USA (southern Florida), throughout Central America to northern South America, and including the Caribbean (Thorbjarnarson 2010) (Fig. 1). Along the Pacific coast of Mexico, the species currently inhabits coastal mangrove and beach habitats from the southern border of Chiapas and Guatemala up to the Fuerte River in Sinaloa (Navarro 2003). Historically, the range of *C. acutus* extended even further north into Sonora to the Yaqui River mouth.

Although fossil evidence has confirmed that *C. acutus* was present on the Baja Peninsula during the late Pliocene (3.6-2.5 million years ago) (Cupul-Magana *et al*. 2017), there is no evidence, oral stories, or written records of its presence in Baja by local communities or scientists. In fact, despite the presence of significant populations along the coast of Sinaloa directly across the Gulf of California, there are not even any records of itinerant American crocodiles from the Baja California Peninsula. Here, we present the details of the first recorded American crocodile on Baja California Peninsula.

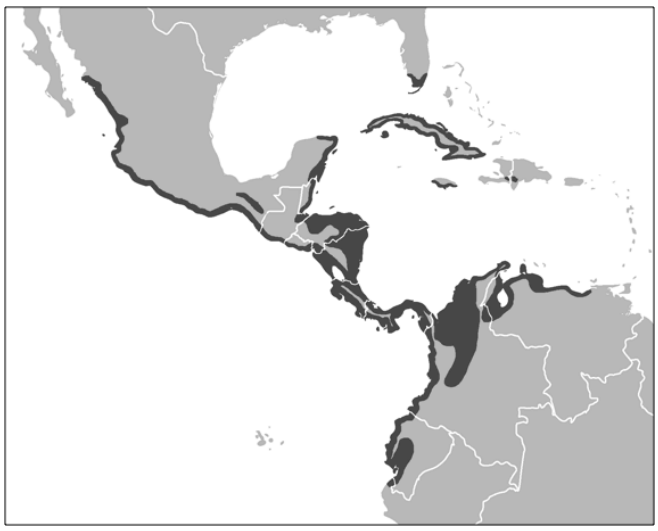

Figure 1. Current distribution of the American crocodile.

On 8 October 2021, local visitors at Piedras Bolas Beach in Cabo Pulmo National Park, found a recently deceased, emaciated adult (2.84 m TL) American crocodile (Fig. 2). Visitors contacted Mr. Lance Peterson, a naturalist of the area, who then contacted Marissa Tellez. To verify this record, MT contacted Brandon Sideleau, who has conducted work in the area. Luis Angel Tello verified the location of the crocodile

Figure 2. Dead American crocodile found in Cabo Pulmo National Park. Photograph: Rafael Marron Fiol (Proteccion de la Tortuga Marina).

Figure 3. Barnacles on the tail and jaw of dead American crocodile. Photograph: Rafael Marron Fiol (Proteccion de la Tortuga Marina).

carcase, and organized for measurements and photographs to be taken. Besides total length, other measurements recorded were snout-vent length (1.34 m), dorsal-cranial length (= head length) (55 cm), and maximum head width (27 cm). The TL:DCL ratio was calculated as 5.2:1. [Note: At the time of writing, DCL was being checked, as the reported value is not consistent with reported TL or SVL (see Labarre *et al*. 2017)]. Many barnacles were observed on crocodile's body (Fig. 3), suggesting that it had spent a substantial amount of time in marine environments.

While it was initially suspected that the crocodile could have been an escapee from captivity, the only known local source confirmed that all their crocodiles were accounted for. Additionally, the presence of barnacles is strongly suggestive of a wild itinerant. The nearest known significant *C. acutus* population is in El Brinco Estuary (24°31'51.9" N 107°35'59.1" W), ≈222 km across the Gulf of California from Cabo Pulmo National Park (Fig. 4). El Brinco Estuary is part of the Ensenada Pabellones Lagoon system southwest of Culiacan in Navolato Municipality. Surveys of the estuary have revealed 217 crocodiles, indicating a relative density of 34.3 non-hatchlings/km, one of the densities reported for the species (Tello-Sahagun 2021). Given the distance and size of this population, it is the most likely source of this individual.


Figure 4. Straight-line distance between El Brinco Estuary and Cabo Pulmo National Park.

The Saltwater crocodile (*C. porosus*) is known to utilize currents to travel considerable distances at sea (eg Campbell *et al*. 2010), and it is likely that the American crocodile does as well. Itinerant Saltwater crocodiles have been encountered well over 2000 km from the nearest source populations, with individuals being found in locations as far flung as Fiji, the Marshall Islands and Japan (Spennemann 2020). For the American crocodile, distances of over 700 km have been recorded, when an individual was identified as having traveled from the Magdalena River of Colombia to San Andres Island, off the eastern coast of Nicaragua (Balaguera-Reina *et al*. 2020). Over the past decade this was not the only crocodile encountered on San Andres, suggesting that such journeys may not be as rare as previously believed. There are reliable records of itinerant American crocodiles from Barbados (1886), Curacao (1914, 1932, 1954), Grand Cayman (2006, 2008, 2012), and South Carolina, USA (2008) (CrocBITE 2021).

In addition to itinerants in non-native regions, there have also been records of individual crocodiles moving back into portions of the range from which they had been extirpated, such as Sonora state of Mexico. In 1973, a ≈2.5 m *C. acutus* was captured in a fishing net at El Ciego Estuary, east of Guaymas in Sonora. The nearest known population in the present day appears to be the lower Fuerte River at the northern tip of Sinaloa, as distance of around 250 km from this Sonoran location. In recent years, several crocodiles have been captured or sighted in Sonora, including in some areas where populations are known to have existed historically (eg Yaqui River) (Cupul-Magana *et al*. 2017). These sightings suggest northward movement of crocodiles along the coast from Sinaloa, which may be indicate of the dispersal of individuals from populations to the south. Some of these populations may have reached "carrying capacity" (given the densities reported from El Brinco Estuary, this is certainly possible) or small-medium sized individuals seeking new habitat away from larger, dominant males, though this likely not as much of an issue with *C. acutus* as it is with the much more aggressive and territorial Saltwater crocodile.

Most records of ocean-going *C. acutus* come from the Caribbean, but there are a few records from the Pacific Coast. The species is known to be present on Isla Maria Magdalena (Casas-Andreu 1992), ≈120 km from the nearest population in Nayarit, though the origin of this population is unclear. In September 2018, a large adult crocodile was encountered and filmed by fisherman ≈64 km off the coast from Punta Ardita, Bahia Solano, in Choco, Colombia (CrocBITE 2021). It is conceivable that some of these crocodiles may venture west further out into the sea, rather than north or south, particularly if currents are supportive.

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## Belize

DENTAL PROCEDURE IN A MORELET'S CROCODILE (*CROCODYLUS MORELETII*) UNDER HUMAN CARE. Crocodiles replace their teeth regularly, including those

broken off during fighting. However, toothless crocodiles are found or seen occasionally. In old crocodiles, this may be due to accumulated damage to the alveoli. Fracturing of a tooth during fighting, or ripping on a prey item, may damage the dental lamina. The affected alveoli may become permanently edentulous, and during a long life, toothlessness may increasingly affect more alveoli in some individuals. Some such toothless alveoli may become calcified (Huchzermeyer 2003).

In March 2019, the Crocodile Research Coalition (CRC) acquired a pair of Morelet's crocodiles (*Crocodylus moreletii* from a private owner, who had cared for them for ~38 years at that point in time. Although the male and female crocodile had lived in a large, natural pond on the owners' property that contained an abundance of fish, the crocodiles were fed a whole chicken or chicken scraps (fat and skin) 2-3 times per week. It should be noted that the owners never directly hand-fed the crocodiles, but just threw the chicken near the edge of the pond. In the early 2000s, the Belize Forest Department required the owners to fence the pond in view of the habituation of crocodiles towards people, which created an enclosure of about 0.13 ha.

Despite both crocodiles being overly obese, the CRC observed adequate health for the male (3 m TL), but the female (1.9 m TL) illustrated skin issues and lacked 87% of her teeth (only 9 teeth were visible, and appeared "normal"). Looking at old photographs and videos of the female from the 1990s to early 2000s, she appeared to have had 68 teeth that appeared in a normal state. Both crocodiles had been put on a diet for 20 months prior to being transported to the CRC facility in November 2020. The male illustrated improved energy over the course of the diet, however the female (later known as "Sam") continued to overall demonstrate minimal improvement in energy despite losing adequate weight, and her skin still appeared in poor condition. In regards to her behaviour, one of the previous owners had mentioned Sam had become more "docile" and shy over the years, thus we speculated at that time her behaviour was not health-related.

The previous owners mentioned that the crocodiles had successfully mated, and the female had laid viable eggs up until at least 2013/2014, but in following years they had not observed any hatchlings, despite observing Sam making a nest. Because they did not go into the pond enclosure, there is no confirmation of Sam laying viable eggs since 2013.

On the day of Sam's transport to the CRC, we found her at the edge of the enclosure in a small puddle of water. We were informed by one of the previous owners that the male crocodile "bullied" Sam, preventing her from eating at times, and even pushing her out of the water and preventing her from going into the pond (for 3 days or more at times). Once taken out of the enclosure and properly restrained, we opened Sam's mouth and examined the areas of missing teeth and sockets covered with connective tissue and skin more thoroughly, in which we noticed some signs of necrotic tissue around some of the teeth sockets. It also appeared that there was inflammation around some sockets. At this moment, we discussed Sam's current condition could be stressed-related, and the decision was made to keep Sam separate from the male at the CRC.

Over the next several months, CRC monitored Sam's health closely during target training sessions. Sam permitted CRC Executive Director Dr. Marisa Tellez to get close enough during the target training, which allowed a close observation of the inflammation around teeth sockets, and lack of improvement in areas that illustrated necrotic tissue previously (Fig. 1). Dr. Tellez then consulted with Luis Sigler from the Dallas World Aquarium with regards to steps to identify pathogen/s that could be impacting Sam's overall health, in addition to causing the lack of teeth regeneration.

Figure 1. Sam before dental procedure. Photograph: Marisa Tellez.

With further consultation from Dr. Douglas Mader, the CRC conducted an x-ray of Sam's mouth in June 2021. They revealed a chronic osteomyelitis infection in various sections of her mouth (Fig. 2). This bacterial infection likely has been the cause of Sam's overall poor health, and lack of teeth regeneration for over a decade (Fig. 3). After identifying the infection, it was suggested a minor dental procedure of cleaning out the most infected teeth sockets may assist at least in improving Sam's health.

On 7 August 2021, at 1000 h, a minor dental procedure began on Sam, led by Dr. Philip de Shield from the Animal Medical Centre in Belize, as well as Luis Sigler. Sam was restrained on a board laid on a surgical table. Her mouth was pried opened and held open with two acrylic bars connected horizontally on the top and the bottom. Local anaesthetic [Lidocaine (2%)] was injected around the teeth sockets that showed osteomyelitis (Fig. 4), and once its effects were established, the infected teeth sockets were opened, and the caseified exudate (pus and fibrin) scraped out of them. All the opened sockets were then flushed and disinfected with hydrogen peroxide and chlorhexidine, and finally, an antibacterial gel (Doxirobe) was placed in the opened tooth sockets. In total, six sockets were cleaned, each one containing between one to three non-erupted teeth (Fig. 5).

We could not find information in the literature regarding the rearrangement of the sockets after a tooth is lost. In this case,

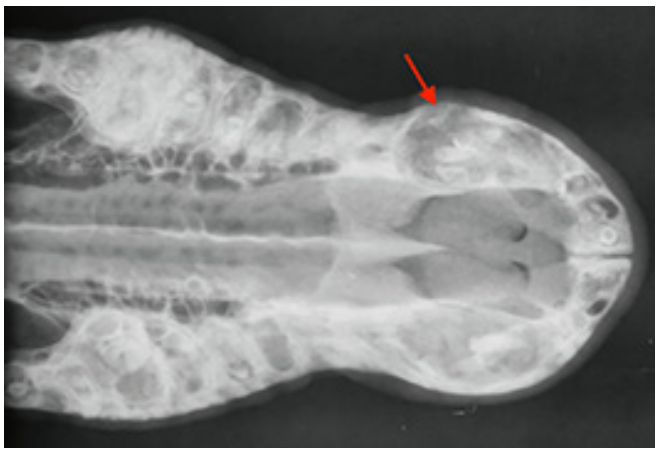

Figure 2. X-ray (D-V view) of upper jaw. Arrow indicates osteomyelitis. Photograph: Philip de Shield.


Figure 3. Sam's teeth diagram before procedure. Photograph: Luis Sigler.

we observed that the socket opening was only covered by skin and connective tissue. Some sockets had the full set of teeth (the functional one and the successional) but were in disarrangement due to inflammation and necrosis of the stem cells. Samples of exudate were cultured for bacteriology and later identified as *Streptococcus* group D and *Escherichia coli*. Prior to ending the procedure, an antibacterial gel (Doxirobe) was placed in the opened tooth sockets.

The procedure took 2 hours, and Sam's heart and respiration rate, as well as temperature, were monitored every 13 minutes. Although the bacteria was cleaned out, we came to the conclusion it was unlikely Sam would ever grow back teeth in the sockets that were heavily infected as the stem cells to regenerate teeth had likely died.

After this invasive procedure, Sam was placed in a small rehabilitation pond to allow monitoring of her behaviour and recovery. The next day, Sam's condition appeared stable, and she was taken back to her normal enclosure, and closely monitored again for 24 hours. To further assist in her recovery,


Figure 4. Lidocaine injection. Photograph: Ray Caperton.

Figure 5. Non-erupted teeth removed through the dental procedure. Photograph: Marisa Tellez.

Sam was given two 480 mg tablets of sulfamethoxazole/trimethoprim every other day for 3 weeks.

Although inflammation around various tooth sockets was reduced, and Sam's remaining teeth were whiter and not as glassy as previously, she died on 4 December 2021, some 4 months after the procedure. Necropsy revealed signs of chronic septicemia, and it is likely the dental procedure may have alleviated some discomfort and improved health minimally given the chronic bacterial infection. It is unknown what caused the bacterial infection or inability of Sam's immune system to fight it off. No husbandry records were kept of Sam pre-CRC, but reports of "bullying" by the larger, male crocodile are considered relevant to this case. We took a blood sample from Sam once captured and restrained, and the

sample indicated signs of anemia.

On the basis of the background information about Sam, it is possible the stressful environment created by the larger male crocodile had resulted in Sam having a weakened immune system. Coupled with a poor diet, this may have made her more susceptible to bacterial infection, including that in the tooth sockets. It is unclear whether the infection itself led to cessation of tooth generation/replacement, or whether it resulted from the generally poor condition of the crocodile as a result of poor diet and negative social interactions with the male over a long period of time.

This case highlighted the importance of obtaining as complete a history as possible (housing, diet, reproductive events, previous health issues, etc.) of crocodiles received for rehabilitation. Previous photographs to compare with actual conditions are also very useful.

We recommend the close observation and evaluation of broken or damaged teeth. If inflammation and/or necrosis of the periodontal tissue is observed and the new tooth has not erupted in the expected time, a simple checking/cleaning procedure can be performed to aid the proper recovery of the tooth avoiding complications that can be detrimental for the crocodile.

Acknowledgements

We would like to thank Gatorland (Orlando, USA) for its financial support to perform this dental procedure. We also thank Dr. Philip de Shield, Savannah Boan and Joe Wasilewski, for their assistance during and after the procedure, as well as Dr. Douglas Mader for his consultation.

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Marisa Tellez *(Crocodile Research Coalition, Belize)* and Luis Sigler *(The Dallas World Aquarium, Texas, USA)*.

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# Australia and Oceania

## Australia

The Northern Territory's Wildlife Trade Management Plan (WTMP) for *Crocodylus porosus* was declared as an Approved Plan under Subsection 303FO(3) of the *Environment Protection and Biodiversity Conservation Act 1999* in December 2015. Under this arrangement, the NT Government, through its Department of Environment, Parks and Water Security (DEPWS), must provide an annual report to the Australian Government Department of Agriculture, Water Resources and the Environment (DAWRE) on the implementation of the WTMP. This report (Clancy and Fukuda 2021) covers implementation of the WTMP in 2019-2020, the final year of the Approved Plan.

The COVID-19 pandemic impacted on the ability to undertake fieldwork in 2020, as well as on industry's business operations. DEPWS conducted spotlight surveys in one of 8 monitoring rivers (7 scheduled) in 2020. Parks Australia North surveyed an additional one of 4 monitoring rivers in Kakadu National Park. Repeat surveys were undertaken of the Adelaide River, one of the most important from a management perspective. The results of the surveys were consistent with recent trends, showing either stable (believed to have reached an asymptote) or increases in both numbers and in biomass (more larger crocodiles observed). The repeat surveys supported the notion of high repeatability of the standard technique. Monitoring will continue in 2021 as per the current Management Program subject to any constraints due to the pandemic.

A total of 249 problem *C. porosus* (72% males) were removed from the wild in 2019-2020 for public safety and to protect stock in pastoral areas. Most (96%) were captured in Darwin Harbour. This number is down from the 283 recorded in 2018-2019 and lower than the historical high of 335 recorded in 2017-2018. The results are consistent with an increasing trend in capture over the last two decades (commensurate with an overall increase in the NT Saltwater crocodile population) with much year on year variation. One factor influencing lower capture numbers (relative to the longer-term trends) has been the much drier than average wet seasons in 2018-2019 and 2019-2020. Size trends do not reflect an increasing proportion of smaller animals, as would be expected in an "overharvest" situation.

DEPWS continued to promote community awareness for safety and participation in 2019-2020 through the "Be Crocwise" campaign using a variety of media. DEPWS delivered 137 "Be Crocwise" face-to-face presentations to 12,071 people. Presentations occurred in schools, regional shows, urban and remote community group events, and camping and boating expos.

Under the annual ceiling of 90,000 viable eggs, 77,000 viable eggs were allocated to harvest, with 41,462 viable eggs collected in 2019-2020. All indications are that the current harvest of eggs is well within sustainable levels. Under the annual harvest ceiling of 1200 non-hatchling *C. porosus*, 78 live crocodiles were reported as harvested in 2019-2020. The majority of reported live-harvested crocodiles were adult males (84%). The total number of crocodiles harvested is known to be a slight underestimate due to a number of harvest permits being multi-year permits that have not yet expired; consequently complete final return/harvest data are not yet available. Despite this underestimate, the total harvest of live crocodiles from all sources at 327 individuals was well below the 1200 threshold. The bulk of removals was related to the NT Government run removal program in designated management zones.

Ten crocodile farms operated in 2019-2020 and production data these farms for the period 1 February 2019 to 31 January

2020 is reported. Farm production reporting is limited to stock held (live crocodiles), total acquisitions and total disposals. As with previous years, most live crocodiles exported from the Northern Territory went to Queensland. In 2019-2020, revenue from the NT's crocodile industry fell 4.1% to $AUD26.7 million. The economic value has been stable in recent years, averaging $25.4 million over the last 5 years, and is an important source of employment and resources for regional communities. Stricter skin grading standards were introduced in 2016-2017, leading to a greater quantity of crocodile skins being classified as lower grade. Around 59.5% of revenue was generated from the production of first grade skins, reflecting an ongoing focus of quality over quantity.

Permit and animal welfare compliance was closely monitored by DEPWS and the NT Department of Industry, Trade and Tourism (DITT). No significant permit compliance or animal welfare matters were reported in 2019-2020. A review of the WTMP 2016-2020 was undertaken in 2018-2020 as previously reported. This review was undertaken in 2019-2020 and is reported on here to finalise this process. The review indicated that there is no evidence that the broader management approach has resulted in any threat to the conservation status of *C. porosus*; indeed it is likely that the commercial value attached to the wild populations has supported retention of good quality nesting habitat and made an important contribution to remote livelihoods. Also, the approach has mitigated demands from NT residents for aggressive culling of the species.

Consultation and the formal review process supported a business as usual approach for the next 5-year period of operation of the WTMP from both industry and management agencies as well as ongoing support from the peak Aboriginal land management agency. A new WTMP has been developed and approved to cover the 2021-2025 period.

Source: *Clancy, T.F. and Fukuda, Y. (2021). NT Saltwater Crocodile (Crocodylus porosus) Wildlife Trade Management Plan: 2020 Monitoring Report. Northern Territory Department of Environment, Parks and Water Security: Darwin.*

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# Europe

RECORD FUNDING AMOUNT RAISED FOR THREATENED CROCODILIANS. The "Zoo Species of the Year" campaign was able to raise more than 150,000 Euros in 2021, a record amount within one year, since the campaign started in 2016! The funds will go towards effective conservation actions for highly endangered crocodilian species in Cuba, Philippines, Borneo and Nepal. Crucial to the success of this year's "Zoo Species of the Year" campaign was the close cooperation with the zoos and their committed participation. With their excellent public relations work, they did important lobbying for highly threatened crocodilians. In addition to their educational mission, zoos also breed endangered species through managed breeding programs, such as the Philippine crocodile (*Crocodylus mindorensis*) (Fig. 1). The Philippine crocodile is a good example of how conservation breeding projects coordinated by zoos actively contribute to *in-situ* conservation.

The Zoological Society for the Conservation of Species and Populations (ZGAP) will announce the next "Zoo Species of the Year", together with its partners, the German Association of Zoological Gardens (VdZ), the German Zoo Society

Figure 1. Adult and hatchling Philippine crocodiles (*Crocodylus mindorensis*) at Cologne Zoo, Germany, December 2021. Photograph: Thomas Ziegler.

(DTG), the Community of Zoo Supporters (GdZ), other zoos and zoo associations, at the beginning of 2022.

Source: *ZGAP media release (Contact: Dr. Viktoria Michel, Project Coordinator "Zoo Species of the Year"; zootierdesjahres@zgap.de).*

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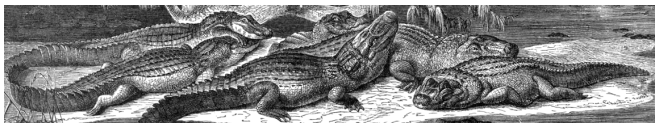

## Recent Publications

Arceo-Carranza, D., Chiappa-Carrara, X., Chávez López, R. and Yáñez Arenas, C. (2021). Mangroves as feeding and breeding grounds. Mangroves as feeding and breeding grounds. Pp. 63-95 *in* Mangroves: Ecology, Biodiversity and Management, ed. by R.P. Rastogi, M. Phulwaria and D.K. Gupta. Springer Nature: Singapore.

Abstract: Mangroves are considered as ecosystems that provide shelter, food and breeding grounds for many groups of inhabiting fauna. Much of the fauna present are organisms in different stages of their life cycle, mostly juveniles. The three-dimensional structure of the mangrove roots and the combination of the aquatic and terrestrial environments are factors that bring together a great diversity. Such diversity within mangrove sites includes aquatic and terrestrial vertebrates and invertebrates such as fish, amphibians, reptiles, mammals and birds. Present within the fauna are representatives of different trophic guilds that perform key functions in the ecosystem, such as pollination, seed dispersal and nutrient recirculation. The food produced by the ecosystem is based on the production of detritus caused by leaf litter and its decomposition, where transformation of energy and accumulation of biomass for higher trophic levels begins with the invertebrates. With regard to breeding activity, many fish families spawn in the mangrove roots (eg Fundulidae), or nest in the canopy (herons and cormorants) that provides protection against predators and food for juvenile organisms. Undoubtedly, mangroves function as feeding and breeding grounds that are essential in maintaining populations of marine organisms, especially fish. Many fish species that grow in the mangroves are important for fisheries. Unequivocally, maintaining these breeding sites for marine and terrestrial fauna is crucial to the general functioning of adjacent ecosystems.

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Medeiros, N.B.C., Rodrigues, M., Morais, D.H. and Nunes-Rodrigues, M.D. (2021). Carcass and commercial cuts yields of caiman (*Caiman crocodilus yacare*) farmed in a ranching system in the Brazilian Pantanal. Anais da Academia Brasileira de Ciências 93(4): e20190949 (doi: 10.1590/0001-3765202120190949).

Abstract: Given the growing use of alternative sources of protein, studies on the commercial viability of amazonians wild species, based on the yield of their carcass, are still scarce in the literature. To evaluate yields of carcass and commercial cuts of caiman meat (*Caiman crocodilus yacare*), according to sex and weight categories, besides analyzing their revenue. Thirty animals in termination phase were selected, separated by sex and weighed. The cuts analyzed was of 59.7% in relation to total live weight, and of 70.7% in relation to the carcass. Regarding the yields of the cuts, the average weight difference in detriment to the sex of the animals was minimal, however, in the weight categories, animals classified as intermediate and heavy (5.9-9.1 kg) resulted in higher cut weights ($p<0.01$) and consequently in revenue for most of the meat cuts (66.7%), especially for tail, back, and sirloin fillets. It can be concluded that the carcass yield of caiman is high, and that heavy animals resulted in higher yields of prime cuts, emphasizing the need to carry out studies that prioritize the cost/benefit ratio taking into account the age and weight of the animals.

Brown, G.J., Forbes, P.B.C., Myburgh, J.G. and Nöthling, J.O. (2021). A comparison of calcium and phosphorus in components of fertile and size-matched unbanded Nile crocodile eggs. African Journal of Herpetology (https://doi.org/10.1080/21564574.2021.1980119).

Abstract: Research in other species suggests that the source of embryonic calcium (Ca) and phosphorus (P) for *Crocodylus niloticus* is likely yolk and shell. Using inductively coupled plasma optical emission spectroscopy (ICP-OES), the Ca and P concentration and content of 30 fertile eggs was determined within 10 days prior to anticipated hatching, and compared with those of size-matched unbanded eggs (eggs that failed to form an opaque band around the lesser circumference, indicative of presumed infertility). Shell contained the highest Ca concentration and content, followed by the foetus, followed by the intra-abdominal yolk. Foetal tissue had the highest P concentration and content, followed by intra-abdominal yolk. The Ca and P concentration of intra-abdominal yolk of foetuses in fertile eggs varied more widely than did the yolk of unbanded eggs, based on coefficient of variation. Ca concentration of fertile egg yolk was in some cases found to exceed that of the yolk of unbanded eggs, suggesting that Ca is stored there after being removed from the shell, however, yolk Ca content was consistently lower in fertile than in unbanded eggs, indicating net yolk Ca depletion. Yolk P concentration and content of fertile eggs was consistently lower than that of unbanded eggs, suggesting a net depletion of yolk P reserves, without replenishment. The Nile crocodile appears to follow the classic archosaurian pattern of Ca mobilisation, whereby the shell supplies the majority of foetal Ca, but the intra-abdominal yolk contains substantial Ca reserves for use by the hatchling. This study provides clinicians and researchers with information on sample collection and analysis of Nile crocodile egg and foetal tissue, provides baseline descriptive data on Ca and P concentration and content, discusses the effect of potential covariates on Ca and P concentration and content, and discusses the movement of Ca and P from reserves within the egg to the developing foetus.

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Ahizi, M.N., Kouman, C.Y., Ouattara, A., Kouamé, N.P., Dede, A., Fairet, E. and Shirley, M.H. (2021). Detectability and impact of repetitive surveys on threatened West African crocodylians. Ecology and Evolution (doi: 10.1002/ece3.8188).

Abstract: West African crocodylians are among the most threatened and least studied crocodylian species globally. Assessing population status and establishing a basis for population monitoring is the highest priority action for this region. Monitoring of crocodiles is influenced by many factors that affect detectability, including environmental variables and individual- or population-level wariness. We investigated how these factors affect detectability and counts of the critically endangered *Mecistops cataphractus* and the newly recognized *Crocodylus suchus*. We implemented 195 repetitive surveys at 38 sites across Côte d'Ivoire between 2014 and 2019. We used an occupancy-based approach and a count-based GLMM analysis to determine the effect of environmental and anthropogenic variables on detection and modeled crocodile wariness over repetitive surveys. Despite their rarity and level of threat, detection probability of both species was relatively high (0.75 for *M. cataphractus* and 0.81 for *C. suchus*), but a minimum of two surveys were required to infer absence of either species with 90% confidence. We found that detection of *M. cataphractus* was significantly negatively influenced by fishing net encounter rate, while high temperature for the previous 48 h of the day of the survey increased *C. suchus* detection. Precipitation and aquatic vegetation had significant negative and positive influence, respectively, on *M. cataphractus* counts and showed the opposite effect for *C. suchus* counts. We also found that fishing encounter rate had a significant negative effect on *C. suchus* counts. Interestingly, survey repetition did not generally affect wariness for either species, though there was some indication that at least *M. cataphractus* was more wary by the fourth replicate. These results are informative for designing future survey and monitoring protocols for these threatened crocodylians

in West Africa and for other endangered crocodylians globally.

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Saldarriaga Gómez, A.M. (2021). Conservation Genetics of the Largest Captive Population of the Critically Endangered Orinoco Crocodile (*Crocodylus intermedius*): A Contribution for its Survival. MSc thesis, Universidad Nacional de Colombia, Bogotá, Colombia.

Abstract: During the last century, many species have become endangered, and conservation through captive breeding programs has become crucial for their survival. One of the primary considerations for the design of reintroduction programs is the preservation of genetic variability, which provides the raw material for adaptation. If management is based only on recorded pedigrees, information may be incomplete or inaccurate and may lead to an underestimation of relatedness. Incorrect management actions can alter the viability of reintroductions due to the loss of genetic diversity and genetic depression of the source population. In this Master thesis, we used a 17 microsatellite loci system to characterize the extent of the genetic variation of the biggest ex-situ population of the critically endangered *Crocodylus intermedius* in Colombia in charge of the Roberto Franco Tropical Biology Station (EBTRF) aiming at proposing management guidelines and at assessing past and future reintroductions. In Chapter 1 we compared genetic indexes of the Founder and Alive populations and we found that the living crocodiles maintain much of the founder diversity, high levels of heterozygosity, and a low overall inbreeding. In Chapter 2 we developed a powerful tool that combined information of relatedness, individual diversity, age, sex, size, and location of the living crocodiles that allowed us to build combinations of individuals to plan future breeding groups that maximize the population´s genetic diversity. We propose different reproductive nuclei, and we demonstrate that molecular data can be used to improve the management of the program, well beyond of what can be achieved with pedigree information alone. To provide insights on the genetic component of the released individuals and to suggest the improvement of crocodile's reintroductions, in Chapter 3 we evaluated the genetic composition of four groups of crocodiles already reintroduced and of juveniles to be released. We propose that in the short term, reintroductions should only be carried out in places where it is certain that the populations have become completely extinct. In case the species is present before implementing reintroduction measures it is necessary to accurately assess its genetic profile and situation as well as to estimate population size.

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Bowman, C.I.W., Young, M.T., Schwab, J.A., Walsh, S., Witmer, L.M., Herrera, Y., Choiniere, J., Dollman, K.N. and Brusatte, S.L. (2021). Rostral neurovasculature indicates sensory trade-offs in Mesozoic pelagic crocodylomorphs. The Anatomical Record (https://doi.org/10.1002/ar.24733).

Abstract: Metriorhynchoid thalattosuchians were a marine clade of Mesozoic crocodylomorphs that evolved from semi-aquatic, "gharial"-like species into the obligately pelagic subclade Metriorhynchidae. To explore whether the sensory and physiological demands of underwater life necessitates a shift in rostral anatomy, both in neurology and vasculature, we investigate the trigeminal innervation and potential somatosensory abilities of metriorhynchoids by digitally segmenting the rostral neurovascular canals in CT scans of 10 extant and extinct crocodyliforms. The dataset includes the terrestrial, basal crocodyliform *Protosuchus haughtoni*, two semi-aquatic basal metriorhynchoids, four pelagic metriorhynchids and three extant, semi-aquatic crocodylians. In the crocodylian and basal metriorhynchoid taxa, we find three main neurovascular channels running parallel to one another posteroanteriorly down the length of the snout, whereas in metriorhynchids there are two, and in *P. haughtoni* only one. Crocodylians appear to be unique in their extensive trigeminal innervation, which is used to supply the integumentary sensory organs (ISOs) involved with their facial somatosensory abilities. Crocodylians have a far higher number of foramina on the maxillary bones than either metriorhynchoids or *P. haughtoni*, suggesting that the fossil taxa lacked the somatosensory abilities seen in extant species. We posit that the lack of ISO osteological correlates in metriorhynchoids is due to their basal position in Crocodyliformes, rather than a pelagic adaptation. This is reinforced by the hypothesis that extant crocodyliforms, and possibly some neosuchian clades, underwent a long "nocturnal bottleneck"- hinting that their complex network of ISOs evolved in Neosuchia, as a sensory trade-off to compensate for poorer eyesight.

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Cowgill, T., Young, M.T., Schwab, J.A., Walsh, S., Witmer, L.M., Herrera, Y., Dollman, K.N., Choiniere, J.N. and Brusatte, S.L. (2021). Paranasal sinus system and upper respiratory tract evolution in Mesozoic pelagic crocodylomorphs. The Anatomical Record (https://doi.org/10.1002/ar.24727).

Abstract: Thalattosuchians were a predominately marine clade of Mesozoic crocodylomorphs, including semi-aquatic teleosauroid and obligately pelagic metriorhynchid subclades. Recent advances in our understanding of thalattosuchian endocranial anatomy have revealed new details of the evolutionary transition from terrestrial to marine to pelagic taxa. Paranasal sinuses, however, have received little attention. Herein, we investigate the evolution of the paranasal sinus system and part of the upper respiratory system (nasopharyngeal ducts) in Thalattosuchia, by reconstructing the nasal and paranasal anatomy in CT scans of seven thalattosuchian skulls: one teleosauroid, two basal metriorhynchoids and four metriorhynchids. Our outgroups were: three extant crocodylian species (including adult and subadult skulls) and the basal crocodyliform *Protosuchus*. We found thalattosuchians exhibit exceptionally reduced paranasal sinus systems, solely comprising the antorbital sinus, as has been previously proposed. The semi-aquatic basal thalattosuchians *Palgiopthalmosuchus gracilirostris* and *Pelagosaurus typus* both have an antorbital sinus partially located medial to a reduced external antorbital fenestra and broadly communicating with the dorsal alveolar canal. In pelagic metriorhynchids, the antorbital cavity is more extensive than in basal taxa and possibly had an active function associated with a hypothesized accessory suborbital diverticulum, but our reconstructions are insufficient to confirm or reject the presence of such a diverticulum. The nasopharyngeal ducts of metriorhynchids are dorsoventrally enlarged, possibly enabling stronger ventilation. The sequence of acquisition of craniofacial adaptations show a mosaic pattern and appears to predate many skeletal adaptations, suggesting these changes occurred early in the thalattosuchian marine transition.

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Zwafing, M., Lautenschlager, S., Demuth, O.E. and Nyakatura, J.A. (2021). Modeling sprawling locomotion of the stem amniote *Orobates*: An examination of hindlimb muscle strains and validation using extant *Caiman*. Frontiers in Ecology and Evolution 9: 659039 (doi: 10.3389/fevo.2021.659039).

Abstract: The stem amniote *Orobates pabsti* has been reconstructed to be capable of relatively erect, balanced, and mechanically power-saving terrestrial locomotion. This suggested that the evolution of such advanced locomotor capabilities preceded the origin of crowngroup amniotes. We here further investigate plausible body postures and locomotion of *Orobates* by taking soft tissues into account. Freely available animation software BLENDER is used to first reconstruct the lines of action of hindlimb adductors and retractors for *Orobates* and then estimate the muscle strain of these muscles. We experimentally varied different body heights in modeled hindlimb stride cycles of *Orobates* to find the posture that maximizes optimal strains over the course of a stride cycle. To validate our method, we used *Caiman crocodilus*. We replicated the identical workflow used for the analysis of *Orobates* and compared the locomotor posture predicted for *Caiman* based on muscle strain analysis with this species' actual postural data known from a previously published X-ray motion analysis. Since this validation experiment demonstrated a close match between the modeled posture that maximizes optimal adductor and retractor

muscle strain and the *in vivo* posture employed by *Caiman*, using the same method for *Orobates* was justified. Generally, the use of muscle strain analysis for the reconstruction of posture in quadrupedal vertebrate fossils thus appears a promising approach. Nevertheless, results for *Orobates* remained inconclusive as several postures resulted in similar muscle strains and none of the postures could be entirely excluded. These results are not in conflict with the previously inferred moderately erect locomotor posture of *Orobates* and suggest considerable variability of posture during locomotion.

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Rosenblatt, A.E., Lardizabal, K., Li, F., Holland, A., Lawrence, D. and Taylor, P. (2021). Tourism value of crocodilians: The Black caiman (*Melanosuchus niger*) as a case study. Herpetologica (https://doi.org/10.1655/Herpetologica-D-21-00017.1).

Abstract: Wildlife tourism, including tourism involving large predators, is a rapidly growing industry that can generate many conservation and economic benefits. Monetary values can be derived for populations of large predators, and even individuals, on the basis of how much money tourists spend to see and interact with these awe-inspiring animals, but valuation studies only exist for a few groups of species. To help fill this gap we quantified the monetary value of crocodilians that are the focus of a wildlife tourism business in South America, the first time such a value has been calculated for crocodilians. We also compared the monetary values we derived with the monetary values of other crocodilians harvested in the hunting and farming industries during the same time period (2009-2014). We found mean minimum and maximum gross values of individual crocodilians per year as part of wildlife tourism were $US422.00 and $US566.67, respectively, both higher than the mean gross value of individual crocodilians per year across hunting and farming industries ($US300.29). Individual crocodilians that were recaptured multiple times as part of wildlife tourism activities reached a peak value of $US2700.00. Thus, our study demonstrates that wildlife tourism can create substantial monetary incentives for local communities that coexist with crocodilians to work toward conservation goals. We conclude that wildlife tourism focused on crocodilians should be viewed as part of a larger strategy for conserving threatened populations, one that may include partners in the farming and hunting industries as well.

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Heckert, A.B., Martinez, R.N. and Celeskey, M.D. (2021). Anatomical details of Aetosauria (Archosauria: Pseudosuchia) as revealed by an articulated posterior skeleton from the Upper Triassic Ischigualasto Formation, San Juan Province, Argentina. Ameghiniana (doi: 10.5710/AMGH.05.09.2021.3426).

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McPherron, S.P., Archer, W., Otárola-Castillo, E.R., Torquato, M.G. and Keevil, T.L. (2021). Machine learning, bootstrapping, null models, and why we are still not 100% sure which bone surface modifications were made by crocodiles. Journal of Human Evolution (doi: 10.1016/j.jhevol.2021.103071).

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Mitova, E. and Wittnich, C. (2021). Cardiac structures in marine animals provide insight on potential directions for interventions for pediatric congenital heart defects. American Journal Physiology: Heart and Circulatory Physiology (doi: 10.1152/ajpheart.00451.2021).

Abstract: Despite recent advances in pediatric diagnosis and surgical intervention, mortality and morbidity continue to be a prevalent issue in both Tetralogy of Fallot (ToF) and Hypoplastic Left Heart Syndrome (HLHS). Therefore, novel approaches to studying both of these conditions is warranted. Investigating cardiac anatomical features of different species in the animal kingdom similar to the defects and complications present in ToF and HLHS (as well as others) could serve as a new avenue for improving the management of congenital heart diseases (CHD). This review reveals that although structures found in HLHS and ToF are pathological, similar structures are found in diving mammals and reptiles that are adaptive. Pathologic aortic dilation in CHD resembles the aortic bulb present in diving mammals, but the latter is more elastic and distensible compared to the former. The unrepaired HLHS heart resembles the univentricular heart of non-crocodilian reptiles. Right ventricle hypertrophy is pathological in HLHS and ToF, but adaptive in crocodilians and diving mammals. Lastly, the increased pulmonary resistance due to pulmonary stenosis in ToF is comparable to increased pulmonary resistance in crocodilians due to the presence of an active valve proximal to the pulmonary valve. Some of these anatomical structures could potentially be adapted for palliative surgery in children with HLHS or ToF. Moreover, further investigating the underlying molecular signals responsible for the adaptive tissue responses seen in other species may also be useful for developing novel strategies for preventing some of the complications that occur after surgical repair in both of these CHDs.

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Suarez, C.A., Frederickson, J., Cifelli, R.L., Pittman, J.G., Nydam, R.L., Hunt-Foster, R.K. and Morgan, K. (2021). A new vertebrate fauna from the Lower Cretaceous Holly Creek Formation of the Trinity Group, southwest Arkansas, USA. PeerJ 9: e12242.

Abstract: We present a previously discovered but undescribed late Early Cretaceous vertebrate fauna from the Holly Creek Formation of the Trinity Group in Arkansas. The site from the ancient Gulf Coast is dominated by semi-aquatic forms and preserves a diverse aquatic, semi-aquatic, and terrestrial fauna. Fishes include fresh- to brackish-water chondrichthyans and a variety of actinopterygians, including semionotids, an amiid, and a new pycnodontiform, *Anomoeodus caddoi* sp. nov. Semi-aquatic taxa include lissamphibians, the solemydid turtle *Naomichelys*, a trionychid turtle, and coelognathosuchian crocodyliforms. Among terrestrial forms are several members of Dinosauria and one or more squamates, one of which, *Sciroseps pawhuskai* gen. et sp. nov., is described herein. Among Dinosauria, both large and small theropods (*Acrocanthosaurus*, *Deinonychus* and *Richardoestesia*) and titanosauriform sauropods are represented; herein we also report the first occurrence of a nodosaurid ankylosaur from the Trinity Group. The fauna of the Holly Creek Formation is similar to other, widely scattered late Early Cretaceous assemblages across North America and suggests the presence of a low-diversity, broadly distributed continental ecosystem of the Early Cretaceous following the Late Jurassic faunal turnover. This low-diversity ecosystem contrasts sharply with the highly diverse ecosystem which emerged by the Cenomanian. The contrast underpins the importance of vicariance as an evolutionary driver brought on by Sevier tectonics and climatic changes, such as rising sea level and formation of the Western Interior Seaway, impacting the early Late Cretaceous ecosystem.

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Bestwick, J., Jones, A.S., Nesbitt, S.J., Lautenschlager, S., Rayfield, E.J., Cuff, A.R., Button, D.J., Barrett, P.M., Porro, L.B. and Butler, R.J. (2021). Cranial functional morphology of the pseudosuchian *Effigia* and implications for its ecological role in the Triassic. The Anatomical Record (https://doi.org/10.1002/ar.24827).

Abstract: Pseudosuchians, archosaurian reptiles more closely related to crocodylians than to birds, exhibited high morphological diversity during the Triassic with numerous examples of morphological convergence described between Triassic pseudosuchians and post-Triassic dinosaurs. One example is the shuvosaurid *Effigia okeeffeae* which exhibits an "ostrich-like" bauplan comprising a gracile skeleton with edentulous jaws and large orbits, similar to ornithomimid dinosaurs and extant palaeognaths. This bauplan is regarded as an adaptation for herbivory, but this hypothesis assumes morphological convergence, confers functional convergence, and has received little explicit testing. Here, we restore the skull morphology of *Effigia*, perform myological reconstructions, and apply finite element analysis to quantitatively investigate skull function. We also perform finite element analysis on the crania of

the ornithomimid dinosaur *Ornithomimus edmontonicus*, the extant palaeognath Struthio camelus and the extant pseudosuchian *Alligator mississippiensis* to assess the degree of functional convergence with taxa that exhibit "ostrich-like" bauplans and its closest extant relatives. We find that *Effigia* possesses a mosaic of mechanically strong and weak features, including a weak mandible that likely restricted feeding to the anterior portion of the jaws. We find limited functional convergence with *Ornithomimus* and *Struthio* and limited evidence of phylogenetic constraints with extant pseudosuchians. We infer that *Effigia* was a specialist herbivore that likely fed on softer plant material, a niche unique among the study taxa and potentially among contemporaneous Triassic herbivores. This study increases the known functional diversity of pseudosuchians and highlights that superficial morphological similarity between unrelated taxa does not always imply functional and ecological convergence.

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Rytwinski, T., Öckerman, S.L.A., Taylor, J.J., Bennett, J.R., Muir, M.J., Miller, J.R.B., Pokempner, A., Lam, W.Y., Pickles, R.S.A. and Cooke, S.J. (2021). What is the evidence that counter-wildlife crime interventions are effective for conserving African, Asian and Latin American wildlife directly threatened by exploitation? A systematic map protocol. Ecological Solutions and Evidence 2(4): e12104.

Abstract: Human activities are driving a global biodiversity crisis. In response, a broad range of conservation actions have been implemented. With finite resources available, and a rapidly narrowing window, the scientific and policy communities have acknowledged the need to better understand the effectiveness of interventions for conserving threatened species. Given the recent emphasis on the use of counter wildlife crime interventions (ie those that directly protect wildlife from illegal harvest, detect and sanction rule-breakers, and interdict and control illegal wildlife commodities), there is a clear need to summarize the available evidence on biological and threat reduction outcomes of such actions to help make evidence-informed management and funding decisions. Here, we present a protocol for a systematic map that will collate the existing body of literature addressing the effectiveness of counter-wildlife crime interventions for protecting targeted species. Our focus will be on select species or species groups directly threatened by exploitation (ie illegal harming whether by harvest as a resource or for control/persecution) and native to Africa, Asia and Latin America, which are regions that have experienced significant wildlife populations declines. The systematic map will aim to capture available evidence found in commercially published and grey literature. We will search for the literature using four publication databases, Google Scholar, 36 specialist websites and databases and sources identified through a call for evidence among relevant networks. Eligibility screening will be conducted at two stages: (1) title and abstract and (2) full text. Relevant information from included papers will be extracted and entered into a searchable, coded database (MS-Excel). Narrative synthesis and descriptive statistics will describe the key characteristics of the relevant evidence base (e.g. geographic location, species, interventions, direct threats, outcomes and study designs). Using visual heat maps, we will identify key knowledge gaps warranting further research and clusters of evidence that could serve as topics for future systematic reviews. The resulting map will guide further exploration on evaluating the effectiveness of counter-wildlife crime interventions, and aid in building an evidence base that supports both management and funding decisions to ensure efficient use of limited resources and maximal conservation benefits.

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Cieri, R.L., Turner, M.L., Carney, R.M., Falkingham, P.L., Kirk, A.M., Wang, T., Jensen, B., Novotny, J., Tveite, J., Gatesy, S.M., Laidlaw, D.H., Kaplan, H., Moorman, A.F.M., Howell, M., Engel, B., Cruz, C., Smith, A., Gerichs, W., Lian, Y., Schultz, J.T. and Farmer, C.G. (2021). Virtual and Augmented Reality: new tools for visualizing, analyzing, and communicating complex morphology. Journal of Morphology (https://doi.org/10.1002/jmor.21421).

Abstract: Virtual and augmented reality (VR/AR) are new technologies with the power to revolutionize the study of morphology. Modern imaging approaches such as computed tomography, laser scanning, and photogrammetry have opened up a new digital world, enabling researchers to share and analyze morphological data electronically and in great detail. Because this digital data exists on a computer screen, however, it can remain difficult to understand and unintuitive to interact with. VR/AR technologies bridge the analog-to-digital divide by presenting 3D data to users in a very similar way to how they would interact with actual anatomy, while also providing a more immersive experience and greater possibilities for exploration. This manuscript describes VR/AR hardware, software, and techniques, and is designed to give practicing morphologists and educators a primer on using these technologies in their research, pedagogy, and communication to a wide variety of audiences. We also include a series of case studies from the presentations and workshop given at the 2019 International Congress of Vertebrate Morphology, and suggest best practices for the use of VR/AR in comparative morphology.

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Canudo, J.I., Badiola, A., Belmonte, A., Cardiel, J., Cuenca-Bescos, G., Diaz Berenguer, E., Ferratges, F., Moreno Azanza, M., Perez Garcia, A., Perez Pueyo, M., Silva Casal, R. and Zamora Iranzo, S. (2021). A window onto the Eocene (Cenozoic): The palaeontological record of the Sobrarbe-Pirineos UNESCO Global Geopark (Huesca, Aragon, Spain). Geoconservation Research (doi: 10.30486/GCR.2021.1912263.1043).

Abstract: The Sobrarbe-Pirineos UNESCO Global Geopark, located in the Central Pyrenees, is a region of remarkable geodiversity that includes extensive Eocene fossil-bearing sites and constitutes an important archive of paleobiodiversity. The Sobrarbe-Pirineos Geopark hosts outcrops of Eocene formations bearing an unusual abundance and diversity of fossils from marine and continental sedimentary environments, making the Sobrarbe-Pirineos Geopark a perfect window for learning about tropical ecosystems of the Eocene of southern Europe. These environments were in part tectonically controlled and offer a unique opportunity to understand how faunas changed in an active area. Here, we outline the main groups of fossils from the Sobrarbe-Pirineos Geopark, including popular examples such as the "Crocodile of Ordesa-Vio" and the sirenian Sobrarbesiren. The Geopark has been a major tool in the geoconservation of Eocene fossils.

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Faure-Brac, M.G., Amiot, R., de Muizon, C., Cubo, J. and Lécuyer, C. (2021). Combined paleohistological and isotopic inferences of thermometabolism in extinct Neosuchia, using *Goniopholis* and *Dyrosaurus* (Pseudosuchia: Crocodylomorpha) as case studies. Paleobiology (doi: 10.1017/pab.2021.34).

Abstract: The evolution of thermometabolism in pseudosuchians (Late Triassic to the present) remains a partly unsolved issue: extant taxa (crocodilians) are ectothermic, but the clade was inferred ancestrally endothermic. Here we inferred the thermometabolic regime of two neosuchian groups, Goniopholididae (Early Jurassic to Late Cretaceous) and Dyrosauridae (middle Cretaceous to late Eocene), close relatives of extant crocodilians, in order to elucidate the evolutionary pattern across Metasuchia (Early Jurassic to the present), a clade comprising Neosuchia (Early Jurassic to the present) and Notosuchia (Middle Jurassic until the late Miocene). We propose a new integrative approach combining geochemical analyses to infer body temperature from the stable oxygen isotope composition of tooth phosphate and paleohistology and phylogenetic comparative methods to infer resting metabolic rates and red blood cell dimensions. *Dyrosaurus* and *Goniopholis* share with extant crocodilians similar lifestyles, body forms, bone tissue organization, body temperatures, metabolic rates, and red blood cell dimensions. Consistently, we infer ectothermy for *Dyrosaurus* and *Goniopholis* with the parsimonious implication of neosuchians and metasuchians being primitively ectothermic.

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Thépot, D. (2021). Sex chromosomes and master sex-determining genes in turtles and other reptiles. Genes 12: 1822.

Abstract: Among tetrapods, the well differentiated heteromorphic sex chromosomes of birds and mammals have been highly investigated and their master sex-determining (MSD) gene, Dmrt1 and SRY, respectively, have been identified. The homomorphic sex chromosomes of reptiles have been the least studied, but the gap with birds and mammals has begun to fill. This review describes our current knowledge of reptilian sex chromosomes at the cytogenetic and molecular level. Most of it arose recently from various studies comparing male to female gene content. This includes restriction site-associated DNA sequencing (RAD-Seq) experiments in several male and female samples, RNA sequencing and identification of Z- or X-linked genes by male/female comparative transcriptome coverage, and male/female transcriptomic or transcriptome/genome substraction approaches allowing the identification of Y- or W-linked transcripts. A few putative master sexdetermining (MSD) genes have been proposed, but none has been demonstrated yet. Lastly, future directions in the field of reptilian sex chromosomes and their MSD gene studies are considered.

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Rosenblatt, A.E., Li, F., Kalicharan, L. and Taylor, P. (2021). What do adult black caiman (*Melanosuchus niger*) actually eat? Biotropica (https://doi.org/10.1111/btp.13038).

Abstract: The Black caiman (*Melanosuchus niger*) is one of the largest predators in South America, yet we know little about adult diets. We studied stomach contents of adults in Guyana and found the largest individuals target mammals instead of fish and males exhibit cannibalism, a behavior never recorded for this species previously.

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Hewitt, L. and Small, A. (2021). Welfare of farmed crocodilians: Identification of potential animal-based measures using elicitation of expert opinion. Animals 11: 3450 (https://doi.org/10.3390/ani11123450).

Abstract: Animal-based measures are the measure of choice in animal welfare assessment protocols as they can often be applied completely independently to the housing or production system employed. Although there has been a small body of work on potential animal-based measures for farmed crocodilians [1-3], they have not been studied in the context of an animal welfare assessment protocol. Potential animal-based measures, that could be used to reflect the welfare state of farmed crocodilians, were identified and aligned with the Welfare Quality® principles of good housing, good health, good feeding and appropriate behaviour. A consultation process with a panel of experts was used to evaluate and score the potential measures in terms of validity and feasibility. This resulted in a toolbox of measures being identified for further development and integration into animal welfare assessment on the farm. Animal-based measures related to 'good feeding' and 'good health' received the highest scores for validity and feasibility by the experts. There was less agreement on the animal-based measures that could be used to reflect 'appropriate behaviour'. Where no animal-based measures were deemed to reliably reflect a welfare criterion nor be useful as a measure on the farm, additional measures of resources or management were suggested as alternatives. Future work in this area should focus on the reliability of the proposed measures and involve further evaluation of their validity and feasibility as they relate to different species of crocodilian and farming system.

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Zamora-Perez, A.L., Luna-Aguirre, J., Zúñiga-González, G.M., Torres-Bugarín, O., Torres-Mendoza, B.M., Gallegos-Arreola, M.P., Ortiz-García, R.G., Gutiérrez-Sevilla, J.E. and Gómez-Meda, B.C. (2021). Micronuclei and nuclear buds induced by cyclophosphamide in *Crocodylus moreletii* as useful biomarkers in aquatic environments. Animals 11: 3178.

Abstract: Micronuclei (MN) are used to assess genotoxic exposure, whereas nuclear buds (NBs) have been linked to genotoxic events. *Crocodylus moreletii* was studied to identify MN and NBs. Three groups were formed: Group 1 (water) and groups 2 and 3 (7 or 10 mg/kg of cyclophosphamide). A drop of blood was obtained daily from the claw tip at 0 to 120 h. Spontaneous micronucleated erythrocytes (MNEs) and erythrocytes with nuclear buds (NBEs) were counted. The frequencies of micronucleated young erythrocytes (MNYEs) and NB young erythrocytes (NBYEs) were evaluated, including the ratio of young erythrocytes (YE)/1000 total erythrocytes. No significant differences were observed in the YE proportion on sampling days; group 1 did not show differences for any parameter, whereas group 2 showed significant differences in MNEs and NBEs, and group 3 showed differences in NBEs and NBYEs. Some mitotic activity in circulation was observed in YEs. In conclusion, NBEs could be a more sensitive biomarker to genotoxic damage than MNEs. The identification of these biomarkers leads us to propose *C. moreletii* as a possible environment bioindicator because these parameters could be useful to analyze the *in vivo* health status of these reptiles and for biomonitoring genotoxic pollutants in their habitats.

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Iijima, M., Munteanu, V.D., Elsey, R.M. and Blob, R.W. (2021). Ontogenetic changes in limb posture, kinematics, forces, and joint moments in American alligators (*Alligator mississippiensis*). Journal of Experimental Biology (https://doi.org/10.1242/jeb.242990).

Abstract: As animals increase in size, common patterns of morphological and physiological scaling may require them to perform behaviors such as locomotion while experiencing a reduced capacity to generate muscle force and an increased risk of tissue failure. Large mammals are known to manage increased mechanical demands by using more upright limb posture. However, the presence of such size-dependent changes in limb posture has rarely been tested in animals that use non-parasagittal limb kinematics. Here, we used juvenile to subadult American alligators (total length 0.46-1.27 m, body mass 0.3-5.6 kg) and examined their limb kinematics, forces, joint moments, and center of mass to test for ontogenetic shifts in posture and limb mechanics. Larger alligators typically walked with a more adducted humerus and femur and a more extended knee. Normalized peak joint moments reflected these postural patterns, with shoulder and hip moments imposed by the ground reaction force showing relatively greater magnitudes in the smallest individuals. Thus, as larger alligators use more upright posture, they incur relatively smaller joint moments than smaller alligators, which could reduce the forces that the shoulder and hip adductors of larger alligators must generate. The center of mass (CoM) shifted nonlinearly from juveniles through subadults. The more anteriorly positioned CoM in small alligators, together with their compliant hindlimbs, contributes to their higher forelimb and lower hindlimb normalized peak vertical forces in comparison to larger alligators. Future studies of alligators that approach maximal adult sizes could give further insight into how animals with non-parasagittal limb posture modulate locomotor patterns as they increase in mass and experience changes in the CoM.

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Pritz, M.B. (2021). Do crocodiles have a zona incerta? The Journal of Comparative Neurology (https://doi.org/10.1002/cne.25269).

Abstract: In mammals, the zona incerta is thought to be involved in a number of behaviors: visceral activity, arousal, attention, and posture and locomotion. These diverse and complex features suggested that the zona incerta functions as a global or integrative node. Nevertheless, despite multiple investigations into its anatomy, physiology, and behavior in a variety of mammals, no specific character identifies the zona incerta besides its appearance in fiber-stained material and its relationship to surrounding structures. One such structure is the thalamic reticular nucleus whose caudal pole often contains some intermingled cells of the zona incerta. In crocodilians, the entopeduncular nucleus (ep) abuts the caudal pole of the thalamic reticular nucleus and displays different

immunohistochemical properties and soma size when compared with neurons in the thalamic reticular nucleus itself. To determine if neurons in the ep differed from those in the thalamic reticular nucleus in *Alligator mississippiensis*, the ep was investigated using Golgi methodology. The morphology and soma size of neurons in the ep differed from those in the thalamic reticular nucleus and indicated that these two areas are indeed separate neuronal aggregates. Based on these data and the known relationships of the zona incerta to surrounding structures in mammals, the ep of crocodilians is suggested to be the counterpart of the zona incerta of mammals.

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Hilevski Loreto, S. and Siroski, P.A. (2021). A novel laxative method for crocodilians and digestibility of soybean (*Glicine max*) in broad-snouted caiman (*Caiman latirostris*). Aquaculture.

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 crocodilians may serve to aid digestion and absorption of dietary nutrients, and not act only as gastroliths. This information could be used to develop crocodilian diets and assist future research to determine optimum nutrient levels and ingredient combinations for farm-raised crocodilians fed compounded diets.

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Bautista, N.M., Petersen, E.E., Jensen, R.J., Natarajan, C., Storz, J.F., Crossley II, D.A. and Fago, A. (2021). Changes in hemoglobin function and isoform expression during embryonic development in the American alligator, *Alligator mississippiensis*. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology 321(6) (https://doi.org/10.1152/ajpregu.00047.2021).

Abstract: In the developing embryos of egg-laying vertebrates, $O_2$ flux takes place across a fixed surface area of the eggshell and the chorioallantoic membrane. In the case of crocodilians, the developing embryo may experience a decrease in $O_2$ flux when the nest becomes hypoxic, which may cause compensatory adjustments in blood $O_2$ transport. However, whether the switch from embryonic to adult hemoglobin isoforms (isoHbs) plays some role in these adjustments is unknown. Here, we provide a detailed characterization of the developmental switch of isoHb synthesis in the American alligator, *Alligator mississippiensis*. We examined the *in vitro* functional properties and subunit composition of purified alligator isoHbs expressed during embryonic developmental stages in normoxia and hypoxia (10% $O_2$). We found distinct patterns of isoHb expression in alligator embryos at different stages of development, but these patterns were not affected by hypoxia. Specifically, alligator embryos expressed two main isoHbs: HbI, prevalent at early developmental stages, with a high $O_2$ affinity and high ATP sensitivity, and HbII, prevalent at later stages and identical to the adult protein, with a low $O_2$ affinity and high $CO_2$ sensitivity. These results indicate that whole blood $O_2$ affinity is mainly regulated by ATP in the early embryo and by $CO_2$ and bicarbonate from the late embryo until adult life, but the developmental regulation of isoHb expression is not affected by hypoxia exposure.

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Pellegrini, R.A., Callahan, W.R., Hastings, A.K., Parris, D.C. and McCauley, J.D. (2021). Skeletochronology and paleohistology of *Hyposaurus rogersii* (Crocodyliformes, Dyrosauridae) from the Early Paleogene of New Jersey, USA. Animals 11: 3067.

Abstract: The paleohistology of dyrosaurids is known from a small sample, despite being common fossils and representing a rare lineage of crocodylomorphs that survived the Cretaceous-Paleogene extinction. Their lifestyle has been inferred only from sections of the snout, vertebrae, partial femur, and tibia. To improve this, we conducted a skeletochronological and paleohistological study of midshaft cross-sections of both femora and humeri of a nearly complete *Hyposaurus rogersii* skeleton. We found lamellar-zonal bone that underwent remodeling, evidenced by resorption cavities and abundant secondary osteons within the primary periosteal cortex. The osteons, mostly longitudinally oriented and arranged in circular rows, often anastomose radially along a linear path, resembling radial rows. The medullary cavity is completely open, lacking trabeculae: endosteal deposition is limited to thin lamellae surrounding the cavity. Analysis of cyclical growth marks and the presence of an external fundamental system indicate the specimen was a fully mature adult 17-18 years of age. Comparison of the skeleton to others suggests sexual dimorphism and that it was female. The open medullary cavity, and no evidence for pachyosteosclerosis, osteosclerosis, osteoporosis, or pachyostosis indicate *H. rogersii* was not a deep diver or a fast swimmer in the open ocean but a near-shore marine ambush predator.

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Farris, S.C., Waddle, J.H., Hackett, C.E., Brandt, L.A. and Mazzotti, F.J. (2021). Hierarchical models improve the use of alligator abundance as an indicator. Ecological Indicators 133 (https://doi.org/10.1016/j.ecolind.2021.108406).

Abstract: Indicator species are species which can be monitored as an index to measure the overall health of an ecosystem. Crocodylians have been shown to be good indicators of wetland condition as they respond to changes in hydrology, can be efficiently monitored, and are a key part of ecosystem trophic relationships. Eye shine surveys at night are a standard method used to sample alligators, but because some individuals that are present in a study area may go undetected and the proportion of individuals counted is not constant over time, appropriate modeling is required to convert counts to estimates of abundance. We analyzed 13 years of American alligator (*Alligator mississippiensis*) survey count data from South Florida using an N-mixture model. Alligator abundance estimates were assigned to quartiles that were then represented as color coded categories of red, yellow, or green to provide a straightforward rating of Everglades restoration based on familiar stoplight coloring. These results were then compared to a previously used method in which unadjusted counts of these same data were assigned to color coded quartile categories. Water depth played a major role in the detection probability of alligators and the stoplight colors between the two methods matched 76% of the time. This suggests that the original stoplight score method provided a good overall snapshot of the trends in alligator abundance in the Everglades; however, the hierarchical models estimate abundance and trends of alligator abundance by incorporating detection probability thus providing unbiased estimates of abundance.

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Karikalan, M., Sandeep, G., Manish, K., Athira, C.K., Beena, V., Rahul G., K., Mohan, C.S., Abhijit M., P. and Sharma, A.K. (2021). Septicaemic form of *Aeromonas hydrophila* infection in a mugger crocodile (*Crocodylus palustris*). Indian Journal of Veterinary Pathology 45(3): 217-220.

Abstract: The present report describes *Aeromonas hydrophila* associated septicaemia and its molecular characterization in free

range Indian mugger crocodile. A carcass of male free ranging mugger crocodile was presented for necropsy examination. Grossly, multiple old cutaneous wounds with necrotic debris throughout the body, severely congested and haemorrhagic gastrointestinal tracts and other visceral organs were observed. Histopathological examination revealed necrosed superficial epidermis extending deep into the dermis and surrounded by infiltration of heterophils and macrophages with haemorrhages. Similarly, the gastrointestinal tract and other visceral organs showed severely engorged blood capillaries with extravasation of red blood cells, degeneration and severe infiltration of polymorphonuclear leukocytes and large mononuclear cells especially macrophages. Large numbers of bacterial colonies were also found in the necrosed areas of the skin, heart and gastrointestinal mucosa. *A. hydrophila* was isolated from the skin scrapings, heart blood and intestinal contents. *A. hydrophila* strain was found to be virulent as it was found positive for aerolysin, AHCYTOEN, cytotonic enterotoxin and lipase genes. Antibiotic sensitivity test revealed that the isolate was resistant to ampicillin and cefazolin and sensitive to Ceftriaxone, Ciprofloxacin, Trimethoprim-Sulfamethoxazole, Amikacin and levofloxacin but partially susceptible to imipenem antibiotics.

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Takamine, C.N., Carvalho, H.J.C., Araujo, M.S., Ribeiro, R.R., Miglino, M.A. and De Melo, A.P.F. (2021). Anatomo-histological evaluation of male reproductive system of the juvenile *Caiman crocodilus yacare*. International Journal of Morphology 39(6): 1688-1693.

Abstract: The *Caiman crocodilus yacare* was once close to extinction. Studies about the male reproductive tract may aid in their reproduction and conservation. In this work, after sedation and euthanasia, seven young male *C. yacare* were submitted to necropsy, and macroscopic evaluation of the reproductive system, while the three others were admitted for histological study. The histological sections were stained with hematoxylin & eosin and Masson's Trichrome. After opening the pleuroperitoneal cavity it was possible toidentify that the testicles were disposed in pairs and attached to its dorsal surface. The epididymis showed elongated and convoluted shapes and were located at the cranial margin of the testicles, following its medial portion, which was the same portion that the "vas deferens" stems from until the opening of the cloaca. The crocodile phallus presented a tubular shape, with conical appearance, displaying little resistance while maintaining its flexibility, compatible with a fibrocartilaginous tissue. On light microscopic analysis it was possible to observe that the testis was delimited by the tunica albuginea. The seminiferous tubules were contorted, and the interstitial space wasfilled with interstitial tissue and Leydig cells. The epididymal ductus were covered with non-ciliated pseudostratified epithelium withcells varying between cuboidal and prismatic shapes. The ductus deferens were characterized by a narrow girth shrouded with non-ciliated pseudostratified prismatic epithelium. The phallus of the crocodile was covered with a non-keratinized squamous epithelium surrounded by connective tissue. The findings support anatomic and histologic knowledge Alligatoridae reproductive system, enabling further research in the *C. yacare* reproduction and conservation.

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Stinson, M. (2021). "I see you; you see me": How a crocodile sanctuary can teach us to create a more sustainable future with our cohabitants. Symposium of University Research and Creative Expression (SOURCE) 26 (https://digitalcommons.cwu.edu/source/2021/COTS/26).

Abstract: Mexico is a diverse and wonderful place for cultures, biospheres, and organisms. Along the Costalegre region of Jalisco there is a vast expanse of habitat called the Chamela-Cuixmala Reserve. Located just south of the reserve is El Cocodrilario de La Manzanilla. El Cocodrilario means crocodile sanctuary, and at just over one 260 hectares, there isn't much free space to spare for nearly 500 hatchlings to fully grown crocodiles. It is operated by a local cocodrilo enthusiast, Pepe Martinez, and was granted its space through the dictation of land action by the Mexican ejido system. Any visiting tourist can pay a fee and experience these behemoths gliding through the water under their feet, view them from a lofty sight tower, and even hold baby crocodiles guided by skilled biologists. El Cocodrilario encourages its municipal locals to visit at a mere fraction of the price in an effort to spread educational material and awareness about this widely feared reptile. This paper analyzes how the use of space balances a close, intimate understanding of crocodiles with a respectful distance and admiration for these creatures. Multiple intersections of bio-tourism, conservation, and preservation create the Cocodrilario's unique environment. The integration of all three provide the resources for people to become educated about animals in a way that promotes a sustainable relationship between people and one of the world's oldest apex predators.

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Wang, Z., Lin, J., Zhong, G., Sun, L. and Fang, S. (2021). Terrestrial habitats in Changxing Chinese Alligator Nature Reserve of Zhejiang and their effects on the egg laying of the female alligators. Journal of Zhejiang University (Agriculture and Life Sciences) 47(5): 598-606.

Abstract: In this research, we surveyed the habitat factors in different regions in the core area of Changxing Chinese Alligator (*Alligator sinensis*) Nature Reserve of Zhejiang Province and their effects on the egg laying of the female alligators during the breeding season. The results revealed that the female alligators preferred to build nests on the regions covered with dense bamboo groves or tall trees. Few nests were found on the regions dominated by weeds and with few tall dominant trees. Investigation on the habitat factors in different regions showed that the dry mass of litter per unit surface area, the height of dominant species and the surface slope were the three major factors that affected the female alligators to choose the site for nesting. The above results could provide references for the habitat optimal transformation, and for the novel habitat selection. Our results could also facilitate the development of conservation programs for Chinese alligator.

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Wu, S., Xu, Y., Feng, W., Hu, Y., Nie, Y., Li, X., Wu, J. and Mai, B. (2021). Residues of DDT and its metabolites in the sediments from a captive breeding center for Chinese alligator. Environmental Chemistry 40(11): 3406-3412.

Abstract: Captive breeding of the Chinese alligator serves as the last resort for *ex situ* conservation of this critically endangered species. However, this effort may be compromised by the environmental chemicals such as DDT-related compounds which are proposed stressors contributing to the declines in some crocodilian populations. Here, we reported the presence of DDT and its metabolites in the sediments from the largest captive breeding center for the Chinese alligator in China. The concentrations of ∑DDXs (sum of the concentrations of DDT and its metabolites) in the sediments ranged from 4.30 to 11.9 $ng \cdot g^{-1}$ dry weight, with significantly higher levels in autumn than spring. The most abundant DDT compound in the sediments was p,p'-DDE, comprising approximately 73% of the ∑DDXs. In particular, two high-order metabolites of DDT, p,p'-DDMU and -DDM, were also consistently detected in the sediments, with contributions of 6.5% and 0.5% to the ∑DDXs, respectively. The profiles of DDT isomers and its metabolites indicated that there is no DDT fresh input in the captive breeding center. The concentrations of DDE and DDT in the sediment samples clearly exceeded the threshold effects level set in sediment quality guidelines, suggesting potential ecological risks of these chemicals.

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Andriyono, S. and Sukistyanawati, A. (2021). New record of Saltwater crocodile *Crocodylus porosus* Schneider, 1801 from East coast mangrove ecosystem in Surabaya, East Jawa, Indonesia. Journal of Aquaculture Science 6(2): 110-114.

Abstract: A single specimen of Saltwater crocodile *Crocodylus porosus* Schneider, 1801 (1.50 m in length) was captured and

photographed by a local fisherman by gill net at fishpond around mangrove ecosystem of east coast Surabaya on December 2020. The location wherethe estuarine crocodile caught is an important wetland area in Surabaya with an excellent mangrove cover. Wonorejo mangrove location is about 10 km from the center of Surabaya, the second-largest city in Indonesia. This finding is considered as a first report of *C. porosus* in Surabaya, and at the same time is proof of the importance of the mangrove area on the east coast of Surabaya as a habitat for wildlife that must be conserved appropriately. Routine monitoring of mangrove areas, including their wildlife, is essential so that they are not displaced by the development of the city which changes the land function to become a residential area.

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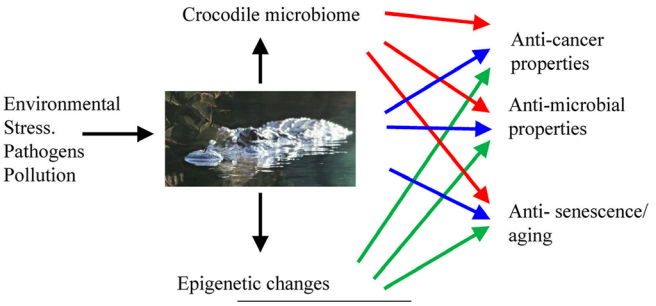
Grigg, G., Nowack, J., Bicudo, J.E.P.W., Bal, N.C., Woodward, H.N. and Seymour, R.S. (2021). Whole-body endothermy: Ancient, homologous and widespread among the ancestors of mammals, birds and crocodylians. Biological Reviews (doi: 10.1111/brv.12822).

Abstract: The whole-body (tachymetabolic) endothermy seen in modern birds and mammals is long held to have evolved independently in each group, a reasonable assumption when it was believed that its earliest appearances in birds and mammals arose many millions of years apart. That assumption is consistent with current acceptance that the non-shivering thermogenesis (NST) component of regulatory body heat originates differently in each group: from skeletal muscle in birds and from brown adipose tissue (BAT) in mammals. However, BAT is absent in monotremes, marsupials, and many eutherians, all whole-body endotherms. Indeed, recent research implies that BAT-driven NST originated more recently and that the biochemical processes driving muscle NST in birds, many modern mammals and the ancestors of both may be similar, deriving from controlled 'slippage' of $Ca^{2+}$ from the sarcoplasmic reticulum $Ca^{2+}$-ATPase (SERCA) in skeletal muscle, similar to a process seen in some fishes. This similarity prompted our realisation that the capacity for whole-body endothermy could even have pre-dated the divergence of Amniota into Synapsida and Sauropsida, leading us to hypothesise the homology of whole-body endothermy in birds and mammals, in contrast to the current assumption of their independent (convergent) evolution. To explore the extent of similarity between muscle NST in mammals and birds we undertook a detailed review of these processes and their control in each group. We found considerable but not complete similarity between them: in extant mammals the 'slippage' is controlled by the protein sarcolipin (SLN), in birds the SLN is slightly different structurally and its role in NST is not yet proved. However, considering the multimillions of years since the separation of synapsids and diapsids, we consider that the similarity between NST production in birds and mammals is consistent with their whole-body endothermy being homologous. If so, we should expect to find evidence for it much earlier and more widespread among extinct amniotes than is currently recognised. Accordingly, we conducted an extensive survey of the palaeontological literature using established proxies. Fossil bone histology reveals evidence of sustained rapid growth rates indicating tachymetabolism. Large body size and erect stature indicate high systemic arterial blood pressures and four-chambered hearts, characteristic of tachymetabolism. Large nutrient foramina in long bones are indicative of high bone perfusion for rapid somatic growth and for repair of microfractures caused by intense locomotion. Obligate bipedality appeared early and only in whole-body endotherms. Isotopic profiles of fossil material indicate endothermic levels of body temperature. These proxies led us to compelling evidence for the widespread occurrence of whole-body endothermy among numerous extinct synapsids and sauropsids, and very early in each clade's family tree. These results are consistent with and support our hypothesis that tachymetabolic endothermy is plesiomorphic in Amniota. A hypothetical structure for the heart of the earliest endothermic amniotes is proposed. We conclude that there is strong evidence for whole-body endothermy being ancient and widespread among amniotes and that the similarity of biochemical processes driving muscle NST in extant birds and mammals strengthens the case for its plesiomorphy.

Siddiqui, R., Maciver, S., Elmoselhi, A., Soares, N.C. and Khan, N.A. (2021). Longevity, cellular senescence and the gut microbiome: Lessons to be learned from crocodiles. Heliyon (https://doi.org/10.1016/j.heliyon.2021.e08594).

Abstract: Crocodiles are flourishing large-bodied ectotherms in a world dominated by endotherms. They survived the Cretaceous extinction event, that eradicated the dinosaurs who are thought to be their ancestral hosts. Crocodiles reside in polluted environments; and often inhabit water which contains heavy metals; frequent exposure to radiation; feed on rotten meat and considered as one of the hardy species that has successfully survived on this planet for millions of years. Another capability that crocodiles possess is their longevity. Crocodiles live much longer than similar-sized land mammals, sometimes living up to 100 years. But how do they withstand such harsh conditions that are detrimental to *Homo sapiens*? Given the importance of gut microbiome on its' host physiology, we postulate that the crocodile gut microbiome and/or its' metabolites produce substances contributing to their "hardiness" and longevity. Thus, we accomplished literature search in PubMed, Web of Science and Google Scholar and herein, we discuss the composition of the crocodile gut microbiome, longevity and cellular senescence in crocodiles, their resistance to infectious diseases and cancer, and our current knowledge of the genome and epigenome of these remarkable species. Furthermore, preliminary studies that demonstrate the remarkable properties of crocodile gut microbial flora are discussed. Given the profound role of the gut microbiome in the health of its' host, it is likely that the crocodile gut microbiome and its' metabolites may be contributing to their extended life expectancy and elucidating the underlying mechanisms and properties of these metabolites may hold clues to developing new treatments for age-related diseases for the benefit of *Homo sapiens*.




Duncan, W.P., Júnior, J.N.A., Mendonça, W.C.S., Santa Cruz, I.F., Samonek, J.F., Morais, E.J., Marcon, J.L. and Da Silveira, R. (2021). Physiological stress response in free-living Amazonian caimans following experimental capture. Journal of Experimental Zoology Part A: Ecological and Integrative Physiology (https://doi.org/10.1002/jez.2565).

Abstract: When captured, free-living crocodilians respond by hyperstimulation of the hypothalamic-pituitary-adrenal (HPA) axis, which triggers a cascade of downstream events of physiological stress. We examined these responses in two unstressed, and stressed Amazonian caimans, *Caiman crocodilus* and *Melanosuchus niger*. Plasma corticosterone levels increased in both stressed caiman species. In *M. niger*, the levels of this hormone increased 5.2-fold compared with the basal range values, while in *C. crocodilus* this was only 1.7-fold. After stress, *M. niger* needed more than 6 h to return its corticosterone levels to basal range values, whereas in *C. crocodilus* just 0.5 h was enough. Downstream events were characterized by an increase in glucose levels, which is associated with corticosterone increments. Excessive muscle activity resulted in increased plasma lactate content in both species. Lactate levels were also related to plasma calcium concentration, possibly due to the buffering capacity for preventing lactic acidosis. Clearance of excessive lactate load was faster in *M. niger* (0.5 h) than in *C. crocodilus* (more than 6 h). Although both caiman species respond in the same way to capture, the amplitude and duration of activation of the HPA axis are different. *M. niger* may be potentially more

sensitive to acute stress than *C. crocodilus*. On the other hand, *C. crocodilus* needs more time to recover from the lactic acid load. Our experiment provides a useful diagnostic tool for management and conservation programs, as well as evaluating the impacts of tourism and recreational capture on caimans in the Amazon.

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Yoshida, J., Hori, A., Kobayashi, Y., Ryan, M.J., Takakuwa, Y. and Hasegawa, Y. (2021). A new goniopholidid from the Upper Jurassic Morrison Formation, USA: Novel insight into aquatic adaptation toward modern crocodylians. Royal Society Open Science 8: 210320.

Abstract: Goniopholididae is a group of basal neosuchian crocodyliforms closely related to Paralligatoridae and Eusuchia that lived during the Jurassic and Early Cretaceous. Goniopholidids have the long, flat snout and secondary palate of modern crocodylians, the acquisition of which is regarded as a key feature in the early evolution of crocodylian body plan and their aquatic adaptation. Here, we report a new species, *Amphicotylus milesi*, with the description from the best-preserved specimen to date of Goniopholididae from Wyoming, USA. Its posterior extension of the nasopharyngeal passage (pterygoid secondary palate) and the shortening and dorsal deflection of the ceratobranchial suggest that basal neosuchians could raise their gular valve to separate oral and pharyngeal cavities as in modern crocodylians. The anatomy of *A. milesi* sheds light on the acquisition of this new respiratory system in the crocodyliform evolution and their early aquatic adaptation, leading to modern crocodylians.

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Campos, Z. and Mourao, G. (2021). Cannibalism events of *Caiman yacare* in the Pantanal, Brazil. Comunicado Técnico, 119. Embrapa Pantanal: Corumbá. (http://ainfo.cnptia.embrapa.br/digital/bitstream/item/228645/1/Canibalismo-jacare-COT119-2021.pdf).

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Campos, Z. and Mourao, G. (2021). Distância movida e área de uso de crocodilianos em área de usina hidrelétrica, Amazônia. Comunicado Técnico, 120. Embrapa Pantanal: Corumbá. (http://ainfo.cnptia.embrapa.br/digital/bitstream/item/228999/1/Hidreletrica-Amazonia-2021-COT-120.pdf).

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González-Solórzano, M., Gómez-Torres, M.A., López-Luna, M.A. and Escobedo-Galván, A.H. (2022). Saurochory in crocodiles does not favor seed dispersal and viability. Revista Acta Biologica Colombiana 27(1).

Abstract: Seed dispersal by reptiles (saurochory) has recently received attention, and the consumption of fruits and seeds has been reported in crocodilians despite being mainly carnivores, acting as potential seed dispersers. We evaluate whether saurochory by *Crocodylus acutus* and *C. moreletii* affect the seed viability of three species of plants (*Delonix regia*, *Inga* sp., and *Citrullus lanatus*). We performed feeding trials, using three juvenile individuals of each species of crocodile, and fed them 22 seeds per plant species for a total of 66 seeds per enclosure (132 for both species). Seeds were combined with the usual diet each week. The unconsumed and excreted seeds were collected and planted in soil treated with compost to evaluate the relative germination rate. A total of 99 seeds were consumed, of which only 14 seeds of *C. lanatus* were recovered from the faeces, and only one of those germinated (7.14 %) with respect to 50% in the control group. The results indicate that saurochory by *C. acutus* and *C. moreletii* has a negative effect on seed viability and germination of the plant species studied, as found in other studies using different species.

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Poapolathep, S., Giorgi, M., Klangkaew, N., Khidkhan, K., Chaiyabutr, N., Wongwaipairoj, T. and Poapolathep, A. (2021). Pharmacokinetic profiles of clarithromycin in freshwater crocodiles (*Crocodylus siamensis*). Journal of Veterinary Pharmacology and Therapeutics (https://doi.org/10.1111/jvp.13034).

Abstract: Clarithromycin (CLA) is a new β-lactamase-resistant macrolide antibiotic with potent activity against gram-positive and some gram-negative bacteria. To the authors' best knowledge, limited pharmacokinetic information to establish suitable therapeutic plans is available for freshwater crocodiles. To assess the prudent use of antibiotic in reptiles, this study was conducted to explore the pharmacokinetic characteristics of CLA in the freshwater crocodile, *Crocodylus siamensis*, following either single intravenous (i.v.) or intramuscular (i.m.) administration at a dosage of 2.5 mg/kg body weight (b.w.). Blood samples were collected at assigned times up to 168 h. CLA plasma samples were cleaned up using liquid-liquid extraction, and analysed by a validated liquid chromatography tandem-mass spectrometry (LC-MS/MS). CLA was quantifiable from 5 min to 72 h after i.v. administration, whereas it was detectable for 168 after i.m. administration at an identical dose rate. A non-compartmental model was used to fit the plasma concentration of CLA versus time curve for each crocodile. The t1/2λz value, similar for both routes (20 h), indicated that the overall rate of elimination of CLA in crocodiles is relatively slow. The average i.m. F% was complete. The protein plasma bound was found to be about 30%. CLA is a time-dependent antibiotic, and the T>MIC is the best PK/PD predictor for its efficacy. The CLA dosage of 2.5 mg/kg appeared to produce an appropriate value of the PK-PD surrogate that predicts antibacterial success for disease caused by susceptible bacteria.

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García Grajales, J., Rubio Delgado, A., Casiano González, C. and Buenrostro-Silva, A. (2021). Nuevos registros of human-crocodile interactions in Mexico since 2018 until the first part of 2021. Revista Latinoamericana De Herpetología 4(2): 153-160.

Abstract: El crecimiento poblacional humano y sus actividades económicas asociadas han incrementado las interacciones humano-vida silvestre. Aquí, proporcionamos nuevos registros de las interacciones humano-cocodrilo (HC) de 2018 a la primera mitad del 2021 en México. Cincuenta y un casos fueron registrados en este estudio, 2018 fue el año con el número más alto de casos (n= 19) y 2021 (en su primer semestre) es el año con el número más bajo de casos. Tamaulipas y Quintana Roo en el Golfo de México representan el 40% de los casos, mientras que Oaxaca y Nayarit en la costa del Pacífico Mexicano representaron el 22%. Las victimas masculinas (n= 32) fueron las más comunmente asociadas a los incidentes entre humanos y cocodrilos que las víctimas femeninas (n= 10). Sin embargo, 44 casos fueron no fatales y solamente siete fueron fatales. Por lo que sabemos, nuestros registros de interacciones HC incrementan el número de conflictos en México a 250 casos entre el año 2000 y la primera mitad del año 2021.

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Fukuda, Y., Moritz, C., Jang, N., Webb, G., Campbell, H., Christian, K., Lindner, G. and Banks, S. (2021). Environmental resistance and habitat quality influence dispersal of the saltwater crocodile. Molecular Ecology (https://doi.org/10.1111/mec.16310).

Abstract: Landscape genetics commonly focuses on the effects of environmental resistance on animal dispersal patterns, but there is an emerging focus on testing environmental effects on emigration and settlement choices. In this study, we used landscape genetics approaches to quantify dispersal patterns in the world's largest crocodilian, the saltwater crocodile (*Crocodylus porosus*), and demonstrated environmental influences on three processes that comprise dispersal: emigration, movement and settlement. We found that both environmental resistance and properties of the source and destination catchments (proportion of breeding habitat) were important factors influencing observed dispersal events. Our habitat quality variables related to hypotheses about resource competition and represented the ratio of breeding habitat (which limits carrying capacity), suggesting that competition for habitat influences emigration and settlement choices, together with the

strong effect of environmental resistance to movement (where high-quality habitat was associated with greatest environmental permeability). Approximately 42% of crocodiles were migrants from populations other than their sampling locations and some outstandingly productive populations had a much higher proportion of emigration rather than immigration. The distance most commonly travelled between source and destination was 150-200 km although a few travelled much longer distances, up to 600-700 km. Given the extensive dispersal range, individual catchments or hydrographic regions that combine two or three adjacent catchments are an appropriate scale for population management.

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Korneisel, D.E., Vice, R. and Maddin, H.C. (2021). Anatomy and development of skull-neck boundary structures in the skeleton of the extant crocodylian *Alligator mississippiensis*. The Anatomical Record (https://doi.org/10.1002/ar.24834).

Abstract: A system-by-system approach dominates morphological and evolutionary study; however, some structures that are better understood within the context of an interface between two systems or traditional units remain less well understood. As part of a larger goal to clarify aspects of skull-neck boundary evolution, we herein describe the morphology and development of the occiput and atlas-axis complex in the crocodylian *Alligator mississippiensis*. We apply micro-computed tomography scanning, clearing and double staining, and histological analyses to skull-neck boundary structures at three stages of development (embryonic stage 22, 23, and hatchling). Regions of ossification that could possibly pertain to a postparietal were found adjacent to the parietal bone and supraoccipital; however, these were not deemed convincing and are considered part of the supraoccipital. Within the atlas-axis complex, the proatlas appears as two discrete cartilaginous elements in Stage 22 that ossify together at Stage 23. Posterior to the proatlas, the atlas-axis complex is composed of two centra, each with cervical ribs ventrally and neural arches dorsally that begin ossifying at Stage 23. Histology and clearing and staining of Stages 22 and 23 embryos reveal a discrete atlas intercentrum applied to the ventral part of the occipital condyle of the skull. Posterior to this is a cartilage that appears to be a co-chondrified atlas pleurocentrum, axis intercentrum, and axis pleurocentrum. Ossification of this cartilaginous structure produces discrete atlas inter- and pleurocentra, as well as a singular axis centrum. Together these data are discussed with reference to clarifying historical discrepancies concerning elements at the crocodylian skull-neck boundary.

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Ryu, J., Fu, Z., Akula, S., Olsson, A-K. and Hellman, L. (2021). Extended cleavage specificity of a Chinese alligator granzyme B homologue, a strict Glu-ase in contrast to the mammalian Asp-ases. Developmental and Comparative Immunology 128 (https://doi.org/10.1016/j.dci.2021.104324).

Abstract: Granzyme B (GzmB) is primarily expressed by mammalian cytotoxic T cells and serves as one of the key components in the defense against viral infection by the induction of apoptosis in virus infected cells. By direct cell to cell contact and delivery into target cells by perforin, cytotoxic T cells activate apoptosis through the action of GzmB by both caspase-dependent and -independent pathways. In search for early ancestors of GzmB we have in the current study identified and characterized a GzmB homologue from a reptile, the Chinese alligator. This enzyme is encoded from the same locus as the mammalian counterparts, the chymase locus. Phage display analysis of the cleavage specificity of the recombinant alligator enzyme (named MCP1A-like) shows that it is a relatively strict Glu-ase, with strong preference for glutamic acid in the P1 position of a substrate. The majority of mammalian GzmB:s are, in marked contrast to the alligator enzyme, relatively strict Asp-ases. The alligator enzyme also showed strong preference for Ala, Pro and Gly in the P2 position and Val in the P3 position indicating that it has a narrow specificity, similar to the mammalian counterparts. Analysis of the three amino acids forming the substrate binding pocket (S1 pocket) in three amphibian homologues to MCP1A-like, from the frogs *Xenopus laevis* and *X. tropicalis*, shows that these amphibian enzymes have similar substrate binding pocket as their mammalian counterparts. This finding, together with the apparent lack of GzmB homologs in fish, indicates that the ancestor of GzmB did appear with the amphibians at the base of tetrapod evolution. This study is a first step in a larger effort to understand the evolutionary processes involved in shaping anti-viral immunity in non-mammalian vertebrates.

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Davidian, A.G., Dyomin, A.G., Galkina, S.A., Makarova, N.E., Dmitriev, S.E. and Gaginskaya, E.R. (2021). 45S rDNA repeats of turtles and crocodiles harbor a functional 5S rRNA gene specifically expressed in oocytes. Molecular Biology and Evolution (doi: 10.1093/molbev/msab324).

Abstract: In most eukaryotic genomes, tandemly repeated copies of 5S rRNA genes are clustered outside the nucleolus organizer region (NOR), which normally encodes three other major rRNAs: 18S, 5.8S, and 28S. Our analysis of turtle rDNA sequences has revealed a 5S rDNA insertion into the NOR intergenic spacer in antisense orientation. The insertion (hereafter called NOR-5S rRNA gene) has a length of 119 bp and coexists with the canonical 5S rDNA clusters outside the NOR. Despite the ~20% nucleotide difference between the two 5S gene sequences, their internal control regions for RNA polymerase III are similar. Using the turtle *Trachemys scripta* as a model species, we showed the NOR-5S rDNA specific expression in oocytes. This expression is concurrent with the NOR rDNA amplification during oocyte growth. We show that in vitellogenic oocytes, the NOR-5S rRNA prevails over the canonical 5S rRNA in the ribosomes, suggesting a role of modified ribosomes in oocyte-specific translation. The orders Testudines and Crocodilia seem to be the only taxa of vertebrates with such a peculiar rDNA organization. We speculate that the amplification of the 5S rRNA genes as a part of the NOR DNA during oogenesis provides a dosage balance between transcription of all the four ribosomal RNAs while producing a maternal pool of extra ribosomes. We further hypothesize that the NOR-5S rDNA insertion appeared in the Archelosauria clade during the Permian period and was lost later in the ancestors of Aves.

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Waknis, P.P., Gadre, K.S., Bawane, S.S. and Kale, L. (2021). Intraoral coronoidectomy modeled on crocodile's death roll: A technical note. Surgical Innovation (doi: 10.1177/15533506211059903).

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Leiva, P.M.L., Frutos, A.E., Lavandera, J., Simoncini, M.S., Labaque, M.C., Piña, C.I. and González, M.A. (2021). Effect of flaxseed and flaxseed oil supplemented in caiman diet on meat fatty acids. Tropical Animal Health Production 53(6) (doi: 10.1007/s11250-021-02974-y).

Abstract: Increasing polyunsaturated or long-chain fatty acids in meat for human consumption improves both nutritional quality and consumer perception. The increase could occur through the addition of rich sources of omega-3 fatty acids (such as flaxseed or flaxseed oil) to the animal diet. The aim of this study was to evaluate the effects of dietary supplement with two presentations of flax (crushed seeds or oil) on the change of FA content in two cuts of caiman meat (tail and neck). We measured fatty profile in two different caiman meat cuts (neck and tail) from 30 animals (total length 96.7 ± 4.9 cm, snout-vent length 47.8 ± 3 cm, weight 4.2 ± 0.6 kg), raised in individual enclosures, fed three a week for 50 days with crushed chicken head and a dry food formulated for these reptiles in a 70/30 ratio (C, n= 10), control diet with 10% crushed flaxseed (FS, n= 10), and control diet with 10% flaxseed oil (FO, n= 10), while the remaining days animals were fed the control diet. Meats from animals fed both enrichment diet (FS and FO) showed an increase of C18:3n-3 and ΣUFA with respect to control diet. Although both enriched diets raised the levels of C18:3n-3, the neck showed higher values than the tail. We observed that the neck is more susceptible

than the tail to be improved by FO, which could suggest that it is more beneficial to consume neck meat. In order to be implemented in caiman farms, flaxseed oil is more expensive than seed, but more effective, easier to manage, and is practical for application on caiman farms.

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Poelmann, R.E., Gittenberger-de Groot, A.C., Goerdajal, C., Grewal, N., De Bakker, M.A.G. and Richardson, M.K. (2021). Ventricular septation and outflow tract development in crocodilians result in two aortas with bicuspid semilunar valves. Journal of Cardiovascular Development and Disease 8(10) (doi: 10.3390/jcdd8100132).

Abstract: The outflow tract of crocodilians resembles that of birds and mammals as ventricular septation is complete. The arterial anatomy, however, presents with a pulmonary trunk originating from the right ventricular cavum, and two aortas originating from either the right or left ventricular cavity. Mixing of blood in crocodilians cannot occur at the ventricular level as in other reptiles but instead takes place at the aortic root level by a shunt, the foramen of Panizza, the opening of which is guarded by two facing semilunar leaflets of both bicuspid aortic valves. Developmental stages of *Alligator mississipiensis*, *Crocodylus niloticus* and *Caiman latirostris* were studied histologically. The outflow tract septation complex can be divided into two components. The aorto-pulmonary septum divides the pulmonary trunk from both aortas, whereas the interaortic septum divides the systemic from the visceral aorta. Neural crest cells are most likely involved in the formation of both components. Remodeling of the endocardial cushions and both septa results in the formation of bicuspid valves in all three arterial trunks. The foramen of Panizza originates intracardially as a channel in the septal endocardial cushion.

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Matsumoto, R., Fujiwara, S-I. and Evans, S.E. (2021). Feeding behaviour and functional morphology of the neck in the long-snouted aquatic fossil reptile *Champsosaurus* (Reptilia: Diapsida) in comparison with the modern crocodilian *Gavialis gangeticus*. Journal of Anatomy (doi: 10.1111/joa.13600).

Abstract: The extinct freshwater choristoderan reptiles *Champsosaurus* and *Simoedosaurus* are characterised by large body size and an elongated snout. They have often been considered as eco-analogues of crocodilians based on superficial similarities. The slender-snouted *Champsosaurus* has been described as a 'gavial-like reptile', which implies it feeds underwater with a lateral swipe of the head and neck, as in the living slender-snouted crocodilians such as *Gavialis gangeticus*. In contrast, the short-snouted *Simoedosaurus* is often compared with short-snouted living crocodilians and is considered to take single prey items. However, the neck mobility and flexibility needed for feeding movements are poorly understood even in extant crocodilians. This study explores the relationship between cervical morphology and neck flexion, focusing particularly on lateral and dorsal movements in *G. gangeticus* by comparison with shorter-snouted crocodilians. The paper also describes a method to estimate the maximum angle of neck dorsiflexion in choristoderes based on the cervical morphology of extant crocodilian species. Three indices were used in this study, of which Index 3 is newly proposed, to compare cervical morphology and intervertebral joint flexibility: (1) Enclosed zygapophyseal angles (EZA) as an index of dorsoventral/ bilateral flexibility, (2) moment arm (M) of dorsiflexor muscles as an Index of resistance against ventroflexion and (3) the orientations of zygapophysial facets for a maximum angle of dorsiflexion. These Indices were validated using $\mu$CT scanning of fresh specimens of *G. gangeticus* and *Caiman latirostris* in lateral and dorsal flexion. A unique mechanism of lateral flexion was identified in *G. gangeticus* that uses a combination of the following features: (1) lateral flexion mainly restricted to the anterior cervical vertebrae (v2/v3: high EZA, with more horizontal zygapophyses) and (2) high degree of dorsiflexion at the v3/v4 and v4/v5 joints with potential for dorsal flexibility through the middle-posterior neck, which is used in inertial feeding. In contrast, *Champsosaurus* and *Simoedosaurus* possess relatively short cervical vertebrae, as in short-snouted crocodilians. The middle-posterior cervical vertebrae of *Champsosaurus* are specialised for lateral flexion (high EZA), and there is only limited capacity for dorsiflexion throughout the neck. Like *G. gangeticus*, therefore, *Champsosaurus* may have used its slender snout to grab fish from shoals using lateral sweeping motions of the head and neck, but the movement is through the neck, not the craniocervical joint. However, inertial feeding is less likely to have occurred in this genus, and the aligned palatal dentition may have aided the lingual transport of prey into the mouth. *Simoedosaurus*, on the other hand, appears to have been less specialised, with a neck that combined lateral and dorsolateral flexion, a move that could have been effective in catching both terrestrial and aquatic prey. Where these two choristoderan genera occurred in the same place, they may have divided their niche by prey types.

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Lamichhane, S., Bhattarai, D., Karki, J.B., Gautam, A.P., Pandeya, P., Tirpathi, S. and Mahat, N. (2022). Population status, habitat occupancy and conservation threats to Mugger crocodile (*Crocodylus palustris*) in Ghodaghodi lake complex, Nepal. Global Ecology and Conservation 33 (https://doi.org/10.1016/j.gecco.2021.e01977).

Abstract: Mugger crocodile is a keystone species of slow flowing fresh water ecosystem. Few studies regarding status and distribution of Vulnerable Mugger have been conducted in Nepal. However, studies on ecology and other aspects of the species are limited. The goal of this study was to determine the Mugger crocodile's population status, habitat occupancy, and conservation threats in the Ghodaghodi lake complex, located in the western lowlands of Nepal. A detailed survey was conducted on 18 lakes of the lake complex in February, 2021. The population status of the Mugger was surveyed by walking along the entire boundary line of each lake. For habitat survey, perimeter of all the lakes of the complex was divided into the number of stations spaced at 500 m intervals. Habitat factors associated with the presence and absence of the Mugger were analyzed using Generalized Linear Model under binary logistic regression and likelihood ratio test was performed to test predictors for statistical significance. During the survey, 26 Muggers were recorded. The probability of sighting Mugger in the lake complex was significantly differ by distance to settlement, distance to river, and human disturbances, among the nine habitat variables examined. Similarly, habitat modification and illegal fishing were ranked as most severe threats to Mugger crocodile in the lake complex. The concerned authorities, responsible for managing the lake complex shall pay attention on controlling the major identified threats like habitat modification, illegal fishing, unmanaged infrastructure development, and pollution in the lake complex in order to support future conservation of Vulnerable Mugger population in the area. Furthermore, a detailed and extensive study is suggested to investigate the movement of Muggers between different lakes of the complex as well as from Ghodaghodi lake complex to the nearby rivers during breeding season in order to support effective planning and execution of habitat management activities of this Vulnerable species.

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Mascarenhas-Junior, P., Maffei, F., Muniz, F., Freitas-Filho, R.F., Gonçalves Portelinha, T.C., Campos, Z. and Bassetti, L.A.B. (2021). Conflicts between humans and crocodilians in urban areas across Brazil: A new approach to support management and conservation. Ethnobiology and Conservation 10 (doi:10.15451/ec2021-12-10.37-1-19).

Abstract: Crocodilian-human conflicts, caused especially by urban expansion and habitat destruction, have been considered one of the main threats to the conservation of these species worldwide. In Brazil, such conflicts have been documented with crocodilian species all over the country. This study identified 400 conflict events between humans and caimans within Brazilian cities between 2016 and 2021. *Caiman latirostris* (57.4%) was the most common species found in large urban centers in the northeastern and southeastern

regions. Most of the encounters (N= 250) were registered in the rainy season and the rescues were mainly carried out by the environmental military police and fire brigades. The management protocols in the presence of crocodilians in urban areas have been outlined, to be carried out by the Municipal Environmental Secretariats to minimize animal stress and the risk of accidents in urban areas. The increasingly common interaction between humans and caimans in urban environments is an important alert to envisage best conducts for the coexistence between humans and crocodilians and shows the need to invest in public policies to mitigate the effects of cities on wildlife.

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Schneider, C.S., Pokines, J.T., L'Abbé, E.N. and Pobiner, B. (2021). Reptile taphonomy. *In* Manual of Forensic Taphonomy, ed. by J.T. Pokines, E.N. L'Abbé and S.A. Symes. CRC Press.

Abstract: The chapter examines the taphonomic effects of crocodilians on bone from either predation or scavenging. Fatal crocodilian attacks on people often take place in the water, and while such attacks are minimal in the USA, they are frequently recorded in Zimbabwe, Madagascar, South Africa, India, and Australia. Crocodilians' feeding behavior, including the "death roll", side-to-side chomping and thrusting action, strong jaws, and prolonged clenching of prey combined with dentition that differs from mammalian carnivores, including their sabre-shaped and carinated (ridged) teeth, contribute to unique defects in bone. A crocodilian can leave sharp-blunt injuries and V-shaped defects with associated striations, both of which can mimic sharp force injuries associated with knives. Three main differences between human-induced sharp force trauma and crocodilian activity are: (1) increased density and randomness of defects on bone in a given area, (2) bisected pits with V-shaped cross sections and hook scores, and (3) an absence of dismemberment of the bone at the joints, with intact proximal and distal ends.

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Pye, G.W. and Bennett, R.A. (2021). Surgical approaches to the reptile coelom. Chapter 8. Pp. 85-95 *in* Surgery of Exotic Animals, ed. by R.A. Bennett and G.W. Pye. John Wiley & Sons: New York.

Abstract: The surgical approaches to the reptilian coelom can be broken down into the three broad taxa: chelonians, snakes, and lizards and crocodilians. This chapter describes the prefemoral and plastron osteotomy approaches in chelonians, the lateral approach in snakes, the ventral paramedian approach in lizards and crocodilians, and the intercostal approach in laterally compressed lizards. In addition, the postfemoral approach to the kidney in iguanids is described.

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Possidónio, C., Piazza, J., Graça, J. and Prada, M. (2021). An appetite for meat? Disentangling the influence of animal resemblance and familiarity. Appetite (https://doi.org/10.1016/j.appet.2021.105875).

Abstract: Consumers in modern society are often less exposed to meat that resembles the animal, and thus are less familiar with it, making it difficult to disentangle the influence of these two inputs (familiarity vs. animal resemblance) on meat appetite. Across three studies, we sought to systematically disentangle the impact of familiarity and animal resemblance on meat appetite using inductive (Study 1) and experimental (Studies 2a-2b) approaches. In Study 1 (N= 229) we separated familiarity and animal resemblance into orthogonal dimensions using 28 meat products. Participants provided free associations and rated the products on familiarity, animal resemblance, and appetitive appeal. In Studies 2a and 2b (N= 514) we experimentally examined the independent contributions of familiarity and animal resemblance, using stimuli normed in Study 1. We hypothesized that animal resemblance has its most pronounced influence on appetite when meat products are unfamiliar. Participants' free associations and ratings of the products were in line with this conditional hypothesis (Study1), as were the experimental manipulations of familiarity and animal resemblance (Studies 2a-2b), confirmed by a mini meta-analysis. In all three studies, familiarity had a pervasive influence on appetite. These findings suggest that product familiarity can attenuate the psychological impact that animal reminders have on appetite. Thus, interventions aimed at eliciting animal associations with meat should consider the familiarity of the products employed.

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Merchant, M., Joanen, T., Berkin, J. and Courville, C. (2021). A comparison of stress levels in farmed and wild American alligators: An indicator of animal health and best farming practices. Journal of Applied Aquaculture (https://doi.org/10.1080/10454438.2021.2017382).

Abstract: Blood was collected from alligators at a large alligator farm in Louisiana to compare stress levels to those in wild alligators. The measurement of corticosterone (CORT) levels and heterophil/lymphocyte ratios were used to assess stress levels because both parameters become elevated during periods of physiological stress. We compared CORT concentrations and H/L ratios in wild animals that were either the same size or the same age class as farmed alligators. Plasma CORT levels and H/L ratios were no higher than those in wild alligators. To ensure consistent results across the farm, we compared plasma hormone concentrations in animals of the same size classes maintained in different enclosures and also in different buildings and found no differences. We believe that results such as these obtained from independent laboratories can be used as evidence for regulatory agencies that crocodylian farms raise their animals in low stress environments under Best Management Practices guidelines.

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Strickland, B.A., Gastrich, K., Beauchamp, J.S., Mazzotti, F.J. and Heithaus, M.R. (2021). Effects of hydrology on the movements of a large-bodied predator in a managed freshwater marsh. Hydrobiologia (https://doi.org/10.1007/s10750-021-04764-x).

Abstract: Wetlands are dynamic environments where aquatic organisms are affected by both predictable and unpredictable changes in hydrology. Understanding how abundant large-bodied predators respond to these changes is especially important in context of wetland restoration. We used satellite telemetry to investigate how individual (eg sex, size, body condition) and environmental factors influenced movement behaviors of American Alligators [*Alligator mississippiensis* (Daudin, 1801)] in a managed freshwater marsh ecosystem of the Florida Everglades. We quantified space use, movement activity, and habitat selection of animals (n= 18) across hydrological seasons and the breeding period and performed stable isotope analyses to infer seasonal dietary changes. Though individual animals did not change space use across seasons, movement activity was lower for some individuals and $\delta^{15}$ Nitrogen isotopic values were higher in the dry season possibly reflecting greater foraging opportunities when marsh dry down concentrates prey. Alligators may be using canals as foraging sites which have abundant prey year-round and shallow sawgrass habitats as spots for basking. Based on our findings, ongoing restoration of water inflow will likely change the distribution and movement behavior of alligators.

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Marlatt, V.L., Bayen, S., Castaneda-Cortès, D., Delbès, G., Grigorova, P., Langlois, V.S., Martyniuk, C.J., Metcalfe, C.D., Parent, L., Rwigemera, A., Thomson, P. and Van Der Kraak, G. (2021). Impacts of endocrine disrupting chemicals on reproduction in wildlife and humans. Environmental Research (https://doi.org/10.1016/j.envres.2021.112584).

Abstract: Endocrine disrupting chemicals (EDCs) are ubiquitous in aquatic and terrestrial environments. The main objective of this review was to summarize the current knowledge of the impacts of EDCs on reproductive success in wildlife and humans. The

examples selected often include a retrospective assessment of the knowledge of reproductive impacts over time to discern how the effects of EDCs have changed over the last several decades. Collectively, the evidence summarized here within reinforce the concept that reproduction in wildlife and humans is negatively impacted by anthropogenic chemicals, with several altering endocrine system function. These observations of chemicals interfering with different aspects of the reproductive endocrine axis are particularly pronounced for aquatic species and are often corroborated by laboratory-based experiments (ie fish, amphibians, birds). Noteworthy, many of these same indicators are also observed in epidemiological studies in mammalian wildlife and humans. Given the vast array of reproductive strategies used by animals, it is perhaps not surprising that no single disrupted target is predictive of reproductive effects. Nevertheless, there are some general features of the endocrine control of reproduction, and in particular, the critical role that steroid hormones play in these processes that confer a high degree of susceptibility to environmental chemicals. New research is needed on the implications of chemical exposures during development and the potential for long-term reproductive effects. Future emphasis on field-based observations that can form the basis of more deliberate, extensive, and long-term population level studies to monitor contaminant effects, including adverse effects on the endocrine system, are key to addressing these knowledge gaps.

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Martins dos Santos, D., Miloni Santucci, R., Maia de Oliveira, C.E. and Brandalise de Andrade, M. (2021). A baurusuchid yearling (Mesoeucrocodylia, Crocodyliformes), from the Adamantina Formation, Bauru Group, Upper Cretaceous of Brazil. Historical Biology (https://doi.org/10.1080/08912963.2021.2001807).

Abstract: Occurrences of young and immature individuals, relatively rare in the fossil record, are important due to the great amount of morphological and evolutionary information they reveal about a lineage's development. Although crocodylomorphs are the most abundant terrestrial vertebrates found in the Bauru Basin, southeastern Brazil, even outnumbering dinosaurian materials, much remains to be understood about their anatomy, ecology, and ontogeny. Egg fragments, nests and nesting sites attributed to Baurusuchus have been previously described, but unfortunately none of these yielded embryonic or hatchling remains. Here, we describe, for the first time, skeletal material of a small notosuchian yearling, recovered from the Adamantina Formation, with osteological features consistent with a baurusuchid affinity. We provide and discuss osteological and histological evidence of its ontogenetic stage, revealing morphological characters distinct from most adult forms, including conspicuous centro-parapophyseal laminae and developed ventral keels. Computerised tomography data also allowed for the identification of incipient ossification and a novel ontogenetic feature in the diminishing volume of the frontal´s internal recesses. Similar materials will increase our understanding of notosuchian ontogeny and diversity, thus requiring growth characters to be integrated into future phylogenies.

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Cavenaghi Altemio, A.D., dos Santos Pais, K., Mendes dos Santos, M. and Graciano Fonseca, G. (2021). Development and characterization of low fat cooked yacare (*Caiman yacare*) meat sausages. Meat Technology 62(2): 130-139.

Abstract: The limited consumption of yacare (*Caiman yacare*) is due to cultural and economic factors, beyond a limited availability of products based on this meat. Here cooked sausages were developed from yacare meat shavings and fat substitutes (inulin and soy protein), and characterized. Moisture ranged from 63.90% (T1) to 59.89% (T3), a decrease with the increase in the inulin content (T1 had the lowest, T3 the highest inulin content). The protein content decreased from 27.67 (T1) to 25.32% (T3). The highest lipid content was 5.36% (T2) and the lowest 1.69% (T3). The ash content ranged from 4.50 to 4.62%. The highest luminosity value was obtained for T2 (59.69) and the lowest for T3 (57.24). The highest average shear force (18.01 N) was obtained for T3. Good sensory characteristics were obtained for all treatments, with acceptability indexes varying from 68.67 to 87.11%. However, the highest purchase intention was declared by 72% of panelists who certainly or probably would purchase T1.

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Gomes, L.G., Stocco, M.B., de Sousa, N.P., Martini, A.C., Morgado, T.O., Spiller, P.R., Moreira, L.F.B. and de Souza, R.L. (2021). Influence of incubation temperature and embryonic motility on the growth of members of *Caiman yacare* (Daudin, 1802). Brazilian Journal of Biology 84: e252845 (doi: 10.1590/1519-6984.252845).

Abstract: This study aimed to evaluate whether skeletal development of the Pantanal Caiman (*Caiman yacare*) is similarly influenced by temperature variation and controlled increases in embryo motility. All eggs were incubated at 90% humidity and 29°C for the first 45 days. Thereafter, the incubation temperature was either maintained at 29°C and embryos were treated with 4-aminopyridine (4-AP) on days 46, 47, 48, and 49 (Group I, 29 °C 4-AP, n= 15); maintained at 29°C (n= 14; Group II); or at 33°C (n= 14, Group III). Embryonic movement was measured using an Egg Buddy® digital monitor on days 30, 35, 42, 49, 56, and 60, at which point embryos were euthanized and samples were collected for analysis. No differences were observed between groups with varying incubation temperatures. In contrast, embryonic motility was greater in embryos treated with 4-AP ($P<0.001$) on day 49, and this was associated with higher proportions of snout-vent and hand lengths. This study demonstrates for the first time that pharmacologically induced increases in embryo motility result in phenotypic changes to the proportion of elements during prenatal ontogeny, thereby effectively altering the adaptation of the species to specific environments.

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Charruau, P., Rissac, A. and Massias Diaz, D.A. (2021). A new case of communal egg-laying by iguanas and American crocodiles (*Crocodylus acutus* Cuvier, 1807) from a Caribbean atoll of Mexico. Caribbean Herpetology 80: 1-5.

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Silva Cordeiro, M.W., Matochi Mouro, D.M., Duarte dos Santo, I. and Wagner, R. (2021). Effect of gamma irradiation on the quality characteristics of frozen yacare caiman (*Caiman crocodilus yacare*) meat. Meat Science 185 (https://doi.org/10.1016/j.meatsci.2021.108728).

Abstract: This study investigated the effect of gamma irradiation (0, 3 and 5 kGy) on the quality characteristics of yacare caiman (*Caiman crocodilus yacare*) meat under typical storage and commercialization conditions (-18 °C for 150 days). The overall quality characteristics (texture profile, TBARS values, water-holding capacity and cooking loss) of the irradiated samples were not significantly affected ($P>0.05$) during frozen storage. However, irradiation promoted the formation of volatile compounds from lipid oxidation known to be important markers in meat odor, particularly hexanal, pentanal and 1-hexanol, in samples treated with 5 kGy after 150 days of frozen storage. The results obtained indicate the need for further research to determine the effect of the doses tested on the sensory attributes of yacare caiman meat.

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Mascarenhas-Junior, P.B., Bassetti, L.A.B. and Sayão, J.M. (2021). Bone histology of Broad-snouted caiman *Caiman latirostris* (Crocodylia: Alligatoridae) as tool for morphophysiological inferences in Crocodylia. Acta Herpetologica 16(2): 109-121.

Abstract: Bone histology is an important tool for the interpretation of life patterns in animals of the past and extant fauna. The crocodylians have been studied as important inferential models for morphophysiological characteristics. We aimed to characterize the osteohistology of captive *Caiman latirostris*, identifying its microanatomy related to growth rates, ontogeny, and environmental

conditions. We analyzed five pairs of humeri (proximal elements of the appendicular skeleton) and ribs (axial skeleton) of females' caiman. Ribs showed, in general, woven-fibered tissues, with low vascularization and parallel-fibered bone and many resorption and erosion cavities. It presented lines of arrested growth (LAGs) in three individuals, without skeletochronological compatibility. Humeri showed a gradientof woven-fibered to parallel-fibered and lamellar-zonal bone as the individuals aging. We observed compacted coarse cancellous bone (CCCB) and a higher number of LAGs in older specimens. Ribs remodel faster than humerus, showing an intra-individual histovariability. The humeri indicated an evident growth pattern with different ontogeny stages and growth rates in different ages. Fast-growing tissues are uncommon in crocodylians, but basal metabolism and optimal growth conditions can lead to this. Bone histology of *C. latirostris* shows patterns that can be used as inferential models for extant and extinct groups, but we encourage further studies for a better understanding, under different environmental conditions, such as temperature and food availability.

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Kasetsomboon, P. (2021). Nora Tang Ke. Asian Journal of Arts and Culture 21(2): 62-70.

Abstract: Rum Tang Ke is part of the Nora Rong Khru ritual performed on the last day called "Song Khru day" (Teacher's departure day). A crocodile model used in the ritual portrays evil and misfortunes. In a strict sequence, Rum Klong Hong (swan lassoing dance) must preceded Rum Tang Ke in order to be granted talisman's blessing as a protection against evil and misfortune from the crocodile. After Rum Klong Hong, Rum Tang Ke comprising seven performers together with one Nora Yai (Head of Nora) who will be the first to stab the crocodile. After that, each of the seven will take turn dancing toward the crocodile and stabbing it. Every participating Nora must board the banana tree's trunk' raft to simulate a raft journey to hunt the crocodile. Nora's dance poses each of the Noras assumes differ. Spears are used as a weapon for both dancing and stabbing the crocodile. A crocodile model is a replica of a crocodile made using banana tree's trunks cut into pieces fitting for each part of the crocodile. Only shamans with expertise in supernatural practices can make a crocodile model. Violating the traditional practice is believed to bring misfortune to a violator.

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Rameh-De-Albuquerque, L.C., Zanotti, A.P., Souza, D.S., Diniz, G.T., Mascarenhas-Junior, P.B., Santos, E.M. and Correia, J.M.S. (2021). Hematological values of wild *Caiman latirostris* (Daudin, 1802) in the Atlantic Rainforest in Pernambuco, Brazil. Acta Herpetologica 16(2): 99-108.

Abstract: Hematological studies in crocodilians are important tools in the evolutionary diagnosis and control of sicknesses, such as anaemia, malnutrition, dehydration, inflammation, and parasitism, among others. We aimed to obtain reference intervals for the hemogram of *Caiman latirostris* in wild populations that inhabit Recife's Metropolitan Region, Pernambuco. We obtained blood samples from 42 caimans, from different sexes (22 males and 20 females) and ages classes (8 hatchlings, 24 subadults and 10 adults) in two areas of Atlantic Rainforest domain. We found that hematological parameters were included within the reference intervals for other crocodilian species. It was possible to observe differences between the areas for the mean corpuscular volume values, suggesting a possible difference between adult and juvenile individuals in the two study areas. When comparing sexes, there was no significant difference between the study parameters, but it was possible to observe differences in the mean corpuscular volume, mean corpuscular hemoglobin and hemoglobin in the Estação Ecológica de Tapacurá region. Although small differences have been observed between the two populations, we can infer that the hematological parameters are similar. We can use this information to evaluate animal's health in nature and for comparations with captive individuals, allowing the establishment of ideal maintenance conditions and assisting in the identification of possible pathologies.

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Gomes da Costa Pereira, P.V.L., Bogado, J.P., Ribeiro, T.B., Belfort, L.P., de Valais, S. and dos Anjos Candeiro, C.R. (2021). Dino on the menu: Tooth traces in a sauropod epiphysis from the Presidente Prudente Formation (Campanian-Maastrichtian), Bauru Group, Brazil - palaeobiological and palaeoecological implications. Historical Biology (https://doi.org/10.1080/08912963.2021.2000603).

Abstract: Ichnofossils are a useful tool in determining some aspects of the palaeoecology from past ecosystems, being often used as evidence of interactions between extinct organisms. In this paper we describe tooth traces found in UFRJ-DG 705 R, a fragmentary sauropod epiphysis, from the Presidente Prudente Formation, Bauru Group. We infer that these traces were made by a small to medium-sized crocodyliform, most likely an itasuchid, in a possible act of necrophagy. This new record of tooth traces in the Bauru Group showcases important evidence concerning trophic relations between sauropods and crocodyliforms in this locality during the Late Cretaceous.

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Segal, N.L. (2021). Twins with craniosynostosis: An unidentified variant/twin research: Kangaroo care for premature twins; developmental delay in MZ twins; osteosarcoma in one identical twin; controversies in twin pregnancy management/media reports: twin and triplet olympians; twin's rescue from a crocodile; twin pandas in Japan; twin surrogacy; identical twins in Pennsylvania. Twin Research and Human Genetics (https://doi.org/10.1017/thg.2021.39).

Abstract: Craniosynostosis involves the early closure of one or more joints connecting the bones of an infant's skull. A case of young monozygotic (MZ) male twins with an unidentified variant of this condition is described, followed by a summary of relevant published reports. This overview is followed by descriptions of a kangaroo care program for premature twins, developmental delay in an MZ twin pair, osteosarcoma in one MZ twin and controversial issues in the management of multiple pregnancies. Media reports of twin and triplet Olympic athletes, a twin's rescue from a crocodile, the birth of twin pandas in Japan, a case of twin surrogacy and the birth of identical triplets are also presented.

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Marchetti, I., Delcourt, R., Tavares, S.A.S., Canalli, J.F., Nascimento, P.M. and Ricardi-Branco, F. (2022). Morphological and paleohistological description of a new Baurusuchidae specimen from the Adamantina Formation, Upper Cretaceous of Brazil. Journal of South American Earth Sciences 114 (https://doi.org/10.1016/j.jsames.2021.103693).

Abstract: The baurusuchids were terrestrial notosuchian crocodyliforms from the Upper Cretaceous of South America. The present study analyzes a partial postcranial skeleton, MPMA 62.0002.02, collected in strata from the Adamantina Formation (Campanian-Maastrichtia, Bauru Basin) near the General Salgado municipality, São Paulo state, Brazil. The specimen was identified as a notosuchian, and more precisely to the family Baurusuchidae because of the presence of a dorsal protuberance on the postzygapophysis, robust ribs, a scapula with a dorsal convex border, and a strong middle constriction. The presence of bone tissues with different growth rates signifies that at least some baurusuchids present different allometric rates for the humerus, vertebrae, and osteoderms. The results also show that there may be a shift between fast and slow growth rates throughout life. Our results suggest a a possible correlation between the developmental delay of these animals and the seasonal environmental changes in semiarid conditions. The histological and morphological descriptions proved to be efficient for identifying the Baurusuchidae family, as well as for defining indicators to comprehend the biology of extinct species.

Siddiqui, R., Maciver, S.K. and Khan, N.A. (2022). Gut microbiome-immune system interaction in reptiles. Journal of Applied Microbiology (doi: 10.1111/jam.15438).

Abstract: Reptiles are ectothermic amniotes in a world dominated by endotherms. Reptiles originated more than 300 million years ago and they often dwell in polluted environments which may expose them to pathogenic microorganisms, radiation and/or heavy metals. Reptiles also possess greater longevity and may live much longer than similar-sized land mammals, for example, turtles, tortoises, crocodiles and tuatara are long-lived reptiles living up to 100 years or more. Many recent studies have emphasized the pivotal role of the gut microbiome on its host, thus we postulated that reptilian gut microbiome and/or its metabolites and the interplay with their robust immune system may contribute to their longevity and overall hardiness. Herein we discuss the composition of the reptilian gut microbiome, immune system-gut microbiome cross-talk, antimicrobial peptides, reptilian resistance to infectious diseases and cancer, ageing, as well the current knowledge of the genome and epigenome of these remarkable species. Preliminary studies have demonstrated that microbial gut flora of reptiles such as crocodiles, tortoises, water monitor lizard and python exhibit remarkable anti-cancer and anti-bacterial properties, as well as comprise novel gut bacterial metabolites and antimicrobial peptides. The underlying mechanisms between the gut microbiome and the immune system may hold clues to developing new therapies overall for health, and possible extrapolation to exploit the ancient defense systems of reptiles for *Homo sapiens* benefit.

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Cook, P., Hawes, J.E., Campos-Silva, J.V. and Peres, C.A. (2022). Human-wildlife conflicts with crocodilians, cetaceans and otters in the tropics and subtropics. PeerJ 9: e12688.

Abstract: Conservation of freshwater biodiversity and management of human-wildlife conflicts are major conservation challenges globally. Human-wildlife conflict occurs due to attacks on people, depredation of fisheries, damage to fishing equipment and entanglement in nets. Here we review the current literature on conflicts with tropical and subtropical crocodilians, cetaceans and otters in freshwater and brackish habitats. We also present a new multispecies case study of conflicts with four freshwater predators in the Western Amazon: Black caiman (*Melanosuchus niger*), giant otter (*Pteronura brasiliensis*), boto (*Inia geoffrensis*) and tucuxi (*Sotalia fluviatilis*). Documented conflicts occur with 34 crocodilian, cetacean and otter species. Of the species reviewed in this study, 37.5% had conflicts frequently documented in the literature, with the saltwater crocodile (*Crocodylus porosus*) the most studied species. We found conflict severity had a positive relationship with species body mass, and a negative relationship with IUCN Red List status. In the Amazonian case study, we found that the Black caiman was ranked as the greatest 'problem' followed by the boto, giant otter and tucuxi. There was a significant difference between the responses of local fishers when each of the four species were found entangled in nets. We make recommendations for future research, based on the findings of the review and Amazon case study, including the need to standardise data collection.

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Raposo, A.C., Lebrilla, C., Portela, R.W., Xu, G. and Oriá, A.P. (2021). The glycoproteomics of hawk and caiman tears. BMC Veterinary Research 17(1) (doi: 10.1186/s12917-021-03088-1).

Abstract: Glycoproteins are important tear components that participate in the stability of the ocular surface. However, the glycopeptides that are present in the tears of wild animals have not yet been described. This work aimed to describe the glycoproteomic profile of roadside hawk (*Rupornis magnirostris*) and caiman (*Caiman latirostris*) tears. Tears collected from 10 hawks and 70 caimans using Schirmer tear test strips were used in this study. The samples were submitted to trypsin digestion and separated using a reverse-phase column coupled to a mass spectrometer associated to a nanospray ionization source. The glycoproteins were categorized as: cellular components, biological processes and molecular function, according to the UniProt Knowledgebase. As shown by the liquid chromatography-mass spectrometry, all glycopeptides found were classified as N-type. Of the 51 glycoproteins that were identified in the hawk tear film, the most abundant were ovotransferrin, globulins and complement system proteins. In the caiman tear film, 29 glycoproteins were identified. The most abundant caiman glycoproteins were uncharacterized proteins, ATPases, globulins and proteasome components. Ontological characterization revealed that the glycoproteins were extracellular, and the most identified molecular function was endopeptidase activity for both species. Glycoproteins are abundant in the tear film of the bird and reptile species studied herein, and all these molecules were shown to have N-type modifications. Location at the extracellular space and an endopeptidase inhibitor activity were the main cell component and molecular function for both species, respectively. These profiles showed differences when compared to human tears, are possibly linked to adaptive processes and can be the basis for further studies on the search of disease biomarkers.

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Lopez Gonzalez, E.C., Odetti, L.M., Latorre, M.A., Avila, O.B., Contini, L.E., Siroski, P.A. and Poletta, G.L. (2022). A comprehensive approach using multiple biomarkers to detect damage induced by pesticides in broad-snouted caiman (*Caiman latirostris*) under *ex-situ* conditions. Heliyon 8: e08667.

Abstract: *Caiman latirostris* is one of the two species of the order Crocodylia that inhabit Argentina and is considered a species of vital ecological and economic importance in the northeast of Argentina. In this region, pesticides are the most common contaminants in natural environments and wild caiman populations are subject to this contamination constantly. The aim of this study was to evaluate the effects the main pesticides used in the region: glyphosate (GLY), cypermethrin (CYP) and chlorpyrifos (CPF)-based formulations, as well as the mixture of them, on *C. latirostris* juveniles under semi-controlled condition of exposure (*ex-situ*) during 75 days. One hundred 10-month-old caimans were equally distributed into five experimental groups (20 animals per group): a negative control (NC -tap water), GLY 2% (Roundup® Full II formulation -RU), CYP 0.12% (Atanor® formulation), CPF 0.8% (Lorsban® formulation), and a mixture of the three pesticides (Mx3: GLY 2% + CYP 0.12% + CPF 0.8%). We applied early warning biomarkers to detect damage induced by these chemicals in peripheral blood: activity of the antioxidant enzymes catalase (CAT) and superoxide dismutase (SOD), analysis of lipid peroxidation (LPO) by the thiobarbituric acid reactive substances (TBARS), DNA damage and specific base oxidation through the standard and modified comet assay (CA), chromosome damage by micronucleus (MN) test and other nuclear abnormalities (NAs), hematological and growth parameters. Results showed a statistically significant increase in MN and NAs frequency, DNA damage, with an important contribution of base oxidation for all exposed groups compared to the NC. Total white blood cells count (TWBCC), and growth parameters showed effects mainly at the Mx3. The principal component analysis (PCA) demonstrated more sensitivity for biomarkers associated to genetic damage, including base oxidation to DNA than LPO, antioxidant enzyme modulation, immunotoxicity or growth parameters, to detect pesticides effects, applied under conditions similar to that found in natural environments.

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De Lima Franco, D., Botero-Arias, R., Moraes Filho, R.A. and Vital, T.W. (2022). Assessment of local community perspective about caiman management in the Mamirauá Reserve, Brazil. International Journal of Social Ecology and Sustainable Development 13(1) (doi: 10.4018/IJSESD.287884).

Abstract: The aim of this study was to identify key aspects for the development of community-based caiman management in the Mamirauá Sustainable Development Reserve (MSDR) from the

perspective of the communities. Between 2014 and 2017, SWOT matrices were used to discuss opportunities and challenges of caiman management in the MSDR. The positive and negative aspects had a similar variation pattern, which suggests that the communities had a homogeneous perception, but there was 27% variation in opportunities and threats. Strengths and opportunities were cited approximately 26% more often, indicating a positive perspective. The main positive aspects refer to environmental conditions, capacity of the organizations, and improvement of the market, while current market conditions, hunting, and problems of organization and legal adequacy were perceived as major challenges. The community-oriented perspective analyzed by a SWOT matrix can be a valuable tool to promote a comprehensive understanding of the productive system of caiman management.

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Leiva, P.M.L., Valli, F.E., Piña, C.I., González, M.A. and Simoncini, M.S. (2021). Characterization and Use of Reptile Meat and Fat from Sustainable Management Programs. COMFAUNA: Argentina. 25pp.

Abstract: Several reptile species are generally associated with the cultural heritage of many regions. These animals are often perceived as sacred and, in other cases, taboo, or have a negative image due to popular legends and beliefs, which would restrict their consumption. However, the use of reptiles may be driven by their medicinal properties and perceived nutritional values, generated through the culture of local people, but without scientific basis. There is a history of local people using the meat of lizards, caimans and snakes for food and the fat for medicinal purposes. Particularly, reptile programs are focused on obtaining and marketing the skins of the species. The market value of a species conditions the possibility of carrying out and maintaining a sustainable use program. Therefore, studying and promoting alternative productions, such as meat and fat, provides the opportunity to develop and exploit other byproducts that have not yet been explored, strengthening sustainable use programs through the integral use of the species, thus making them more profitable. In Argentina, there are three reptile species managed by programs, Broad snouted Caiman (*Caiman latirostris*), Black and white Tegu (*Salvator merianae*) and Yellow Anaconda (*Eunectes notaeus*). Thus, evaluations of possible applications or uses of unused by-products derived from these species would not only increase economic return for the program of sustainable use and conservation of those species, but would also give start to new activities that could be undertaken at local, regional, national and even international scale, as the results could be replicated in other countries with other reptile species. Therefore, this chapter describes the methodology used to study the suitability of the meat for consumption, to evaluate the physic-chemical and organoleptic characteristics of the meat, to characterize fats and compare methods of obtaining the oil, as well as to determine its characteristics and possible uses, and the potential commercial development of these new by-products derived from reptile species under management in Argentina.

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Balamayooran, G., Cooper, C., Paul, N.C., Ferro, P.J., Rice, L., Gomez, G. and Díaz-Delgado, J. (2022). *Yokenella regensburgei*, a novel pathogen in farmed American alligators. Veterinary Pathology (doi: 10.1177/03009858211069165).

Abstract: Increased acute mortality of farmed American alligators (*Alligator mississippiensis*) was observed in various pens from 2 different farms in Louisiana over 2 years (2019-2021). A total of 14 alligators from multiple events of increased mortality were subjected to postmortem investigations. Except for one alligator with acute neurologic signs, no premonitory signs were observed. All animals had pneumonia (14/14), coelomitis (14/14), and intravascular short Gram-negative bacilli (14/14). Myocarditis (13/14) was common. *Yokenella regensburgei* was isolated from all alligators tested (13/13). These data suggest the respiratory tract may be a primary target system and could be involved in transmission, either through exhaled bacteria or through swallowing of contaminated respiratory fluids with passage through the feces. Available sensitivity data for *Y. regensburgei* in this study indicates *in vitro* sensitivity to aminoglycosides, fluoroquinolones, chloramphenicol, and trimethoprim/sulphamethoxazole antibiotics. *Yokenella regensburgei* should be included in the differential diagnosis of septicemia and acute death in alligators.

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Lucifora, L.O., Scarabotti, P.A. and Barbini, S.A. (2022). Predicting and contextualizing sensitivity to overfishing in Neotropical freshwater stingrays (Chondrichthyes: Potamotrygonidae). Reviews in Fish Biology and Fisheries (https://doi.org/10.1007/s11160-021-09696-2).

Abstract: Neotropical freshwater stingrays (Potamotrygonidae) are conspicuous components of the South American ichthyofauna, and may be regionally important as an economic resource. The smallest individuals are exploited in ornamental fisheries, while large individuals are caught in consumptive fisheries for their meat or liver oil. Potamotrygonid life history is poorly known, which complicates fisheries management and conservation. Here, we compiled life history traits of potamotrygonids and predict unknown traits from their relationship with body size, to compute the maximum population growth rate ($r_{max}$), a widely-used metric of sensitivity to overfishing. Potamotrygonid $r_{max}$ was compared with that of marine chondrichthyans and South American crocodylians. Marine chondrichthyans include the closest relatives of potamotrygonids, and South American crocodylians are a group with known overexploitation history sharing the habitat and general life history strategy with potamotrygonids. Simulations for species with known traits indicated that predictions were close to real values and unbiased. Potamotrygonid $r_{max}$ varied from 0.14 to 0.39, well within the range of marine chondrichthyans (0.03-1.37) and lower than crocodylians (0.23-0.52). Generation time ranged from 6.7 to 19.5 years. These figures indicate that sustainable exploitation of potamotrygonids is possible. However, tight regulations (eg size and catch limits) and science-based management are necessary, especially for species with small geographic range, low population size, or low $r_{max}$ (<0.2). Empirical studies on potamotrygonid life history and ecology are urgently needed to aid management. Potential scenarios for sustainable exploitation of potamotrygonids are discussed, including ornamental and consumptive fisheries, and sighting-based tourism.

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Whitaker, N. and Sivaraman, C. (2022). Behavior in a captive family group of Siamese crocodiles (*Crocodylus siamensis*) at the Madras Crocodile Bank Trust near Chennai, India. Reptiles & Amphibians 29: 71-75.

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Lawrence, T.J. (2021). Thermal Tolerances and Preferences of Adolescent Louisiana Alligators (*Alligator mississippiensis*). MSc thesis, The University of West Florida, USA.

Abstract: With global temperatures achieving new extremes each year, it is not immediately clear the effect these temperatures will have on American alligators (*Alligator mississippiensis*). Thermal tolerances have been estimated on American alligators before, but a full thermal niche has never been determined. An eccritic temperature, thermal preference, has been estimated for alligators, but results have varied. I used standardized thermal methodologies to estimate acclimation ranges, upper and lower acclimation response ratios, thermal niche areas, and the eccritic temperature in adolescent alligators. Alligators had an upper chronic limit of 39.1°C and a lower chronic limit of 16.2°C. Alligators exhibited a larger gained cold tolerance zone in their niche than anticipated at 131.6°C$^2$ and an intrinsic tolerance and gained heat tolerance zones of 509.7°C$^2$ and 61.4°C$^2$, respectively. Cold acclimation response ratio was roughly twice that of the heat response, with alligators losing or gaining 0.5°C or 0.2°C heat tolerance per every 1°C

change in acclimation temperature. Alligators expressed an eccritic temperature of 32°C with little variation between animals. Evidence suggested there is an undescribed physiological process that allows alligators to acclimatize to lower temperatures. Comparing thermal niche and eccritic temperature data to temperature trends in alligator's natural habitat suggested that alligators could be affected by changing temperatures.

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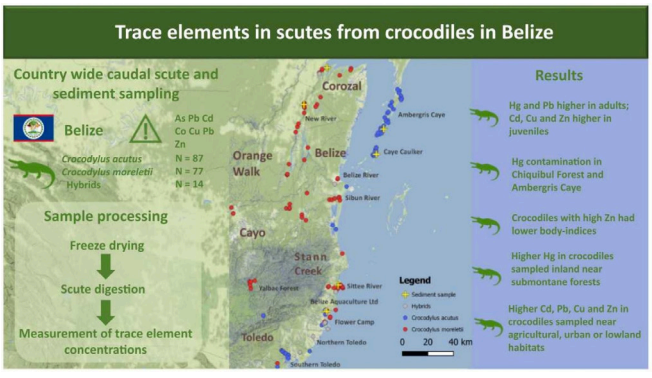
Thirion, F., Tellez, M., Van Damme, R. and Bervoets, L. (2022). Trace element concentrations in caudal scutes from *Crocodylus moreletii* and *Crocodylus acutus* in Belize in relation to biological variables and land use. Ecotoxicology and Environmental Safety 231 (https://doi.org/10.1016/j.ecoenv.2022.113164).

Abstract: *Crocodylus moreletii* (Morelet's crocodile) and *Crocodylus acutus* (American crocodile) are generalist, apex predators of subtropical aquatic habitats in Central America. As top predators, crocodiles may be exposed to high levels of micro pollutants, such as trace elements via bioaccumulation that enter the food web as a consequence of human activities. As such, the status of their population can be considered indicative of that of the entire ecosystem - ie crocodiles constitute as genuine indicator species. In this study, we report on the concentrations of trace elements found in the caudal scutes of 178 specimens of *C. acutus* and *C. moreletii* from Belize. Our objectives were three-fold: (1) to assess variation in trace element concentration between species, sexes, age classes and body index; (2) to identify areas with elevated exposure to trace elements by comparing concentrations in the scutes of crocodiles at various sites in Belize; and, (3) to explore links between crocodile trace element load and local land use. All elements tested (Hg, Pb, Cd, As, Cu, Zn, Co) could be detected in at least some scutes. Many of the readings of As and Co were under or close to the detection limit and were not further analyzed. Relatively high Hg concentrations were observed in adults from Chiquibul Forest (median 3.170 $\mu$g/g) and Ambergris Caye (0.834 $\mu$g/g). Concentrations of Hg and Pb tended to be higher in adult animals than in juveniles, especially in *C. acutus*. On the other hand, concentrations of Cd, Cu and Zn were higher in juveniles than in subadult/adults. Concentrations of Cu were higher in *C. acutus* than in *C. moreletii*, but otherwise no species-effects were found for the other trace elements. We found a negative correlation between Hg and Zn concentrations; correlations among Cd, Pb, Cu and Zn concentrations tended to be positive. In both juveniles and adults, animals with high concentrations of Zn had lower body-indices (a proxy for physiological condition). None of the other element concentrations correlated with the body-index. Specimens of *C. acutus* were more often sampled at coastal sites, while *C. moreletii* sampling points were typically closer to agricultural or forested areas. A canonical correlation analysis revealed a significant association between trace element load and habitat characteristics. Animals sampled inland, near submontane forests, contained higher levels of Hg, while animals sampled near agricultural, urban or lowland habitats tended to have higher concentrations of Cd, Pb, Cu and Zn. This study identifies the most prevalent trace element concentrations impacting Belizean watersheds while highlighting the exposure risk to non-essential trace elements in less-urbanised areas or protected areas.




Rodas-Trejo, J., Ocampo-González, P. and Mandujano-Camacho, O. (2021). Population estimate of *Crocodylus moreletii* in four sites of the Pantanos de Centla Biosphere Reserve. Ecosistemas y Recursos Agropecuarios 8(1): e2663 (doi: 10.19136/era.a8nI.2663).

Abstract: The quantification of crocodiles in natural environments represents basic information to establish management and conservation strategies for these species. With the aim to estimate the encounter rate (ER), abundance and population structure of Morelet's Crocodile (*Crocodylus moreletii*) in the Pantanos de Centla Biosphere Reserve (PCBR), between the months of September to December 2018, they were carried out monthly night tours in the localities Tabasquillo, Tembladeras, La Mixteca and Lázaro Cárdenas. In total, 797 records were obtained in 16 night counts. In Tembladeras locality, the lowest ER and population size were recorded with 1.12 crocodiles linear km$^{-1}$ and 54.09 ± 6.31 individuals, respectively, while the highest values are shown in La Mixteca locality with 3.14 crocodiles linear km$^{-1}$ and 84.79 ± 6.44 individuals. Significant differences were found between the individuals observed by transect (H= 14.3457, gl.= 3, p<0.01). Individuals of all size classes were observed at all four locations. The highest proportions were presented in classes I and II. This information contributes to the knowledge about population ecology and a first approximation of the current state of the swamp crocodile and represents the first study for *C. moreletii* in this locaties of the PCBR.

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Mahfooz, S., Singh, P. and Akhter, Y. (2022). A comparative study of microsatellites among crocodiles and development of genomic resources for the critically endangered Indian gharial. Genetica (doi: 10.1007/s10709-021-00148-0).

Abstract: Next-generation sequencing has allowed us to explore new methods, where comparative and population genomics can be used simultaneously. Keeping this in mind, we surveyed and analyzed the frequency and distribution of microsatellites in the Indian gharial (*Gavialis gangeticus*) and compared it with American alligator (*Alligator mississippiensis*) and saltwater crocodile (*Crocodylus porosus*) to enrich them with genomic resources. The Indian gharial has a low frequency, relative abundance (RA), and relative density (RD) of microsatellites as compared to other crocodilians. RA and RD were positively correlated with the GC content of genomic and transcriptomic sequences. The genomic sequences were dominated by dinucleotide repeats, whereas the transcriptomic sequences had an excess of trinucleotide repeats. Motif conservation studies among the three crocodilians revealed conservation of 69.2% of motifs. Species-specific unique motifs identified in this study could be used as molecular probes for species identification. A total of 67,311 primers were designed in all three species to enrich the crocodilians with genomic resources. The genomic resources developed in this study could accelerate diversity analysis within its individuals to design a proper mating plan to reduce inbreeding stress and further improve the species.

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Leeds, A., Riley, A., Terry, M., Mazorra, M., Wick, L., Krug, S., Wolfe, K., Leonard, I., Daneault, A., Alba, A.C., Miller, A. and Soltis, J. (2022). Out of sight, out of mind or just something in the way? Visual barriers do not reduce intraspecific agonism in an all-male group of Nile crocodiles (*Crocodylus niloticus*). Animals 12: 269.

Abstract: Here, we evaluated if visual barriers could reduce intraspecific agonism in an all-male group of Nile crocodiles (*Crocodylus niloticus*) living in a zoo. Crocodiles were monitored for nearly 100 h, and four "hotspots" of aggression within their exhibit were identified. Within these four locations, visual barriers were placed at the surface of the water with the goal of reducing agonism by targeting sight lines associated with their species-typical minimum exposure posture, where crocodiles submerge their body but maintain facial sensory organs above the water line. Crocodile behavior was then monitored for 226 h, evaluating both short- and

long-term effects of the visual barriers. In both observation periods, intraspecific agonism was unaffected by visual barriers. However, crocodiles were more likely to be on land and closer together, after the barriers were installed, showing the barriers affected nonagonistic behaviors. Monitoring of such unintended effects is significant to ensure no welfare concerns are created in any exhibit or husbandry modification attempt. Additionally, time of day and temperature were significant predictors of behavior, highlighting the importance of such factors in the analysis of reptilian behavior. While ineffective at reducing agonism, this is the first published study evaluating exhibit design and behavior of crocodilians in zoos and aquariums. The methodologies and findings here should provide useful information for future behavioral and welfare studies of this understudied taxa.

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Truter, J.C. and Myburgh, J.G. (2021). *In ovo* manipulation of Nile crocodile embryos: egg windowing and potential dental research applications. International Journal of Developmental Biology 65: 551-556.

Abstract: Crocodilians exhibit continuous tooth replacement (ie polyphyodonty) and have been identified as suitable models for tooth regeneration research due to the similarity in dental cavity and tooth anatomy between these creatures and humans. Various studies reporting *in ovo* bird embryo manipulation exist, but such reports for reptiles are virtually non-existent. Egg windowing enables direct access to oviparous vertebrate embryos and is therefore an important component of *in ovo* embryo manipulation experiments. The aim of the present study was to window Nile crocodile, *Crocodylus niloticus* eggs and assess the potential of direct manipulations, targeting the pharyngeal region where the maxilla and mandible originates. *Crocodylus niloticus* eggs were successfully windowed, and a limited number of individuals survived the entire gestation period. The 1st trimester of gestation was the most sensitive, and 96.78% of the mortalities occurred within this period. Our data indicate the suitable window for embryo manipulation targeting the mandibular arch and maxillary process, without a risk of damaging the chorioallantoic membrane (CAM) (which may be fatal), was between day 6 and 8 after laying for embryos incubated at 31°C. This data will be of use for future embryo-based experiments related to jaw and tooth development in crocodiles as well as human tooth regeneration research.

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Thiendedsakul, P., Santativongchai, P., Boonsoongnern, P., Yodsheewan, R. and Tulayakul, P. (2022). Glutathione-S-transferase activity in various organs of *Crocodylus siamensis* and its attenuation role in aflatoxin B1-induced cell apoptosis in human hepatocarcinoma cells, Veterinary World 15(1): 46-54.

Abstract: The crocodile is a model for studying relevant sources of environmental contamination. They were determined an appropriate biomonitoring species for various toxins. The cytosolic and microsomal fraction of crocodiles plays a role in detoxifying xenobiotics. Cytochrome P450 1A2 (CYP1A2) metabolizes aflatoxin B1 (AFB1) to aflatoxin M1, while glutathione-S-transferase (GST) catalyzes carcinogenic agents. This study aimed to investigate the GST activity in various organs of *Crocodylus siamensis*. Further, the fate of microsomal and cytosolic fractions from various crocodile organs against AFB1-induced apoptosis in human hepatocarcinoma (HepG2) cells was investigated. The liver, lungs, intestines, and kidneys tissues from a 3-year-old *C. siamensis* (n= 5) were collected. The cytosolic and microsomal fraction of all tissues was extracted, and protein concentrations were measured with a spectrophotometer. Subsequently, a comparison of GST activity from various organs was carried out by spectrophotometry, and the protective effects of CYP450 and GST activity from various crocodile organs were studied. *In vitro* AFB1-induced apoptosis in HepG2 cells was detected by reverse transcription-quantitative polymerase chain reaction. Comparisons between the metabolisms of the detoxification enzyme in organs were tested using the Kruskal-Wallis one-way analysis of variance and Dunn's multiple comparison tests. All kinetic parameters were analyzed using GraphPad Prism software version 5.01 (GraphPad Software Inc., San Diego, USA). Total GST activity in the liver was significantly higher than in the kidneys, intestines, and lungs ($p<0.05$, respectively). The highest GST pi (GSTP) activity was found in the liver, while the highest GST alpha-isoform activity was in the crocodile lung. The kinetics of total GST and GST mu activity in the liver had the highest velocity compared to other organs. In contrast, the kinetics of GSTP enzyme activity was the highest in the intestine. The *in vitro* study of microsome and cytosol extract against apoptosis induced by AFB1 revealed that the level of messenger RNA expression of the Bax and Bad genes of HepG2 cells decreased in the treatment group in a combination of cytosolic and microsomal fractions of the crocodile liver but not for Bcl-2. Interestingly, the downregulated expression of Bax and Bad genes was also found in the microsome and cytosol of crocodile kidneys. The crocodile liver revealed very effective GST activity and expression of the highest kinetic velocity compared to other organs. The combination of liver microsomal and cytosolic fractions could be used to prevent cell apoptosis induced by AFB1. However, further study of the molecular approaches to enzyme activity and apoptosis prevention mechanisms should be carried out.

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Godfrey, S.J., Collareta, A. and Nance, J.R. (2022). Coprolites from Calvert Cliffs: Miocene fecal pellets and burrowed crocodilian droppings from the Chesapeake Group of Maryland, U.S.A. Rivista Italiana di Paleontologia e Stratigrafia 128(1): 69-79.

Abstract: New finds of remarkable coprolites (fossilized feces) are here reported from the famous Miocene marine sediments of the Chesapeake Group exposed along Calvert Cliffs (Maryland, U.S.A.).Although vertebrate coprolites have been described from these deposits, here we provide the first description of tiny invertebrate fecal pellets. Thus far, these fecal pellets have only been found in the upper Miocene (Tortonian) St. Marys Formation. The micro-coprolites represent the coprulid ichnospecies *Coprulus oblongus*. The fecal pellets are found in small clusters or strings of dozens to masses of many hundreds. Pellets range in size from approximately 0.4-2.0 mm wide by 1.0-5.0 mm long, and range in color from gray to brownish black. Their length/diameter ratio is always very nearly 2. These coprulids have been found in a variety of Miocene fossils/concretions including a uranoscopid neurocranium, naticid gastropod, bivalve shells, barnacle tests, and in pellet-backfilled sinuous burrows through sediment. Because the fecal pellets are often found in tiny spaces or spaces thought to be inaccessible to shelled invertebrates, the coprulids are attributed to small and soft-bodied polychaetes or other annelids. Some coprolites attributed to crocodilians from the lower-middle Miocene Calvert Formation were tunneled into, presumably the result of coprophagy, by some unknown kind of organism(s). These complex trace fossils are in the form of burrows that excavate the coprolites, the sides of which are sculptured by scratch/gouge marks.

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Aiyer, A., Shine, R., Somaweera, R., Bell, T. and Ward-Fear, G. (2022). Shifts in the foraging tactics of crocodiles following invasion by toxic prey. Scientific Reports 12(1): 1267 (doi: 10.1038/s41598-021-03629-6).

Abstract: Biological invasions can modify the behaviour of vulnerable native species in subtle ways. For example, native predators may learn or evolve to reduce foraging in conditions (habitats, times of day) that expose them to a toxic invasive species. In tropical Australia, freshwater crocodiles (*Crocodylus johnstoni*) are often fatally poisoned when they ingest invasive cane toads (Rhinella marina). The risk may be greatest if toads are seized on land, where a predator cannot wash away the toxins before they are absorbed into its bloodstream. Hence, toad invasion might induce crocodiles to forage in aquatic habitats only, foregoing terrestrial hunting. To test this idea, we conducted standardised trials of bait presentation to free-ranging crocodiles in sites with and without invasive toads. As anticipated, crocodiles rapidly learned to avoid consuming toads, and shifted to almost exclusively aquatic foraging.

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